Decision-Making Process with Respect to the Reliability of Geo-Database

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Abstract. The aim of this paper is to propose a method that would focus on data and spatial information precision and reliability evaluation. The resulting characteristics of data reliability can be applied in various command and control systems. The method to contribute to increase the quality of decision-making process is proposed. Finally, the case scenario is focused on an intervention of a fire rescue unit and presents the proposal for the use of the system in practice.

Keywords: reliability, decision-making process, mathematical modeling, spatial data, GIS, quality assessment, utility value.

1 Introduction

Command and control systems used in various branches of rescue systems use digital geographic data and information increasingly more often. Geographic data are collected from various sources with the use of various technologies. It results into position and thematic properties inhomogeneity. In spite of this situation, data are stored and used in a common spatial database or they are used for various kinds of spatial analyses. Obtained information can be applied in a decision-making process. Precision and reliability of such information can significantly influence the final solution.

The aim of exploiting geographical data is to accelerate decision-making processes and to optimize deployment of forces and resources. In case of fire and rescue service, it is the elimination of consequences of technical and environmental disasters.

However for correct decision-making it is necessary to know the complex characteristics of geographical data in relation to the task that is being solved so that the reliability of background analyses for decision-making was clear.

By implementing the methods of value analysis and mathematical modeling it is possible to create an assessment system of spatial data complex usability. Based on

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input characteristics of the used spatial data and databases, quality characteristics and their changes can be calculated with the help of analytical methods. By comparing costs necessary for different variants of enhancement or for an adjustment of database quality it is possible to optimize both the total usability and the costs securing the required data quality.

2 Possibilities of Assessment of Digital Geoinformation Quality

Each product including DGI has to be made for the specific user and only his satisfaction with the product is the final criterion for quality of this product evaluation. Usability as an expression for a product's potential to accomplish the goal of the user is often mentioned term. Usability can be described as results of technical quality parameters evaluation added with textual remarks related to customer requirements. The other approach is to apply some system which enables to combine different possibilities of expression of quality parameters. The application of the Value Analysis Theory (VAT) (Miles, 1989) is one of possibilities.

Five essential criteria imply from DGI quality review. Their assessment gives the baseline for relatively reliable determination of each product utility value (Talhofer & Hofmann, 2009). Each of the criteria is mathematically assessable through independent tests and can be described as a quality parameter. In the next table (Table 1) there is a list of main used criteria. The whole criteria are in (Talhofer, Hoskova-Mayerova, & Hofmann, 2012).

Table 1. List of the main criteria for the spatial geodatabase utility value evaluation

Main criteria	Main criteria characteristics
Data model content – k_1	Complexity of conceptual landscape model and compliance of required resolution of geometric and thematic data
Technical functionality – k_2	Transparency of data sources and methods for secondary data derivation, position accuracy, thematic accuracy, logical consistency, and data completeness
Database timeliness – k_3	Degree of adherence geographic data to the time changes in the landscape
Landscape importance – k_4	Value of inverse distance to objects of interest
Techniques of application and safety – k_5	Data standardization, independency on application software, data protection

2.1 Assessment Function

The product or a part of the product resultant function utility degree may be assessed based on the above mentioned criteria using a suitable aggregation function (Talhofer, Hoskova-Mayerova, & Hofmann, 2012), (Talhofer, Hoskova, Hofmann, & Kratochvil, 2009).

$$F = p_3 k_3 p_4 k_4 (p_1 k_1 + p_2 k_2 + p_5 k_5) \quad (1)$$

The chosen form of the aggregation function concerns also the case the user gets data on an area beyond his interest or data obsolete so that their use could seriously affect or even disable the DGI functions. The weight of each criterion is marked as p_i, where $i = 1, \ldots, 5$. The mentioned aggregation function proves the product status at the questioned instant and its utility rate. It is applicable also to experiments to find the ways of how to increase product utility at minimum cost increment.

2.2 Individual Benefit Cost Assessment

Organizations, such as the Geographic Service of the Army of the Czech Republic or the Czech Office for Surveying, Mapping, and Cadastre, are usually responsible for DGI databases development continuously covering all the Czech Republic area or some parts of the World. Digital Landscape Model (DLM25 or DMU25 in the Czech language), Multinational Geospatial Co-Production Program (MGCP) or Vector Map Level 1 (VMap1) can be mentioned as examples from military branch (for more see (Talhofer, Hoskova-Mayerova, & Hofmann, 2012), (Talhofer & Hofmann, 2009)).

The DGI are usually developed and maintained by individual partial components of the complete database, such as save units, measurement units, map sheets, etc. Therefore, it is quite a good idea to assess their utility value in the above-described system within the established storing units introducing *individual benefit value*. Similarly, the individual benefit value can be applied for the selected part of master databases from given *area of interest* which is used for certain task.

When assessing database utility, it is useful to define *ideal quality level* at first. The ideal level is used as a *comparison standard* to express each criterion compliance level. Using the comparison standard the individual criteria compliance level and consequently aggregate utility may be assessed.

The compliance level of each individual criterion $u_{n,s}$ is given as $u_{n,s} = k_s / k_s^*$, where k_s is for the value of s^{th} criterion compliance and k_s^* is for the level of compliance of s^{th} criterion or its group criterion of the comparison standard.

Thus the aggregate individual benefit value (*individual functionality* – U_n) of the n^{th} save unit is defined by the aggregation function of the some type as (1). Therefore:

$$U_n = p_3 u_{n,3} p_4 u_{n,4} (p_1 u_{n,1} + p_2 u_{n,2} + p_5 u_{n,5}) \tag{2}$$

The individual criteria weights are identical with the weights in database utility value calculation.

Particular criteria usually consist of several sub criteria (see Table 1). The authors took 20 criteria into their consideration; hence the equation for calculation the aggregate individual utility value is therefore a function of 20 variables that characterize the levels of compliance for each individual criterion.

Any modification of selected criterion has an impact on the value of U^n. Individual variables are independent one to another, so the derivation of the function can model the changed utility values or individual utility values.

$$dU = \frac{dU_n}{du_{n,i}} \tag{3}$$

where $i = 1,\ldots, 5$, $n = 1,\ldots, N,$ and N is number of all saved units in the database.

Determination of dU value is thus feasible in two ways regarding the desired information structure. When assessing *individual variables effects* on the individual functionality value, while the other variables keep constant values, it is necessary to differentiate U function as follows:

$$dU = \frac{dU_n}{du_{n,i}} \frac{du_{n,i}}{dx} \tag{4}$$

where x is one of the 20 mentioned variables.

In practice, however, such situations may arise that multiple factors may change at the same time. For example the technical quality of database changes in all its parameters—the secondary data derivation methods will improve location and attribute accuracy and the data integrity will increase, and moreover, the data stored in a geodatabase accessible to all authorized users. In this database the data are maintained properly with respect to all topologic, thematic, and time relations. In such a case it is suitable to define dU value as a total differential of all variables describing the modified factors. For more details see (,).

Database functionality degree is comparable to the cost necessary for provisions—direct used material, wages, other expenses (HW, SW, cost of amortization, tax and social payments, etc.), research and development cost, overhead cost, and others. One example of the whole expenses for up-dating of one map sheet (area of it is 64 km^2) is in the next table (Table 2). Listed expenses are valid for operations doing in the conditions of the Military Geographic and Meteorological Institute of the Czech Armed Forces (MGMI).

Functionality and cost imply *the relative cost efficiency (RCE)* calculated as follows:

$$RCE = \frac{F}{\sum_{i=1}^{n} E_i}, \qquad i = 1, \ldots, N \tag{5}$$

In this formula F is the aggregation function calculated by (1). Similarly to individual utility value, it is possible to consider the impact of particular variables of expenses E_i on final RCE. The goal is to find such solution as the functionality will be maximized and the expenses will be minimized.

Table 2. Expenses for up-dating one sheet of digital geodatabase DMU25

Stage	Working operation	Norm in hours	Direct wage in CZK	Direct materi-al in CZK	Social found in CZK	Total direct costs in CZK	Production overheads in CZK	Administrative expenses in CZK	Total expenses in CZK
Preliminary works	Documentary establishment	0,5	60	-	22	81	146	159	408
	Sources collection and preparing	16,0	1919	-	706	2611	4698	5099	13114
	Basic editorial preparation	12,0	1 432	-	530	1962	3524	3825	9841
	Data structure preparation	1,0	152	-	56	208	374	406	1044
Database up-dating	Topographic evaluation	178,8	25081	1335	9280	35696	61700	66967	173643
	Revision	71,3	10001	1	3700	13703	24604	26704	68711
	Photogrammetric evaluation	13,8	1784	-	660	2444	4390	4765	12259
	Revision	0,6	77	-	28	106	190	207	531
	Check-in in the field preparing	2,5	350	-	129	480	862	936	2407
	Check-in in the field	12,5	1753	-	648	2402	4313	4681	12044
	Data completion	20,0	2805	1	1038	3844	6901	7490	19273
	Final revision of up-dating	25,0	3506	-	1297	4804	8626	9363	24090
	Control drawing	1,0	140	2	51	194	345	374	964
	General revision	2,0	280	-	103	384	690	749	1926
	Export of data	0,5	76	-	28	104	187	203	522
Database management	Data storage in the database	1,0	152	-	56	208	374	406	1044
Total		358,5							341821

3 Usage of Value Analyses in the Decision–Making Process

The DGI benefit cost assessment including individual benefit cost is a task for a data manager or a geographer-analyst who is responsible to provide a demanding project. The system enables him to consider which quality parameters are possible to improve in given time, with given technological conditions, with given sources, with given co-workers, etc.

The system of spatial data quality evaluation and application of the VAT should help to answer most of the previous questions.

Frequent task in decision-making processes is based on judging various options of solutions of the given problem. The options are calculated with the help of spatial analyses, in which technical and technological factors are taken into account, for instance the performance of technical resources, their usability in terrain, questions of co-operation of the individual units, etc. Spatial analyses work with available data, yet it is always necessary to take into account also the quality of the data. This can significantly influence the whole decision-making process.

Geographical information systems used in management systems usually work with a certain version of spatial database that has a certain level of quality which is projected into the quality of the solution of the resulted analysis. It is not possible to approach the solution of analysis as a final result but it is necessary to take into consideration also a certain level of vagueness (Hoskova & Cristea, 2010). The vagueness level of the result is then given to the manager either verbally or with the help of visualization (Kubíček & Šašinka, 2011). In any case, it is essential to take into account the vagueness level in the final phase of decision-making.

Decreasing the vagueness level of the resulted analysis is possible, e.g., by improvement of quality of the database which is, however, a time-consuming process.

The complete system of relations between a geographical database and a decision-making process is described in a case study in the following chapter.

4 Case Study

In order to verify the VAT methodology the task of *Cross Country Movement* (CCM) was chosen as an example. CCM can be solved as a common problem or with consideration of certain types of vehicles. The detailed theory of CCM is explained in (Rybansky & Vala, Relief impact on transport, 2010) and (Rybansky, 2009). This publication is actually related to the questions of military technology, however, with regard to the fact that it is a study describing the interaction of chassis of vehicles and terrain; the conclusions are valid also for the rescue technology used by the fire and rescue service.

The case study was solved in two phases. In the first phase, the relation between database quality and reliability of the decision-making process was judged. In the second phase, a database of higher quality was used and its qualitative characteristics in relation to more types of emergency vehicles were examined.

The solution can offer to the officer in duty not only one possibility, but the variants from which he/she can choose according to his/her intentions and the current situation in the given area.

4.1 Cross Country Movement

The main goal of CCM is to evaluate the impact of geographic conditions on a movement of vehicles in terrain. For the purpose of classification and qualification of geographic factors of CCM, it is necessary to determine:

- particular degrees of CCM
- typology of terrain practicability by kind of military (civilian) vehicles
- geographic factors and features with significant impact on CCM

As a result of the geographic factors impact evaluation we get three degrees of CCM: passable terrain, passable terrain with restrictions, or impassable terrain.

The impact of geographic factor can be evaluated as a *coefficient of deceleration* 'C_i' from the scale of 0 to 1. The coefficient of deceleration shows the real (simulated) speed of vehicle v in the landscape in the confrontation with the maximum speed of given vehicle v_{max}. The impact of the whole n geographic factors can be expressed by the formula:

$$v = v_{\max} \prod_{i=1}^{n} C_i, \qquad n = 1, \ldots, N. \tag{6}$$

The main coefficients of deceleration are listed in the next table.

Table 3. Main coefficients of deceleration

Basic coefficient	Geographic signification and impact
C_1	Terrain relief (gradient of terrain relief and micro relief shapes)
C_2	Vegetation cover
C_3	Soils and soil cover
C_4	Weather and climate
C_5	Hydrology
C_6	Build-up area
C_7	Road network

Each coefficient consists of several subcoefficients. For example decisive effect on the coefficient of deceleration of vehicle movement by effect of soil type C_3 have such factors as the sort of soil (depends on soil granulation); a type of soil at factual weather conditions, which affects above all the adhesive force and rolling friction of vehicle wheels/tracks; the vegetation cover of soil; the roughness of terrain surface. These factors have decisive effect, which is given by relation:

$$C_3 = \prod_{i=1}^{n} C_{3i}, i = 1,2,3$$

where:

- C_{31} is coefficient of deceleration by effect of soil type (sort) factor,
- C_{32} is coefficient of deceleration by effect of factor of vegetation cover,
- C_{33} is coefficient of deceleration by effect of surface roughness factor.

For given vehicle (its technical properties) the values of deceleration coefficients are counted from ascertained properties of geographic objects stored in the spatial geodatabase. Using formula (6) it is possible to create a cost map in which the value of each pixel is the final (modeled) speed. The *cost map* can be used as a source for calculation of the fastest path, the most reliable path etc.

4.2 First Phase of the Case Study

In the first phase of the case study, dependence of the results of analyses on the quality of used data and the way of interpretation of the results of analyses in decision-making processes were examined. The aim was to find an optimized path for a terrain vehicle TATRA 815 in free terrain (Tatra, 2010). The complete procedure is described in (Talhofer, Hofmann, Hošková-Mayerová, & Kubíček, 2011). Only results and main conclusions are stated in the following text.

The master DGI database is usually used as a base for spatial data analyses. The national or international databases as DMU25, VMAP1, or MGCP are very detailed, carefully maintained, and used in many applications. But nobody can suppose that those databases contain all information he could need.

The task of CCM solution could require more information that is available in the master database. Geographer-analyst has to consider which information and in what quality can he/she obtain from the master database. E.g., all forests in the area of interest are necessary to be selected for mentioned C_{2i} coefficients. Further he has to find out all their properties and their accuracy or count how many characteristics are missing. The next step is the individual functionality value of the given part of master database evaluation. In the next picture (Fig. 1) there is a basic scheme of the database for CCM creation.

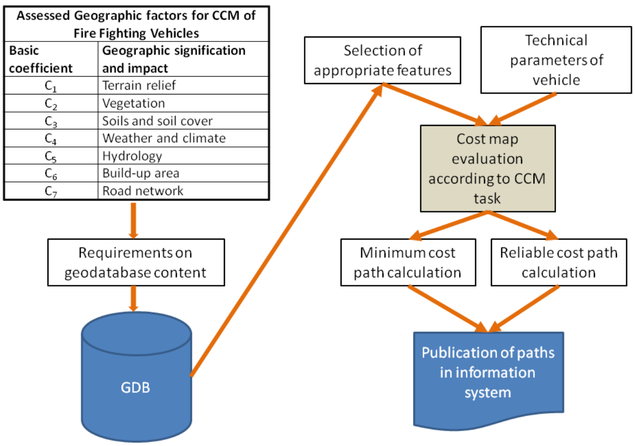

Fig. 1. Spatial analyses without database quality evaluation

Not all attributes are available within the used thematic spatial databases. So far the incompleteness of attributes has been omitted. Thus, the real state-of-the-art has not been taken into account and the resulting CCM path has been considered as 'certain'. One of the possibilities to make the resulting path closer to reality is to take the data attribute incompleteness into account and inform the decision maker (commander) about the uncertain parts of the path.

Two variants of the DMU25 database were utilized for the case study. The feature properties were defined according to the *Feature Attribute Coding Catalogue* (FACC) adapted as *Catalogue of the Topographic Objects* (CTO) (MTI, 2005) in the first variant updated in 2005. The 4th edition of CTO was transformed in accordance with the *DGIWG Feature Data Dictionary* (DGIWG-500, 2010) in 2010 and a transformed edition (updated in 2010) was used in the second variant (MoD-GeoS, 2010).

The smaller personal database was created in the area of Brno of the size approximately 400 km^2 and all objects necessary for CCM evaluating were selected from DMU25 databases of both variants. The individual utility value was counted for both variants. On the base of statistical analysis 12.65% objects have problems mainly due to incomplete attributes in the first variant of DMU25 while 3.45% objects have similar problems in the second one. The time difference is 5 years between both variants. Hence, the individual utility value was calculated using the formula (3) as 0.6887 for the 2005 variant and 0.8825 for the 2010 variant. The ideal quality level is 1.0068. Both variants were used for CCM of TATRA 815 evaluation.

ArcGIS 9.3 was used for all calculations and analyses. In the next figures there are the main results – cost maps. The cost of each pixel, which is the simulated speed of vehicle, is symbolized in the gray scale where a darker tone signifies higher costs, higher speed in this case.

The minimum cost paths were evaluated using both cost maps and the same process created in ModelBuilder were applied. The results are shown in the next figures.

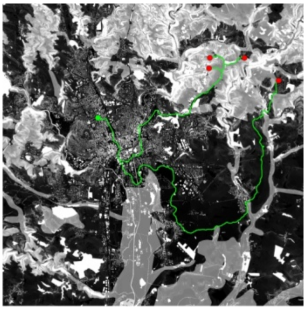

Fig. 2. The minimum cost paths in CM of 2005 version. The initial point is green, the destinations are red

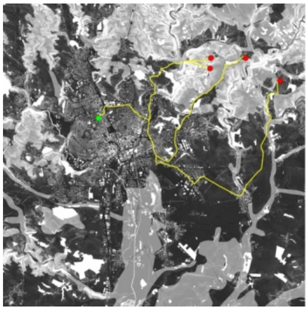

Fig. 3. The minimum cost paths in CM of 2010 version. The initial point is green, the destinations are red

The comparison of both results presented over the topographic situation is shown in the next picture (Fig. 4).

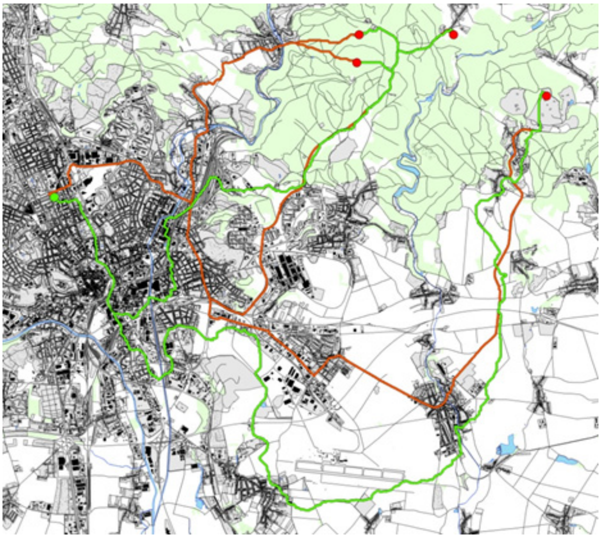

Fig. 4. Comparison of two variants of minimum cost paths. Red ones correspond to 2005 version and the green ones to 2010 version.

The obtained results proved that the results of spatial analyses are highly dependent on overall quality of digital spatial data. Relatively small changes in the database can cause significant differences in received results.

4.3 Model Conditions of the Second Phase of the Case STUDY

Conditions for the solution of the second phase of the case study came from the established operational procedures that are used in actions of fire and rescue service units. The aim of this phase was to show possibilities of using geographical data to optimize decision-making, i.e., reduction of time before the action is commenced, optimization of engaging of equipment and human resources, and last but not least cost-saving of financial sources.

For the solution itself the following model task was chosen:

Let's have an averagely equipped fire and rescue service station, in which these vehicles are available:

- one road fire fighting vehicle with the tank capacity of 9,000 liters,
- one terrain fire fighting vehicle with the tank capacity of 9,000 liters,
- one terrain fire fighting vehicle with the tank capacity of 3,000 liters,
- one road transport vehicle (transport car, hoses, and pump)

At this station a fire in relatively inaccessible terrain is reported. The intensity of the fire is so high that it is presumed that at least 20,000 liters of water will be needed to extinguish it. There is no hydrant available in that locality; what is more, weather conditions make the use of helicopter impossible. Operational officer must command the vehicles to go in a way so that he/she optimized time and exploitation of the available fire fighting vehicles. The task is to decide to engage specific Technical parameters of Fire Fighting Vehicles

After consultation with officers in Fire Brigade in Brno, the following vehicles were chosen for the case study (see Table 4). Technical details were obtained from websites of producers (THT, 2012) and specified also in Brno Fire Brigade.

Table 4. The technical characteristics of available Fire Fighting Vehicles

Vehicle number	1	2	3	4	5
Parameter	Tatra T815-731R32 6x6	Mercedes-Benz Unimog 4x4	Mercedes-Benz Atego 1329 AF 4x4	Mercedes-Benz Actros 3355 A 45 6x6	Renault Midlum
Length (m)	9,19	6,70	7,60	10,07	6,42
With (m)	2,55	2,34	2,55	2,55	2,37
High (m)	2,85	3,20	3,33	3,76	3,05
Maximum climbing capability	36°	45°	30°	20°	15°
Maximum climbing capability up to rigid step (m)	0,5	0,5	0,5	0,5	0,3
Maximum width of trench (m)	0,9	0,5	0,5	0,9	0,3
Maximum road speed (kph)	100	90	105	100	90
Maximum depth of wade (m)	1,2	1,2	0,5	0,5	0,5
Water tank capacity (liters)	9000	3200	1200	9500	0

4.4 The Procedure of Solution

As the base for the solution, database of the same locality as in the first phase of the case study was used, only in version of 2010. According to the parameters of the solved CCM task and technical characteristics of the fire fighting vehicles, requirements of its contents were derived, which were later used to calculate traffic ability in the terrain.

Based on the stated requirements, appropriate data of the geo-database were taken and a cost map was calculated from the given space. With the help of the cost map for individual vehicles, possible variants of path from the fire station to the action point were calculated. Such a solution is possible to be made for various emergency vehicles, or more precisely for vehicles which are available and suitable for the given kind of action. The procedure of solution was once again processed in the environment of ArcGIS 10 using Model Builder tool, in which the input parameters of vehicles may be changed.

Results can be visualized on the operational officer's screen who—according to the calculated paths and their parameters (distance, travel time, possibility to come directly to the place of fire, or more precisely the necessity to include time to spread hoses from place where the given vehicles can go to in case the traffic ability is limited) and with inclusion of water tanks capacity of vehicle—has to decide which vehicle or vehicles will be sent to an action.

4.5 Procedure of Calculation

According to CCM theory (Rybansky & Vala, Relief impact on transport, 2010), individual coefficients of deceleration C_1 to C_7 were calculated, based on which complete cost maps for individual types of vehicles were calculated. The simulated speed of the given vehicle in the given pixel was once again taken as a pixel cost in the cost map. In the individual cost maps the cheapest—in this case the fastest paths—from the fire brigade station to the place of fire were calculated. The place of fire was purposely set away from settlements in free terrain and away from communications. Also, time of arrival to the place of fire for individual vehicles was calculated and the possibility for vehicles to go through the free terrain to the place of fire was checked.

The complete calculation was once again—based on the mathematical model—programmed in the environment ModelBuilder of ArcGIS system. In the picture (Fig. 5) model of calculation of coefficient of deceleration of maximum speed C_3 is shown and there is also stated a formal mathematical description of the calculation.

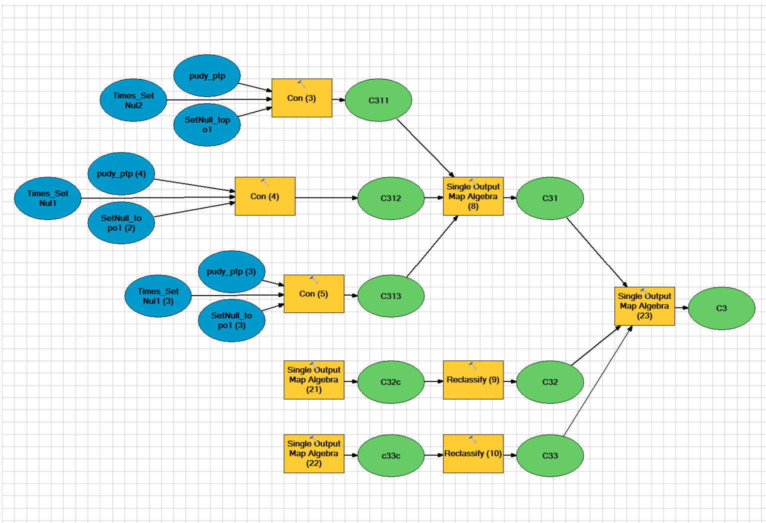

Fig. 5. Example of data procedure model in ArcGIS ModelBuilder

4.6 Reached Results

Reached results of calculation of the individual routes are collectively stated in the chart (Table 5). Although the place of action was purposely chosen to be away from other communications, the differences of routes with the individual vehicles were smaller than we had expected. Apparently, the reason is the fact that the studied location was chosen in an urbanized area with a sufficient number of hard communications and technical parameters of the chosen emergency vehicles enable reasonable movement also in the free terrain unless they get into extreme conditions. The authors suggest continuing in this case study also with phase three, in which less urbanized area will be chosen. This will enable to compare the reached results.

Using our results, the optimization of decisions of the operational officer would concern only the composition of the sent vehicles. Based on the calculations, the operational officer gets information that all vehicles that are available are able to arrive to the place of fire practically at the same time. He/she can then choose the variant that he/she sends simultaneously vehicles 1, 2, and 4; or 1, 3, and 4.

Also average speeds of all vehicles were calculated. Basically, they correspond to the experience of members of fire and rescue brigade from real action.

Table 5. Results of calculation of the individual routes

Vehicle number	**1**	**2**	**3**	**4**	**5**
Parameter	Tatra T815-731R32 6x6	Mercedes-Benz Unimog 4x4	Mercedes-Benz Atego 1329 AF 4x4	Mercedes-Benz Actros 3355 A 45 6x6	Renault Midlum
Total distance (km)			11. 2		
Time (min)	12.0	13.6	12.0	11.4	13.6
Calculated average speed (kph)	56	51	56	61	51
Water tank capacity (liters)	9000	3200	1200	9500	0
Number of ways needed	3	7	17	3	1*

* Transport lorry - for transportation of hoses and portable motorized fire engine

Examples of cost maps and calculated routes are shown in the following pictures.

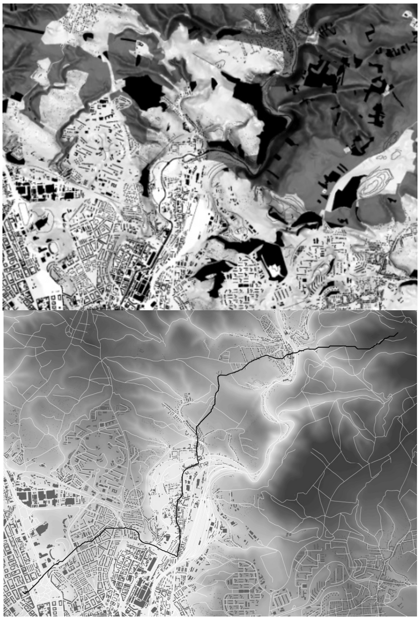

Fig. 6. Cost map and path example

Fig. 7. Cost map calculation example

5 Discussion and Conclusion

The first phase of the case study has demonstrated a strong relationship between quality data and the results of spatial analysis. Likewise, it has pointed to the problem of defining quality.

In the second phase of the study, the resulted paths gained in the described spatial analysis are basically the same for all tested vehicles. This case frequently happens in reality, especially in an urbanized locality. Then the results of the geographical analyses are used in the decision-making process as one of the bases for optimization of engaging forces and sources. Nevertheless, it is not possible to underestimate also these procedures as there can happen a situation when it is necessary to send vehicles to a complicated terrain, and the operational officer must be able to correctly interpret occasional different routes of the individual emergency vehicles which are given not only by their technical parameters but also by the quality of used data, and to optimally decide accordingly.

Values of technical parameters of vehicles under consideration were used for all calculations. From the experience of members of fire departments, however, it is clear that the real reached average speed of vehicles especially in urbanized areas is usually half with regard to their technical specifications. We could not take this thought into our consideration so far. However, in the further development we will take into account level I of traffic density related to the time of day when the routes will be calculated. The level of traffic density will be taken as another coefficient of deceleration.

For both cases were developed formalized procedures, the samples are in the preceding text. This procedure is applicable to the whole territory of the Czech Republic.

Models for support of decision-making processes are generally always multi-criterial and their success depends both on the correct setting of count and structures of used criteria as well as on the reliability of real values that are being worked with at the particular moment. As the results of the procedure described in this article as well as scientific studies and procedures (e.g., (Condorelli & Mussumeci, 2010), (Linlin, Lijun, Jianming, Chao, & Xiangpei, 2012)) prove, models can be very useful in the complete decision-making process. However, it is necessary to approach critically their results with respect to the data reliability and to the level of the complete model complexity.

In the future a real-time risk analysis approach which dynamically evaluates the risk at discrete time points during the whole transportation process will be considered.

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