ASPECTS REGARDING THE QUALITATIVE ANALYSIS OF RISKS DUE TO THE OCCURRENCE OF LOW PROBABILITY AND VERY HIGH IMPACT EVENTS

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Abstract: *Extreme events, such as earthquakes, floods, tsunami, nuclear accidents, terrorism etc., have a very high impact, they are claiming large material losses and casualties in many cases. For the assessment of such low probability events it is necessary to use qualitative analysis techniques. Risk matrices used in qualitative analysis places these risks in the medium risk category, meaning an acceptable level. The paper proposes a means of changing matrices used in qualitative analysis, so that extreme risks from increasingly present to be classified as having a high level. Such theoretical repositioning will lead to changes in treatment applied.*

Keywords: *extreme event, qualitative analysis, risk, probability impact, matrix*

1. INTRODUCTION

As a result of economic globalization become multi-national with divisions and productive units dispersed across territories political, legislative, social, cultural, economic, competitive and natural factors are different from one territory to another. This situation generates a multitude of risks highly complex, with different manifestation from one territory to another. Diversity and dynamic factors give rise to a whole series of global risks, decisively influencing management decisions.

Together with the economic globalization, the competition gains another dimension, also through its globalization, and the factors of the competitive external environment linked to: industrial rivalry, suppliers, consumers and substituting products. As a result, generates a whole series of risks: exploitation risks, financial and bankruptcy risks which require adaptability and flexibility in the decisional and managerial systems of the economical organizations.

In the case of a trans-national company, the internal environment gains a new territorial dimension, which comes with new series of risk factors, such as: work attitude, work costs, cultural and religious elements, workforce qualification etc. Certain factors that may represent a particular territory strengths other territories become weaknesses, is on the one hand generating risks, and on the other hand increasing the number of variables in decision-making processes. Economic globalization creates an environment where factors such as: natural catastrophes, threats from new technologies (nuclear risks), demographic and climatic changes lead to a large number of risks which have to be taken into account by enterprise management in the decision making process [1]. The "Global risks 2015" report, presents as the most important risks for trans-national companies, the following [2]:

- geopolitical risks: international conflict, failure of national governance, state collapse or crysis, proliferation of the weapons of mass distruction etc.;
- social risks: diminished water resources, quick spread of infectious disease;
- environmental risks: extreme meteorological events, failure to adapt to climatic change etc.;
- economic risks: high unemployment or underemployment rates, failures of or attacks on energy, water and transport systems etc.

A large part of the risks faced by economic entities is generated by events with a low probability to appear but with a very high impact (EPAMIR). Events such as high earthquakes, extreme weather events (hurricanes, tsunamis), terrorism, massive population migrations, economic crisis etc. belong to this category.

2. THE QUALITATIVE ANALYSIS OF RISKS CAUSED BY EPAMIR

In order to be placed in the EPAMIR category, an event must meet the following conditions:

- is extreme, well beyond normal expectations, as nothing from the past can indicate convincingly the possibility of its appearance;
- has an extreme impact;
- although the event is extreme, human nature makes us produce the explanations required to explain it only after its appearance, making the event look predictable and explainable.

Because very small probabilities are difficult to determine, analyze qualitative gains, in case of EPAMIR phenomena, a major issue in the process of risk management and involves the following steps [4]:

- choosing the scales of probability and risk impact;
- establishing a risk matrix reference;
- determining the risk score and risk matrix composition;
- risk hierarchy.

2.1 Choosing the risk probability and impact scales. The appearance probability of an extreme phenomenon is very low and hard to determine. On the other hand, the probability does not indicate the timing of the event. This is the reason why a scale with risk probability levels can be used to place each risk factor within certain probability levels. This can usually a number of levels ranging between 3 and 5. Such an example of risk probability scale is shown in Table 1. It can be built with the help of two values categories [4]:

- ordinal values, in which case each risk level gets a grade, respectively: very low (almost impossible), low (improbable), medium (possible), high (probable), very high (almost certain);

Table 1. Risk probability scale

Qualitative evaluation of probability	Quantitative evaluation of probability	Probability score
Very high	Once in 5 years	5
High	Between 5 and 10 years	4
Medium	Between 10 and 20 years	3
Low	Between 20 and 50 years	2
Very low	Above 50 years	1

- cardinal values, in which case each level is attributed a probability score, respectively: 1, 2, 3, 4 şi 5, where 1 is the score for a risk with a very low probability of appearance and 5 is the score for a risk with a very high probability of appearance.

Also, for the risk impact a scale with impact levels is chosen which reflects the damage severity in the event that risk and it can have:

- ordinal values, respectively impact grades: very low, low, moderate, high, very high;
- cardinal values, with values of the risk impact of 1, 2, 5, 10 and 20, where 1 is the value for a very low impact risk, and 20 for a very high impact. An example scale for the risk impact is presented in Table 2 [5].

Table 2. Risk impact scale

Qualitative impact evaluation	Quantitative evaluation of impact	Impact score
Very high	Material damage is higher than 20% of the objectives' value, serious injuries for more than 10 people and/or loss of human lives	20
High	Material damage between 5 and 20% of the objectives' value, severe injuries for 1-10 people.	10
Moderate	Material damage between 3 and 5% of the objectives' value, light injuries for 3-10 people.	5
Low	Material damage between 1 and 2% of the objectives' value, light injuries for 1-3 people.	2
Very low	Material damage below 1%, no injuries.	1

2.2 Establishing the risk reference matrix. The risk reference matrix is built by combining the risks' probability and impact scales shown in Tables 1 and 2. The risk matrix can be represented both in a ordinal form (the risk level matrix) and a cardinal form (the risk score matrix). The risk matrix can be built using 3, 4 or 5 levels of probability or impact. Some authors use a matrix of risk level consists of 4 levels of probability and impact [6], while others recommend five such levels [7]. The authors propose for this study, the level of risk matrix with 5 levels of probability and impact presented in Table 3. The aim, through this approach, is to improve decision support regarding the choice treatment to apply to extreme risk.

The risk level matrix shown in table 3 is obtained by combining the ordinal probability and impact scales from tables 1 and 2. This matrix contains five risk levels, which are: very low, low, moderate, high and very high. Each risk level is given a color, that is: dark green for very low, light green for low, yellow for moderate, orange for high and red for very high.

Table 3. Risk level matrix

Very high	5	Low	Moderate	High	Very high	Very high
High	4	Very low	Low	Moderate	High	Very high
Medium	3	Very low	Low	Moderate	High	Very high
Low	2	Very low	Very low	Moderate	Moderate	High
Very low	1	Very low	Very low	Low	Moderate	Moderate
	Score	1	2	5	10	20
PROBABILITY		Very low	Low	Moderate	High	Very high
		IMPACT				

The risk score (SR), is a criterion which can be used to rank risks and it is calculated as the the product between the probability score for the risk (sp) and its impact score (SI), according to Relation 1:

$$SR = SP \times SI \quad (1)$$

The risk score matrix, which confers a quantitative aspect to the qualitative analysis, is shown in table 4 and is obtained in two stages:

- replace the ordinal probability and impact scales in table 3 with the cardinal scales chosen in tables 1 and 2;
- **establish in each cell of table 4 the values of the risk scores, calculated with the relation 1.**

Risk classification, respectively associating the colors corresponding to both the risk level matrix and the risk score matrix is shown in table 5.

Table 5. Risk classification

SR Value	Risk Level	Associated color
$50 \leq SR \leq 100$	5 – very high risk	Red
$25 \leq SR \leq 40$	4 – high risk	Orange
$10 \leq SR \leq 20$	3 – medium risk (moderate)	Yellow
$5 \leq SR \leq 8$	2 – low risk	Light green
$1 \leq SR \leq 4$	1 – very low risk	Green

2.3 Risk evaluation. A frequently approach used in risk evaluation, known under the ALARP acronym (As Low As Reasonably Practicable) it is treated extensively in the literature [8][9][10] [11]. ALARP method divides the risks in three zones:

- the unacceptable zone, which includes the high and very high risks, with the red and orange colors in Table 5. The risk is considered unacceptable and in this case risk reducing measures are obligatory, regardless of the costs involved;
- the tolerable zone, which includes the medium risks, with the yellow color. The risk is considered tolerable, if reducing it is impossible or the costs to reduce it surpass the obtainable results;
- the acceptable zone, which includes the low and very low risks, with the dark and light green colors. No measures are required for these risks, as long as they stay at these levels.

2.4 Determining the risks' scores and building the risk matrix. For each of the identified risks of risk factors (Ri), the probability score (SPi) and the impact score (SIi) area established according to the chosen probability and impact scales and the SRi score is calculated, where i = 1, 2,…, n, using the relation 1. The global risk score is determined by using the Relation 2:

$$SRM = \sum_{i=1}^{n} SR_i / n, \quad (2)$$

where n is the number of risk factors.

With the help of these data, the risk matrix, presented in Table 6, is built.

Table 6. Risk matrix

Risk	**Probability**					**Impact**					**IPR**
Score	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**5**	**10**	**20**	
R_1		SP_1						SI_1			$SR_1 = SP_1 \cdot SI_1$
R_2				SP_2			SI_2				$SR_2 = SP_2 \cdot SI_2$
...											...
R_i			SP_i						SI_i		$SR_i = SP_i \cdot SI_i$
...											...
R_n			SP_n					SI_n			$SR_n = SP_n \cdot SI_n$
SRM											$\sum SR_i/n$

In order to evaluate the risk factors, the risk score matrix is ordered after the descending values of the calculated risk score, thus obtaining the ordered risk matrix. Such an example is shown in Table 7.

Table 7. Risk matrix

Risk	**Probability**					**Impact**					**IPR**
Score	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**5**	**10**	**20**	
R_1		SP_1						SI_1			$SR_1 = SP_1 \cdot SI_1$
R_2				SP_2			SI_2				$SR_2 = SP_2 \cdot SI_2$
...											...
R_i			SP_i						SI_i		$SR_i = SP_i \cdot SI_i$
...											...
R_{n-1}		SP_{n-1}							SI_{n-1}		$SR_{n-1} = SP_{n-1} \cdot SI_{n-1}$
R_n			SP_n					SI_n			$SR_n = SP_n \cdot SI_n$
SRM											$\sum SR_i/n$

Inside this matrix, each risk is associated, depending on its score, the corresponding color, in accordance with the classification in Table 5 and, depending on this level, measures are taken to reduce the risk by following the ALARP risk evaluation model.

2.5 The limits of the risk's qualitative analysis model in the case of extreme phenomenon. In the case of EPAMIR, according to the risk matrix shown in Table 3, the risk associated with the very low probability and very high impact is classified as moderate being colored yellow. [4][5] [12]. According to ALARP, moderate risks are considered tolerable and they don't require special measures. Calculating the risk score according to relation (1), we obtain SR = 1 × 20 =20.

This score places the risk, according to the risk score matrix shown in Table 4, in the moderate category, which is acceptable. In authors opinion , they are rare events having a devastating impact and are unacceptable.

These risks must benefit from one of the two categories of measures to reduce them:

- elimination – for example, in the case of airplane terrorism, the risk can be eliminated through thorough passenger, crew and airport personnel checks;
- impact reduction – for example, the risk of strong earthquake, higher than 7, can't be avoided, but its effects can be considerably reduced by consolidating vulnerable buildings or by designing buildings with the proper supporting structure.

3. REFERENCE MATRICES USABLE IN THE QUALITATIVE ANALYSIS OF EXTREME EVENTS

For the qualitative analysis of EPAMIR events, a risk level matrix is proposed where the pair very low probability and very high impact. Is associated brown color and its risk level is considered high. The new risk level matrix is shown in Table 8.

Table 8. Risk level matrix

Very high	5	Low	Moderate	High	Very high	Very high
High	4	Very low	Low	Moderate	High	Very high
Medium	3	Very low	Low	Moderate	High	Very high
Low	2	Very low	Very low	Moderate	Moderate	High
Very low	1	Very low	Very low	Low	Moderate	High
	Score	1	2	5	10	20
PROBABILITY		Very low	Low	Moderate	High	Very high
		IMPACT				

According to this matrix, EPAMIR are no longer part of the medium risks, acceptable according to ALARP, they are now part of the *high risk category,* which must be dealt with, either by eliminating them or by reducing their impact.

In the case of the risk score matrix, the very high impact level gets a score of SI = 25. The risk scores corresponding to the (*very low probability – very high impact*) pair becomes SR = 1 × 25 =25.

This score brings this category of risks to level 4 – *high risks*, which must be either eliminated or their potential impact reduced.

The risk score matrix thus obtained is presented in Table 9.

Table 9. Risk score matrix

Very high	5	5	10	25	50	125
High	4	4	8	20	40	100
Medium	3	3	6	15	30	75
Low	2	2	4	10	20	50
Very low	1	1	2	5	10	25
	Score	1	2	5	10	25
PROBABILITY		Very low	Low	Moderate	High	Very high
		IMPACT				

The new risk matrix, above, can be used in the qualitative analysis of risk events EPAMIR framing them in the high risk category, which can not be accepted. If the latter category, analyze risk factors, even after the events and the establishment of appropriate treatment will be impossible to produce such events.

CONCLUSIONS

The EPAMIR type eventsmust be included in the high risk category, which means that measures must be taken to either eliminate them or reduce their impact.

The qualitative analysis gains special importance in the risk management process for EPAMIR, as it allows the risks to be evaluated and the decision to be made on the appropriate response measures. Evaluating the risk factors, events occurred and establishing the appropriate corrective measures will lead to the prevention of similar future events.

The risk matrices currently used place EPAMIR in the medium risk category, which are considered acceptable and do not require corrective measures. The matrices proposed in this paper place EPAMIR in the high risk category, where corrective measures, such as impact reduction or elimination, are obligatory.

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