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NÁSTROJ VYHODNOCOVÁNÍ SOCIÁLNÍ, TECHNICKÉ A ENVIRONMENTÁLNÍ BEZPEČNOSTI ÚZEMNÍHO ROZVOJE

THE ASSESSMENT TOOL OF SOCIAL, TECHNICAL AND ENVIRONMENTAL SECURITY OF SPATIAL DEVELOPMENT

Abstrakt

Příspěvek přináší základní informace o nástroji vyhodnocování sociální, technické a environmentální bezpečnosti územního rozvoje, který byl vytvořen týmem bezpečnostních inženýrů z České a Slovenské republiky. Tento nástroj přispívá k preventivní ochraně obyvatelstva, technické infrastruktury a životního prostředí před negativními vlivy nešetrného územního rozvoje. Po krátkém představení a zhodnocení souvislostí mezi udržitelným rozvojem a územním rozvojem je čtenáři přiblížena stručná deskripce nejvýznamnějších semi-kvantitativních metod analýzy rizik, jež se staly východiskem pro tvorbu nástroje vyhodnocování bezpečnosti územního rozvoje. V druhé částí příspěvku je prezentován zmiňovaný analytický nástroj vyhodnocování sociální, technické a environmentální bezpečnosti územního rozvoje, který nese název Spatial Development Impact Assessment. V rámci této kapitoly jsou představeny hlavní části nástroje, kterými jsou Algoritmus hodnotícího procesu, Katalog skupin hrozby a aktiva a Matice vlivu územního rozvoje.

Klíčová slova: územní rozvoj; sociální bezpečnost; technická bezpečnost; environmentální bezpečnost; udržitelný rozvoj.

Abstract

The paper provides information on the tool for assessing the social, technical and environmental security of spatial development, which has been developed by the team of security engineering experts from the Czech Republic. The tool contributes to the preventive protection of population, technical infrastructure and the environment against the negative impacts of inconsiderate spatial development. Firstly, the relations between sustainable development and spatial development are briefly presented together with the most significant semi-quantitative methods of risk analysis being the starting points for creating the spatial development security assessment tool. The second part of the paper is focused on the presentation of the above mentioned analytical tool named "The Spatial Development Impact Assessment". The following principal parts of the tool are presented in the chapter: The Assessment process algorithm; The Catalogue of hazard and asset groups; and The Spatial development impact matrix.

Key words: spatial development; Social security; Technical security; Environmental security; Sustainable development.

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1 Introduction

The development of a territory, spatial development, is as old as humankind. During the whole existence of humankind people have tried to adapt newly settled territories to their needs and increase their utility values. They mainly built individual residences and other facilities in a given area (*Spirn, 1986*). At present the spatial development experiences a considerable expansion again. Population more often concentrates in large urban agglomerations, which continuously expand (*Beardsley et al., 2009*). New industrial plants are permanently built as well and their appropriate location is a necessary prerequisite for approving the spatial plan (*Mander, 2004; Weber, 2003*). Moreover, in the last years all the areas suffer from the impacts of natural elements and it results in requirement for the improved quality of all spatial development process (*Jones and Jones, 2007*).

In the past there were quite a lot of cases of inconsiderate spatial development resulting in a negative impact on the environment (e.g. integration of heavy industry into the centres of urban areas, inconsiderate mining of mineral resources causing an irreversible damage to important ecosystems, and improper location of huge buildings disrupting the character of landscape). After some time such inconsiderate anthropogenic activities have further negative impacts not only on economic activities of people, e.g. in the form of additional costs to be covered in order to maintain a classical economic growth rate and to restore the environment (*Pediaditi et al., 2010*), but also on people´s health and a gene pool. Therefore it is advisable to search for such a model of spatial development, which would enable a dignified way of living to our generation and also maintain good conditions for future generations (*Termorshuizen et al., 2007; Potschin and Haines-Young, 2006; Leitão and Ahern, 2002*).

2 Materials and Methods

The most significant materials and methods that were the basis for creating the spatial development security assessment tool are presented in the subchapters on Sustainable and Spatial Development and Semi-Quantitative Methods of Risk Analysis.

Sustainable Development and Spatial Development

The issue of sustainable development has been high on the agenda of governments and public since the sixties of last century. The first serious warning to the extensive development of economy and ignoring the environment was monitored in the conflicting first half of seventies during a sudden world energetic crisis. A significant milestone was the UN conference on the human environment held in Stockholm in 1972. The principle 13 of the Stockholm Declaration can be considered to be the most important idea (*Declaration, 1972*), which has the following wording: "In order to achieve a more rational management of resources and thus to improve the environment, states should adopt an integrated and coordinated approach to their development planning so as to ensure that development is compatible with the need to protect and improve environment for the benefit of their population."

Another significant milestone in the area of sustainable development is the Concept of sustainable development (*Brundtland, 1987*) of modern world, which was developed in 1987 and represents an alternative model of social development in relation to the dominant industrial economy. Before the birth of the concept of sustainable development there was not any reflection on natural environmental limits of economic growth. The economic growth was generally considered to be the criterion of increasing welfare and successful social development. However, since the 80-ies the attention especially in the developed countries is aimed at "sustainability" and a qualitative aspect of development. A well known definition from the Report of the UN Commission on Environment and Development (so called Brundtland report) is as follows: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs and that does not happen at the expense of other nations".

Spatial development is defined from various perspectives in specialized literature. It is often understood as an economic development of a territory regarding the increase of revenue (*Maier and Rezac, 2006*). Such an economic understanding is very biased and leads to negative consequences, especially if it was the only criterion for the environment and sustainable development. It is necessary to understand spatial development from a wider perspective as a complex development of territories including all their components. The most suitable definition, which has been developed by the Institute of Spatial Development (*Collective of authors, 2009*), is as follows: "The spatial development is a complex development of a territory, which includes the development of all material assets, activities and processes related to the territory and their mutual relations. It is thus a continuous process of development and changes in the utilization of areas, sites, buildings (urban structures) and landscape (natural structures), including their maintenance and protection of values. The goal is the sustainable and balanced development of all the above mentioned components in the territory. The instruments for coordinating the spatial development are mainly spatial planning, regional policy, care of the environment, and care of cultural and natural heritage".

Semi-Quantitative Methods of Risk Analysis

At present there are many relevant methods of risk analysis employed in the area of security engineering (*Bartlova and Balog, 2007; Senovsky et al., 2009*), but none of them is fully suitable for the analysis and assessment of spatial development security. More detailed analysis of the subject matter identified three relevant semi-quantitative methods of risk analysis on which the development of a new tool of spatial development security assessment was based on. These methods are Fire & Explosion Index, Hazard & Vulnerability Index and Hazard & Impact Index.

The Fire & Explosion Index Method (*Dow, 2005*) is a step-by-step index system the aim of which is to realistically assess the threat of fire and explosion depending on the potential of technological facility. It can be stated on the basis of thorough analysis that this system of step-by-step analysis is an optimal decision making algorithm. Its advantages are mainly simplicity, clarity and unambiguity when implementing individual stages of the method. Therefore the above mentioned principle was used during developing the assessment process algorithm, which is the key part of the spatial development environmental impact assessment. However, the process of the method itself is completely unsuitable as it is specifically aimed only at particular areas of hazard, i.e. fire and explosion. At the same time it may be stated that the method is rather time demanding.

The Hazard & Vulnerability Index Method (*Vojkovska and Danihelka, 2002*) is applied for assessing the weight of impact the accidents have on the environment. It may also be used for assessing and prioritizing the risks on the territories up to the size of region. The assessment of larger territorial units would require the implementation of geographic information system. The method is based on clear mathematical procedures which provide clear overview of final index values and subsequent determination of impacts the hazardous substances have on the environment. At the same time the clarity of indexation is supported by the principle of separate indexation for individual environmental elements. Therefore the above mentioned principle was applied not only within the indexation, but also the classification of negative aspects of spatial development and the areas of their impacts.

The method of preventive military training environmental impact assessment called the Hazard & Impact Index (*Rehak and Dvorak, 2010; Komar et al., 2006; Komar et al., 2000*) is a semi-quantitative method, which was developed by the team of Czech environmentalists from 2007 to 2009 within the project of the Czech Academy of Sciences Grant Agency. After being completed in the first half of 2010 it was the subject of practical testing. After successful negotiations with the Czech Ministry of Defence Logistic Section the method was implemented in the Army of the Czech Republic in the form of guidelines in June 2010 (*Rehak et al., 2010*). The algorithm used the outcomes of study aimed at the methods of technological risks analysis based on a semi quantitative assessment. The final algorithm comprises individual steps determining the level of risk to the environment caused by military training. Its advantages are mainly simplicity, clarity, unambiguity and operability when applying the individual stages of the method. Therefore the assessment algorithm was used when developing the assessment process algorithm, which is the key part of the spatial development environmental impact assessment tool.

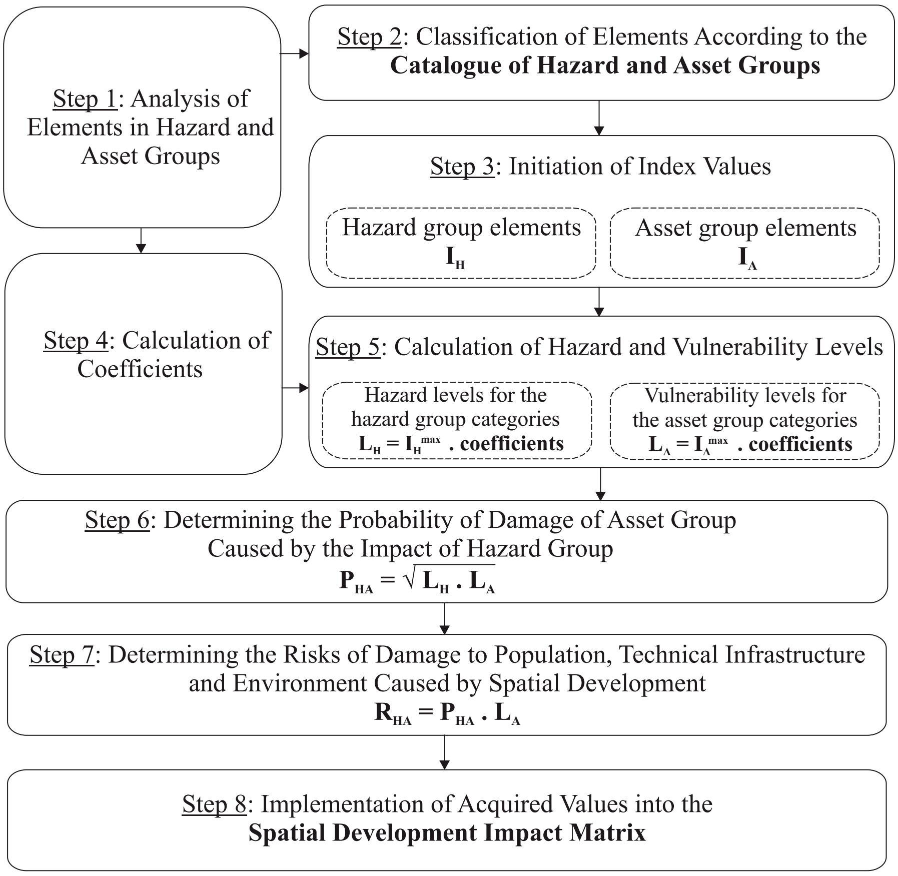
3 Results

The essential prerequisite of social, technical and environmental security of spatial development is to assess preventively all possible risks of planned spatial development and minimize them prior the realization of spatial development. The spatial development security assessment is rather complicated activity during which it is necessary to consider a large number of various input data and factors, which may significantly affect these data in particular time and location.

The Spatial Development Impact Assessment Method was developed is based on the principle of semi-quantitative assessment of potential negative aspects of spatial development and the areas of their possible impacts. The aim is to realistically assess the potential hazards resulting from spatial development. The tool was developed in compliance with national legal regulations and thus the impact assessment process will be acceptable from both technological and legislative viewpoints.

Assessment Process Algorithm

The following part of the paper outlines the structure of the assessment process algorithm assessing the impacts of spatial development on population, infrastructure and the environment. This algorithm defines basic relations among individual elements of the process, which are divided into two basic groups: 1) the group of hazards, which includes individual negative aspects of spatial development (*ISO, 2004*); 2) the group of assets (includes population, infrastructure and environment). The algorithm itself consists of individual steps which result in determining the level of potential risk that the elements of assets group will be damaged due to spatial development (see Picture 1).



Picture 1: *Assessment Process Algorithm*

Step 1: Analysis of Elements in Hazard and Asset Groups

The analysis of elements in hazard and asset groups is the essential step in the assessment process algorithm. The analysis consists in the setting of all social, technical, and environmental aspects of planned spatial development with the potential negative impacts on population, technical infrastructure and environment. This part of the analysis may be carried out according to the data from territorial plans. The analysis of the elements of asset group located in the planned area of spatial development consists in identifying all elements within the subgroups entitled as population, technical infrastructure and environment the value of which may be reduced or completely lost due to the negative impact of threats. This analysis may use information from maps and particular state administration authorities (e.g. district fire rescue corps and municipal authorities).

Step 2: Classification of Elements According to the Catalogue of Hazard and Asset Groups

In the next step it is necessary to classify the elements according to the Catalogue of Hazard and Asset Groups, which consists of individual categories and their elements. There are the categories of hazard group (i.e. the individual negative aspects of spatial development) and the categories of asset group (i.e. the negative aspects of spatial development and individual areas of their impacts on population, technical infrastructure and environment).

Step 3: Initiation of Index Values of the Elements in Hazard and Asset Groups

Once the elements are classified into particular categories it is necessary to initiate the index values of the elements of hazard group (I_H) and the elements of asset group (I_A). Thus the elements are assigned corresponding index values.

Step 4: Calculation of Coefficients

Another step of the algorithm is the calculation of coefficients. The user adds selected criteria into preset formulae and then various coefficients are calculated for both hazard group and asset group. The final coefficients consider variables, such as range, frequency and probability.

Step 5: Calculation of Hazard and Vulnerability Levels

The calculation of hazard levels for individual categories of hazard group (L_H) and vulnerability levels for individual categories of asset group (L_A) is made with the help of easy mathematical operations (*Riha et al., 2008*). The level of each category is calculated as the product of maximum index value of initiated elements belonging to the given category and particular coefficients ($L = I^{max} \cdot$ coefficients).

Step 6: Determining the Probability of Damage of Asset Group Caused by the Impact of Hazard Group

Determining the probability of damage (P_{HA}) of asset group caused by the impact of hazard group starts from the logical reasoning that this probability of damage is the highest if the category with the highest level of hazard has impact on the category with the highest level of vulnerability and vice versa. Mathematically the probability of damage is determined by goniometric average of hazard and vulnerability levels of the assessed categories ($P_{HA} = \sqrt{L_H \cdot L_A}$).

Step 7: Determining the Risks of Damage to Population, Technical Infrastructure and Environment Caused by Spatial Development

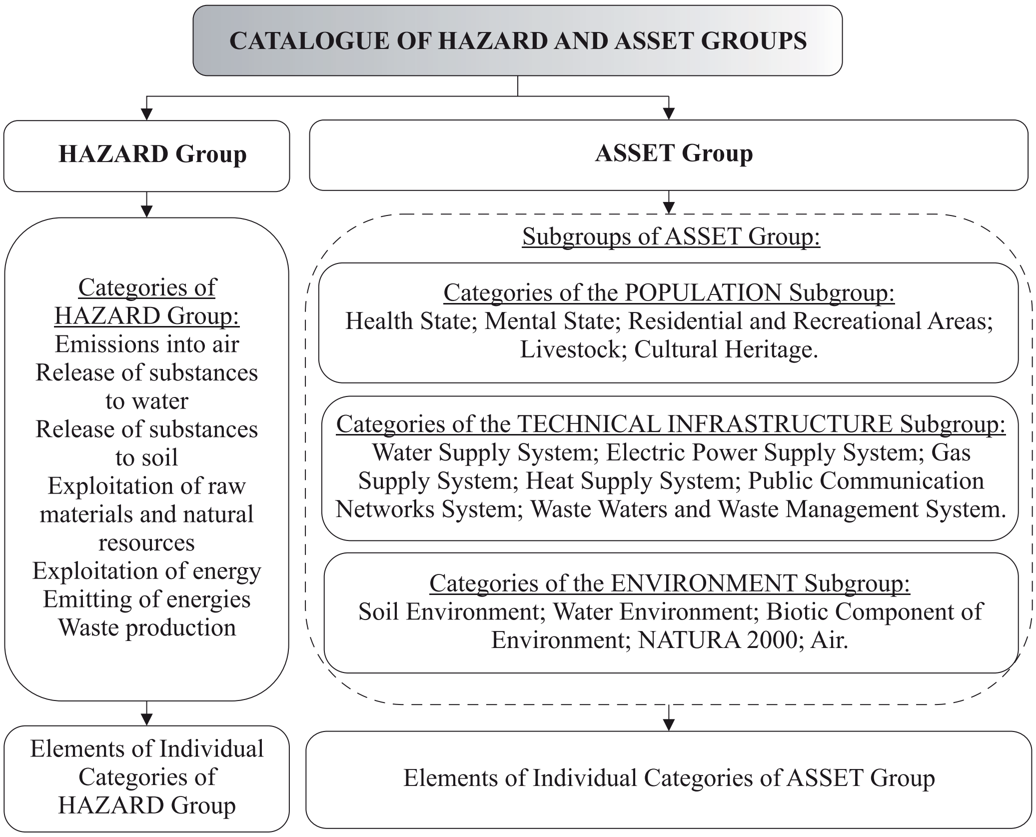
Last but one step in the assessment process is determining the risks of damage to population, technical infrastructure and environment caused by spatial development (R_{HA}). The calculation of such risk is based on general platforms (*ISO, 2009; Grasseova et al., 2010*). The level of risk is then determined as the product of vulnerability level of particular category of asset group and the probability related to the assessed categories of hazard and asset groups ($R_{HA} = P_{HA} \cdot L_A$).

Step 8: Implementation of Acquired Values into the Spatial Development Impact Matrix

The outcome of the assessment process will be the matrix presenting the potential level of risk for population, infrastructure and environment caused by intended spatial development. This risk is classified into three categories (A, B and C) described below.

Catalogue of Hazard and Asset Groups

The Catalogue of Hazard and Asset Groups is a significant part of the spatial development security assessment method. It consists of individual categories and elements. These categories are classified into the categories of hazard group and the categories of asset group. Individual categories then include elements, to which appropriate index values are assigned. The index values consider their hazardousness (in case of hazard group elements) and vulnerability (in case of asset group elements). The structure of the Catalogue of Hazard and Asset Groups is shown in Picture 2.



Picture 2: *Catalogue of Hazard and Asset Groups*

Spatial Development Impact Matrix and Risk Categories

The final risks of damage of population, technical infrastructure and environment caused by the intended spatial development are in the final phase of assessment shown in the Spatial Development Impact Matrix (see Picture 3).

SPATIAL DEVELOPMENT IMPACT MATRIX		Potential Negative Aspects of Spatial Development						
		A_A	A_W	A_S	A_R	A_X	A_E	A_P
Population	Health State				▒	▒		
	Mental State				▒	▒		
	Residential and Recreational Areas	▒	▒	▒	▒	▒		▒
	Livestock				▒	▒		
	Cultural Heritage		▒	▒	▒	▒		▒
Technical Infrastructure	Water Supply System	▒						
	Electric Power Supply System	▒	▒	▒				▒
	Gas Supply System	▒	▒	▒				▒
	Heat Supply System	▒	▒	▒				▒
	Public Communication Networks System	▒	▒	▒				▒
	Waste Waters and Waste Management System	▒	▒	▒	▒	▒		▒
Environment	Soil Environment	▒			▒	▒		
	Water Environment	▒			▒	▒		
	Biotic Component of Environment				▒	▒		
	NATURA 2000				▒	▒		
	Air		▒	▒	▒	▒		▒

Picture 3: *Spatial Development Impact Matrix*

Legend:

A_A - Emissions into air,
A_W - Release of substances to water,
A_S - Release of substances to soil,
A_R - Exploitation of raw materials and natural resources,
A_X - Exploitation of energy,
A_E - Emitting of energies,
A_P - Waste production.

Note:

The cross-hatched field signals that the given aspect and category are not related and therefore the level of risk is not determined for this relation.

The outcome of the assessment process will be the matrix presenting the potential level of risk for population, infrastructure and environment caused by intended spatial development. Such a risk will be classified in three categories.

The description of individual risk categories and the determination of acceptability of potential risk as well as the measures to be taken (i.e. the recommendations which should be followed by the assessor) are as follows:

- The A category of risk level: Spatial development indicates a low potential risk of damage to the environment in the assessed area (the risk is acceptable). Even potentially highly hazardous elements may be located in the given area when standard safety measures are followed. This category of risk is a necessary prerequisite for building new industrial facilities;
- The B category of risk level: Spatial development indicates an increased potential risk of damage to the environment in the assessed area (it is necessary to reduce such a risk). It is not suitable to carry out the planned spatial development in the given area. It is recommended to look for another area or modify the spatial development so that it does not cause damage to the environment. At the same time it is recommended to reassess the planned spatial development and possibly replan it;
- The C category of risk level: Spatial development indicates a high potential risk of damage to the environment in the assessed area (the risk is unacceptable). This category indicates that it is the most probable that the planned spatial development will cause an extensive and serious damage to the environment in the given area. Therefore it is recommended not only to look for another, less vulnerable area, but also thoroughly check the range and level of hazard of the planned spatial development.

4 Conclusion

Spatial development brings number of risks which may have negative impacts on balanced relations among spatial conditions and the environment, economic development and integrity of communities of population, i.e. on the sustainable development of territory. Therefore the continuous provision of security is one of the basic conditions of spatial development (*Kozlowski, 1990*).

Based on the existing knowledge in the area of methods and tools of assessing the various impacts it is proposed to provide security of spatial development by applying an easy algorithmic procedure, which seems to be suitable for several reasons. There is not an easy and universal tool of assessing the impacts of spatial development on population, infrastructure and environment in relation to the intended spatial plan. The universality of theépalgorithm is emphasized by the fact that it can be easily optimized and implemented in various countries despite their various legal regulations and variable values of areas planned for further development.

At present the methods and tools of impact assessment represent the best way of preventing the occurrence of activities with negative impacts on population and environment in the area of technological risk analysis (*Bartlova and Balog, 2007; Senovsky et al., 2009*). For this reason it is absolutely necessary to create and implement similar tool of assessing the impact of spatial development. It is important to mention the fact that the proposed tool of providing social, technical and environmental security of spatial development is not intended to be developed as a directive mechanism, but only as an informative tool giving recommendations to assessors whether it is suitable to carry out the planned spatial development in a given area or not.

At present the team of authors works on an electronic software of the above mentioned methodology and on the way of visualizing the outcomes through geographic information systems (GIS), which are generally considered to be a strong tool for displaying the geographic elements, processes and their relations in the areas of interest (*Hrdina et al., 2010*). The GIS should contribute to the clearer interpretation of acquired outcomes.

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References

[1] BARTLOVA, I.; BALOG, K.; 2007.: *Hazard analysis and prevention of industrial accidents I*. 2nd edition. Czech Republic, Ostrava: SPBI.

[2] BEARDSLEY, K.; THORNE, J.H.; ROTH, N.E.; GAO, S.; McCOY, M.C.; 2009.: *Assessing the influence of rapid urban growth and regional policies on biological resources*. Landsc. Urban Plan. 93, 172-183.

[3] BRUNDTLAND, G.H.; 1987.: The Concept of Sustainable Development. In *Report of the World Commission on Environment and Development: Our Common Future* (A/42/427). Greven: World Commission on Environment and Development.

[4] Collective of authors, 2009.: *Principles and Rules of Spatial Planning*. 1st edition. Czech Republic, Brno: Institute of Spatial Development.

[5] Declaration of the United Nations Conference on the Human Environment, 1972. Sweden, Stockholm: United Nations Environment Programme.

[6] *Dow's Fire & Explosion Index Hazard Classification Guide* (FEI), 2005. 7th edition. USA, New York: American Institute of Chemical Engineers. ISBN: 978-0816906239.

[7] GRASSEOVA, M.; DUBEC, R.; REHAK, D.; 2010.: *Analysis of the enterprise at the hands of managers: 33 most frequently applied methods of the strategic management*. 1st edition. Czech Republic, Brno: Computer Press. ISBN: 978-80-251-2621-9.

[8] HRDINA, P.; KOTATKO, A.; DOBES, P., 2010.: *Territorial Unit Risk Analysis with the Use of Geographic Information Systems*. Spektrum 10, 25 29. ISSN 1211-6920.

[9] ISO 14004:2004. Environmental management systems - General guidelines on principles, systems and support techniques.

[10] ISO 31000:2009. Risk management - Principles and guidelines.

[11] JONES, H.; JONES, P., 2007.: *Cities and sustainability*. Landsc. Urban Plan. 83, 1.

[12] KOMAR, A.; DVORAK, J.; BOZEK, F.; 2000.: Index of Environmental Acceptability of Training. In *Record of Proceedings*. NTG/ASG Environmental Training Working Group. Aachen, Germany, Annex O, 10 p.

[13] KOMAR, A.; REHAK, D.; DVORAK, J.; 2006.: *Effect of Training on the Environment: Case Study of Hazard & Impact Index Method*. Record of Proceedings. NTG/ASG Environmental Training Working Group. Bucharest, Hungary, Annex R, pp. 150-166.

[14] KOZLOWSKI, J.M.; 1990.: *Sustainable development in professional planning: a potential contribution of the EIA and UET concepts*. Landsc. Urban Plan. 19, 307 332.

[15] LEITÃO, A.B.; AHERN, J.; 2002.: *Applying landscape ecological concepts and metrics in sustainable landscape planning*. Landsc. Urban Plan. 59, 65 93.

[16] MAIER, K.; REZAC, V.; 2006.: *Economy in the Territory*. 3rd edition. Czech Republic, Prague: CVUT. ISBN: 80-01-03447-X.

[17] MANDER, Ü.; PALANG, H.; IHSE, M.; 2004.: *Development of European landscapes*. Landsc. Urban Plan. 67, 1-8.

[18] PEDIADITIA, K.; DOICK, K.J.; MOFFAT, A.J.; 2010.: *Monitoring and evaluation practice for brownfield, regeneration to greenspace initiatives: A meta-evaluation of assessment and monitoring tools*. Landsc. Urban Plan. 97, 22-36.

[19] POTSCHIN, M.B.; HAINES-YOUNG, R.H.; 2006.: *Landscapes and sustainability. Landsc*. Urban Plan. 75, 155-161.

[20] REHAK, D.; DVORAK, J.; 2010.: *The Method of Preventive Military Training Environmental Impact Assessment* (Hazard & Impact Index). [Final Report on the progress made on the Grant project KJB606070701]. Czech Republic, Prague: Academy of Sciences of the Czech Republic.

[21] REHAK, D.; DVORAK, J.; NOVOTNA, L.; KOMAR, A.; 2010.: *Methodical Instructions for Providing the Environmental Security of Military Training Activities Conducted Outside Military Training Areas*. [Certified methodology]. Czech Republic, Prague: Ministry of Defence Logistic Section.

[22] RIHA, J. et al.; 2008.: Vulnerability of Infrastructure and Environmental Systems. In *SPEKTRUM* 8, 22-27. ISSN 1211-6920.

[23] SENOVSKY, M.; ADAMEC, V.; KROCOVA, S.; SENOVSKY, P.; 2009.: *Assessment of Risks of Critical Infrastructure Elements*. Spektrum 9, 5-7. ISSN 1211-6920.

[24] SPIRN, A.W.; 1986.: *Landscape planning and the city*. Landsc. Urban Plan. 13, 433-441.

[25] TERMORSHUIZEN, J.W.; OPDAM, P.; BRINK, A.; 2007.: *Incorporating ecological sustainability into landscape planning*. Landsc. Urban Plan. 79, 374-384.

[26] VOJKOVSKA, K.; DANIHELKA, P.; 2002.: *Methodology for the environmental impact analysis of accidents involving hazardous substances* (Hazard & Vulnerability Index). 1st edition. Czech Republic, Ostrava: VSB - TUO.

[27] WEBER, Ch.; 2003.: *Interaction model application for urban planning*. Landsc. Urban Plan. 63, 49-60.