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Comparison of Transport Problems in Process of Evacuation

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Abstract

Current global environment affects formation of crisis events, which have fluctuant nature nowadays. In order to effectively protect human life, health, and property crisis managers should use new methods, techniques and tools. It is necessary to solve crisis events and give more attention to prevent crisis events. Crisis managers should analyze new systematic approaches, which are used to support of decision-making processes. The aim of the article is to describe selected methods, which may be used in process of evacuation planning. The article highlights possibilities of use transport problems in process of evacuation planning. Selected decision-making processes in the field of evacuation transport are analyzed in this article.

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Keywords: crisis management, crisis events, evacuation, transport problems, decision-making processes

1. Introduction

Crisis events have specific status in the crisis management system. Natural disasters may affect people and have negative effects on territory. Consequences of natural disasters have negative impacts on people, environment, material and cultural value in threatened territory. They may also affects a transportation network which plays a critical role in delivering disaster relief, or facilitating mass evacuations (Titko 2016). The functionality and relative stability of the Slovak economy may be disrupted by extensive natural disasters. Reaction to natural disasters, especially evacuation, is important to minimize negative consequences. Using decision-making processes are current trend not only at the central government level but in local government level, too. The current increase and severity of natural

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disasters requires a change of access to disaster management on the part of the state as well as on the part of the population.

2. Theoretical background and actual status of the crisis management

According to Šimák (2016), a crisis events are all remarkable events, emergencies, crisis situations, crises and state of crisis that may occur in different environment in social, technical and natural environments. Despite the versatility of this term, it is not one of the often used ones.

Ishikawa (2006) consider that crisis events may caused by natural factors, which are related as Theory of Chaos. An example of Theory of Chaos is the butterfly effect which points to moving the wings of a butterfly on one side of the planet can cause a hurricane on the other side planet over time. In essence, there are relatively non-serious events that can trigger crisis events.

According to Badiru (2014), a crisis situation is every situation that threatens or can endanger human health or damage property.

State of crisis is defined as the legal status that is declared by a competent public authority in a particular territory to solution of crisis event, and is directly dependent on its scale and nature (Šimák 2005).

The extraordinary event is significant, difficult predictable and defined incident that has caused the disruption of the stability of the system and processes with consequences for the lives and health of persons, tangible and cultural assets or the environment. Extraordinary events are divided into natural disasters, technological disasters, catastrophes and terrorist attacks (Šimák 2005). In accordance with the Act no. 355/2007 about the protection, promotion and development of public health and on the amendment and supplementation of some laws have been supplemented with a threat to public health.

As Šimák (2005) consider, natural disaster as event in which undesirable release of accumulated energies or materials. They can cause dangerously and they have devastating factors on life, health and property.

The Act no. 7/2010 about flood protection describes flood as a natural event, during which water temporarily territory that is not usually occupied by water.

Crisis management introduce all activities that are related to the crisis management tasks, from the preparation to solving the crisis events (Rektořík 2004).

According to Drenman (2015), crisis plan is a document that includes the procedures, processes and activities, which are needed to respond to the crisis events. Crisis plans serve to guide organization staff, resource efficiency and communication, with emphasis on crisis communication.

Neubauerová (2010) characterizes the local government level as the budgetary organization of the state, which is connected to the budget of the Ministry of the Interior of the Slovak Republic through financial relations. Local government level authorities represent a hierarchically lower level of government level. They consist of bodies that are directly subordinated to a central government.

According to the Act no. 180/2013 about organization of local government level, district office is a local government authority and an ancillary organization of the Ministry of the Interior of the Slovak Republic. Crisis staff and security council are established by district office, where it is necessary.

According to the Constitutional Act no. 227/2002 about state security in times of war, war status, exceptional status and emergency status, as amended, the Security Council evaluates the security situation and prepares proposals for measures to safeguard safety and imposes obligations on other state competent authorities or legal and natural persons within their territorial competence.

The status, establishment and composition of crisis staffs are described in the Act no. 387/2002 about the state management in crisis situations outside times of war and war status. Crisis staffs are not established but are created by actual situation at different levels (state, regional, district and local). Commisions for the solution of crisis events are part of crisis staff.

The district office processes the analysis of the territory. Novák (2005) define the analysis of the territory as a document which describe a particular territory on the base of predetermined and defined criteria. The analysis of the territory is made in the form of a set of documents and is composed of a written and a graphical part.

Evacuation means the removal of endangered persons, animals, or things from a particular territory (Act no. 42/1994).

3. Data and methodology

Aim of this article is optimization of decision-making processes on local government level using methods, which are focused on solving transport problems. Authors have analyzed and optimized information flows in the process of crisis events solution on local government level.

The methodology, which was used in this article is based on the analysis of crisis management system at local government level be interview with representatives of district offices in the Žilina region and application of methods for transport problems. Transport problems are specific part of stochastic methods of systematic and operational analysis. There are different methods of transport problems solution, for example Vogel's Approximation Method (VAM), Modified Distribution Method (MODI), North West Corner Method (NWC) and Stepping Stone Method (SS). Authors applied and compared all this methods on concrete territory which may be threatened by floods.

Mathematical model of transport problems may be solved through simplex algorithm. The basis is a special algorithm whose theoretical derivation is based on the solution of the dual task (dual asymetric task) to the original model of the transport problem. The general framework procedure is formally identical to the simplex algorithm, but the details in each step are fundamentally different. (Máca 2002).

According to Leitner [2002], the basic scheme of the transport problem solution consists of the following three steps:

1. Obtaining a baseline solution
2. Checking the optimal baseline solution
3. Iteractive calculation until optimum

The mathematical model of a transport problem can be written in a matrix and in a table form (Table 1.).

Table 1. Matrix of rate.
Source: Leitner, 2002.

O/D	D1	...	Dj	...	Dn	a (i)
O1	c (1,1)	...	c (1,j)	...	c (1,n)	a (1)
...	...	...	...	...	...	...
Oi	c (i,1)	...	c (i,j)	...	c (i,n)	a (i)
...	...	...	...	...	...	...
Om	c (n,1)	...	c (m,j)	...	c (m,n)	a (m)
b (j)	b (1)	...	b (j)	...	b (n)	

The uniform material (product of the same properties) is located in m-places the sources O (i) in known quantities a (i). This material is needed to transport to each of the n-points of consumption D (j) in quantities b (j). Transport value (rate) per unit of quantity of the concerned material c (i, j) from all sources to all consumers. Purpose function of the sum of the cost of transporting all material has shape:

$$z = \sum_{i=1}^{m} \sum_{j=1}^{n} x(i, j) * c(i, j) \tag{1}$$

All mentioned stochastic methods of systematic and operational analysis were applying on a specific case study in the field of crisis management in public sector. Case study represents evacuation of certain amount people from concrete place that has been affected by 100-years flood.

Table 2. Input data for next calculations.

Type of flood	100-years flood
Place intended for evacuation	Horelica
Number of evacuees	1 400
Number of evacuation collection places	2
Number of places for evacuees	12
Car brands	Grossway Low Entry (bus)
Average fuel consumption	18,6 litre per 100 kilometres
Cost per 1 liter of diesel	1,23 € (up to December 2018)
Cost per 1 kilometer of ride	0,22878 €
Average gross monthly earnings of bus driver	1 016 €
Average gross daily earnings of bus driver	33,87 €
Food expenditure for 1 bus driver	3,50 € per 1 day
Number of people in 1 bus	50

It is necessary to evacuate 1400 people from Horelica (part of the city of Čadca) for the continuous rise of the Kysuca river level. According to predictions, it can be expected 100-years flood. There was determined 12 places for evacuations where there is no danger to life or property (primary and secondary schools located in short distance from place intended for evacuation). Evacuation collection places are designated O1 (950 evacuees) and O2 (450 evacuees). Places for evacuees are designated D1, D2,…D12 (Table 3.).

Table 3. Places for evacuees.

Place No.	Places for evacuees in Čadca	Capacity
D1	Primary school (Rázusová 2260)	110
D2	Primary school (Komenského 752)	80
D3	Primary school (Podzávoz 2739)	130
D4	Primary school (Štefánika 2007)	200
D5	Primary school (Milošová 477)	90
D6	Primary school (Školská 945)	40
D7	Secondary school (17. novembra 1296)	230
D8	Secondary school (17. novembra 2701)	50
D9	Secondary school (Horná 137)	220
D10	Secondary school (Okružná 693)	70
D11	Secondary school (17. novembra 2579)	80
D12	Secondary school (Horná 136)	100
Overall capacity		1400

All places for evacuees have at least one gym (D4 and D7 have three gyms) and canteens. Places for evacuees may be also school dormitories, which are in Čadca, too.. It is necessary to established expected costs, which are needed to evacuees transport. Table 1 describes the information needed for establishing of vehicles amortisation. It was calculated by online calculator.

Table 4. Calculation of transport costs per 1 evacuee

	Direction from O1 to Dn		Direction from O2 to Dn		Direction from Dn to VF	
Designation	Distance [km]	Amortisation [€]	Distance [km]	Amortisation [€]	Distance [km]	Amortisation [€]
D1	5,2	2,14	6,0	2,47	3,0	1,24
D2	9,0	3,71	9,8	4,04	4,0	1,65
D3	6,9	2,84	7,7	3,17	2,8	1,15
D4	2,8	1,15	3,6	1,48	3,6	1,48
D5	10,3	4,24	11,1	4,57	6,1	2,51
D6	5,2	2,14	6,0	2,47	3,4	1,40
D7	3,7	1,52	4,5	1,85	3,4	1,40
D8	3,6	1,48	4,4	1,81	3,1	1,28
D9	3,3	1,36	4,3	1,77	2,8	1,15
D10	5,5	2,26	6,1	2,51	3,7	1,52
D11	3,4	1,40	4,2	1,73	2,8	1,15
D12	3,3	1,36	4,1	1,69	2,8	1,15

Table 5. Calculation of transport costs per 1 evacuee.

O/D	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	Capacity
O1	0,85	0,89	0,87	0,84	0,92	0,86	0,84	0,84	0,84	0,86	0,84	0,84	950
O2	0,87	0,91	0,88	0,85	0,94	0,87	0,86	0,86	0,85	0,88	0,85	0,85	450
Capacity	110	80	130	200	90	40	230	50	220	70	80	100	1400

Calculation of transport costs per 1 evacuee (Table 5.) are also input data for software MATLAB which authors used for the calculations. It was finding the lowest costs for transport evacuees per MATLAB, too. Real input data inserted to software MATLAB was rounded to 4 decimal places, but data are rounded to 4 decimal places for the scope in Table 5. Software MATLAB combines a desktop environment tuned for iterative analysis and design processes with a programming language that expresses matrix and array mathematics directly.

4. Results and discussion

First, it was necessary establish matrix of rate with 3 rows and 12 columns. Subsequently, we input the data that are known (e.g. costs for transport evacuees and transport limitations representing capacity place for evacuees) to matrix of rate. After inputting data, the software MATLAB generates not only the result but also the whole process of the crisis events solution. Due to are presented scope of this article only results of transport problem.

```
Elapsed time is 0.019656 seconds.
Total cost of Non-degeneracy VAM
   1.2065e+03

Occupied matrix of VAM
     0    10   130     0    90    40   230    50   220     0    80   100
   110    70     0   200     0     0     0     0     0    70     0     0
```

Fig. 1. Results of transport problem with using Vogel's Approximation Method (VAM).

Figure 1 shows an evacuation plan of transport evacuees from evacuation places to places for evacuees with using Vogel's Approximation Method. This method is one of the simplest methods that give fairly accurate results, approaching to a great extent optimally. The box in the table is not selected according to the rate. Account must also be taken of the difference between the smallest rates in rows and columns in the table. According results in Figure 1, evacuees is possible to optimal deploy as follow: 950 evacuees would be relocated from evacuation collection places O1 to places for evacuees D2 (10 evacuees), D3 (130 evacuees), D5 (90 evacuees), D6 (40 evacuees), D7 (230 evacuees), D8 (50 evacuees), D9 (220 evacuees), D11 (80 evacuees), D12 (100 evacuees). 450 evacuees would be relocated from evacuation collection places O2 to places for evacuees D1 (110 evacuees), D2 (70 evacuees), D4 (200 evacuees), D10 (70 evacuees).

```
Elapsed time is 0.173212 seconds.
Total cost of MODI
   1.2065e+03

Occupied metrix of MODI
     0    10   130     0    90    40   230    50   220     0    80   100
   110    70     0   200     0     0     0     0     0    70     0     0
```

Fig. 2. Results of transport problem with using Modified Distribution Method (MODI).

In Figure 2 we can see an evacuation plan of transport of evacuees from evacuation collection places to places for evacuees with using Modified Distribution Method. Unoccupied boxes is easier evaluating through this method with the corrective degeneracy problem. This method is a more sophisticated method that requires the initial solution. The convenience criteria for the MODI are determined using rows and column numbers (dual variables). Results of transport problem with using Modified Distribution Method are same as results of transport problem using Vogel's Approximation Method in Figure 1. Process of calculation of results took 9 times longer than in the case of use Vogel's Approximation Method.

```
Occupied matrix of NWC
   110    80   130   200    90    40   230    50    20     0     0     0
     0     0     0     0     0     0     0     0   200    70    80   100
     0     0     0     0     0     0     0     0     0     0     0     0

Non-degeneracy problem
Total cost
   1.2068e+03
```

Fig. 3. Results of transport problem with using North West Corner Method (NWC).

Figure 3 shows an evacuation plan of transport of evacuees from evacuation collection places to places for evacuees with using North West Corner Method. This method is the starting method of transport problems. The solution which was achieved by this method is acceptable, but it is not optimal and definitive. The principle is in the table of transport relations. The box in the table are filled from the upper left corner to the lower right corner. According to results in Figure 3, evacuees are possible to optimal deploy as follows: 950 evacuees would be relocated from evacuation collection places O1 to places for evacuees D1 (110 evacuees), D2 (80 evacuees), D3 (130 evacuees), D4 (200 evacuees), D5 (90 evacuees), D6 (40 evacuees), D7 (230 evacuees), D8 (50 evacuees), D9 (20 evacuees). 450 evacuees would be relocated from evacuation collection places O2 to places for evacuees D9 (200 evacuees), D10 (70 evacuees), D11 (80 evacuees), D12 (100 evacuees).

```
Occupied matrix of SS
     0    80   130   200    90    40   230    50   130     0     0     0
   110     0     0     0     0     0     0     0    90    70    80   100

Total cost
   1.1956e+03
```

Fig. 4. Results of transport problem with using Stepping Stone Method (SS).

In Figure 4 is illustrated an evacuation plan of transport of evacuees from evacuation collection places to places for evacuees with using Stepping Stone Method. This method was used to check the optimality of the initial feasible solution determined by using any of the North West Corner method or Vogel's Approximation Method. Stepping Stone Method is a procedure for finding the potential of any non-basic variables (empty cells) in terms of the objective function. This method determine that what effect on the transport cost would be in case one unit is assigned to the empty cell. Results of transport problem using Stepping Stone Method are almost same as results of transport problem with using North West Corner Method in Figure 3. 130 evacuees from evacuation collection places O1 would be relocated to places for evacuees D9 and 90 evacuees from evacuation collection places O2 would be relocated to same places for evacuees D9. This is the only exception.

5. Conclusion

Prompt reaction to crisis events is the main role of crisis managers at all government levels. This article highlights possibilities for optimizing the decision-making processes, at local government level in particular. The means of obtaining reliable data for a credible decision are very important in the field of crisis management. Linear programming is one of the methods for this purpose. Authors focused on issue of crisis management in public sector and they applying different stochastic methods of systematic and operational analysis, dealing with transport problems. Selected algorithms for solution of transportation problems are analyzed, with the focus on the possibility of application of algorithms for data processing. Of course, in terms of scope, it was not possible able to get acquainted with all the nuances of this transport problem. The solution of crisis events, especially natural disasters, can not be done mechanically. Basic algorithm or input data is needed to adapt material, personal and economic requirements in the concrete specific territory.

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