The role of Geographic information systems and their Databases in the Process of Emergency Management in the Czech Republic

J. Rak, D. Ulcikova, L. Jurikova, and D. Sevcik

Abstract— The article describes possibilities of the use of geographic information systems (GIS) within the field of emergency management (population sheltering) in order to avoid consequences and impacts of an outbreak of chemical, biological, radiological and nuclear weapons, industrial accidents or other extensive extraordinary events (EE).This contribution is focused on data for GIS application. The data and databases are the most underlying issues within the field of the GIS usage in the process of planning and implementation of emergency management.The paper presents the possible ways of data integration, coming from different sources, by using the software tools and their application of planning, managing and supporting the processes in the area of emergency management.

Keywords— Geographic information systems; Crisis management; Emergency management; Information support; Civil protection.

I. INTRODUCTION

IN the Czech Republic the protection of the population by sheltering undergoes extensive modifications. In accordance with a document "Concept of protection of population by the year 2013 until the year 2020" the permanent shelters are being cancelled while improvised shelters are to be relied on in the future. Due to cost savings and a reduced urgency of the issue, less attention is being paid to sheltering. The situation differs slightly in individual territories (regions and municipalities); generally, it is not being dealt with effectively. "The concept of protection of population" assumes the recognition of the increasing hazard (risk) of an extensive military conflict within a sufficient time scale. In a period of approximately 2 to 3 years the eventual construction and rebuilding of premises into improvised, and

Ing. Jakub Rak, Faculty of Logistics and Crisis Management, Tomas Bata University in Zlín, Studentské nám. 1532, 686 01 Uherské Hradiště, Czech Republic. E-mail: jrak@flkr.utb.cz

Mgr Danuse Ulcikova, Faculty of Logistics and Crisis Management, Tomas Bata University in Zlín, Studentské nám. 1532, 686 01 Uherské Hradiště, Czech Republic. E-mail: ulcikova@flkr.utb.cz

Ing Lucie Jurikova, Faculty of Applied Informatics, Tomas Bata University in Zlín, Nad Stráněmi 4511, 760 05 Zlín, Czech Republic. E-mail: ljurikova@fai.utb.cz

Ing David Sevcik, Faculty of Applied Informatics, Tomas Bata University in Zlín, Nad Stráněmi 4511, 760 05 Zlín, Czech Republic. E-mail: ljurikova@fai.utb.cz

to a limited extent, into permanent shelters are planned. This basic idea appears to be correct and its objective is in the first place to save substantial financial expenses. However, its execution is complex. This procedure is not interconnected with any methodology, systematic instructions or methods stating how and to what extent sheltering should be provided. To what extent the issue will be handled is the responsibility of the municipalities. Nevertheless, the municipalities do not deal with the problems in order to save on financial resources. For this reason, the situation in individual regions of the Czech Republic differs considerably. Issuing of an obligatory methodology or instructions on the matter of sheltering would be a comprehensive solution. No matter what form the methodology takes, the evaluation of elements and infrastructure (in the field of sheltering and emergency quarters), and their mapping in the territory of the given region, municipality or other subject, should be a part of it. Specifically in this field the use of geographic information systems (GIS) appears to be quite appropriate.

This contribution deals with the creation of thematic maps, mapping the infrastructure and also with additional tools for the support of processes of population sheltering (e.g. search for the most suitable site for the distribution of building materials for modifications of improvised shelters).

Apart from the trained personnel (staff) capable of operating the GIS the data is of a fundamental significance. Only accessible quality and relevant data can provide a basis for obtaining high-quality results.

II. PROBLEM FORMULATION

A. Main features of the preparation and implementation process of population sheltering (the use of the IS)

The tasks connected to planning, preparation and implementation of population sheltering include rather extensive and complex processes, such as:

Planning – from the perspective of the current situation in the field of sheltering (primary the use of the IS), it represents the foundation phase. It should be noted that putting the IS into operation and use will only be performed when the EE status is set (at hazard). The eventual outcome of the whole process is thus dependent on the proper processing of this

phase. The main tasks of the planning phase are:
- Mapping and evaluation of hazards.
- Characteristics of the surroundings (the area).
- Specifying the number of sheltered persons and their position in the surroundings.
- Finding suitable premises for the IS.
- Mapping the modifications (construction works) necessary for putting the IS into operation.
- Determining the required amount of building and other material for putting the IS into operation.
- Finding distribution sites in order to provide building material [9].

Implementation – the actual implementation of scheduled tasks and procedures of the planning phase. From the perspective of the functionality of the entire process (system) of sheltering the population, this stage is crucial. The implementation is carried out on the occurrence of the EE, or shortly after its onset, so that there is a minimum time lag to correct possible errors of the previous stage.

B. The spatial character of population sheltering – the use of the GIS

The common factor of the individual parts of the sheltering process is their spatial character. Individual elements (PS, IS, warehouses of materials, evacuation routes, etc.) are also defined by their positions (a spatial relation to the ground). Apart from the spatial data the individual elements are also defined (described) by the attribute data. These factors predetermine the GIS for solving problems associated with planning, preparation and implementation of potential population sheltering. Fig. 2 (the basic scheme of the GIS) clearly depicts a way of processing the spatial and attribute data in general terms.
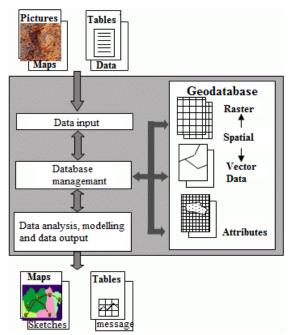

Fig.1. The basic scheme of the GIS [13]

C. Data acquisition and processing – the fundamental problem in the process of the use of the GIS in the process of sheltering the population

Owing to its properties the GIS is perfectly suited for solving tasks associated with planning and the possible implementation of population sheltering. Nevertheless, the data and its sources (see Figure 1 Key components of the GIS) are fundamental issues for the effective use of the GIS.
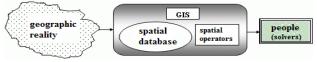

Fig.2. Key components of the GIS [13]

The quantity and quality of data correspond proportionally to the acquired outputs (results). For this reason data acquisition (sharing or creating) represents an essential building block of the entire process and it is therefore necessary to pay particular attention to this stage. In the Czech Republic and in most countries of Central Europe there exists only a limited amount of suitable data and in most cases it is necessary to generate data (to convert available data on the population sheltering and shelter infrastructure to an electronic form suitable for use in the GIS) [13 - Geographic information systems, online: 01.04.2013 http://geologie.vsb. cz/geoinformati ka/ kap06.htm.].

As previously implied, databases are the most underlying issues within the field of the GIS usage in the process of planning and implementation of population sheltering. For a better understanding of the subject and possible solutions, related areas within which the GIS is relatively widespread may be analyzed; this also includes extensive databases of geographic data. These areas include, for instance, environmental protection, emergency management and other. The next step is to define the types of basic requirements imposed on data in the GIS.

D. Data for the GIS – types and sources

With respect to the issues being dealt with, the data is divided as follows:
- *Reference;*
- *Thematic;*

- **Reference data:**

Reference data is the initial data, which is not thematically focused on issues being dealt with (e.g. base map of the Czech Republic, map of road and railway systems, etc.).

In the Czech Republic, the reference data has a relatively broad base. The most significant databases of the reference data are as follows (6):
- cadastral map in digital form ("DKM/KM-D"), large-scale maps;

- base map in the scale of 1:10,000 –"ZABAGED" (the basic database of geographic data) or "RZM 10" (raster base map);
- military topographic map in the scale of 1:25,000 – "DMU 25" (digital model of the territory);
- special map of surface situation ("UMPS"), large-scale maps;
- other maps for "wider territorial coverage" – in the scale of 1:500,000;
- spatial data of basic registers of Information systems of public administration ("ISVS") – address points, the basic residential unit;
- orthophotomaps.

- **Thematic data:**

Thematic data is primarily related to the issues being dealt with (e.g. structures of the PS and IS). This data is acquired in two possible ways:
- Internally, by the staff of regional and local authorities;
- Externally, by purchasing or directly using data generated by external subjects (e.g. mutual data exchange / sharing).

From a technical point of view the data can be divided, based on the characteristics, as follows:
- *Spatial data ("Geodata"),* which is directly related to surface – it describes geometric properties of an element;
- *Attribute data,* which describes non-geometric properties of the element (e.g. capacity of a shelter, etc.);
- *Metadata*, which describes content together with qualitative and other characteristics of spatial data [8].

The spatial data is further divided into vector and raster data. The GIS operates with a variety of these types of data. In the world and in the Czech Republic in particular, the widely used format of the vector data is "shapefile", the native format of the ESRI software. The file name extension is SHP. In addition to their location and shape, each of the individual elements in the data layer (e.g. a river, a school, a region of the Czech Republic) bears additional information called attributes. The attribute data is stored in a table; in case of vector data of the shapefile format, the format of the database table is dBASE IV (DBF).

Geo-objects describing the same theme are joined and saved into map layers, sometimes called thematic map layers of the GIS. These themes can be, for instance, waters, roads, soil types, altitude, etc. The division of geographic data into map layers simplifies the data analysis. The actual analysis is the most common reason for the use of the GIS for reality modeling.

Each map layer is stored in a single data file that can be separately transferred and used in several mapping projects. The map layer is sometimes called the monothematic map, or just the map for short (e.g. river map, road map, etc.). According to the modeled data and its purpose, the GIS map layers can be divided into two groups – vector and raster.

The GIS operates with a variety of formats of vector and raster data. In the world and in the Czech Republic in particular, the widely used format of the vector data is "shapefile", the native format of the ESRI software. In addition to their location and shape, each of the individual elements in the data layer (e.g. a river, a school, a region of the Czech Republic) bears additional information called attributes. The attribute data is stored in a table; in case of vector data of the shapefile format, the format of the database table is dBASE IV (DBF). (Fig. 3). A more detailed description of data formats suitable for the GIS is beyond the scope of this article. More information can be found, for example, in [8], [32].
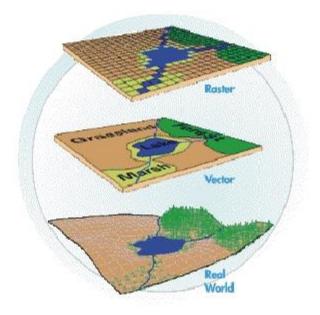

Fig.3. Reality model in GIS. [24]

E. The creation of thematic layers in the field of population sheltering

The thematic map layer consists of a set of thematic data (elements) related to a certain common area. At present, there are not many suitable databases in the field of sheltering of population. From the perspective of standardization at the national level, there is not any methodology or standard specifying the form and content of such data. However, at the level of administration units (regions) there is a methodology called "data model for digital processing of monitored phenomena of territorial analytic sources in the GIS". One of observed phenomena is also a field of "civil protection" which includes warehouses of civil protection, evacuation sites, permanent shelters and improvised shelters. Nevertheless, the scope of the provided information is rather narrow. The title of the data layer, type and geometry of the element, designation of the shelter, its location along with its capacity are insufficient with respect to the IS (see Tab.1). Other essential information that allows increasing the usability of

GIS is missing. Another problem is the extent to which the document is used. Only 5 out of 14 regions of the Czech Republic use the document.

Title of the entry	the object of CP, municipality
Reference to the legal regulation defining the entry	Act No. 239/2000 Coll., on the Integrated Emergency System, and Amendments to Certain other Acts, as Amended
Definition of the entry	Civil protection constructions intended for the population protection during the EE, improvised shelters constructed in accordance with the records of municipalities
Importance for spatial planning	the informative element
Resource	municipal authority
Note	
Title of the data layer	CO Improvised Shelters_b
Saving the data layer (directory, geodatabase, etc.)	Crisis
Identification of the data source	
Geometry type of an entry	point
Description of the layer	improvised shelters of CP
Title of the attribute	id
Type of the attribute	Text
Description of the attribute	registration number of the improvised shelter
Attribute domain	
Title of the attribute	capacity
Type of the attribute	Integer
Description of the attribute	capacity of the shelter (number of persons)
Attribute domain	

Table 1 Part of the Unified data model for population sheltering [32]

At the municipal level (towns), there is no conceptual material and thus, municipalities are dependent on an individual approach. In most cases, however, the issue of population sheltering from the perspective of the GIS implementation is not being dealt with at all, or the section of the IS is dealt with but not sufficiently. A notable exception is the municipality of Most and by means of the GIS it can be seen that premises suitable for building the IS for the public can be identified (see Fig.1). However, there is also a lack of more extensive databases of shelters with additional information.

There are three chief reasons why the field of databases for improvised shelters is not comprehensive.

- Sheltering is marginalized owing to the lack of procedures for setting the IS into operation and the lack of other documents;
- The lack of methodologies for modifications of the IS;
- Low funding in the field of sheltering.

Paradoxically, the third reason should contribute to the development of the GIS as it increases in efficiency and reduces the need for resources. However, during its first phase it brings a short-term workload for the staff and impacts on the budgets of municipalities.

III. PROBLEM SOLUTION

Determination of information to be included is an essential step of solving the problem of insufficient scope of the data model of the IS and sheltering in general. The determination of such information can be based on the research of Jurikova who analyzes the issues of improvised sheltering and outlines the basic aspects of IS modifications. Jurikova defines the standard for designing the IS which contains the following parts:

- The basic specification of the shelter processor-owner
- The present situation without adjustments
- The suggested (proposed) adjustments
- Situation after finishing the suggested (proposed) adjustments
- Notes, attachments, links to related documents and etc.

The scope of the "standard" is rather broad and it includes a large amount of information, which is not directly applicable to the planning of population sheltering by means of the GIS. For the purposes of the GIS it is then desirable to reduce the "standard" to essential information on the location of the building, its characteristics and modifications. Some of the most significant information that the database should include is as follows:

- ID;
- Address;
- Capacity;
- Classification;
- Owner:
- Location;
- Identification / type of the shelter (premises);
- Person in authority;
- Civil use;
- Technical data;
- Facilities;
- Short description of the building (material, construction, etc.);
- Time required for putting into operation. [27]

This information represents the basis for the creation of the "sheltering layer". Obtaining this information is simple if based on correctly defining methods for its presentation (unified terminology, format, data length, etc.). The possible format is specified in Fig.4.

The creation of such a layer enables the determination of the capacity for sheltered persons, revealing the weak and strong points, finding suitable shelters for various types of extraordinary events and many more. There are, however,

several issues connected to the creation process. Above all, for instance a large amount of time is needed to create ("fill up") the layer of the database.

If necessary, the layer may be extended by other data. The extension allows for an increase in the usability of the layer but at the same time, by its nature, it significantly increases the amount of required time and effort. The extension may, for instance, include:

- The type of building material needed for modifications;
- The quantity of building material.

Beside the actual shelters, the layer (data model) should also be supplemented by other structures related to the process of sheltering. These are, for example, material warehouses of civil protection, sites for the distribution of materials for modifications of improvised shelters, locations of sirens of the unified warning and notification system, and other.
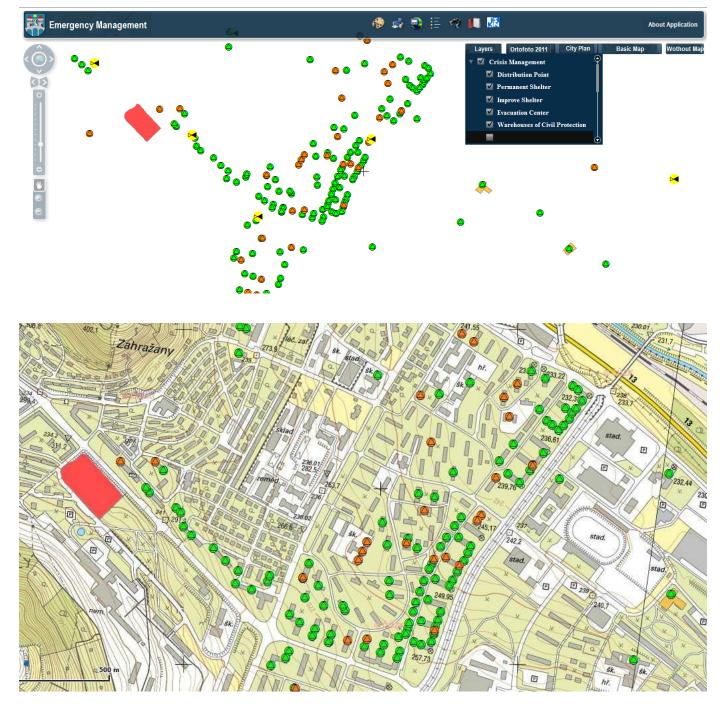

Fig.4. Map of shelters [9]

The PS and IS are primal means of protection against the effects of chemical, biological, radiological and nuclear weapons (substances). In the process of creation of the data model structure (the layer) the chosen premises (especially IS) should, however, also be evaluated from the perspective of use for other purposes, e.g. emergency quarters, sheltering from floods, extensive fires, etc. This approach shall extend the usability of the data model.
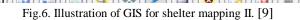
A. Standardization of evaluation of the data model (layer) in population sheltering.

With respect to the use of the GIS it is significant to standardize the individual evaluated elements, strictly speaking, to standardize the created database. There is a need for the maximum possible use based on a numerical scale in the evaluation of the individual elements (e.g. the use of shelter: 1 – protection from CBRN, 2 – protection from floods, 3 – protection from fires, etc.). Consequently, this method of standardization allows the use of mass processing of such a database. Compared to a verbal evaluation it shows better results. Certainly, this method is not appropriate for all evaluated elements (e.g. address, or person in authority). These elements cannot be expressed numerically due to their uniqueness.

A detailed description of standardization is rather extensive and should be given due attention. Its full description is beyond the scope of this article.

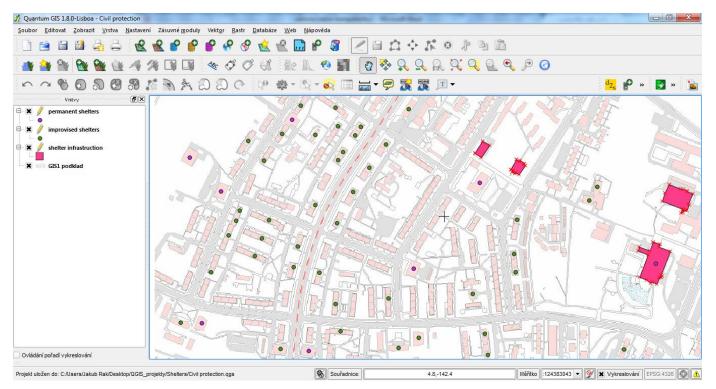Fig.6. Illustration of GIS for shelter mapping II. [9]

Fig.5. Illustration of GIS for shelter mapping I. [9]

B. Demonstration of the data model (layer) in population sheltering.

One of the main possibilities of using the data model (layer) of the population sheltering is the support of planning and implementation of population sheltering. Specifically, these are the following tasks:
- Location – where the element is situated;
- Condition – finding the premises that fulfills a specific condition;
- Spreading – motion on the defined surface;
- Structure – spatial layout;
- Modeling – dependences, prediction, trend.

Typical examples are simple presentation tasks such as the creation of thematic maps showing the distribution of the shelters (see Fig. 7). The scope of the database enables accomplishing even more demanding analyses, such as:
- Finding shelter-free areas;
- Creating statistics on capacity of shelters in individual parts of a town;
- Finding the most suitable site for distribution of building material;
- Finding evacuation routes and zones, etc.

C. Example of finding areas not covered.

In searching for areas that are not covered the knowledge of accessible distance and catchment areas of individual shelters are taken into consideration.

Description of the procedure:

By means of the reference map (topography) and thematic layer of sheltering the accessible zones of individual shelters were determined (1000 m for the PS and 500 m for the IS). Subsequently, the buildings situated outside the accessible zones were located. The buildings found are depicted in Fig. 4. For better clarity two buildings are highlighted by red polygons; other buildings are depicted as pink polygons. In the event of the use of a more extensive reference map it is also possible to search for house numbers of individual buildings and the numbers of persons outside the accessible zone.

CONCLUSION

The use of the GIS in the process of population sheltering and emergency management offers good prospects as it allows for considerable development of the system. The GIS provides advantages via its databases. At the same time it allows visualization of the acquired results and enables the use of their spatial components in the creation of maps. Compared to text outputs, the data in the graphical form is better accepted by the users and therefore, it allows processing larger quantities of information in a shorter time. With respect to this fact, the GIS appears to be fully convenient.

Fig.7. Evacuation zones [9].

Nevertheless, its application is accompanied by certain issues, for instance, insufficient user knowledge of the software applications, unavailability of relevant data, a large amount of work and time required during the first stage of the GIS implementation, or the need of appropriate setting of evaluated elements and their standardization.

Specifically, the standardization of elements in population sheltering and the methods of their evaluation are some of the major problems, which need to be solved in the future. This article proposes the creation of evaluative numerical scales as a possible way of tackling these issues. The creation of such scales enables to mathematize certain steps and thus to process data en masse and in large quantities. A more detailed study of possibilities of using these evaluation methods is a topic for the prospective research.

ACKNOWLEDGMENT

REFERENCES

[1] B. Booth, A. Mitchell, "ArcGIS9 – What is ArcGIS 9.2?". New York : ESRI 2001. p. 252

[2] B. Sadoun, B. Saleh, "A Geographic Information System (GIS) to define indicators for development and planning in Jordan," e-Business (ICE-B), Proceedings of the 2010 International Conference on , vol., no., pp.1,7, 26-28 July 2010.

[3] E. Ricchetti, M. Polemio, "Vulnerability mapping of carbonate aquifer using Geographic Information Systems," Geoscience and Remote Sensing Symposium, 2001. IGARSS '01. IEEE 2001 International , vol.7, no., pp.3087,3089 vol.7, 2001

[4] F.T. Fonseca, M.J. Egenhofer, "Knowledge sharing in geographic information systems," Knowledge and Data Engineering Exchange, 1999. (KDEX '99) Proceedings. 1999 Workshop on , vol., no., pp.85,90, 1999

[5] G. Chengcheng, W. Wengu, Y. Hongyong "GIS-Based Forest Fire Risk Assessment and Mapping," Computational Sciences and Optimization (CSO), 2011 Fourth International Joint Conference on , vol., no., pp.1240,1244, 15-19 April 2011.

[6] T.J. Cova, "GIS in emergency management, Geographical Information Systems": Principles, Techniques, Applications, and Management, USA - New York, 1999. p. 845-858.

[7] *Geographical information systems*: Wikipedia open encyclopedia, online: 20.06.2012, http://cs.wikipedia.org/wiki/Geografický_ informační_systém.

[8] Geographic information systems, online: 01.04.2013 http://geologie.vsb. cz/geoinformati ka/ kap06.htm.

[9] Geographic information systems, online: 25.03.2013,http://gis.mesto-most.cz/krizove rizeni/index.html.

[10] Information website of Praha 14 city part, online: 28.07.2013, http://www.praha14jinak.cz/clanky/Informace-urcene-verejnosti-v-zone-havarijniho-planovani-Plnirny-Satalice.html

[11] Introduction to GIS, online: 22.07.2013, http://www.colorado.edu/ geography/class_homepages/geog_4103_f10/

[12] GIS Applications, online: 15.06.2013, http://www.supergeotek.com/ library_GISApplication.aspx

[13] J. Jensen, R. Jensen, "Introductory Geographic Information Systems", Boston : Pearson 2012. p. 400, ISBN 978-0-13-614776-3

[14] J. Kovarik, M. Smetana. "Fundamentals of Civil Protection", Ostrava : SPBI 2006, ISBN 86634-85-X

[15] F. Janecek, J. Marusak, J. Valasek. "CO-6-1/c Preparation, Projection and Construction of antiradiation shelters", Prague : Ministry of National Defence 1978.

[16] J. Pecina, "Principle of spatial data analysis", Pilsen: University of west bohemia, Faculty of Applied Sciences 2005. p. 84.

[17] Quantum GIS (QGIS), online: 18.08.2013, http://www.qgis. org/en/documentation/manuals.html

[18] J.Rak, L. Jurikova, M. Adamek, "The System of Population Protection by Sheltering from the Perspective of Municipalities", NAUN: International Journal of Mathematical models and methods in applied Sciences, www.naun.org, 2011, p. 1038 – 1043. ISSN: 1998-0140B

[19] J.Rak, L. Jurikova, M. Beneda, "Possible solutions to the civil protection by the concealment under the Czech republic conditions", Proceedings of the International Conference on Military Technologies 2011, ICMT'11, Brno : University of Defence, 2011, p. 1147-1152, ISBN 978-80-7231-787-5.

[20] J.Rak, L. Jurikova, M. Adamek, "The Information System of the Municipality with Extended Powers for Population Protection – the Structure Proposal", Proceedings of the 8th WSEAS International Conference on Engineering Education; and Proceedings of the 2nd International Conference on Education and Educational Technologies , Corfu Islands, Greece, 2011. ISBN: 978-1-61804-021-3

[21] J.Rak, L. Jurikova, "The Use of the GIS for Mapping Hazard, Risk and Vulnerability within Population Sheltering", Proceedings of the 12th WSEAS International Conference on Applied Informatics and Communications (AIC '12), Istanbul, Turkey, 2012. ISBN: 978-1-61804-113-5

[22] J.Rak, L. Jurikova, D. Sevcik, "The Use of the GIS for Population Sheltering – A Case Study of the Use of Spatial Analyses", Proceedings of the 12th WSEAS International Conference on Applied Informatics and Communications (AIC '12), Istanbul, Turkey, 2012. ISBN: 978-1-61804-113-5

[23] J.Rak, L. Jurikova, M. Adamek, "Improvised shelters - projecting methodology and chosen aspects of building materials", 13th WSEAS International Conference on AUTOMATIC, Canary Islands, Spain, 2011. ISBN: 978-1-61804-004-6

[24] M. Hromada, L. Lukas, "Management of Protection of Czech Republic Critical Infrastructure Elements", 13th WSEAS International Conference on AUTOMATIC, Canary Islands, Spain, 2011. ISBN: 978-1-61804-004-6

[25] L. Necesal, L. Lukas, "Entities of critical infrastructure protection in the Czech Republic", 13th WSEAS International Conference on AUTOMATIC, Canary Islands, Spain, 2011. ISBN: 978-1-61804-004-6

[26] L. Jurikova, J.Rak, M. Adamek, "Suggestion of improvised shelter design", 13th WSEAS International Conference on AUTOMATIC, Canary Islands, Spain, 2011. ISBN: 978-1-61804-004-6

[27] L. Jurikova, J. Rak. "Proposal for technology of improvised shelters design in conditions of the Czech republic", Annals of DAAAM for 2010 & Proccedings of the 21 st International DAAAM Symposium, Austria - Vienna: DAAAM International, Croatia 2010, ISBN 978-3-901509-73-5

[28] *Terex* – terrorist expert: Website of T-soft, online: 17.06.2012, http://www.tsoft.cz/terex.

[29] The Cornerstones of a Functioning GIS, online: 22.07.2013, http:// www.cookbook.hlurb.gov.ph/book/export/html/6

[30] Geographic information systems of regions, online: 05.06.2013, http:// 195.113.178.19/html/help/Studie.htm

[31] GIS data, online: 05.06.2013, http://gisdoskol.fp.tul.cz/index.php/ proucitele/datagis/78-clanekogisdatech

[32] Unified model for civil protecton, online> 15.03.2013, http://www.c-budejovice.cz/ cz/magistrat/odbory/.../DMG_ÚAP_verze_4.p.

[33] H. Zhang, Y. Jie, X. Zhang, G. Jing, J. Yang, B. He, "GIS-Based Risk Assessment for Regional Flood Disaster," Environmental Science and Information Application Technology, 2009. ESIAT 2009. International Conference on , vol.2, no., pp.564,567, 4-5 July 2009.

[34] L.D. Murphy, "Geographic information systems: are they decision support systems?," System Sciences, 1995. Proceedings of the Twenty-Eighth Hawaii International Conference on , vol.4, no., pp.131,140 vol.4, 3-6 Jan 1995.