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How Outrage Can be Quantified in Risk Assessment

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Abstract

In the article the problem how an emotional state influences quantitative risk profile is discussed. Risk as a concept enhances two equivalent dimensions. The first dimension relates to experts' risk assessment. The second one is related to public risk perception, named outrage. One can understand outrage as the emotional state concerning risk. Five different degrees of hazardous situations are described and public emotional attitude towards them is analyzed by structured interview. A correlation between the emotional attitude and readiness to act is calculated to describe amplification of risk by the emotional state. Then a risk profile is constructed.

Keywords: outrage, state of emotion, perception of risk, risk profile

Как возмущение может быть количественно оценено при оценке рисков

Аннотация

В статье обсуждается проблема влияния эмоционального состояния на количественный профиль риска. Риск как понятие усиливает два эквивалентных измерения. Первое измерение связано с экспертной оценкой рисков. Второй связан с общественным восприятием риска и называется возмущением. Возмущение можно понимать как эмоциональное состояние по отношению к риску. Описаны пять различных степеней опасных ситуаций и проанализировано эмоциональное отношение населения к ним с помощью структурированного интервью. Для описания усиления риска эмоциональным состоянием рассчитывается корреляция между эмоциональным настроем и готовностью к действию. Затем строится профиль риска.

Ключевые слова: возмущение, эмоциональное состояние, восприятие риска, профиль риска

Introduction

In this paper one should understand the term safety as a state of natural environment and /or civilizational space characterized by a parameter called risk. Risk and safety are antonyms and according to SRA statement (Society for Risk Analysis Glossary, 2015) safe means without unacceptable risk and safety is interpreted in the same way as safe and is the antonym of risk (the safety level is linked to the risk level; a high safety means a low risk and vice versa). So, analyzing a degree of safety independently, both personal, local or regional risk has become a fundamental concept. The value of risk (despite it is quantitative or qualitative) fully characterized safety. It can be said that risk is a measure of safety. Knowing the value of risk means knowing "all" about safety. Since safety has two dimensions, objective and subjective, the risk concept reflects this fact. According to the mentioned concept, the risk constitutes two elements: roughly speaking, engineering calculations of risk and linked with them risk perception by public.

The purpose of this article is to quantify the perception of risk and to determine "emotional" risk profiles for five different risk sources, namely:

1) Building a chemical industry plant processing dangerous substance near a place of residence – major chemical accident is possible;
2) Building an atomic power station near a place of residence – radioactive and nuclear hazard is possible in case of accident;
3) Establishing a waste dump near a living place – negative environmental impact;
4) Building a fur farm near a place of residence – environmental hazards, especially odour;
5) Natural hazards (especially windstorms or floods) extremely often striking place of your residence – big damages or property losses are possible.

The risk profiles were constructed based on a questionnaire. Questions in the questionnaire concerned emotional states, such as apathy, irritation, anger, rage, fear and a way of action related to them: to take an activity to eliminate the source of risk, to leave the place of residence, to do nothing.

Risk as an elusive concept

Risk as a measure of safety is a very convenient tool to be implement in practice (Karlsson et al., 2017; Karlsson et al., The Baltic, 2017; Marszałek-Kawa, Plecka, Hołub, 2018). There are many papers exploring the risk concept. Review of these works allows to draw conclusions that there are two main categories of them. On the one hand, risk can be calculated with engineering tools (Aven, 2012; Aven, 2011; Zhou, Liu, 2012; Jonkman, Jongejan, Maaskant, 2011) – *engineering aspect* including elements of its uncertainties. On the other hand, risk concept embraces psychological and social aspects (Sandman, 2012; Chipangura et al., 2016; Gerkensmeier, et al. 2018; Xie et al., 2011) – *psychosocial aspect* (*outrage*) including elements of its own uncertainties as well. According to Sandman (Sandman, 2012) statement, both of them are equal for all dimensions, that is they have the same meaning in risk management. They are measurable and play identical role during studying the risk and eventually, both of them influence a decision making process.

It is worth stressing that outrage is:

- as real as hazard,
- as measurable as hazard,

- as manageable as hazard,
- as big as part of risk as a hazard.

Symbolic mathematical expression illustrating the risk by definition is the following[8]:

$$R = R_0 + \text{outrage} \quad (1)$$

here, R – total risk, R_0 – calculated risk (engineering aspect) determined as $R_0 = p \times c$, that is unwanted event occurrence probability *p* multiplied by measure of consequences of this event *c* and outrage which can be interpreted as emotional attitude of individuals, groups, local society etc. toward a given risk. Note, that sign plus is conventional in formula (1) however, if "outrage" is calculated and expressed by numbers[6] sign plus one should be considered as operation of simple summation.

The following section describes a tentative approach illustrating a method of assessing outrage quantitatively.

Quantifying the outrage

It is rather surprisingly that individual or collective emotional state can influence the real value of risk thus it influences safety. So, to assess the risk quantitatively the problems of quantifying outrage seem to be very important and they should be included to methodology of risk calculation.

Risk perception is a multi-dimensional phenomenon. It depends on many factors which are often mutually dependent. Some of them are illustrated in Table 1.

Table 1. Selected elements that have impact on risk perception

Criteria	Risk Perception	
	Perceived as lower	**Perceived as higher**
Source	Natural	Man- Made (technological)
Voluntary character	Voluntary	Involuntary
Disclosing	Immediate	Delayed or unnoticed
Severance	Common: a few endangered persons	Disastrous: a lot of endangered persons
Limitation	Controllable	Uncontrollable

Criteria	Risk Perception	
	Perceived as lower	Perceived as higher
Profit	Obvious	Obscure
Familiarity with risk	Known	Unknown
Frequency	Frequent	Accidental
Necessity	Indispensable	Superfluous (luxury)

Source: Klein, 1997.

However, independently if risk is perceived lower or higher in relative meaning this perception according to formula (1) always at least increases the risk.

Here an equation (1) can be presented:

$$R = p\ c\ \alpha \quad (2)$$

Here, p – probability of unwanted event occurrence, c – consequences of unwanted event (for instance, the number of victims or economic losses) and α – dimensionless coefficient for $\alpha \geq 1$.

Then substituting equation (2) for (1), there is:

$$p\ c\ \alpha = p\ c + \text{outrage} \quad (3)$$

The expression (3) can be rewritten in the form

$$\text{outrage} = p\ c\ (\alpha - 1) \quad (4a)$$

or

$$\text{outrage} = R_0\ (\alpha\text{-}1) \quad (4b)$$

Substituting expression (4b) into equation (1), there is:

$$R = R_0 + R_0\ (\alpha\ \text{-}1) \quad (5)$$

The definition of coefficient α can be introduced, knowing that $\alpha \geq 1$ in the following way:

$$\alpha = 1 + \frac{\beta W\left(J_i\right) n}{N} \quad (6)$$

where β – fraction of sampled population expressing the given state of emotion J_i; $W(J_i)$ – outrage coefficient which characterizes the emotional state of population; n – the number of people with given action to be taken towards a given threat, N total number of sampled population.

In further considerations, to calculate coefficient α product of the fraction of population expressing given state β and n/N is determined for highest correlated state of emotion and activity for a given hazard.

Substituting equation (6) into equation (1) there can be finally found

$$R = R_0 \left(1 + \frac{\beta W\left(J_i\right) n}{N}\right) \quad (7a)$$

or

$$R = p \times c \left(1 + \frac{\beta W\left(J_i\right) n}{N}\right) \quad (7b)$$

The last equation corresponds with equation (2).

The emotional state can be expressed in many ways (Barret, 2017; Cao, Li, Tian, 2018; Petersen, 2010). In this paper five emotional states categories J_i, for I =1,2,3,4,5 are introduced, they are: *apathy, irritation, anger, rage* and *fear.* To each category value of outrage expressed by outrage coefficient $W(J_i)$ is assigned. It is assumed that for: J_1 = apathy outrage coefficient is equal to $W(J_1) = 0$; for J_2 = irritation, $W(J_2) = 0.1$; J_3 = anger, $W(J_3) = 1$; J_4 = rage, $W(J_4) = 10$; J_5 = fear, $W(J_5) = 100$.

The scale of outrage coefficient is strictly correlated with value of limit of calculated societal risk. There are two limits dividing risk into three categories of risk (Suddle, 2004) in a given area. Risk can be: *not acceptable,* that is the probability of unwanted event is higher than 10^{-4}; then *ALARP* area where risk is controlled and managed according to a rule **A**s **L**ow **A**s **R**easonably **P**racticable. In this case probability of unwanted event is higher than 10^{-6} and lower than 10^{-4} and at last, *negligible risk where* probability of unwanted event is lower than 10^{-6}. It can be seen that such scale allows outrage to influence risk through values of risk from negligible to unacceptable.

Research methodology

There were carried out investigations of impacts of five selected threats of social outrage. Then using relation (7b) values of different kinds of risks were determined. A questionnaire research method was used. Risk sources were chosen, they are:

1) Building a chemical industry plant processing danger substances near a place of residence – major chemical accident is possible;
2) Building an atomic power station near a place of residence – radioactive and nuclear hazard is possible in case of accident;
3) Establishing a waste dump near (your) living place– negative environmental impact;
4) Building a fur farm near a place of residence – environmental hazards, especially odour;
5) Natural hazards (especially windstorms or floods) extremely often striking place of residence – big damages or property losses are possible.

The questionnaire was divided into three parts. The first one is an introduction which contains information about a participant: the number, sex, age and place of residence. The second part contains questions about possible action which the participant could take in the face of given threats. What do you do if the source of risk is created or if often wind storms or floods occur near you place of residence. There were three answers of action possible:

a) to take an activity to eliminate the source of risk.
b) to leave the place of residence.
c) to do nothing.

The third part containing questions describing emotional states related to the given threat. Five emotional states were distinguished, they are:

a) apathy – existing source of risk has no meaning and the participant is indifferent to it;
b) irritation – existing source of risk causes nervousness and disaffection;
c) anger – existing source of risk causes strong feeling of indignation;
d) Rage – existing risk causes huge anger;
e) Fear/panic- existing risk causes uncontrollable fear.

Among participants there were 106 men and women. The questionnaires were fulfilled via social media in Internet. In Table 1 participants were characterized.

Table 2. Participants' Characteristics

Sex	Value (%)
Women	23
Men	77
Age	
18–25	85
26–49	13
50<	2
Place of residence	
Country	13
Small city less than 20 thousand inhabitants	25
Big city more than 100 thousand inhabitants	62

Most of the responders were young (85%) men (77%) from big cities (62%).

Regarding the answers about activities in face of risk (Table 2), it can be seen that for such risk sources as chemical plant and atomic power plant where risk is perceived as highest, the most population, independently from emotional state do not undertake any action (doing nothing 51% and 53% – accordingly, Table 3).

In case of natural disaster 59% responders declared that they would be able to leave the place of residence because of such a kind of risk. It seems that they consider to take this kind of action due to the fact that human being is helpless in face of natural hazards and the only way to avoid it is to move out. Contrary to this, risks related to dumping site and fur farms that couldn't be tolerated by responders are relatively 68% and 58% of responders who are ready to take the action to eliminate the risks. The reason of such an activity is that the risks are established by human being and influence day-to day life by the production of unpleasant odour in surrounding atmosphere which is out of control.

Table 3. Action which can be taken in the face of risk

Source of risk	Action taken: doing nothing (DN) %	Action taken: trying to eliminate source of risk (E) %	Action taken: trying to leave place of residence (L) %
1. Building a chemical industry plant processing danger substances near your place of residence – major chemical accident is possible	51	28	21
2. Building an atomic power station near your place of residence – radioactive and nuclear hazard is possible in case of accident	53	28	19
3. Establishing a waste dump near (your) living place – negative environmental impact	17	68	15
4. Building fur farm near the place of residence – environmental hazards, especially odou	34	58	8
5. Natural hazards (especially wind storms or floods) extremely often striking place of your residence – big damages or property losses are possible	26	15 I'll be waiting for climate change	59

In Table 4 results of exploring the emotional state are illustrated. It is interesting that among all sources of risks, on the one hand, *fear* dominates regarding chemical and atomic power plants. On the other hand, *to do nothing* dominates regarding the same plants.

Table 4. Emotional states in the face of risks

Source of risk	apathy	irritation	anger	rage	Fear
1. Building a chemical industry plant processing dangerous substances near your place of residence – major chemical accident is possible	28	41	21	4	28
2. Building an atomic power station near your place of residence – radioactive and nuclear hazard is possible in case of accident	51	9	8	6	26
3. Establishing a waste dump near (your) living place – negative environmental impact	6	28	41	15	6
4. Building a fur farm near place of residence– environmental hazards, especially odour	24	23	26	23	4
5. Natural hazards (especially wind storms or floods) extremely often striking place of your residence – big damages or property losses are possible	30	28	23	2	17

The next step of research was calculating correlations (Pearson coefficients) between emotional state and possible action which can be taken. These calculations were done for two cases. The first one included natural hazards and the second one – only manmade hazards. These two cases allowed to compare correlations between emotional states and action taken in both situations. In Table 5 Pearson coefficients including natural hazards are illustrated. Analysing values of Pearson coefficients, it is clear that *irritation* and any "actions taken" are not correlated at all. Emotional state *anger* vs action "doing nothing" has relatively strong negative correlation and simultaneously not so strong but positive correlation with "trying to eliminate". It seems that lack of correlation between *irritation* and any action arises from weak distinguishability by participants between emotional states *irritation* and *anger*. For the most participants anger is much clearer than irritation.

Table 5. Pearson correlations between emotions including natural hazards

Emotions / Actions	Doing nothing DN	Trying to eliminate (E)	Trying to leave a place of residence (L)
Apathy	0.79	-0.74	0.17
Irritation	-0.12	-0.02	0.11
Anger	-0.86	0.73	-0.14
Rage	-o.36	0.88	-0.70
Fear	0.80	-0.97	-0.26

The strongest negative correlation turned out between *fear* vs "trying to eliminate" and *fear* vs "doing nothing" although the latter is not so strong. Generally, Table 5 reveals the lack of correlation between emotional states and activity in most cases. Independences of emotional states and activity seems to be unnatural. The one possible reason of such a result is inclusion of natural hazards as one of the threats to a list of manmade threats. Natural hazards usually are perceived as Act of God. So, they can generate state of helplessness. Having in mind this fact in further research natural hazards were excluded from the list of threats. In Table 6 there are values of Pearson correlation coefficients calculated excluding natural hazards as risk sources.

Table 6. Pearson correlation between emotion states action excluding natural hazards

Emotions / Actions	Doing nothing DN	Trying to eliminate (E)	Trying to leave a place of residence (L)
Apathy	0.884	-0.828	0.384
Irritation	-0.131	0.052	0.199
Anger	-0.936	0.877	-0.409
Rage	-0.681	0.831	-0.989
Fear	0.876	-0.963	0.893

Statistical significance p for t- distribution and for all Pearson coefficients is less than $p < 0.2$. Analysing results presented in Table 5, it can be seen that correlation coefficients have much higher values than in the previous table. Emotional states are more correlated with potential action if natural hazards are separated from manmade hazards. However, *irritation* does not have any correlations with actions again. As it was mentioned above, *irritation* and *anger* are not enough distinguished for participants. In further considerations emotional states of *irritation* and *anger* will be joined as one category of the emotional state. Consequently, *Irritation* and $W(J_2) = 0.1$ will be omitted in the further discussion. Eventually, for considerations four manmade sources of hazards were left, namely: building a chemical plant (1), building an atomic power plant (2), establishing a waste dump (3) and building a fur farm (4). The results of the questionnaire were analysed for: four emotional states: *apathy, anger, rage* and *fear* and three actions which could be taken to respond to hazards. They are "doing nothing" (DN), "trying to eliminate" (E) and "trying to leave a place of residence" (L). Analysing results shown in Table 5 it is seen that most values Pearson coefficients r have the following pairs:

Apathy, r = 0.884 for DN; *anger,* 0.877 for E; *rage,* r = 0.831 for E and *fear*, r = 0.893 for L and r = 0.876 for DN. The last emotional state *fear* has doubled high Pearson's coefficient. The reason of this is that in the questionnaire to action *doing nothing,* related to atomic power as the source of hazard, a comment "*doing nothing being aware of utility of atomic power station for society"* was added. The general conclusion from this question can be drawn that although the emotional state has strong value on scale *fear,* awareness of utility leads many of all participants to rather passive attitude DN towards

this source of hazard. However, little bit stronger correlation coefficient for this state of emotion is given to the action "trying to leave". This ambiguity seems to reflect "fighting" participants between the emotion of *fear* and awareness of atomic power station utility.

Rather natural is that there is a strong positive correlation between *apathy* and the action of "doing nothing" (Fig. 1).

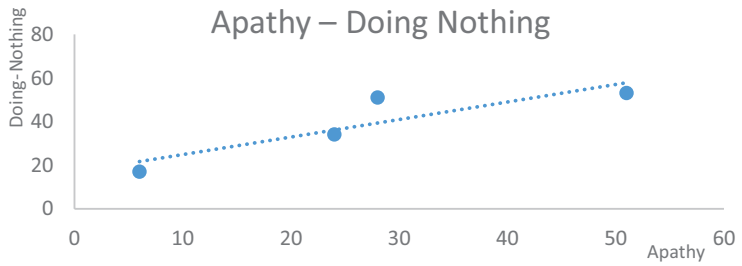

Fig. 1. Correlation coefficient r = 0.884 and trend line y= 0.804x +16.848 for *apathy* vs "Doing Nothing"

Similarly, pairs of emotional states *anger vs* "trying to eliminate" and rage vs "trying to eliminate" have strong Pearson coefficients (Fig. 2 and Fig. 3).

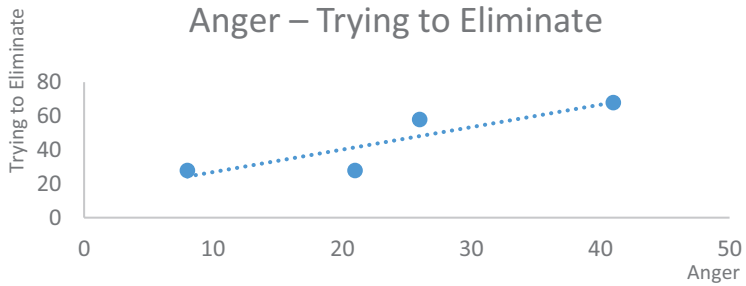

Fig. 2. Correlation coefficient r = 0.877 and trend line y = 1,36x +13.72 for *anger* vs "trying to eliminate"

The last but not least emotional state is fear which is very close to panic. Here, there are results which can be shortly summarised: more fear/panic more "Doing nothing" (Fig. 4) and more "willing to leave" (Fig. 5). These correlation coefficients fully characterise the state of panic. However, higher value of Pearson coefficient has the action "trying to leave".

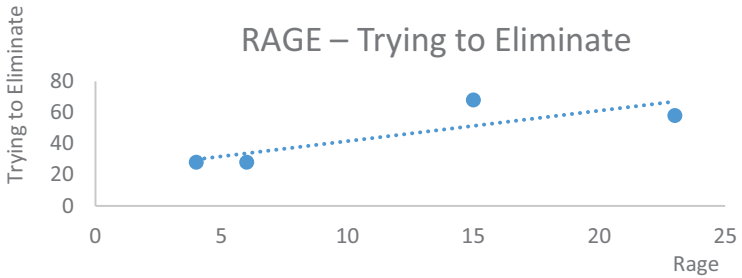

Fig. 3. Correlation coefficient r = 0.831 and trend line y =1.957x + 22.02 for rage

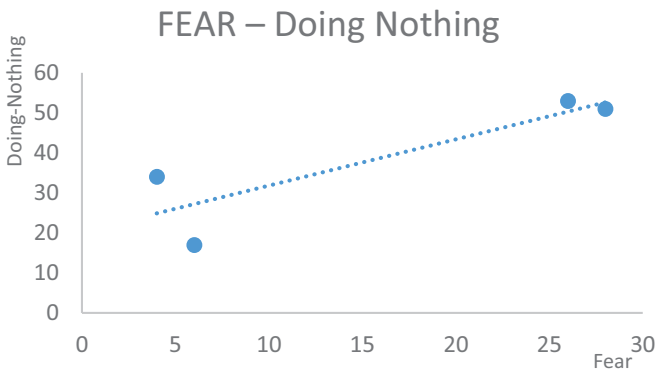

Fig. 4. Correlation coefficient r = 0.873 and trend line y = 1.156x +20.258 for fear vs "Doing Nothing"

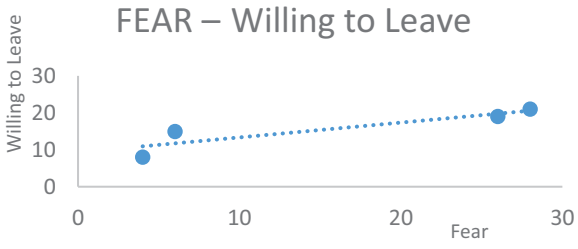

Fig. 5. Correlation coefficient r = 0.893 and trend line y = 0.401x +9.323 for fear vs "Willing to leave"

Having Pearson coefficient of the emotional state, the action taken related to this state can be assigned.

Outrage measure

It is assumed that the best way to quantify outrage is determination of its risk profile. One should understand risk profile as the probability of exceedance the certain value of random variables in our case that is outrage. Necessary data needed to calculate outrage risk profile for source of risk No. 1 are gathered in Table 7. These data embrace emotional states mass function distribution, probability of exceedance in the given emotional state, activity related to the given state and outrage coefficient.

Using the questionnaire outcomes as statistical data, a cumulative probability distribution (CPD) for each emotional state can be found, then the probability of exceedance (1-CPD) is calculated.

Table 7. Gathered outcomes for risk source No. 1

Emotional state	Distribution B %	Probability of exceedance %	Activity n/N % action	Outrage coefficient
apathy	28	72	51 DN	W(J1) =0
anger	62	10	28 E	W(J2) =1
rage	4	6	28 E	W(J3) = 10
fear	6	0	21 (51) L (DN)	W(J4) =100

Substituting data from Table 7 into equation (7a) the value of arisen risk is obtained which takes into account different degrees of outrage and that is presented in equation set (8):

R_1 =Ro for *apathy*

R_2 =Ro(1+0.62x0.28x1)=Ro(1+0.17); R=1.17Ro for *anger*

R_3 =Ro(1+0.17+0.04x0.28x10)=1.28 R0; R=1.28Ro for *rage* (8)

R_4 =Ro(1+0.06x0.21x100)=2.54Ro; R=2.54Ro for *fear*

The last risk R_4 is counted for higher risk activity that is for "willing to leave" (L) and activity "doing nothing" is omitted. In Table 8, calculated risk profile is revealed which is graphically presented on fig. 6.

Table 8. Probability of exceedance of a given emotional states vs. risk increasing for source of risk 1

Emotional state	Risk increasing	Probability of exceedance (%)
Apathy	0,00	72
Anger	1,17	10
Rage	1,28	6
Fear	2,54	0

It can be seen that more than 72% of population expresses apathy according to building the chemical plant near their place of residence. More than 10% of population expresses anger increasing risk 1,17 times. More than 6% of population expresses more than rage, in this case it means that population expresses fear, increasing risk 1,28 times.

Obtained results need some supplementary interpretation. First of all, average risk $R_{av.}$ should be calculated according to formula:

$$R^{i}_{av.} = \Sigma_j p_j R_j \quad (9)$$

here $R^{i}_{av.}$ – average risk of ith source of threat i = 1, 2, 3, 4; p_j – weight (β), fraction of sampled population expressing the given state of emotion; R_j – increased risk for the given emotional state, j = apathy, anger, rage, fear.

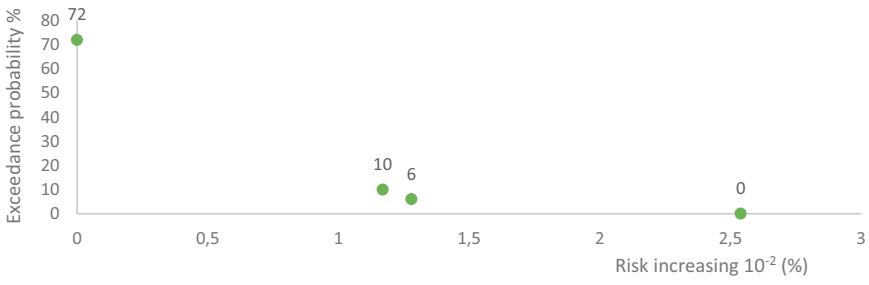

Fig. 6. Risk profile for source of risk No. 1

The average risk of source of risk No. 1, i.e. risk related to chemical plant building is equal to $R^{1}_{av.}$ = 1,20 R_0. Such a value of risk means that the

emotional state of population is anger, at least. Measure of uncertainty of statistic data for the risk profile is value of entropy defined in the following way:

$$H_j^i = -\sum_j p_j \log_2 p_j \qquad (10)$$

where H – entropy of i^{th} risk sources; p_j (β) – weight j^{th} of the emotional state. Entropy for the risk profile related to risk source No. 1 is equal to 1,371.

Analogous consideration and calculations were repeated for the next three sources of risk.

Table 9. Gathered outcomes for the risk source No. 2, No. 3 and No. 4

Emotional state	Distribution β %			Probability of exceedance %			Activity %			n/N action	Outrage coefficient
	No. of risk source			No. of risk source			No. of risk source				
	2	3	4	2	3	4	2	3	4		
apathy	51	6	24	49	94	76	53	17	34	DN	W(J1) =0
anger	17	69	49	32	25	27	28	68	58	E	W(J2) =1
rage	6	19	23	26	6	4	28	68	58	E	W(J3) = 10
fear	26	6	4	0	0	0	19	17	8	L	W(J4) =100

In Table 9 all necessary data to calculate risk and exceedance probability are illustrated and in Table 10 the risk increasing for each source of risk and emotional state is presented.

Table 10. Risk increasing vs state of emotions

Risk increasing			
Emotional state	**No. 2**	**No.3**	**No. 4**
apathy	$1{,}00R_0$	$1{,}00R_0$	$1{,}00R_0$
anger	$1{,}05R_0$	$1{,}47R_0$	$1{,}28R_0$
rage	$1{,}21R_0$	$2{,}76R_0$	$2{,}61R_0$
fear	$6{,}00R_0$	$3{,}78R_0$	$2{,}93R_0$

Below, risk profiles for the rest sources are demonstrated (fig. 7, fig. 8, fig. 9).

Fig. 7. Risk profile for source of risk No. 2

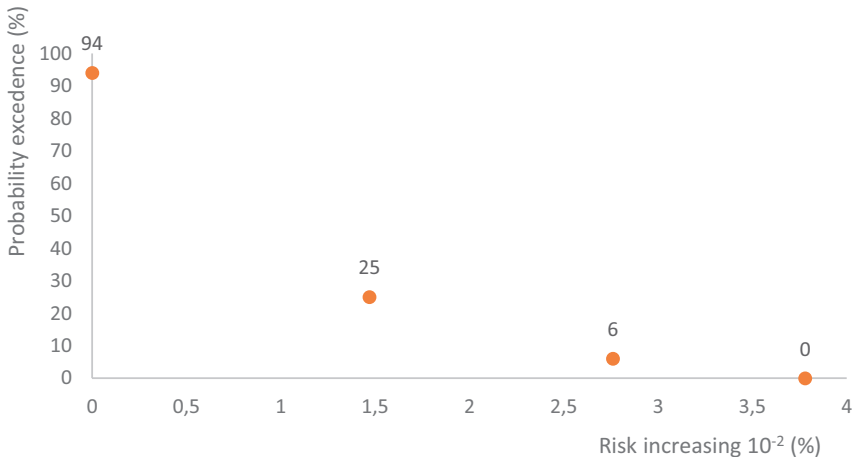

Fig. 8. Risk profile for source of risk No. 3.

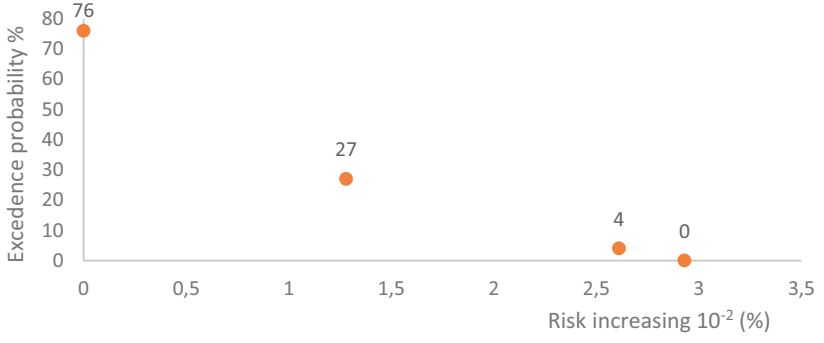

Fig. 9. Risk profile for source of risk No. 4.

Table 11. refers to the increased average risk characteristic, connected with the emotional state and entropy.

Table 11. Risks characteristic

Question number	Average risk	Emotional state Related to average risk	Entropy (uncertainty/diversity of emotional state)
1	$1{,}20R_0$	more than apathy	1.371
2	$1.811R_0$	more than rage	1.67 (max. uncertainty/diversity)
3	$1.766R_0$	more than anger	0.88 (min. uncertainty/diversity)
4	$1.346R_0$	more than anger	1.33

Conclusions

Presented in this article method is universal and may be a useful tool to calculate all kinds of risks which take into account their psychological aspect expressed by outrage. Outrage plays a sufficient role not only in risk perception, but it is the real element included in numerical value of risk. As it was shown in this article, outrage is calculable. The research indicated that outrage calculation needed some restrictions. While preparing the questionnaire one should separate natural from man-made hazards. This conclusion comes from different sources of threats – natural are perceived as Act of God versus manmade sources of risk – and lead the participant to fuzzy emotions and in accordance with it to hesitation to make any action. The questions should be univocal, i.e. for the given source of threat they should exclude more than one choice of the emotional state as well as the action taken.

It should be stressed that the sample size is small, and these findings are needed to be repeated on a greater one. The more threats identified the more credibility of correlations is between the emotional state and the action. Having at our disposal the emotional state and correlated with it action for the given hazard, risk can be increased, average risk can be calculated and profile of risk can be constructed. The last one can serve for decision makers as an indicator revealing how emotions influence risk. Supplementary information can be drawn from entropy value which is a measure of diversity of emotional states.

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