TRANSPORT MODELLING OF CITIZENS EVACUATION

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Abstract: There is presented a software product intended for evacuations by using road transport while keeping to all the binding conditions. This software displays all the points important for evacuation and its process by means of digital maps puts out routes in dependence on an extraordinary event. It is possible to manually control inputs, parameters and process of the solution.

Keywords: evacuations, software, road transport

1 Introduction

One of the basic means for saving a human life is an escape (or evacuation) from affected area to safer area. In the occurrence of an extraordinary event (which endangered human life or health) is necessary to decide about evacuation or about another sheltering process. This decision depends on the responsible authority. From the realised analyses is no doubt that evacuation of citizens or group of persons is a basic mean for saving human lives. Moreover, evacuation could be necessary at every moment in every place.

An evacuation could be characterised like a transfer of endangered persons, animals or endangered things from designated area. In the basic form, evacuation is characterised like a summary of activities including management and realisation for timely and good organised moving of citizens, moving of necessaries, moving of animals etc. It could be realised during the peacetime or during the war or state of emergency, too. Evacuation is organised moving of persons, animals from the

definite area. Stay in that definite area could be caused serious injury or restriction of living conditions.

[1], [5], [8]

2 Definition of areal evacuation system

With the controlled long-time evacuation of the large area occurred problem about moving of demanded numbers of persons (or animals, or necessary thing) in the possible shortest time period in the definite area. For this evacuation should be used all available transport means. During evacuation, persons are concentrated in the evacuation centres. They are transported from evacuation centres to the reception centres. These reception centres could be situated near the short-time emergency accommodation.

For management during evacuation is necessary to know input data about:

- Transport network
- Location of evacuation centres and reception centres
- Location and capacity of the short-time emergency accommodation
- Numbers of evacuated persons
- The structure of rolling-stock, numbers and capacity of vehicles, location of vehicles

Like a next step is a necessary draft of evacuation routes with sufficient capacity. On these routes, evacuation will be realised. The solutions are optimal location of evacuation centres to short-term emergency accommodation. Like criteria for the location could be used the distance between definite places or time for transport between these places. Furthermore, is necessary solve allocation of transporting vehicles (stands or garage places) for definite evacuation centres (it is necessary for minimalizing of vehicles delivery delay).

[2], [9], [15]

3 Modelling of the long-term areal evacuation

For finding another input of data and evacuation process realisation is necessary to use minimum paths search algorithm on the transport network.

Upgraded Danzig algorithm can be found minimal path length, the approximate time for passing, as well. Algorithm is suitable for using distance like criteria (length of minimal path) or time for passing like criteria. For calculation of driving time could be used planned time of passing on designated roads (definite by the class of the road). In this algorithm is easy to use for riding ban on selected paths. With these banned paths algorithm couldn't calculate due to some restrictions on operation.

Like a data input for evacuation is an information about numbers of evacuation centres m with numbers of evacuated persons a_1, a_2,..., a_m and n

numbers of short-term emergency accommodation places with capacity b_1, b_2,..., b_n. Location of the bus garage (bus stand) c_1, c_2,..., c_k is included, too. These data are pasted in the matrix. First matrix *X* is pasted evacuation centres with places of short-term emergency accommodation for the consumer. In this matrix is solved allocation of evacuation centres to the accommodation (reception centres). In the second matrix *Y* is bus stand (or bus garage) like a supplier for places of short-term emergency accommodation (the placing of buses for the definite centres). The capacity of garages c_1, c_2,..., c_k are well known and the need for individual evacuation centres d_1, d_2,... d_m will be settled by evacuation manager.

Like criteria in both matrix could be used the time for movement between this places with the capacity respecting. For solution is necessary equality between needs on the consumer side and capacity on the supplier side. This problem could be used by the *simulated supplier* or *simulated consumer*. In the matrix *X* is not possible to create simulated (fictional) member (any person couldn't stay in evacuation centres. It is necessary to be valid: $\sum_{i=1}^{m} a_i \leq \sum_{j=1}^{n} b_j$

The numbers of evacuated persons must be same or smaller than the capacity of all property for emergency accommodation. In the cases:

$\sum_{i=1}^{m} a_i < \sum_{j=1}^{n} b_j$ Create a factious supplier with capacity $a_{m+1} = \sum_{j=1}^{n} b_j - \sum_{i=1}^{m} a_i$.

In the matrix *Y* is necessary to take in the account limitation in a number of buses for individual evacuation centres (it couldn't exceed the total number of vehicles). In this case valid: $\sum_{i=1}^{k} c_i \geq \sum_{j=1}^{m} d_j$

For cases that $\sum_{i=1}^{k} c_i > \sum_{j=1}^{m} d_j$ will be added to the matrix factious consumer with demand $d_{m+1} = \sum_{i=1}^{k} c_i - \sum_{j=1}^{m} d_j$.

For optimisation of *X* matrix and *Y* matrix is available Danzig algorithm. Optimisation of evacuation centres allocation to the places of short-term accommodation centres and allocation of vehicle garage to the evacuation centre is realised by that. The calculated value of movements (in matrix *X*) is numbers of evacuated persons from evacuation centre to the short-term emergency accommodation centres. Values in *Y* matrix are a number of buses from *i*-garage to *j*-evacuation centre.

The evacuation coordinator, try to minimise total time for evacuation process. The basic allocation of the object couldn't be optimal (because there is a lot of necessary movements between centres), Therefore is defined optimal location and

allocation of objects and means, but this location couldn't be optimal with accordance numbers of journeys which are necessary for the move of all persons between objects. The decision about evacuated persons from evacuation centre to the short-term emergency accommodation is necessary to divide to the two phases.

In the first phase number of persons are replaced by an integer number of buses (capacity of buses). The number of buses must cooperate with a number of persons in an evacuation centre. The volume of transport in this assign matrix is information about total seat capacity or about transported persons (after multiplying with numbers of seats) from evacuation centre to the short-time emergency accommodation centre. A number of persons transported in the first phase are subtracted from the number of persons in evacuation centres and available places in place of accommodation. The number of persons in evacuation centres after the first phase is smaller than the capacity of one vehicle.

The second phase of the solution is about the placement of remains persons in evacuation centre of the free capacity in short-term emergency accommodation. For the second placement is possible to change the charge of the journey between evacuation centres and accommodation places. It is applicable for minimization of journeys numbers. Volumes calculated in the second phase are added in the volumes in the first phase and it is a complete assign of evacuated persons by Danzig algorithm.

In the basic of the calculated values, distances, travel times, etc., between individual points, etc. is solved continuance of evacuation. Total time of evacuation for one vehicle t_{e1} is consist of time for ride from time to depart t_v, time for ride between garage and evacuation centre t_{ges} time for Getting of persons t_{nc} time for journey from evacuation centre to the place for short-term emergency accommodation t_{esmnu}, time of getting-out person $t_{vc,}$ time for ride between place of accommodation to garage t_{mnug}. Time for getting-on t_{nc} and getting-off t_{nv} depends on numbers of passengers and the average time for getting-on (getting-off) for one person. Total time for one evacuation vehicle is:

$$t_{e1} = t_v + t_{ges} + k \cdot \left(t_{nc} + t_{esmnu} + t_{vc}\right) + (k-1) \cdot t_{mnues} + t_{mnug}$$

and k is a number of journeys between evacuation centre and accommodation centre. The value k depend on numbers of evacuated persons, numbers of used vehicles and on the capacity of vehicles. The total time of evacuation for all evacuation centres equals to the maximal time of individual vehicles using.

The continuity of evacuation must be solved in one time for all vehicles. Algorithm about continuity of evacuation could be in the form:

1. Evacuation announcement (start); time 0
2. The time between announcement and departing from garage – time of depart.
3. Arrival to the evacuation centres – time of arrival.

From the total number of the person in *i*-evacuation centre is subtract capacity of the vehicle. If is there fewer persons that capacity of the vehicle, subtract that number.

4. A number of persons multiply time of getting-on of one person → Result is dwell time and by the dwell time could be found time of depart from an evacuation centre.
5. Time of arriving to the short-term emergency accommodation centre.
6. A number of persons in vehicle multiply time of getting-off of one person → Result is dwell time in accommodation centre and by the dwell time could be found the time of depart from accommodation centre.
   Check of person, whether is still necessary go to evacuation centre:
   A. If yes: in evacuation centre will be reserve proper number of persons. The vehicle will travel back to the evacuation centre and the algorithm continues with step no. 3.
   B. If no: vehicle goes back to the garage.
7. Time of arriving to the garage is recorded.
8. Total time of evacuation is the maximal time from individual operation times of vehicles.
9. End

[3], [4], [5], [11], [12]

4 SOFTWARE MODEL FOR SOLUTION

The software is a graphical environment for a map of road network edit, for pasting important point for evacuation planning and for evacuation process management. Graphics outputs of that program could be printed of exported in BMP or JPEG format.

The core part of the software is digital maps of the area. These maps are saved in ESRI Shapefile format (for the ESRI Browsers). For the minimal path, algorithms are necessary to edit data to the graph theory logic (especially about the description of the graph: the edge of the graph is a connection of two incident vertexes). In this data are not included cross (vertex of the graph) and therefore is necessary create an algorithm that the crosses found on the map. After finding the vertexes and incidence assignment to the edges of the graph was there another complication for data use. The curves (individual roads) not correspond with vertexes. It was also necessary to decide about incidence with vertexes and assign them the correct information about incidence with vertexes. Function for that assignment and data editing are an integral part of the software. Information about the geographical location of individual points, curves are saved in the coordinate system S42, it is another advantage of the digital data. This system identifies distance by the coordinates X and Y from the imaginary point [0,0]. Thank this method, the

geographical identification of individual points and distance between that points can be calculated, very easy.

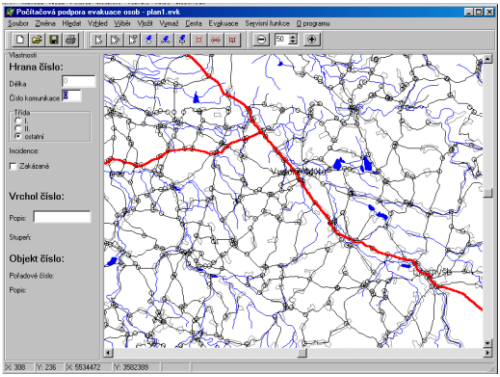

Fig. 1: *Software*
Source: Authors with using software

The program is typical for Microsoft Windows (control by mouse and keyboard, like another application created for Microsoft Windows environment). Access to the individual functions of the program is possible through the application menu.

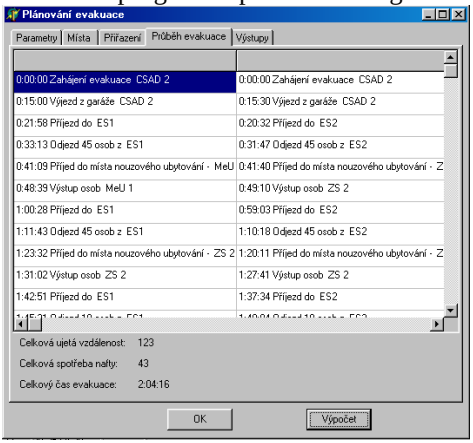

Fig. 2: *Process of evacuation*
Source: Authors with using software

[3], [8] [9], [15], [16]

5 Conclusion

For planning and decision making during a crisis situation is software one of possible auxiliary and support tool. Software support allows making a decision in limited time with evaluation of the large volume of information.
The process of transport ensures planning for evacuation can be automatized with mathematical modelling followed by a software solution.
Currently, any tool is not used for planning of evacuation. By the author's opinion it a detrimental, because software solution can help with planning in the financial cost and reaction speed.

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