On the Human Perception of Risk. Questions of Presumed Security

Judit Kovács

Óbuda University, Tavaszmező u. 15-17, H-1084 Budapest, Hungary
kovacs.judit@kvk.uni-obuda.hu

Abstract: During the process of disaster management, new challenges like globalization, technology development or terrorism appear. Meanwhile, the presence of natural disasters is also urging new perspectives. Thus, the development of disaster management processes meeting the criteria of the new challenges and the continuous reconsideration of disaster management are required. To eliminate the errors, the analysis of the human factor may provide technical expertise.
After the introduction of the human perception of risk, the result of a survey on the topic is introduced. As the human factor is always present among the main reasons of accidents, and since according to different papers, 45-80% of errors are due to the human factor, it is vital to be aware of the nature of human risk-perception. Nevertheless, man is able to cope with unforeseen situations, to analyse and to create solutions. There is no doubt that without human actions more incidents would lead to accidents. Safe behaviour does not mean the absence of errors but the positive human contributions to safety, even in the form of prevention. For this reason, too, understanding the psychological background of risk perception is unquestionable.
The concept of presumed security is introduced in connection with the essence of risk perception. According to Seveso directives, mathematical modelling as a tool for aiding decision-making has a significant role when quantifying severe risks. The mathematical model of the cognitive human dislocation towards the direction of the preference of uniformity during the perception of cumulative risks is also presented. The subjective probability of hazardous incidents are also analysed to achieve a better understanding of the human perception of risk.

Keywords: human factor; risk perception; presumed security

1 Introduction

When considering catastrophes in our civilized world, it turns out that human factor has always had an important role among the possible causes. Meanwhile, new challenges like globalization, technology development or terrorism appear, and the presence of natural disasters is also urging new perspectives. The human factor is always present among the main reasons of accidents. According to different papers, 45-80% of errors are due to the human factor. On the other hand, the views that ”human commits errors”, ”humans are the weak part of the system” or ”human actions have to be replaced by automation” are too simplistic. Man is able to cope with unforeseen situations, to analyse and to create solutions. Without human actions more incidents would lead to accidents. Safe behaviour does not mean the absence of errors but the positive human contributions to safety, even in the form of prevention [1]. So, the impact of human performance is always significant. The appropriate treatment of human interaction has a key role in understanding its part in total risk and in the sequences of accidents. Although it is the Human Reliability Assessment (HRA) techniques that principally deal with the analysis of the human factor, there are also other methods that aim modelling some aspects of the human factor. In order to provide this wider view, understanding the psychological background of risk perception is unquestionable. Presumed security is a parallel concept to risk perception: supposing security on the basis of probability.

2 The Probabilistic Nature of Risk Perception

When doing research on the human factor, there has been a great demand for me to analyse the subjective probability of hazardous incidents in order to achieve a better understanding of the human perception of risk.

Human perception of risk is based upon probabilities. It does not necessarily provide quantitative estimates of the likelihood of risks, although this is not to say that any mental method refuse the use of supplemental quantification where useful. Numbers may represent a wide range of risks, and they may be useful as indicators. In these mental processes numbers are not treated as objective truths but rather as starting points. Qualitative and quantitative predictions are very closely related in risk perception.

Generally, two common views are followed in this topic. First, the incidents that happen frequently, or that have happened lately are easier to imagine, so in risk perception, their supposed probability is relatively higher. On the other hand, there is an opposite second view, according to which incidents that rarely happen, or have not happened recently are more probable to happen in future. These two and rather contradictory views make the base of the psychological background of risk perception. In addition to these two views, there may be another theoretical view, i.e. no connection is supposed between the subjective probability and the actuality or frequency of a risk happening.

Both the first two views define the related presumed security using subjective probabilities. In connection with the first view, presumed security means preparedness for quite well-known incidents, ignoring the hypothetic incidents that are unfamiliar. The second view privileges security of avowed incidents and urges preparations for unexplored ones. Supposing the third, theoretical view, it is not at all obvious what makes the base for presumed security in this case.

In order to develop human error prevention and to enhance the positive human contribution to security, it is vital to be aware which tendency of the three above is of statistical superiority, considering the new challenges in disaster management. For this reason, I have carried out a survey on the topic.

3 A Recent Survey on Risk Perception

In 2016, I carried out a survey with 80 people participating. The aim was to discover the way people perceive risks among the new approaches of hazards, with a technical development never seen before. I wanted to examine whether there is (and what type of) a correlation between the human perception of risks and the actuality and frequency of the same risks happening.

Participants were asked to answer two questions. The first question was to make an order of seven disasters according to their probabilities. As there had not been any previous hints on the probabilities of disasters, participants answered by the subjective probabilities of their own. The second question was to give the time and frequency of the same disasters occurring in the environment (country) of each participant. Here again, each participant answered using his/her own subjective (and not necessarily correct) memories. In order to use to word “disaster” correctly, the definition of disaster was given for the participants. There were the same seven disasters listed alphabetically for both questions. Actually, from the point of view of the research, there could have been any other disasters mentioned instead or parallel. The number seven may be regarded large, but it was given exactly to grant the highest and lowest two probabilities to be adequate to examine. For this reason, the three disasters with middle probabilities were not examined. This way, to each participant an order of four disasters were assigned. Then, from the second part, the orders of actuality and frequency of the same four disasters were assigned to the previous order. For the probability – actuality and probability – frequency orders, a Spearman rank correlation coefficient was calculated.

The questionnaire was the following:

The word disaster is used in the following sense:

Disaster: an event which harms or endangers the life or health of a great number of people, or considerable material values, basic care, or the environment the extent that the cooperation of authorities, institutions and organizations is required to eliminate it and get it under control.

Question 1) Number the following disasters, based on the probabilities of their future occurrence in your environment (the country where you live). **(For the disaster you think most probable: 1, least probable: 7.)**

Accident (train, airplane, etc.)	
Chemical disaster	
Earthquake	
Epidemic	
Flood	
NPP accident	
Terrorist attack	

Question 2) Has either of the following disasters occurred in your environment? If so, enter the (last) time of occurrence in the second column. (If you are unsure, you may enter: about two months ago, about five years ago, etc.) If a disaster has occurred several times in your area, enter the number of times in the third column.

	Last time of occurrence	Number of occurrences
Accident (train, airplane, etc.)		
Chemical disaster		
Earthquake		
Epidemic		
Flood		
NPP accident		
Terrorist attack		

4 Evaluation of the Survey

A relatively simple technique that can be used for exploratory data analysis is the Spearman rank correlation coefficient. The Spearman rank correlation coefficient is a nonparametric technique, so it is unaffected by the distribution of the data. Because the technique operates on the ranks of the data, it is relatively insensitive to outliers. It can be used with very small sample sizes and it is easy to apply. The idea behind the rank correlation is simple. The variables are ranked separately from lowest to highest, and the difference between ranks for each data pair is recorded. The general Spearman rank correlation coefficient is calculated according to the following formula:

$$\rho_n = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2 - 1)} \tag{1}$$

where d_i is the difference between ranks for each data pairs, and n is the number of data pairs. Equation (1) is constructed so that it gives $\rho_n = 1$ when the data pairs have a perfect positive correlation, and $\rho_n = -1$ for a perfect negative correlation [2]. If $\rho_n \approx 0$ then there is no (or very little) correlation between the data pairs.

By the Spearman rank correlation coefficient I measured the correlation of both the probability – actuality and the probability – frequency orders. About 10% of the questionnaires were invalid, due to either improper ranking (using the same number several times) or not answering the second question. From the valid questionnaires, 29% gave an answer only in connection with actuality for the second question. The remaining 71% answered both actuality and frequency. Here, 67% of the Spearman rank correlation coefficient of the probability – actuality and the probability – frequency orders were the same, while 33% were different.

The average Spearman rank correlation coefficient for the above cases are as follows:

Where only the actuality part of the second question was answered: the Spearman rank correlation coefficient of the probability – actuality order is 0.67381.

Where the Spearman rank correlation coefficient of the probability – actuality and the probability – frequency orders were the same: the Spearman rank correlation coefficient of both the probability – actuality and the probability – frequency orders are 0.692424.

Where the Spearman rank correlation coefficient of the probability – actuality and the probability – frequency orders were different: the Spearman rank correlation coefficient of the probability – actuality order is 0.575.

Finally, where the Spearman rank correlation coefficient of the probability – actuality and the probability – frequency orders were different: the Spearman rank correlation coefficient of the probability – frequency order is 0.598438.

In the final analysis, the coefficients indicate the following:

(1) There is a relatively high positive correlation of both the probability – actuality and the probability – frequency orders.

(2) In the cases where the Spearman rank correlation coefficient of the probability – actuality and the probability – frequency orders were different, a higher positive correlation of the probability – frequency order was obtained.

It means that from the three views mentioned before (First: the supposed probability of the incidents that happen frequently, or that have happened lately is relatively higher. Second: incidents that rarely happen, or have not happened recently are more probable to happen in future. Third: no connection is supposed between the probability and the actuality or frequency of a risk happening), the first one has statistical superiority.

Hence, it may be concluded that the incidents that happen frequently, or that have happened lately are easier to imagine, so in risk perception, their supposed probability is relatively higher. In connection with this view, presumed security means preparedness for quite well-known incidents, ignoring the hypothetic incidents that are unfamiliar.

The results of this survey are consistent with Engländer's concept of the risk – perspective effect: People attribute a higher probability to events that may easily be recalled or imagined. Recent events may be recalled in an easier way than events that are distant in time, so people tend to attribute a higher probability to recent events. Hence, people behave as if they perceived risks in perspective: risks closer in time seem of higher probability, while those distant in time seem of lower probability. This effect is called the effect of risk – perspective [3].

The outcome of the survey also confirms the theorem of Benedikt, Kun and Szász: The human perception of risk is based on the perception of the time period to the risk event. The human perception of risk is based on the perception of a logarithmic scale distortion of the time period to the risk event even if the probability per time unit of the event may be regarded as known [4].

It means that neither the new challenges in disaster management, nor the technical development change the way of the human perception of risks.

5 Other Features of Risk Perception

Besides the effect of risk – perspective that was confirmed by the results of the survey discussed, Engländer analysed several other features of human risk perception. He demonstrated the human preference of the uniformity of risks by an experiment [3].

5.1 The Experiment on the Human Preference of the Uniformity of Cumulative Risks

The experiment was a gambling situation. A disc (based on the method of a roulette wheel) was divided into 16 congruent sectors numbered 1-16. The four quadrants were painted in different colours. One could bet on a sequence of numbers, colours, and parity, according to the following sequences:

<u>Sequence 1</u>: number, parity, parity
<u>Sequence 2</u>: parity, number, parity
<u>Sequence 3</u>: parity, parity, number
<u>Sequence 4</u>: colour, colour, colour.

For all of the sequences, winning was identified if and only if all the three tips given had been proved to be correct.

In the case of a number and according to the formula of geometric probability: $P(\text{winning}) = \frac{1}{16}$ and $P(\text{losing}) = \frac{15}{16}$.

In the case of parity: $P(\text{winning}) = \frac{1}{2}$ and $P(\text{losing}) = \frac{1}{2}$.

In the case of colour: $P(\text{winning}) = \frac{1}{4}$ and $P(\text{losing}) = \frac{3}{4}$.

The chances of winning and losing are the same for all of the four sequences, as:

<u>Sequence 1</u>: chances of winning are $\frac{1}{16}, \frac{1}{2}, \frac{1}{2}$, respectively. The probability of winning in Sequence 1 is $\frac{1}{16} \cdot \frac{1}{2} \cdot \frac{1}{2} = \frac{1}{64}$.

<u>Sequence 2</u>: chances of winning are $\frac{1}{2}, \frac{1}{16}, \frac{1}{2}$, respectively. The probability of winning in Sequence 2 is $\frac{1}{2} \cdot \frac{1}{16} \cdot \frac{1}{2} = \frac{1}{64}$.

<u>Sequence 3</u>: chances of winning are $\frac{1}{2}, \frac{1}{2}, \frac{1}{16}$, respectively. The probability of winning in Sequence 3 is $\frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{16} = \frac{1}{64}$.

<u>Sequence 4</u>: chances of winning are $\frac{1}{4}, \frac{1}{4}, \frac{1}{4}$, respectively. The probability of winning in Sequence 4 is $\frac{1}{4} \cdot \frac{1}{4} \cdot \frac{1}{4} = \frac{1}{64}$.

For the first three sequences, the betting preference occurred according to the effect of risk – perspective. However, from all of the sequences, participants considered Sequence 4 as having the highest probability of winning. Engländer called it the preference of uniformity during the perception of cumulative risks. In fact, long-term prevailing situation-characteristics are easier to handle for people. So, uniformity means a form of optimization of the risks.

For all the above sequences, mathematically, the total risk is calculated by multiplying the individual risks. Nevertheless, Engländer claims that the preference of uniformity and the naïve optimization mentioned above imply that instead of multiplication, people mentally apply an "operation close to addition" when perceiving cumulative risks [3].

In the following, this cognitive "operation close to addition" is going to be specified.

5.2 The Mathematical Model of the Cognitive Human Dislocation towards the Direction of the Preference of Uniformity during the Perception of Cumulative Risks

Let us consider first what is obtained by adding up the individual probabilities:

Sequence 1: $\frac{1}{16}+\frac{1}{2}+\frac{1}{2}=\frac{17}{16}$

Sequence 2: $\frac{1}{2}+\frac{1}{16}+\frac{1}{2}=\frac{17}{16}$

Sequence 3: $\frac{1}{2}+\frac{1}{2}+\frac{1}{16}=\frac{17}{16}$

Sequence 4: $\frac{1}{4}+\frac{1}{4}+\frac{1}{4}=\frac{3}{4}$.

It is obvious from the sums that adding up the probabilities of winning for the first three sequences, the same value (greater than 1) is obtained, while for the preferred Sequence 4, the sum of the probabilities of winning is a value that is less than 1.

So, that "operation close to addition" Engländer refers to may be the mental minimizing of the sum. It may be proven in several ways that if the product of positive numbers is a constant then the sum of the same numbers is minimal exactly when all the numbers are the same [5].

For pedagogical purposes, a proof that may be used in the basic mathematics subject for university students of engineering is shown below.

5.2.1 During the Perception of Cumulative Risks, the Cognitive Human Dislocation towards the Direction of the Preference of Uniformity may be Mathematically Modelled by Minimizing the Sum. The Proof Using Multivariable Functions

The statement is going to be proved for 3 numbers, as it best fits the original experiment of Engländer.

We know that

$xyz = c$, where x, y, z are positive, and c is a constant. (2)

Hence,

$$z = \frac{c}{xy} \tag{3}$$

The minimum of $x + y + z$, i.e. the minimum of $x + y + \frac{c}{xy}$ is to be obtained now.

Let the two-variable real function $f(x, y)$ be the following:

$$f(x, y) = x + y + \frac{c}{xy} \tag{4}$$

and let us determine the points where the function (4) has local extrema.

The first-order partial derivatives are the following:

$$f'_x = 1 + \frac{c}{y} \cdot (-1) \cdot x \tag{5}$$

$$f'_y = 1 + \frac{c}{x} \cdot (-1) \cdot y^{-2} \tag{6}$$

Stationary points are determined by solving the next system of equations:

$$\begin{cases} f'_x = 0 \\ f'_y = 0 \end{cases} \tag{7}$$

Solving the system of equations (7),

$$x^2 y = c \tag{8}$$

and

$$xy^2 = c \tag{9}$$

are obtained. It follows that

$$x = y = \sqrt[3]{c} \tag{10}$$

which means that the point $P\left(\sqrt[3]{c}, \sqrt[3]{c}\right)$ is a stationary point.

It still has to be proved if there is in fact an extremum at the stationary point, and if so, what the type of it is (maximum or minimum).

To check it, the second-order partial derivatives have to be determined.

The pure ones are:

$$f''_{xx} = \frac{c}{y} \cdot (-1)(-2) \cdot x^{-3} = \frac{2c}{x^3 y} \tag{11}$$

and

$$f''_{yy} = \frac{c}{x} \cdot (-1)(-2) \cdot y^{-3} = \frac{2c}{y^3 x} \tag{12}$$

while the mixed ones are

$$f''_{xy} \left(= f''_{yx}\right) = \frac{-c}{x^2} \cdot (-1) \cdot y^{-2} = \frac{c}{x^2 y^2} \tag{13}$$

The determinant D may be obtained by substituting the stationary point into the second-order partial derivatives.

$$D = \begin{vmatrix} \frac{2}{\sqrt[3]{c}} & \frac{c}{\sqrt[3]{c^4}} \\ \frac{c}{\sqrt[3]{c^4}} & \frac{2}{\sqrt[3]{c}} \end{vmatrix} = \frac{3c^2}{\sqrt[3]{c^8}} > 0 \tag{14}$$

It follows that there is in fact an extremum at the stationary point. As $f''_{xx} > 0$, there is a local minimum at the stationary point.

Hence, by choosing $x = y = z = \sqrt[3]{c}$, exactly the minimum of the sum $x + y + z$ is obtained.

So, during the perception of cumulative risks, the cognitive human dislocation towards the direction of the preference of uniformity may be mathematically modelled by minimizing the sum.

Conclusions

As the human factor is always present among the main reasons of accidents, it is vital to be aware of the nature of human risk-perception. For this reason, understanding the psychological background of risk perception is unquestionable. Presumed security is a parallel concept to risk perception: supposing security on the basis of probability.

Human perception of risk is based upon probabilities. There are three common or imaginary views concerning risk perception. First, the supposed probability of incidents that happen frequently, or that have happened lately is relatively higher. Second, incidents that rarely happen, or have not happened recently are more probable to happen in future. Third, no connection is supposed between the subjective probability and the actuality or frequency of a risk happening. In connection with the first view, presumed security means preparedness for quite well-known incidents, ignoring the hypothetic incidents that are unfamiliar. The second view privileges security of avowed incidents and urges preparations for unexplored ones. Supposing the third view, it is not at all obvious what makes the base for presumed security in this case.

In order to enhance the positive human contribution to security, it is vital to be aware which tendency of the three above is of statistical superiority. For this reason, I have carried out a survey on the topic. The aim was to discover the way people perceive risks among the new approaches of hazards, with a technical development never seen before. I wanted to examine whether there is (and what type of) a correlation between the human perception of risks and the actuality and frequency of the same risks happening. By the Spearman rank correlation coefficient I measured the correlation of both the subjective probability – actuality and probability – frequency orders of given disasters. In the final analysis, the coefficients indicated the following:
(1) There is a relatively high positive correlation of both the probability – actuality and the probability – frequency orders.
(2) In the cases where the Spearman rank correlation coefficient of the probability – actuality and the probability – frequency orders were different, a higher positive correlation of the probability – frequency order was obtained.
It means that from the three views mentioned before, the first one has statistical superiority. Hence, it may be concluded that the incidents that happen frequently, or that have happened lately are easier to imagine, so in risk perception, their supposed probability is relatively higher. In connection with this view, presumed security means preparedness for quite well-known incidents, ignoring the hypothetic incidents that are unfamiliar. The results of this survey are consistent with Engländer's concept of the risk – perspective effect. The outcome of the survey also confirms the theorem of Benedikt, Kun and Szász: The human perception of risk is based on the perception of the time period to the risk event.
It means that neither the new challenges in disaster management, nor the technical development change the way of the human perception of risks.

Several other features of human risk perception have also been analysed. Engländer demonstrated the human preference of the uniformity of risks by an experiment. He claimed that the preference of uniformity implied that instead of multiplication, people mentally apply an "operation close to addition" when perceiving cumulative risks. I proved that the "operation close to addition" Engländer referred to may be the mental minimizing of the sum. For pedagogical purposes, a proof that may be used in the basic mathematics subject for university students of engineering was shown.

References

[1] NEA (2003): Nuclear Regulatory Challenges Related to Human Performance ISBN : 92-64-02089-6, OECD, Paris

[2] Thomas D. Gauthier: Detecting Trends Using Spearman's Rank Correlation Coefficient, Environmental Forensics (2001) pp. 359-362

[3] Engländer Tibor: Viaskodás a bizonytalannal. A valószínűségi ítéletalkotás egyes pszichológiai problémái, Akadémiai Kiadó, 1999.

[4] Benedikt, S.-Kun, I.-Szász, G.: Individual and Collective Risk Perception in Decision Criteria. ”Cybernetics and Systems 2004”(edited by Robert Trappl). University of Vienna and Austrian Society for Cybernetics Studies, Volume 1, pp. 321-325 (2004)

[5] Kovács Judit: Az emberi tényező matematikai modellezésének lehetőségei a katasztrófavédelmi kockázatértékelés és kockázatkezelés területén Doktori (PhD) értekezés, 2011. ZMNE