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Modelling and Simulation of Entropy in Human Resource Training [1]

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Abstract

This article deals with the subject of risk management associated with a human resource training program by applying the concept of entropy. In the application presented in the article, I used the mathematical model of entropy defined by Claude Shannon adapted to human resource training and we performed risk simulation in Microsoft Excel program that can provide adequate and appropriate risk management, before and during running training program.

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1 Introduction

In the paper "A Mathematical Theory of Communication" (1948) Claude Shannon defined the concept of entropy as a measure of the amount of indeterminacy contained in a finite probability field [1,4].

By analogy, we define the entropy risk specific for of human resource training as a measure of the degree of ignorance of the risks that may occur and compromise the objectives of human resource training. Entropy refers to the values and the levels of risk that can affect to a smaller or greater extent the normal conduct of business by continuing training.

2 Modelling and properties of entropy in human resource training

Thus, we consider as a possible experiment a training program on the establishment in which there may be n risks that we will call and we will note $r_1, r_2, ..., r_n$ and the

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probability of occurrence of these events. Thus, we create a mathematical model of the probability field regarding situations, factors, events and vulnerabilities that may come up and affect the activities and objectives of the training provided in a training program as in the formula below:

$$R : \begin{pmatrix} r_1 \dots r_n \\ p_1 \dots p_n \end{pmatrix}, \ p_k \geq 0, \ \sum_{k=1}^{n} p_k = 1 \tag{1}$$

where:

$R =$ is array of risks and probabilities of occurence

$p_k =$ positive value of a probability of string $p_1, \dots, p_n$

$\sum_{k=1}^{n} p_k =$ represents the amount of risk probabilities, equal to 1.

So, mathematically, we define the entropy of the risk in human resource training (or the corresponding entropy probability distribution $(p_1, p_2, \dots, p_n)$) as being:

$$H_n(R) = h_n(p_1, p_2, \dots, p_n) = -\sum_{k=1}^{n} p_k \log p_k \tag{2}$$

where:

$H_n(R) =$ entropy risk

$\log p_k =$ is a function which is applied to the value p_k.

Logarithm can be considered in any base greater than 1.

In order to have a correct definition of $H_n(R)$, we assume that $p_k \log p_k$ is zero when $p_k = 0$. This term is defined as the contribution of risk k probability p_k in global entropy formula (2). Entropy risk properties [2,3] so defined will allow us to interpret the $H_n(R)$ as a measure of the amount of probability contained in R field, prior to the training course, during its deployment or evaluation phase of the trainings.

Property 1. *Risk entropy is always positive for any probability greater than or equal to 0, the sum is equal to 1, according to the following inequalities:*

$$H_n(p_1, \dots, p_n) \geq 0 \ \textit{for any} \ p_k \geq 0, \ k = 1, \ \sum_{k=1}^{n} p_k = 1$$

Proof. Given the convention $p_k \log p_k = 0$ for $p_k = 0$ and the fact that $p_k \leq 1$, so $\log p_k \leq 0$ for any $k = 1, ..., n$, such feature is demonstrated. Interpretation of this property is as follows: any training course, contains a certain amount of indeterminacy, namely the degree of ignorance of the risks that may occur and affect the training objectives. Naturally, the question arises "when do we have zero indeterminacy quantity?" The minimum degree of ignorance will always be, obviously, zero. We will answer that question in the following property.

Property 2.*If a probability is 1 and the others are 0, then the entropy is null, according to the above relation.*

If $p_{i_0} = 1$ *and* $p_i = 0$ *for all* $i = 1, ..., n,\ i \neq i_0$ *then*

$$H_n(p_1, \ldots, p_n) = 0$$

Proof. Again, considering that $p_i \log p_i = 0$ for all indices i different from i_0, and $p_i = 0$, the property is demonstrated as such.

The interpretation of this property is as follows: a deterministic experiment, in which one result is with probability 1, other results with probability null (impossible) will not contain any non-determination of the amount of risk. In other words, if a training course is affected by a single risk, probability 1, there is no degree of ignorance on the running course on how it will affect that risk, since the probability is certainly a known and those responsible for training will act accordingly.

Property 3. *For any positive probability that their sum is 1, the entropy does not change by adding a probability value of zero, according to the relationship below.*

For any $p_k \geq 0,\ k = 1, ..., n,\ \sum_{k=1}^{n} p_k = 1$ *we have:*

$$H_{n+1}(p_1, \ldots, p_n, 0) = H_n(p_1, \ldots, p_n).$$

Proof. To demonstrate this property, please note that $(p_1, \ldots, p_n, 0)$ is a probability distribution for $(n+1)$ elementary events with where $P(A_i) = p_i,\ i = 1, \ldots, n,\ P(A_{n+1}) = 0$, where $P(A_i)$ represent the probability of the event A_i then:

$$H_{n+1}(p_1, \ldots, p_n, 0) = -p_1 \log p_1 - p_2 \log p_2 \ldots - p_n \log p_n - p_0 \log p_0 =$$

$$= H_n(p_1, \ldots, p_n).$$

Interpretation of this property is: in the case of a training course an emerging risk of zero probability (this is not considered at risk) shall be without any change in the degree of ignorance in the field of probability of risk attached to human resource training. So, any risk factor with zero probability of occurrence does not affect the associated entropic field of human resource training.

Property 4. *For* $p_k \geq 0,\ k = 1, ..., n,\ \sum_{k=1}^{n} p_k = 1$ *we have:*

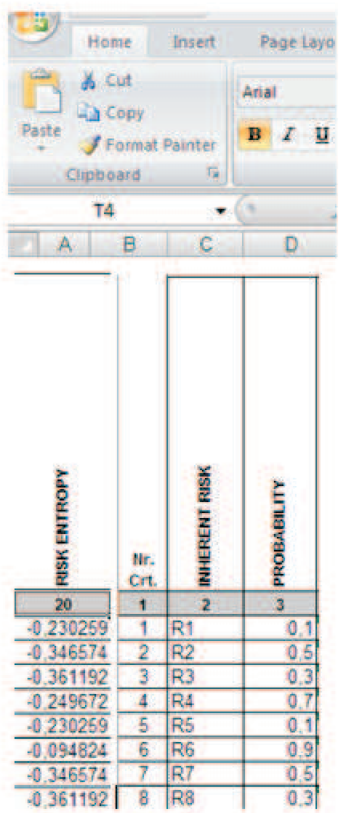
$$H_n(p_1, \ldots, p_n) \leq H_n\left(\frac{1}{n}, \ldots, \frac{1}{n}\right) = \log n.$$

According to the above relation, the maximum entropy is $\log n$, this maximum being obtained for risks with equal probability. Entropy will always be a real number in the range $[0, \log n]$, while the probability of any misunderstanding risks associated with field training course is a number from the interval [0,1]. Therefore, if the probability is the same for each risk and the amount is equal to a probability, that each probability is $1/n$. According to the above relation, maximum entropy value is $\log n$, this maximum being obtained for risks with equal probability. The entropy will always be a real number between $[0, \log n]$, while the probability of any risk from misunderstanding field of risks associated with the training course is a number between [0,1]. Therefore, if the probability is the same for each risk, and the sum of probabilities is equal to 1, then each probability is $1/n$. Interpretation of this property is as follows: entropy defined as a measure of ignorance of the risks that may occur during a training course is maximum when the risks are equally likely. If the risks do not have equal chances to occur as well as others, entropy risk will have a value strictly less than $\log n$. Entropy calculation of the risk in human resource training may be an essential information for human resource training officers, according to which they can decide whether or not to start a training course, further or corrected during the course of activities impacted risks, and the correct evaluation of training.

3 Simulation of entropy in human resource training

In order to simulate the entropy of risk we will use the entropy formula as a mathematical pattern (2). The pattern simulation will be made using the programme Microsoft Excel as follows:

Step 1. I realized in Microsoft Excel a file where I introduced encoded: risks, probabilities, from table 1. To calculate the entropy I added to the file a column as shown below:



RISK ENTROPY	Nr. Crt.	INHERENT RISK	PROBABILITY
20	1	2	3
-0,230259	1	R1	0,1
-0,346574	2	R2	0,5
-0,361192	3	R3	0,3
-0,249672	4	R4	0,7
-0,230259	5	R5	0,1
-0,094824	6	R6	0,9
-0,346574	7	R7	0,5
-0,361192	8	R8	0,3

Table 1. The main risks associated with a training programme

No. crt.	Fields (targets impacted)	Risk definition	Factors/Causes
1	Designing a training program	**R1**.Design inadequate training	**C1**.Lack of knowledge about human resource training domain
2	Determining real training needs	**R2**.Incomplete or inadequate identification of training needs of human resources	**C2**.-Insufficient items in questionnaires or misinterpretation of their results. -Lack of knowledge about methodology for determining training needs
3	Clearly define the real aims of training	**R3**.Unrealistic or inappropriate training objectives	**C3**.Not taking into account the objectives of training policy and training needs arising from the analysis
4	Establishing training curriculum	**R4**.Generic contents or too detailed	**C4**.Superficiality in preparing thematic content
5	Building the training groups or fields of work areas	**R5**.Heterogeneous training groups	**C5**.Testing and inappropriate nominations in the training group
6	Design the methodology instrument to achieve the training curriculum and evaluation	**R6**.Planning tools and/or inadequate methods of implementation and evaluation of training topics	**C6**. A certain degree of incompetence in choosing and planning the methodological tools
7	Providing technical and material supplies for training	**R7**.Inadequate logistics elements in the project training	**C7**.Undischarged state of logistics equipment and where the training will take place
8	Competence in implementing training project	**R8**. Leadership failures in conducting and evaluating training	**C8**.Lack of qualified trainers in achieving proper training and evaluation of its results

Step 2. Using the keyboard, I introduced estimates of probabilities and impacts of each risk into the file, and the program automatically set the risk exposures, risk contribution for each entropic field ($p_k \log p_k$), and global entropy training course 2,221, as follows :

- For the first risk with the probability $p_1 = 0,1$, its contribution has been calculated as $p_1 \log p_1 = -0,230259$;

- For the second risk with the probability $p_1 = 0,5$, its contribution has been calculated as $p_2 \log p_2 = -0,346574$;

- For the third risk with the probability $p_1 = 0,3$, its contribution has been calculated as $p_3 \log p_3 = -0,361192$;

- For the fourth risk with the probability $p_1 = 0,7$, its contribution has been calculated as $p_4 \log p_4 = -0,249672$;

- For the fifth risk with the probability $p_1 = 0,1$, its contribution has been calculated as $p_5 \log p_5 = -0,230259$;

- For the sixth risk with the probability $p_1 = 0,9$, its contribution has been calculated as $p_6 \log p_6 = -0,094824$;

- For the seventh risk with the probability $p_1 = 0,5$, its contribution has been calculated as $p_7 \log p_7 = -0,346574$;

- For the eighth risk with the probability $p_1 = 0,3$, its contribution has been calculated as $p_8 \log p_8 = -0,361192$. Global entropy training course, as the formula (2) opposite amount of such contributions of risk, that is:

$$H(p_1, ..., p_8) = -(-0,230259 - 0,346574 - 0,361192 - 0,249672-$$
$$0,230259 - 0,094824 - 0,346574 - 0,361192) = 2,221.$$

4 Conclusions

Table 2. Map summary of the results obtained from the simulation of entropy associated with a training programme

No.	**Risk description**	**Risk level**	**Risk contribution to global entropy of 2,221** ($p_k \; log p_k$)	**Priorities and solving steps**
1	**R4**. General or too detailed contents	High	-0,249672	Priority 1/1 day Writing thematic content, with appropriate extension according to the needs and training objectives
2	**R2**. Incomplete or inadequate identification of training needs of human resorce	moderate	-0,346574	Priority 2/2 days -Reviewing the contents of the questionnaires used in assessing the results of the judgments issued -Learning and applying the methodology to identify training needs
3	**R3.** Unrealistic or inadequate training objectives	moderate	-0,346574	Priority 2/2 days Redefine objectives and their implementation according with the actual policy and training needs
4	**R8**. Leadership failures in conducting and evaluating training	moderate	-0,361192	Priority 2/2 days Replacing the trainer or develop the existing competence
5	**R6**. Planning tools and/or inadequate methods of implementation and evaluation of training topics	moderate	-0,230259	Priority 2/2 days Restoration of design tools methodology, or, if necessary, replace the designer
6	**R5**.Heterogeneous training groups	minor	-0,094824	Priority 3/3 days Retesting and appropriate selection of the group according to the requirements of homogeneity
7	**R7**. Inadequate logistic elements in the project training	minor	-0,346574	Priority 3/3 days Prior testing and verifying the logistics training place for conducting training
8	**R1**. Inadequate design of the training	minor	-0,230259	Priority 3/3 days Reassesment of the field in which the training is made or nominate other responsibles with the design

The simulation results presented in table 2 offer to the person responsible with human resources training information regarding the level, hierarchy and contribution of each risk at the global value of entropy, as a measure of risk assessment values, which may occur and affect the training objectives of human resource.

As we can see, the simulation indicates higher or smaller contributions of some risks at the global entropy value that is why the trainer will have to intervene before, during or at evaluation risks management training course.

The value and the contribution of each risk provide analysis support and decision for human resource trainer to prevent, eliminate and decrease negative risks, to exploit and increase the positive risks, in order to achieve training objectives. In the case of negative risks, global entropy will decrease or will tend to zero, so the training course objectives will be fulfilled according to the initial planning.

Entropy values obtained by simulation can also be compared with other entropy values, courses or similar training and experience in relation to the management of entropy, it can decide whether or not to start training, where appropriate, decide on preventive measures and risk management simulated or newly identified risks that might occur in carrying out training.

From the map synthesis (Table 2), we notice that a single risk is high - is too generic or detailed - four risks are moderate and three minor risks, to which the decision maker or responsible for human resource training may establish measures response to risk. In the last column of Table 2 some recommendations are included for risk treatment depending on the solving priorities.

Modelling and simulating entropy risk of human resource training, as a method of optimizing decisions in conditions of risk, can be used both before the start of a training program as well as in its design, implementation and evaluation.

References

[1] A. Bucur, *Applied Mathematics in Biology and Ecology*, Lucian Blaga University, Sibiu, 2008.

[2] J. Jia, J. S. Dyer, *A Standard Measure of Risk and Risk; Value Models.* Working Paper No. 1, Risk; Value Study Series, Deparment of Management Science and Information Systems, The Graduate Scool of Business, University of Texas at Austin, Management Science, 1995.

[3] J.W. Payne, D. J. Laughhunn, R. Crum, *Translation of Gambles and Aspitation Level Effects in Risky Choice Behaviour*, Management Science, 26, 1980, 1039-1060.

[4] C. E. Shannon, *A mathematical theory of communication*, Bell System Technical Journal, Vol. 27, 379-423 and 623-656, July and October, 1948.

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