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ALGORITHM OF THE PROCESS OF MILITARY TRAINING ACTIVITIES ENVIRONMENTAL IMPACT ASSESSMENT: HAZARD AND IMPACT INDEX

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Abstract

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This research presents a comprehensive assessment process algorithm of the Hazard & Impact Index Method, which is based on an integrated approach. The algorithm clarifies basic relationships among individual activities in the process. The paper then clarifies the methods of determining the levels of hazards, the vulnerabilities of individual elements and the principles involved in determining potential risk levels. Determining these levels by means of the . index values of individual elements was based on co-operation with a team of selected expert assessors. Thus, the possibility of a user´s subjective effect on the assessment process was further eliminated. The presented coefficients aided the assessors in considering variable parameters, such as the number of personnel, the number and weight of vehicles and the climatic conditions. The risk categories are defined in the final part of the paper and the outcome of the Hazard & Impact Index methodology is the chart of referential values and the means of providing environmental security in planned military activities.

Key words: Army of the Czech Republic, hazard, impact, matrix, method, risk, vulnerability

Introduction

Social demand in the NATO member countries for effective environmentally-friendly training resulted in the NATO Training Group – Army Subgroup establishing the Environmental Training Working Group (ETWG) which deals with issues of reducing the negative impacts of military training on the environment (STANAG, 2008). One of the goals of the working group was to develop a suitable method which would easily and rapidly determine significant effects of military activities and to classify their potential impacts on given habitats (ETWG, 1997a).

A number of countries cooperating in the Alliance and the Partnership for Peace Programme became interested in the principles of training impact assessment. Consequently, a military training environmental impact assessment carried out with the help of a universal method won recognition in the practice of military control, and the first procedures were proposed during the meetings of the ETWG (ETWG, 1997b, 1998a, b, 2000, 2001). However, these did not meet the requirements for being universal , operational, easy, and especially objective.

An essential turning point was recorded at the ETWG meeting in Toulon in 2009, when the team of Czech environmentalists presented a unique algorithm of the assessment process called the Hazard & Impact Index Method (Řehák, Dvořák, 2009). This method was developed to assess the potential impacts of NATO armies' military training activities on the environment. It is an online software tool (Řehák, Dvořák, 2010), and its development and testing were completed at the beginning of 2010. In June 2010, it was implemented into the Army of the Czech Republic in the form of certified methodology (Řehák et al., 2010).

Methods

The preventive method of military training environmental impact assessment called the Hazard & Impact Index is based on the principle of assessing the potential negative aspects (FEI, 2005; Vojkovská, Danihelka, 2002) of military training (i.e. hazard groups) and the areas of their possible impacts on the environment (i.e. impact groups). The aim of the method is to realistically assess the potential environmental risks resulting from the training of troops in peacetime conditions (Komár et al., 2000). Since it has been developed in compliance with national legal regulations, the assessment process is acceptable from both environmental and legislative standpoints.

Hazard groups include all areas of military training and its logistic support which can have a negative impact on individual environmental components or on the socio-cultural environment. The subgroups are divided into:

- vehicles during training,
- vehicles during logistic support,
- personnel during training,
- personnel during logistic support.

Impact groups, or impact areas of military training, are divided into two groups. The first group represents the individual environmental components, the environmental value of which can be reduced or fully lost due to the negative impacts of hazard groups (Martis, 2006). The second group includes the socio-cultural environment, the elements of which can have their social, historical, aesthetic and economic values damaged or fully destroyed by military training. These groups are divided as follows:

- natural environment,
  - soil environment,
  - water environment,
  - biotic component of the environment – including fauna and flor,
- socio-cultural environment (including the impact on population, farm animals, real estate properties, infrastructure and areas of historical or cultural importance near the training area).

The H&I Index assessment of military training on the above mentioned impact groups considers the following four relevant negative environmental aspects of military training: mechanical (damage caused e.g. by vibration or strike), noise, fire and toxicologic aspects (Haška et al., 2007). The relationships between these aspects and impact groups are specified in Table 1.

Based on the existing knowledge in the area of impact assessment systems and methods (Ijäs et al., 2010; Božek et al., 2004; Hrnčiarová, 2002; Pastakia, Jensen, 1998; Canter, Kamath, 1995), the H&I Index Method is focused on the environmental protection during military exercises by applying a simple algorithmic procedure suitable for being implemented into military practice. Therefore the method is based on an easy and universal methodology of parallel impact assessment of military activities on the environment in relation to the significance

T a b l e 1. Relationship between the impact groups and the negative environmental aspects of military training.

			Negative environmental aspects of military training			
			mechanical	noise	fire	toxicologic
Impact groups	natural environment	soil environment	X			X
		water environment				X
		biotic component of the environment	X	X	X	X
	socio-cultural environment		X	X	X	X

of the environment (its quality) in the area of training. The universality of the method is emphasized by the fact that it can be easily optimized and implemented in various countries despite their various environmental legal regulations and variable ecological values of training areas.

The universal application of the method is not dependent on the variable organic composition of units of various army branches and national armies. The flexibility of the proposed method supporting the environmental protection is in the fact that it may be successfully used on the territories under both Department of Defence (military domains, garrison training areas) and private ownership. Conservative procedures of military directives and restrictions are changed to a universal assessment system in which commanders are held responsible for decisions made within their areas of responsibility. It has to be mentioned that the Hazard & Impact Index Method is in full compliance with the principles of environmental management system (ISO, 2004; EMAS, 2009), the implementation of which is successfully in progress in the EU member countries.

A significant fact is that the proposed method of the military training environmental impact assessment has not been developed as a directive mechanism, but only as an informative tool giving recommendations to training commanders, whether it is suitable to carry out particular training activity in a given area or not. The method is primarily designed for the environmental impact assessment of new military training facilities in the existing training areas and for the training conducted out of the existing training areas.

Results

The development of fully operational H&I Index method (version 2.0) has been mainly focused on the development of the assessment process algorithm (see Fig. 1). It is a key element of the method, which is based on an integrated approach as well as on the outcomes of study aimed at the methods of technological risks analysis, based on the semi-quantitative way of assessment (FEI, 2005; Vojkovská, Danihelka, 2002; Bartlová, Balog, 2007). The final algorithm comprises individual steps determining the level of risk to the environment caused by military training.

Determining the levels of hazards and vulnerabilities

Based on the index values of hazard and impact groups elements and on individual coefficients it was possible to define the relations which are the basis for calculating the hazard

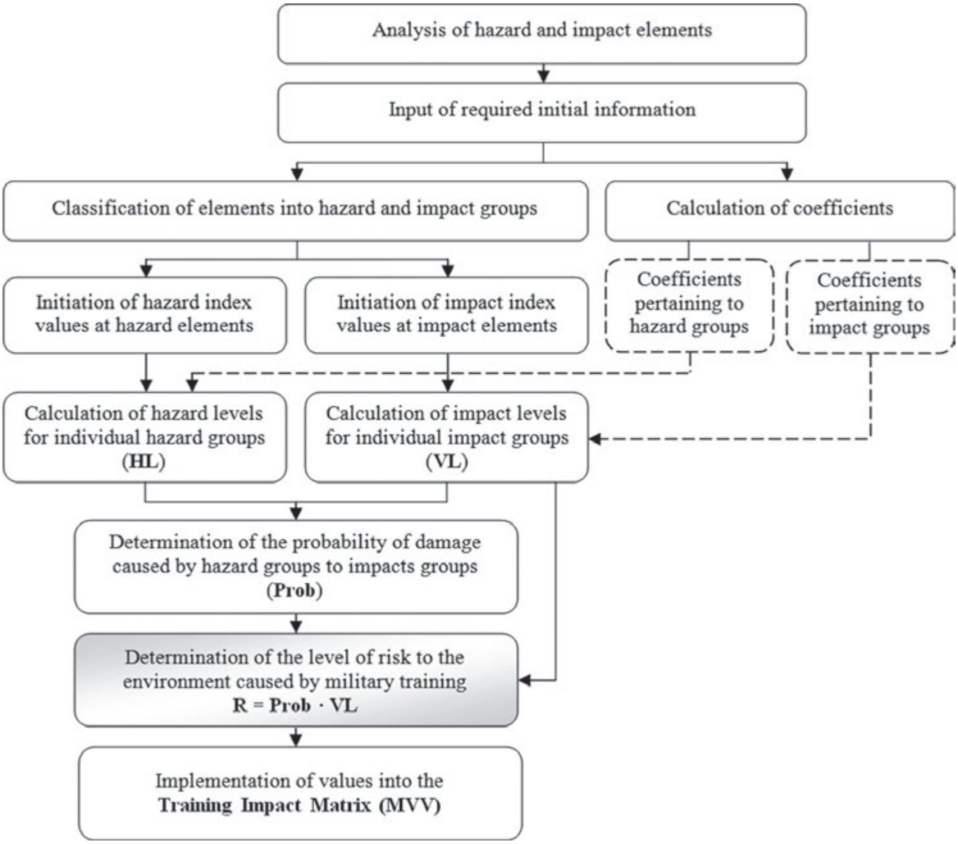

Fig. 1. Hazard & Impact Index Method assessment process algorithm.

level (HL) for each group of hazard and the vulnerability level (VL) for each group of impact. Formulas have been defined with the help of easy mathematical operations. Thus the level of hazard and vulnerability of each group are always calculated through arithmetic weighted mean (Ø) of initiated index values of elements pertaining to given groups. Coefficients are used in case the groups include variable parameters in order to make the values more accurate. The following formulas have been defined for individual groups:

- Hazard level of vehicles during training:
  $HL_{VT} = \varnothing\, I_{VT} \cdot D \cdot U \cdot N_V \cdot A$
- Hazard level of vehicles during logistic support:
  $HL_{VL} = \varnothing\, I_{VL} \cdot D \cdot N_V \cdot A$
- Hazard level of personnel during training:
  $HL_{PT} = \varnothing\, I_{PT} \cdot D \cdot U \cdot N_{TP}$
- Hazard level of personnel during logistic support:

$HL_{PL} = \varnothing\, I_{PL} \cdot D \cdot N_{TP}$

- Vulnerability level of soil environment:
  $VL_{SE} = \varnothing\, I_{SE} \cdot C_V$
- Vulnerability level of water environment:
  $VL_{WE} = \varnothing\, I_{WE}$
- Vulnerability level of biotic component of environment:
  $VL_{BE} = \varnothing\, I_{BE} \cdot F \cdot C_F$
- Vulnerability level of socio-cultural environment:
  $VL_{SC} = \varnothing\, I_{SC}$

Determining the levels of potential risk

Relation for calculating the level of potential risk could be defined after the relations for individual hazard and impact groups had been defined. The level of potential risk is always calculated for the interaction of each hazard group with each impact group. The Formula 1 is based on the relation, which ensues from a general platform for calculating risk (ISO, 2009).

$$R = Prob \cdot WI \qquad \text{(Formula 1)},$$

where:

R represents the level of potential risk of damage to the environment caused by military activities;

Prob represents the probability of environmental damage caused by military activities;

WI represents the potential weight of impact on the environment caused by military activities.

The probability of damage to the environment caused by military activities is the first significant factor in calculating the level of potential risk. The key for determining the probability of damage is based on the assumption that the probability of undesirable event (i.e. damage to the environment) is the highest in case the most dangerous group interacts with the most vulnerable group (i.e. if the value of HL = 5 and the value of VL = 5 the probability is the highest and conversely if the value of HL = 1 and the value of VL = 1 the probability is the lowest). It means that the process of determining probability is based on knowing the values of the interacting groups of hazards and impacts. The value can be acquired through the arithmetic average of hazard group level and impact group level (see Formula 2). Minimal and maximal values of hazard and impact groups are calculated without coefficients for the purpose of determining mutual interactions and reach the values of Min = 1 and Max = 5.

$$\text{Value of interaction} = (HL + VL)/2 \qquad \text{(Formula 2)}$$

In the second step it is necessary to convert the final values of interaction into probability and ensure their correct mathematical notation, i.e. in interval $< 0;1 >$. With the help of the key above it is possible to divide the final probability into five intervals and assign a median value to the final value of interaction (see Table 2).

This way of conversion ensures that probability never reaches limit values, i.e. 0% and 100%, because their practical feasibility is quite impossible. Based on the above mentioned

T a b l e 2. Convert the final values of interaction into probability.

Value of interaction	Probability divided into intervals	Median values of intervals
1	⟨ 0;20 ⟩	10 %
2	(20;40 ⟩	30 %
3	(40;60 ⟩	50 %
4	(60;80 ⟩	70 %
5	(80;100 ⟩	90 %

procedures and conditions (i.e. the set key) it is possible to determine the Formula 3 with the help of which it is possible to convert all the values of interaction into probability and formulate them in correct mathematical record.

$$Prob = (HL + VL)/10 - 0.1 \qquad \text{(Formula 3)}$$

The second factor in the calculation of the level of potential risk is the weight of environmental impact of military activities, i.e. the potential range of damage to the environment caused by military activities. When setting the weight of impact it is possible to assume that in case of interaction between a hazard group and an impact group detriment will be caused to the group of impact (e.g. damage to the soil environment caused by vehicles during training). At the same time it is clear that the higher vulnerability of impact group is the higher weight of its damage is and vice versa. This fact may be expressed in the following Formula 4.

$$WI = VL \qquad \text{(Formula 4)}$$

Based on the above mentioned the formula for calculating the level of potential risk can have the weight of impact changed for the level of vulnerability of the assessed impact group. The final Formula 5 for calculating the level of potential risk is as follows:

$$R = [(HL + VL)/10 - 0.1] \cdot VL \qquad \text{(Formula 5),}$$

where:

R represents the level of potential risk of damage to the impact group caused by the hazard group (i.e. damage to the environment caused by military activities);

HL hazard level of the assessed hazard group;

VL vulnerability level of the assessed impact group.

As mentioned above, the level of potential risk will always be individually calculated for the interaction of every hazard group with every impact group except for the impact of vehicles and personnel during logistic support on the socio-cultural environment, because the level of potential risk is so low that it will not be determined. Thus particular variables have been introduced into the relation (see Formula 5) and 14 formulas have been defined. For clarity, Formula 6 represents the calculation of the potential risk of damage to the soil environment caused by vehicles during training.

$$R_{VT\_SE} = [(HL_{VT} + VL_{SE})/10 - 0.1] \cdot VL_{SE} \qquad \text{(Formula 6)}$$

The final index values of risks are shown in the Training Impact Matrix (see Table 3) in the final stage of assessment.

Table 3. Training Impact Matrix.

Training Impact Matrix			Hazard groups			
			vehicles		personnel	
			training	logistic support	training	logistic support
Impact groups	*natural environment*	soil environment	$R_{VT/SE}$	$R_{VL/SE}$	$R_{PT/SE}$	$R_{PL/SE}$
		water environment	$R_{VT/WE}$	$R_{VL/WE}$	$R_{PT/WE}$	$R_{PL/WE}$
		biotic component of the environment	$R_{VT/BE}$	$R_{VL/BE}$	$R_{PT/BE}$	$R_{PL/BE}$
	socio-cultural environment		$R_{VT/SC}$		$R_{PT/SC}$	

Development of coefficients

Coefficients play an irreplaceable role in the Hazard & Impact Index Method. They consider variables, such as number of personnel, number and weight of vehicles and climatic conditions. It can be said that coefficients are some regulators of possible deviations in hazard or vulnerability of the assessed elements (e.g. vulnerability of soil environment in relation to climatic conditions) and ensure more accurate outcomes in determining the individual levels of hazard and impact groups. The coefficients are aimed at increasing the levels of hazard and impact groups according to the current state of variables. The coefficients may be divided into two categories according to their relation to the groups of hazard and impact as follows:

- Coefficients related to the hazard groups:
  – duration of training (D),
  – number of training personnel (N_{TP}),
  – number of vehicles (N_V),
  – age of vehicles (A),
  – level of experience of unit (U).
- Coefficients related to the impact groups:
  – climatic conditions – vehicles (C_V),
  – climatic conditions – fire (C_F),
  – vulnerability of fauna (F).

The relation of coefficients to the assessed elements of hazard and impact groups is shown in Table 4.

T a b l e 4. Relation of coefficients to the assessed elements of hazard and impact groups.

			Coefficients							
			D	N_{TP}	N_V	A	U	C_V	C_F	F
Assessed elements	I_{VT}	training in driving combat vehicles	X		X	X	X			
		engineering training	X		X	X	X			
		fire training	X		X	X	X			
	I_{VL}	parking of vehicles	X		X	X				
		maintenance of vehicles	X		X	X				
		clean-up of vehicles	X		X	X				
		petroleum, oil, and lubricants disposal (POL)	X		X	X				
	I_{PT}	engineering training	X	X			X			
		fire training	X	X			X			
		tactical training	X	X			X			
	I_{PL}	catering	X	X						
		maintenance of hand weapons	X	X						
		sanitary waste disposal	X	X						
		personal hygiene waste waters disposal	X	X						
	I_{SE}	soil environment						X		
	I_{WE}	water environment								
	I_{BE}	biotic component of the environment							X	X
	I_{SC}	social areas in contact with training areas								
		significant cultural elements in training areas								

Specifying the categories of risks

Upon completing the assessment process it is always necessary to assign a suitable scale of referential values to the final index values (R), which alone neither describe the situation nor the measures to be taken. Then the index values are classified into particular categories of risks. The scale has been created through determining the limit referential values.

The specification of limit referential values has been carried out by calculating the level of potential risk upon the interaction of groups, while the hazard (HL) and vulnerability levels (VL) of these groups are in the same categories. The index values HL and VL referring to individual categories have been introduced according to the limiting criteria of categorization. The results in individual categories are as follows:

I category:

$R = [(HL + VL)/10 - 0.1] \cdot VL = [(1 + 1)/10 - 0.1] \cdot 1 = \mathbf{0.1}$

II category:

$R = [(HL + VL)/10 - 0.1] \cdot VL = [(2 + 2)/10 - 0.1] \cdot 2 = \mathbf{0.6}$

III category:

$R = [(HL + VL)/10 - 0.1] \cdot VL = [(3 + 3)/10 - 0.1] \cdot 3 = \mathbf{1.5}$

IV category:

$R = [(HL + VL)/10 - 0.1] \cdot VL = [(4 + 4)/10 - 0.1] \cdot 4 = \mathbf{2.8}$

V category:

$R = [(HL + VL)/10 - 0.1] \cdot VL = [(5 + 5)/10 - 0.1] \cdot 5 = \mathbf{4.5}$

Attention was then aimed at specifying the categories of risk. These categories and their intervals have been determined on the basis of the above mentioned outcomes of limit referential values. However two additional measures have been taken as follows:

- As the Ist category includes only one final value (i.e. 0.1) it has been affiliated with the IInd category.
- As the limit referential value in the Vth category has been determined without the implementation of coefficients, its real value may reach the index higher than 4.5 and therefore the upper interval of this category is not defined.

Four categories of risk which have been specified are shown in the chart of referential values (see Table 5).

T a b l e 5. Chart of referential values.

Categories of risk	Final index value	Level of potential risk
A	⟨ 0.1;0.6 ⟩	low risk
B	(0.6;1.5 ⟩	increased risk
C	(1.5;2.8 ⟩	high risk
D	(2.8;10 ⟩	extreme risk

The last step in the process of classifying the categories of risk was to define their content, i.e. to describe individual categories, determine the acceptability of potential risk (see Fig. 2) and classify suitable measures, i.e. the instructions to be followed by an assessing subject:

- **Category of risk A:** the military activities have low potential risk of damage to the environment in the assessed area (risk is acceptable). Even highly hazardous activities may be carried out in the given area when standard safety measures are followed. This category of risk is a necessary prerequisite for creating new military training areas.
- **Category of risk B:** the military activities have increased potential risk of damage to the environment in the assessed area (it is suitable to reduce such a risk). Training activities may be carried out with certain limitations in the given area. An increased precaution has to be considered with regard to the possible level of damage. At the same time it is necessary to calculate on ex-post costs which might occur during the training on this level. It will be advisable to consult the activities and their location with a military environmentalist and possibly prepare rescue equipment to minimize an impact of emergency.
- **Category of risk C:** the military activities have high potential risk of damage to the environment in the assessed area (it is necessary to reduce such a risk). This category indicates that it is not suitable to carry out a planned activity in the given area. It is recommended

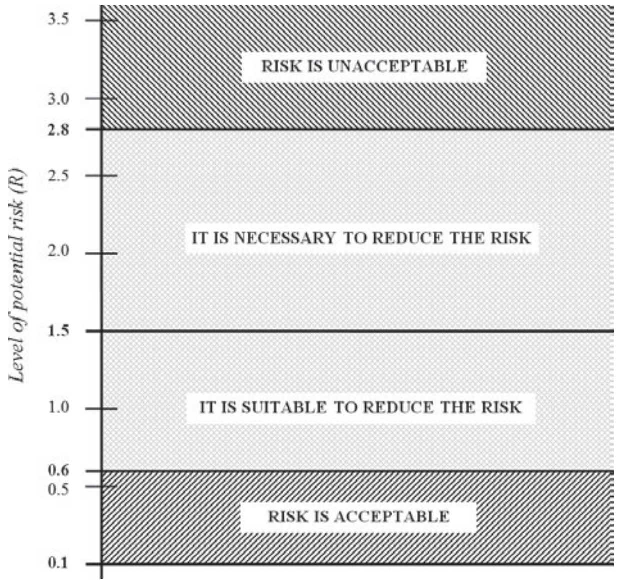

Fig. 2. Acceptability of potential risk.

to look for other areas or modify the training activity so that it does not cause damage to the environment.

- **Category of risk D:** the military activities have extreme potential risk of damage to the environment in the assessed area (the risk is unacceptable). This category indicates that the planned training activities will most likely cause an extensive and serious damage to the environment. Therefore it is recommended to look for other areas and also thoroughly check the range and level of hazard of the intended training activities.

Verification of Hazard & Impact Index Method

After being finished the Hazard & Impact Index Method was the subject of theoretical and practical verification. The theoretical verification was carried out in order to check the software reliability performance (i.e. the electronic form of the Hazard & Impact Index Method) and remove the defects of technical nature. The practical verification consisted of three steps, i.e. the description of the Czech Army Land Forces and the selection of four units for testing the method (step 1), the description of the Czech Army military domains and the selection of four training facilities for testing the method (step 2), and the method verification itself carried out through case studies (step 3). The shortcomings were removed on the basis of findings and the method was prepared to be implemented into practice.

Conclusion

Hazard & Impact Index Method (version 2.0) is a semi-quantitative method the aim of which is to realistically assess the potential hazard to the environment resulting from the training of troops in peacetime. The core of the method is the assessment process algorithm on the basis of integrated approach. The key support element of the method is an on-line software tool (Řehák, Dvořák, 2010) with an integrated user's manual.

The method was developed by the Czech team of environmentalists from 2007 to 2009 within the project of the Czech Academy of Sciences Grant Agency. Upon its completion in the first half of 2010 it was subject to practical verification and after a number of successful negotiations with the Czech DoD Logistics Section it was implemented in the Army of the Czech Republic in the form of certified methodology (Řehák et al., 2010) in June 2010. The method is also tested by some NATO armies (Canada, Sweden, Great Britain and the Netherlands), which showed interest in implementing it after its modification according to national conditions.

At present the authors work on the modification of the method for the needs of preventive assessment of potential negative impact of spatial development on the environment, population and infrastructure, i.e. on the sustainable development (Nooteboom, 2007). Thus a software tool is being developed in order to provide the environmental, social and technical security of spatial development.

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