A TRAFFIC ABILITY OF THE TERRAIN

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Abstract: The article deals with the capability of the terrain earlier and nowadays, and then with the geographical conditions, which affect the movement of military vehicles. It describes their effect on speed and safety of movement of people and vehicles too. Finding of the optimal routes outside the communication is studied in the Army environment, but it occur in civilian as well, primarily in crisis situation, or by the provision of assistance when natural disasters such as floods, fires, storms etc., have happened. These movements require the optimization of routes when effects of geographical factors should be included. The most important factor is the surface of a terrain. Their mutual impact has been given by coefficient of deceleration. This coefficient can be used for the commander’s decision. New approaches and methods are necessary parts of this evaluation.

Keywords: Traffic Ability, Movement, Terrain Testing

1. Introduction
War conflicts in the last twenty years have shown the need for digitisation of area, when the Commander needs a lot of input data for the correct decision. These data are becoming an essential part of the decision-making process when planning of a successful movement (for peace and for war) is one of the fundamental questions. For its fulfilment it is necessary to know the impact of geographical factors on the manoeuvre, and if it is possible to use algorithms to find optimal routes. The algorithms of the route optimization (for communication and outside of them) may not be intended only for the war purposes because finding optimal routes outside the communication may be relevant also in civilian crisis situations, or the provision of assistance when natural disasters such as floods, fires, storms etc. "The optimization of the routes" means not only finding the shortest route, but also to ensuring the safety of movement, or at least limitation of risk factors and so the compliance with time limits or acceptance of the economic aspects of the movement can play an important role [1].

2. Traffic Ability of the Terrain from historical perspective
The first recorded scientific experiment of the traffic ability and analysis of terrain is proved by around 100-50 BC (the epoch of Gaius Julius Caesar), when the army of the Roman Empire tried to re-conquer the territory around today’s Britain. The first attempt failed due to neglected geographic factors. Operating directions path have changed under the influence of the rainfall in the mud, the cars fit and it was not possible to complete the movement, although the units have wheeled wagons (and they were legendary for its capabilities of rapid movements of up to 40 miles a day). The Roman Empire attempted to annex this territory, but communications have been muddy, even
going in the marshy and swampy areas and the influence of this campaign the clearness of the underpriced ended poorly.
The second trial occurred during the reign of the Emperor Claudius. This time, the army could have done nothing and created the first intelligence unit which acceded to evaluate the terrain more than scientifically. "Spies" issuing, for example, for traders have been sent to areas of potential Theatre of war, and they collected samples and analyzed the potential suitable routes for the then wheeled vehicles. They have tried to estimate the number of cars that pass under the conditions in a given field. The research was valuable and the Roman army managed (thanks to the previous survey), after the invasion of the Islands quickly build a network of suitable transport routes, and so it was possible the selected territory to conquer.

With the demise of the Roman Empire occurs (in terms of scientific development methods that define the throughput of the terrain) to the deterioration, when the area of logistics, transport, movement of troops, etc. has been affected. With the passage of time the troops dwindled considerably – while in the days of the Roman Empire, it was necessary to secure an army of 50-100 thousand of soldiers, at the time of medieval battles, this army was about one order of magnitude less, approx. 5-10 thousand men. The influence of geographical factors on the movement of the terrain, however, did not change.

Communications at the time of the middle ages were in the dismal state (it is possible to think of them as beaten paths or as journey covered by gravel or rocks). Were potholed, mud, and in the winter the path were not cleaned, so were full of snow... These were the reasons why only a small number of troops could move through these routes, it was not possible logistically to ensure no more drive. The great advantage was that the fighting was conducted in particular foot troops. For them, it was much easier to overcome obstacles, whether in the form of various micro-relief shapes (ditches, embankments) or the forest units. These forest units would not be passable (perhaps due to distances between trees), for example for the current wheeled vehicles. Passability in the woods was not paramount, but cases (e.g. from Poland) are recorded when the dense impermeable forests have been used to guide the enemy troops of the German Knights on the routes, where they were expected by home army. Similarly, these massive forests were also used during the second war. Forest units so are representative of how the geographical factor, so the tactical factor and already signs of mutual influence a larger number of positive and negative parameters were evident. It is clear analysis of the cross-country movement is a complex analysis.

Time has progressed and once again it was the development of intelligence and military facilities. It was the reform and for the thirty years ' war the army was again more numerous. Communications have been developed. Manoeuvres on the strategic levels used the communications network in a way which was called "eat up region" – the movements were planned so that the troops still had something to eat. The throughput of the field resulted in the surroundings of Brno, when the Swedes failed to overcome the long routes. They weren't able to get heavy artillery to their destination in a timely manner, and it was one of the reasons why the Austrian Empire was rescued. Water network began to use and, in particular, the heavy costs were transported along the navigable stretches of watercourses. If the weather and climatic conditions permit, it was possible to extend the communication network of frozen water areas or streams, with all the pros and cons. The sledge was the ideal type of vehicle after snow or ice and became the pioneers of the tracked vehicles. Thirty years ' war clearly showed that if a large army to be used, construction of roads must be improved. It is a shining example of Napoleon's campaign from Smolensk to Moscow, where the influence of the snowy
roads occurred during the short period of time to total collapse and the end of Napoleon also.

The correct data sources play a distinct role. Even Napoleon's defeat at the battle of Waterloo (as scientists have recently proved) was largely due to the erroneous map handout, which Napoleon received from their own units. Important landmarks and the correct position of the communications were not included on the maps. The battle therefore was not guided, as it would in the case of the correct maps were kept.

Another case is the Russian route in Spain in the years 1810-1816. Spain was known by taking a walk along mountain massifs has been very problematic. But the British were able to capitalize on the knowledge of its highly advanced cartographic service, they were able to map out the territory very quickly (sources were old maps of the ancient empire, the interviews with the local population, other old maps and plans). The British then skirted the French very quickly – especially after the road on which the French did not have the faintest idea (they knew the passages in the rocks, etc.). The basics of British maps are used today (thanks to quality processing).

War events, developments and technological progress have continued. The emphasis began to be put on the exploration of the terrain characteristics and their possible changes under the influence of meteorological conditions, climatic conditions and the probable type of military activities. It found that the terrain is due to the rainy season waterlogged and such area if it is exposed to the effects of artillery fire, very significantly changes its structure. Absolutely impermeable marshes were created from damaged drainage channels (even for infantry units). The conditions were very bad. Neither horse nor the cars pass. Questions arose: how to overcome this terrain? How faster and better? How to get over the territories which are under enemy fire? The Tank was developed, came to use tracked vehicles.

In the interwar period, it comes to the further development of the research. At that time, the CSR is at the top of cartography. On the basis of the findings of the first WW, very good, secret maps of cross-country movement were created (the Germans these maps did not have). Documents were used in the construction of fortifications around the borders. The routes, after which the enemy troops could arrive, were evaluated. The gun ports were built so that firing on these routes has been effective. Also the mountain massifs around the borders and the possibility of flooding in alluvial soils in South Moravia were used. Here, the light infantry forts were built. When Czechoslovakia sophisticated handle issues, like France. Experts, however, have not always right. French claimed that Arden is absolutely impassable for tanks. Even the German cartographers did not believe in the possible passage of these forests. Despite this, tank-drivers claimed that they pass through the forest and home were surprised when, despite a negative theoretical assumptions the Germans went through this forest and really contributed to winning over France (the collapsed within a few weeks). After this incursion took place to fill the places where troops was not expected and where the French had almost no defence resources.

The Germans have not only the achievements but also the failures. A shining example is Russia, where communications were almost at the level of the middle ages and the highway, which were in the maps, were just a dusty earthen paths – generally the Russian communication were a great problem for the Germans in the process forward. Even the dust level was an important factor, not only that nothing was visible, but the engines got choked – indeed, a similar problem is in the areas of contemporary conflicts (due to sand and dust computing or the printers are destroyed). Autumn 1941, when the Germans first encounter with RASPUTICOU, which is a term that defines the total muddy paths in the immense scale. Tanks were incapable of movement – fit, and the
entire German manoeuvre is completely in the autumn stopped. The many millions Russian army did not stop the Germans, since the influence of geographical conditions, prove it. Even the Russians had problems with transport, but Russian tanks had much wider belts. After the rigid cold came and the Wehrmacht suddenly moved forward, the Germans travelled of 50-60 km in a single day and again began to threaten the very heart of Russia – Moscow. Again came the influence of terrain-came the flooding of snow (for example, 2-3 m per night), that absolutely prevent movement of the tank and caused the total cessation of the Germans. The Russian counterattack came when units which have been deployed to Siberia, came to Moscow. They were equipped with skis, sled, by wide belts and the Germans retreated up to 100 miles back. The war was still 4 years old. There are considerations, that if the Germans were then adapted to the rapid changes in the conditions, they could conquer the Moscow and the whole history of the second WW could be completely different.

Figure 1 The terrain that is called by term “Rasputica”

The throughput of the terrain has been examined on the Western front - in Normandy. Special teams have been sent by removing the soil samples to determine the carrying capacity of the ground. Reporting agents disembarked secretly from submarines, measured the height of the water at high tide and low tide, and other factors that could have an impact on the fight.

Another known issue related to the continuity of the terrain is the Korean war. UN troops repelled the attack and moved to North Korea, which almost took. In the winter months they got close to the border with China, and to the massive Chinese attack occurred. Armament was incomparably worse, but the Chinese were able to long pedestrian movement and were accustomed to winter, typical of these areas – cold dry air, temperature of up to-40th. And the snow. Soldiers froze to death, weapons have had malfunctions. The Chinese attacked and UN soldiers started to retreat, when it was about saving the lives of their own and the wounded. Damages on the technology were huge.

Where the fight is lead today? The current period is characterized as a low-intensity conflicts, it is a country where infrastructure is poor, for example. Afghanistan, Syria, Mali). This brief overview of the events, where natural conditions prevailed over human pride and technique, should serve to briefly ponder how to avoid similar setbacks.

3. **Cross-country Movement**

This chapter deals with geographical conditions in terrain and their effect on the movement of vehicles, their effect on speed and safety of movement of people and vehicles [2,3]. Finding of the optimal routes outside the communication is studied in the
Army environment, but it occurs in civilian as well, primarily in crisis situations, or by the provision of assistance when natural disasters such as floods, fires, storms etc., have happened. These movements require the optimization of routes when effects of geographical factors should be included [4]. The most important factor is the surface of a terrain. It is based on several geographical factors as are slopes, soil conditions, micro-relief, a type of surface and meteorological conditions. Their mutual impact has been given by coefficient of deceleration. This coefficient can be used for the commander’s decision. New approaches and methods of terrain testing, mathematical computing, mathematical statistics or carto-metric investigation are necessary parts of this evaluation [5].

The issue of capability of the terrain (Cross-Country Movement, Traffic Ability of a Terrain) is still a current topic, despite the fact that for a long time the new approaches are developed [6]. These approaches could contribute to optimizing the search paths [7,8]. Finding of the relevant algorithms is not a trivial matter, because the selection of the most appropriate routes and the estimate of the time that is needed for the move is a function of the quantity various factors: geographical, tactical, technical and the influences that are predetermined by the human behaviour.

**Analysis of the Cross-Country Movement (trafficability, capability) means the assessment of several geographical and tactical factors together, i.e. that it is complex multi-field analysis** [2,3,6,9,10,11]. Apart from these geographical factors and their parameters that affect the choice of routes, it includes:

- Relief (a parameter is a gradient);
- Micro-relief – i.e. embankments, excavations, holes, terrain steps, rock cliffs, terraces, rock groups, boulders, stone fields or rows of stones, etc. (parameters are height or depth, length, slope gradient, width);
- Vegetation – structure of partial forests, vineyards or hop-gardens (dimension, shape, orientation), structure and specific characteristic of woody plants (spacing between trunks, thickness of trunks measured at height 1,3 m over terrain, vegetation height, sort of plants);
- Soils – a sort of soil (depends on soil granulation), a type of soil at factual weather conditions, a vegetation cover of soils, a roughness of terrain surface;
- Waters – rivers, streams, lakes, dams, etc. (their parameters are width, depth, water flow rate and flow speed, characteristics of banks and of bottom, overall covering of terrain by drainage and mutual position of drainage and other geographical subjects);
- Weather conditions – precipitation, fogs, temperatures, humidity, wind speed, light conditions;
- Settlements – built-up of given territory by settlements, location, structure, shape and orientation in regard of troop movement, construction material, height of buildings, Fire behaviour of buildings;
- Communications – railways (number of tracks, traction – the kind of drive, track gauge, transportation significance) and roads (width or number of traffic lanes, quality of roadway wear course, transportation significance).

The impact of all factors is expressed by „Coefficient of the deceleration,” (abrev. CoD). These factors and their parameters determine 3 levels of Cross-Country Movement – GO, SLOW GO and NO GO. The level called “GO” means the movement without a loss of speed the level “SLOW GO” means partial deceleration of the speed of the movement and the last level “NO GO” signifies that the movement is not possible. These terms are given in [2,3,6,9,10,11].
From the point of view of means of transport (used for movement) following basic types of terrain are determined:
- Terrain passable for full track vehicles;
- Terrain passable for wheeled vehicles;
- Terrain passable for other means of transport;
- Terrain passable for infantry troops.

4. What about Factors, data and methodologies?

4.1 Factors
The goal of the research is the elaboration of the issue of the influence of the surface of the terrain on the movement of vehicles in terms of appropriate data and methods of evaluation. The following factors were examined: the surface of the terrain – this means the soil to a depth of layer influencing the driving characteristics of the vehicle, the elemental slopes, the frequency, size and shapes of the micro-relief and the specific material of surface routes (grass, sand, clay, gravel, concrete, asphalt and more). Properties of the surface were changed due to climatic and meteorological conditions also.

![Diagram](image)

**Figure 2**
There is the schema, which shows the influence of GF together. The bold pointer means a significant relation, the weak pointer means a minor relation. The highlighted GF are now the subject of a research in order to improve the system for Cross-Country Movement

4.2 Data
The scheduling of movement routes may take place in an office, often far from the real battle field. At this point we can use all the available sources as maps, plans, aerial photos, scenes (obtained by RS – Remote sensing of Earth). In real time the soldier often has only an analogue map or evaluation of the supporting documents, which thanks to the devastating effects of war need not be current. The determining of the correct routes of a movement or suitable visible or hidden areas may not be easy. That is why it is calculated with the introduction of the “System of the 21st century Soldier” in the future. This system is developing, verifying and applying in similar versions in many advanced armies all of the world.

4.3 Methodologies
Thanks to the joint consideration of these factors and their standards indicating the degree of continuity, it would be possible to determine the correct route transfers and calculate the time estimates for the movements of various military or ambulance units. Speeds are relevant not only to the type of terrain, but also the type of (military) equipment. To devise a methodology for estimating the speed of movement of the
influence of the terrain surface is necessary to establish a method of obtaining the relevant data (inclination of slopes, the frequency of the micro-relief shapes, types of surface soil conditions, terrain and weather conditions), analyse data, identify ways to evaluate the data and build the algorithms for the calculation of time limits movements. It would be possible to modify the algorithms and other aspects (in terms of security, economic, or the shortest distance).

Several methodologies (in particular assessing the impact of geographical factors on the movement) were created at the Department of Military geography and Meteorology in the course of carrying out the tasks relevant to the specific research [12, 13]. Several effects, which had a majority influence on the ride of vehicles in the terrain, and which were still relatively neglected were evaluated during the research. Influence of micro-relief on the movement of military vehicles was the first [9], the influence of human reactions and of the surrounding environment was the second. New approaches for a comprehensive evaluation of the operating factors and their parameters, it has also been described in some articles [14, 15].

5. New approaches and methods of terrain testing

Some earlier models (Micro-relief – Matlab and 3D Terrain [2, 4]) have not been tested in the field, because they were based on the cartometric investigation, mathematical modelling of the terrain and the subsequent simulation of rides in it. The tests directly in the field are necessary for verifying the methodologies referred to above. Times passes of different types of vehicles on different surfaces were measured, profiles of routes were targeted and other characteristics of the individual spaces by different methods (penetry-metric measurement, sampling the soil samples...) were detected.

The use of environmental variability and the typical characteristics of each type of terrain with regard to the availability of these spaces, as well as on the available types of military vehicles is most important when testing the polygons are drawn. Straight and sloping spaces, flat and rough were tested. The surfaces of a grassy, rocky, sandy, clay, asphalt and snowy were investigated. For the preparation and implementation of these tests a large number of calls with the appropriate personnel is necessary and ensuring these areas is not easy. It is possible to use different methods for obtaining and evaluating these data, it is the right to choose the most practical. [16, 17]

Figure 3

On the first picture there is a ploughed field (in summer) as one of the typical terrain in the Czech Republic.

In the middle frame there is vehicle UAZ 469 on the snowy slope of 6.4 degrees inclination. It was not able to overcome a combination of road resistances and had to be pulled up by the second vehicle.

At the bottom there is a tank, that is trying to overcome the 15 degrees slope on sandy terrain. Slope went only with difficulty, unlike the same slope on the clay surface, which came without the problem.
6. New approaches and methods of evaluation data

The result of the research, which takes place in the present, should be used to design a digital interface for collecting, managing, and redistribution of geographic data relevant to a given issue. Documents containing database tactical-technical data of vehicles and their traction diagrams (on whose basis it is possible to define the maximum possible speed attainable on exit or descent of the concrete slopes), detailed geographic data, algorithms for the determination of the coefficient of the slowdown on the basis of the frequency and the size of the micro-relief shapes, the coefficients of a deceleration defined on the basis of adhesive factors for the main types of surfaces and the coefficients of deceleration determined on the basis of meteorological characteristics would have been necessary for the new information system. These coefficients slowdown associated with each field types, however, interact and, therefore, it is not easy to quantify the impact of elementary.

An overview of the technologies, methodologies and models for determining the speed of the vehicles is given in these articles [18, 19]

7. Conclusion

A brief historical overview showed that the effect of geographical factors totally influenced the history of mankind. It follows the lesson that even world powers failed to defy the natural conditions. But it is obvious the system for evaluation of traffic ability of terrain is necessary.

A comprehensive evaluation of the GF, their parameters, and tactical factors is very difficult, since between those there are many related links. Minor problems emerged while processing data, but these were removed, and the methodology was clarified. Practical verification of calculation algorithms in the field is a necessary part. So far the tests have been carried out in two military areas in the territory of the Czech Republic. The appropriate conditions have been found here (different types of surfaces, various roughness of micro-relief, different slopes, various soil conditions, weather conditions) and the required types of vehicles were available. Final tests are scheduled for Slovakia in Zahorie, where the ideal conditions for the imitation of the ground areas of current war conflict are. A prerequisite for the successful creation of the steps of a complex system is to create a perfect methodology for the acquisition of crucial data and samples from the field, their appropriate evaluation and determination of NO GO areas and an exact determination of the CoD, which is the basis for the time calculation of the movement. In the case of the optimization of routes based on different criteria than the search for the quickest path it is necessary to evaluate the potential route of the value corresponding to a certain criterion (safety, distance, economic costs, etc.).

Today, it is still necessary to consider the question of data sources, but it may not be needed to address in the future. Even the area unsuitable for a direct mapping (for geographical, political, or other reasons) will be mapped in detail thanks to noncontact methods. It is assumed that the application of the results of the field tests, which have not been carried out in such a large scale, will be significant.
References


