DETERMINATION OF RISK FACTORS SIGNIFICANCE OF OIL AND GAS PRODUCTION ENTERPRISES’ ACTIVITY

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ABSTRACT: The efficiency of risk management software depends on the quality of risk assessment at the stage of such system development. The number of potential variables (factors) in many risk management software applications is large. Another important aspect is that the scientists and engineers face the challenge of which risk factors are significant or what the acceptable range of its values is at the initial stage of the risk controlling system development. The paper suggests a way to determine the significant specific risk factors of domestic oil and gas production enterprises’ activity and to screen out the insignificant factors. In order to achieve these goals, the simulation analysis was conducted by the aid of 2-level full factorial experiment. Empirical data-processing operation was carried out through the instrumentality of mathematical statistics methods. It has been suggested to exclude (screen) at the stage of model construction eleven risk factors (of thirty-five ones identified), which impact on the financial and economical state of analyzed companies is insignificant (less than 5%).

JEL CLASSIFICATIONS: C99, G32, L71

KEYWORDS: Risk, risk factors, factor screening, 2^k full factorial experiment, oil and gas production enterprises

CITATION (APA): Gryniuk, O. (2017). The determination of risk factors significance of oil and gas production enterprises’ activity. Perspectives of Innovations, Economics and Business, 17(1), 37-51. http://dx.doi.org/10.15208/pieb.2017.03

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http://dx.doi.org/10.15208/pieb.2017.04

1. Introduction

Business environment complications of oil and gas production enterprises against the background of world structural changes and increased costs of production of hydrocarbons lead to the need for risk controlling system implementation by such enterprises.

The efficiency of risk management software depends on the quality of risk assessment at the stage of such system development. The number of potential variables (factors) in many risk management software applications is large. Another important aspect is that the scientists and engineers face the challenge which risk factors are significant or what the acceptable range of its values is at the initial stage of the risk controlling system development.
The procedure of selection (screening) of factors which insignificantly affect the financial and economical state of the company is applied to reduce the number of factors analyzed by the risk controlling system. In order to enhance the research in this area, the project team has (based on two indices, namely probability of risk event and the degree of risk impact on the resultant value) to rank factors by the value of the risk, generated by them, and to exclude insignificant factors. This selection of factors allows focusing on the improvement of the process of management of risks, occurrence of which is caused by the significant risk factors only.

2. Statement of the research problem

In Ukraine, the application of internationally developed methodical approaches to the determination of the risk level by oil and gas companies is considerably complicated; it sometimes seems to be impossible due to the lack of information. The lack of complex experimental studies of specific risks, typical for domestic oil and gas enterprises, has caused us to perform the agreed expert assessment of its risk factors. For each risk factor of certain groups of risks, typical for by oil and gas companies, the experts have given the values for the probability of risk events and determined the degree of impact of risk factors (by each risk group) on the financial and economical state of oil and gas companies (Gryniuk, 2016a). Taking into account the significant amount of factors identified, we consider it necessary to identify and exclude those factors which have an insignificant impact on the financial and economical state of the companies. The main task of mathematical modeling of the object, in relation to which the factor screening is being carried out, is to select the significant factors and to eliminate the insignificant ones, using special methods, with a high degree of confidence of obtained results upon a minimum number of experiments. There are a lot of approaches to the screening of insignificant factors or its bad values in the mathematical statistics perspective. According to Wen Li (2015), there are different statistical methods available for factor screening, such as one-factor-at-a-time method, Taguchi’s method, application of full factorial experiment design, fractional factorial experiment design, as well as Plackett-Burman designs. The following designs are also often used for screening: 1) 2-level full and fractional factorial designs; 2) Plackett-Burman fractional factorial design; 3) general full factorial design (with more than two levels of variation) (Minitab 17 Support, 2016). Insignificant risk factors will be eliminated based on the performance of $2^k$ full factorial design.

The aim of the research is to determine significant specific risk factors of domestic oil and gas production enterprises’ activity and to screen out the insignificant factors using $2^k$ full factorial design.

3. Literature review

Nowadays, there are many domestic and foreign scientists’ academic papers, dedicated to the topics of identification and assessment of the risk of business enterprises. The considerable contribution to the study of identification of factors of individual groups of risks (like ecological or geological risk factors), typical for the activity if the oil and gas production enterprises, as well as to its assessment approaches, has been made by many scientists. The latest research results concerning
identification of risks, its analysis and assessment techniques that are used in the oil and gas industry have been obtained by Johnsen, Aas, & Qian (2012), Marhavilas, Kououriotis, & Gemeni (2011), Andersen & Mostue (2012), AlKazimi & Grantham (2015), Skogdalen & Vinnem (2011), Shahriar, Sadiq, & Tesfamariam (2012).

Risk identification is an initial stage of designing of the risk management system. Johnsen, Aas, & Qian (2012) have characterized the major accidents, threats, and defences in the perspective of Man-Technology-Organization (MTO) in oil and gas sector in their research paper. Examples of some major accidents in oil and gas industry from 1980 have been listed from the area’s perspective (offshore drilling, process plants, and transport). Johnsen et al. (2012) also have suggested a set of “best practices” to mitigate the risks, explored with success in Norway.

Methodological approaches to risk assessment are listed in the significant amount of academic papers. The risk analysis and evaluation techniques are classified into three main categories: the qualitative, the quantitative, and the hybrid methods (qualitative, quantitative, semi-quantitative) (Marhavilas, Kououriotis, & Gemeni, 2011). Marhavilas et al. (2011) have represented the classification of the main risk analysis and assessment methodologies, which have been analyzed in detail and can be used for assessment of risks of oil and gas production enterprises’ activity. Andersen & Mostue (2012) have represented the overview of risk analytical methods for risk analysis and have performed the survey of the use of risk analysis in the Norwegian oil and gas industry. Common risk assessment tools used in the petroleum industry also have been described and analyzed by AlKazimi & Grantham (2015).

The analysis and assessment of risk factors of a particular group of risks of oil and gas industry occurs in academic papers more often than complex analysis of risks. Skogdalen & Vinnem (2011) have investigated human and organizational factors as the potential cause of failure in oil and gas industry. There are also many articles focused on risk analysis of the failure of equipment in oil and gas industry (drilling equipment, production, and transport equipment, and so on). Shahriar, Sadiq, & Tesfamariam (2012) have provided the complex experimental study of various risk factors associated with pipelines failures and proposed framework for risk analysis under uncertainty.

4. Methodology

4.1. Risk analysis

There are three main categories (classes) of risk analysis and assessment techniques: the qualitative, the quantitative and hybrid techniques (qualitative-quantitative, semi-quantitative).

The lack of reliable information, statistical data with reference to which we could assess the risk level of domestic oil and gas extraction enterprises’ activity, and the lack of complex studies of specific risks of such companies determined the need for the expert survey. At the initial stage of our research, we had identified groups of the risk of domestic oil and gas extraction enterprises’ activity, risk factors of each group and developed the research questionnaire (checklist) to conduct a qualitative risk analysis. Each risk factor of the certain group of risk was given by experts the values of probability of risk events; the experts determined the degree of impact of risk factors (by each risk group) on the financial and economical state of the observed companies (severity of risk factor).

The following step of our research is to conduct a risk assessment with the use of quantitative techniques. According to Marhavilas, Kououriotis, & Gemeni (2011), the “quantitative” methods are the most-frequently-used.
Quantitative risk analysis is generally conducted by measuring the risk as a product of the likelihood of the occurrence of any undesirable event and the consequence of the corresponding undesirable event (Shahriar et al., 2012).

According to the almost all methodological approaches for quantitative risk analysis, the measure of the risk (risk index) can be calculated on the basis of available data or experts’ judgment as the product of the probability of occurrence of the risk factor (accident, error of the system) and the severity of associated harm. Quantitative risk analysis can be applied to many different fields, among them: engineering, medicine, chemistry, biology, agronomics, etc. and to any company or production process. Described risk assessment method is exact and easy-to-use. The choice of this method of risk assessment was determined due to the advantages of the method and output parameters of experts’ judgment. The methodology adopted to the object of research is shown below.

Therefore, a probability of risk event is denoted by \( p_{ij} \). The rank, assigned to each risk factor by experts, in terms of its impact on the financial and economical state of the analyzed companies, is denoted by \( n_{ij} \), where \( i \) is a sequence number of the risk factor in the group \((i = 1...k, k\) is the number of factors in the group (subgroup) of risk) and \( j \) is a consecutive number of the expert, who has provided two variables (probability of risk event and its consequence (rank)) for each factor of analyzed risk groups \((j = 1...m, m\) is the number of experts). For analyzed risk factors of 1.2. subgroup (“Machinery breakdowns by the causes of its occurrence”) of the production and technological risk factors, \( i \) is equal to six and \( j \) is equal to eight. The identified risk factors of oil and gas production enterprises’ activity are represented in Table 1 (Appendix) (Gryniuk, 2016b). The probability of risk event by the groups (subgroup) of risk factors and its consequences (ranks, assigned by the experts) are listed in (Gryniuk, 2016a).

Specific risk magnitude \( R_{ij} \) is the multiplication of the probability of risk factor event \( p_{ij} \) by its rank \( n_{ij} \). Furthermore, the sum of the probability of occurrence of all risk factors of the group (subgroup) is equal to one. The value of each risk factor is ranked by the degree of risk factor impact in the total value of risk of the group (subgroup) and is normalized, i.e. each risk factor is assigned by certain rank (point) from 1 to \( k \). For 6-factor risk group, 1 is a minimum point, assigned to the factor, and 6 is a maximum point, assigned to the factor. Thus, the risk magnitude of the analyzed factor (risk index) can be calculated using the following formula:

\[
R_{ij} = p_{ij} \times n_{ij},
\]

Where, \( R_{ij} \) is risk magnitude, \( p_{ij} \) is probability of risk event and \( n_{ij} \) is the rank, assigned to risk factor by experts, its impact on the financial and economical state of the analyzed companies.

If no risk factors are identified, then a mark of zero is awarded. According to the expert estimates for the risk factors, included into 1.2 subgroup of technological and production risk factors, calculated \( R_{ij} \) values based on the data, presented in
(Gryniuk, 2016a), are listed in Table 2; the average value of $i$-risk factor has been calculated using the following formula:

$$ R_{aver.i} = \frac{\sum_{j=1}^{m} R_{ij}}{m}, $$ (2)

Where, $R_{aver.i}$ is an average value of $i$-risk factor, $\sum_{j=1}^{m} R_{ij}$ is the sum of risk magnitude calculated according to the given expert estimation for each risk factor, $m$ is the number of experts.

**Table 2. Determination of Risk Magnitude for Factors Analyzed Within 1.2 Subgroup of Production and Technological Risk Factors**

| Rates | $R_1$ | $R_2$ | $R_3$ | $R_4$ | $R_5$ | $R_6$ |
|-------|-------|-------|-------|-------|-------|-------|
| $p_{ij}$ | $n_{ij}$ | $R_{ij}$ | $p_{ij}$ | $n_{ij}$ | $R_{ij}$ | $p_{ij}$ | $n_{ij}$ | $R_{ij}$ | $p_{ij}$ | $n_{ij}$ | $R_{ij}$ | $p_{ij}$ | $n_{ij}$ | $R_{ij}$ |
| 0.37 | 6 | 2.22 | 0.06 | 2 | 0.12 | 0.15 | 4 | 0.6 | 0.25 | 5 | 1.25 | 0.04 | 1 | 0.04 | 0.13 | 3 | 0.39 |
| 0.3 | 6 | 1.8 | 0.02 | 1 | 0.02 | 0.2 | 4 | 0.8 | 0.22 | 5 | 1.1 | 0.08 | 2 | 0.16 | 0.18 | 3 | 0.54 |
| 0.2 | 4 | 0.8 | 0.1 | 3 | 0.6 | 0.28 | 5 | 1.4 | 0.36 | 6 | 2.16 | 0.02 | 1 | 0.02 | 0.04 | 2 | 0.08 |
| 0.35 | 6 | 2.1 | 0.08 | 2 | 0.16 | 0.1 | 3 | 0.3 | 0.27 | 5 | 1.35 | 0.05 | 1 | 0.05 | 0.2 | 4 | 0.8 |
| 0.28 | 5 | 1.4 | 0.03 | 1 | 0.03 | 0.14 | 4 | 0.56 | 0.4 | 6 | 2.4 | 0.04 | 2 | 0.08 | 0.11 | 3 | 0.33 |
| 0.3 | 6 | 1.8 | 0.2 | 3 | 0.6 | 0.16 | 4 | 0.64 | 0.24 | 5 | 1.2 | 0.03 | 1 | 0.03 | 0.07 | 2 | 0.14 |
| 0.24 | 5 | 1.2 | 0.09 | 2 | 0.18 | 0.36 | 6 | 2.16 | 0.15 | 4 | 0.6 | 0.06 | 1 | 0.06 | 0.1 | 3 | 0.3 |
| 0.22 | 5 | 1.1 | 0.04 | 2 | 0.08 | 0.32 | 6 | 1.92 | 0.18 | 4 | 0.72 | 0.17 | 3 | 0.51 | 0.07 | 1 | 0.07 |
| Total | x | x | 12.42 | x | x | 1.49 | x | x | 8.38 | x | X | 10.78 | x | x | 0.95 | X | x | 2.65 |
| $R_{aver.i}$ | 1.55250 | 0.18625 | 1.04750 | 1.34750 | 0.11875 | 0.33125 |
| $n$ | 0.338696 | 0.040633 | 0.228525 | 0.293973 | 0.025907 | 0.072266 |

Source: Own.

Due to the fact, that $\sum_{i=1}^{n} R_{aver.i} > 1$, the partial values of certain risk magnitude ($r_i$) are estimated to simplify the following calculations. In this case $\sum_{i=1}^{n} (r_i) = 1$.

**4.2. Screening experiment**

To carry out the design of experiment, the risk assessment should be taken into function first. A structured, organized method for determining the relationship between factors affecting a process and the output of that process is known as “Design of Experiments”.

When using factor-screening design, it is necessary to construct a planning matrix and to carry out the pilot experiment. After considering the results of the pilot experiment, the factors’ impact on the investigated process can be determined. Due to the fact, that, at the present stage of experiment performance, the resources (financial, labor, time resources, etc.) are limited, it is critical to get the most relevant information during each experiment, being performed. A well-designed experiment can produce significantly more information, provide identification of key risk factors and assessment of its impact on the resultant value and often requires fewer runs of the simulation model as compared to the random or unplanned experiments.
In order to illustrate the ED (experimental design) concept, let’s consider the performance of simulation experiment of possible risk situations at oil and gas production enterprises for the study of negative impact of $q_i$ parameters (risk factors) - $q_1, q_2, ..., q_i$ (where $k$ is quantity of factors in risk groups) - on the output result of the model, namely on the financial and economic state of the companies (its loss rate). The parameters, being studied, have a low (minimum) value and a high (maximum) value. These values are known as levels. During the simplest simulation, used in this work, each factor has two levels - low and high ones. These experimental simulations belong to a group of designs known as $2^k$ factorial experiments (designs), where $k$ is the number of parameters being studied (Quinao & Zarrouk, 2014). The full factorial design provides for the taking into account of all combinations of factors at levels studied, creating $2^k$ combinations of factorial design conditions and is (Walpole, Myers, Myers, & Ye, 2012).

The 2-level full factorial experiment is applied to divide risk factors into two parts: risk factors that have a significant impact on the financial and economical state of the observed enterprises and insignificant factors. During the screening experiment, the matrix of possible combinations of risk factors influencing the financial and economical state of oil and gas production enterprises has been developed (Table 3). There has been performed the pilot experiment, based on the results of which there was evaluated the risk factor impact on the resultant value. According to the results of the $k$-factors experiment, there have been defined $w = 2^k$ of possible combinations of risk factors. Matrices of possible combinations of risk factors for 6-, 5- and 3-factors experiments are represented in Table 3.

### Table 3. Matrices of Possible Combinations of Risk Factors for K-Factors Experiment

| Type of experiment | Risk event ($P_w$) | Risk factor ($q$) | $q_1$ | $q_2$ | $q_3$ | $q_4$ | $q_5$ | $q_6$ | $y_w$ |
|-------------------|------------------|------------------|------|------|------|------|------|------|------|
| 6 Full factorial experiment | $P_1$ | 1 | 0 | 0 | 0 | 0 | 0 | 0 | $y_1$ |
| | $P_2$ | 0 | 1 | 0 | 0 | 0 | 0 | 0 | $y_2$ |
| | $P_3$ | 0 | 0 | 1 | 0 | 0 | 0 | 0 | $y_3$ |
| | $P_4$ | 1 | 1 | 0 | 0 | 0 | 0 | 0 | $y_4$ |
| | $P_5$ | 1 | 0 | 1 | 0 | 0 | 0 | 0 | $y_5$ |
| | $P_6$ | 0 | 1 | 1 | 0 | 0 | 0 | 0 | $y_6$ |
| | $P_7$ | 1 | 1 | 1 | 0 | 0 | 0 | 0 | $y_7$ |
| | $P_8$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $y_8$ |
| | $P_9$ | 0 | 0 | 0 | 1 | 0 | 0 | 0 | $y_9$ |
| | $P_{10}$ | 0 | 0 | 0 | 0 | 1 | 0 | 0 | $y_{10}$ |
| | $P_{11}$ | 1 | 0 | 0 | 1 | 0 | 0 | 0 | $y_{11}$ |
| | $P_{12}$ | 1 | 0 | 0 | 0 | 1 | 0 | 0 | $y_{12}$ |
| | $P_{13}$ | 0 | 1 | 0 | 1 | 0 | 0 | 0 | $y_{13}$ |
| | $P_{14}$ | 0 | 1 | 0 | 0 | 1 | 0 | 0 | $y_{14}$ |
| | $P_{15}$ | 0 | 0 | 1 | 1 | 0 | 0 | 0 | $y_{15}$ |
| | $P_{16}$ | 0 | 0 | 0 | 1 | 1 | 0 | 0 | $y_{16}$ |
| | $P_{17}$ | 0 | 0 | 0 | 1 | 0 | 1 | 0 | $y_{17}$ |
| | $P_{18}$ | 1 | 1 | 0 | 1 | 0 | 0 | 0 | $y_{18}$ |
| | $P_{19}$ | 1 | 1 | 0 | 0 | 1 | 0 | 0 | $y_{19}$ |
| | $P_{20}$ | 1 | 0 | 1 | 1 | 0 | 0 | 0 | $y_{20}$ |
| | $P_{21}$ | 1 | 0 | 1 | 0 | 1 | 0 | 0 | $y_{21}$ |
Table 3. Matrices of possible combinations of risk factors for K-factors experiment

| Type of experiment | Risk event ($P_w$) | Risk factor ($q_i$) | $y_{wq}$ |
|--------------------|--------------------|---------------------|-----------|
|                    | $P_{22}$            | $q_1$ 0 0 1 1 1 0 0 | $y_{22}$  |
|                    | $P_{23}$            | 0 1 1 1 1 0 0       | $y_{23}$  |
|                    | $P_{24}$            | 0 1 1 0 1 0 1       | $y_{24}$  |
|                    | $P_{25}$            | 0 1 0 1 1 0 1       | $y_{25}$  |
|                    | $P_{26}$            | 0 0 1 1 1 0 1       | $y_{26}$  |
|                    | $P_{27}$            | 1 1 1 1 1 0 1       | $y_{27}$  |
|                    | $P_{28}$            | 0 1 1 1 1 0 1       | $y_{28}$  |
|                    | $P_{29}$            | 1 0 1 1 1 0 1       | $y_{29}$  |
|                    | $P_{30}$            | 1 1 0 1 1 0 1       | $y_{30}$  |
|                    | $P_{31}$            | 1 1 1 0 1 0 1       | $y_{31}$  |
|                    | $P_{32}$            | 1 1 1 1 1 0 1       | $y_{32}$  |
|                    | $P_{33}$            | 0 0 0 0 0 0 0       | $y_{33}$  |
|                    | $P_{34}$            | 0 0 0 0 0 0 1       | $y_{34}$  |
|                    | $P_{35}$            | 0 1 0 0 1 0 0       | $y_{35}$  |
|                    | $P_{36}$            | 0 0 0 1 0 0 1       | $y_{36}$  |
|                    | $P_{37}$            | 0 0 0 0 0 0 1       | $y_{37}$  |
|                    | $P_{38}$            | 0 0 0 1 0 1 0       | $y_{38}$  |
|                    | $P_{39}$            | 1 1 0 0 0 0 1       | $y_{39}$  |
|                    | $P_{40}$            | 1 0 1 0 0 0 1       | $y_{40}$  |
|                    | $P_{41}$            | 1 0 0 0 1 0 1       | $y_{41}$  |
|                    | $P_{42}$            | 1 0 0 0 0 1 1       | $y_{42}$  |
|                    | $P_{43}$            | 0 1 1 0 1 0 1       | $y_{43}$  |
|                    | $P_{44}$            | 0 1 0 1 0 1 0       | $y_{44}$  |
|                    | $P_{45}$            | 0 1 0 0 1 1 0       | $y_{45}$  |
|                    | $P_{46}$            | 0 0 1 1 1 0 1       | $y_{46}$  |
|                    | $P_{47}$            | 0 0 0 1 1 1 1       | $y_{47}$  |
|                    | $P_{48}$            | 1 1 1 0 1 0 1       | $y_{48}$  |
|                    | $P_{49}$            | 1 1 1 1 1 0 1       | $y_{49}$  |
|                    | $P_{50}$            | 1 1 1 0 1 1 1       | $y_{50}$  |
|                    | $P_{51}$            | 1 0 1 1 1 0 1       | $y_{51}$  |
|                    | $P_{52}$            | 1 0 1 0 1 0 1       | $y_{52}$  |
|                    | $P_{53}$            | 1 0 0 1 1 1 1       | $y_{53}$  |
|                    | $P_{54}$            | 0 1 1 1 1 0 1       | $y_{54}$  |
|                    | $P_{55}$            | 0 1 1 1 1 0 1       | $y_{55}$  |
|                    | $P_{56}$            | 0 1 0 1 1 1 1       | $y_{56}$  |
|                    | $P_{57}$            | 0 0 1 1 1 1 1       | $y_{57}$  |
|                    | $P_{58}$            | 1 1 1 1 0 1 1       | $y_{58}$  |
|                    | $P_{59}$            | 1 1 1 0 1 1 1       | $y_{59}$  |
|                    | $P_{60}$            | 1 1 0 1 1 1 1       | $y_{60}$  |
|                    | $P_{61}$            | 1 0 1 1 1 1 1       | $y_{61}$  |
|                    | $P_{62}$            | 0 1 1 1 1 1 1       | $y_{62}$  |
|                    | $P_{63}$            | 1 1 1 1 1 1 1       | $y_{63}$  |
|                    | $P_{64}$            | 0 0 1 1 0 1 1       | $y_{64}$  |

Source: Author’s development based on Doroshenko (1993).

Such number of combinations is caused by the direction of risk management system selected by the enterprise for each risk group investigated and its factors. Table 3 shows potential risk events ($P_w$) and respective values of its negative impact on the
financial and economical state of oil and gas production enterprises \((y_w)\), where \(w\) is possible risk event number (for 6-factors experiment, it is equal to 64). \(y_w\) represents the risk magnitude in the context of non-performance of actions, aimed at the decrease of negative impact of certain \(i_{neg.ef.}\) risk factors \((i = 1...k)\) and in case of availability of positive impact of application of risk management techniques for neutralizing of possible losses, caused by \(i_{pos.ef.}\) factors. In this case,

\[
k_{neg.ef.} + k_{pos.ef.} = k, \tag{3}\]

Where, \(k_{neg.ef.}\) is the number of factors whose negative impact isn’t neutralized by risk management system, \(k_{pos.ef.}\) is the number of factors whose negative impact is neutralized.

Thus, \(i_{neg.ef.}\) risk factors are those, for which the level of risk neutralization is insignificant, i.e. those risk factors which may lead to possible negative results in case of \(P_w\) risk event; and \(i_{pos.ef.}\) risk factors are those which negative impact has been neutralized by risk management system. Table 3 shows two types on risk level: 1 - for \(i_{neg.ef.}\) risk factors and 0 - for \(i_{pos.ef.}\) risk factors. So, basically, we have considered two situations:

1) if the negative impact is not reduced, when the value of risk level is denoted by “1” in Table 3;

2) if the negative impact is reduced, when the value of risk level is denoted by “0” in Table 3.

For example, negative impact of first, fourth and sixth factors hasn’t been reduced against \(y_{41}\) of risk event \(P_{41}\), but the negative impact of second, third and fifth risk factors has been reduced. The value of negative impact on the financial and economical state of oil and gas production enterprises \((y_{41})\) is equal to the sum of \(r_1, r_4, r_6\) values of relevant \(q_1, q_4, q_6\) risk factors.

5. Results and discussion

Based on the matrices of possible combinations of \(k\)-factors experiments, which are represented in Table 3, \(y_w\) values of every possible risk event \((P_w)\) of risk factors group (subgroup) are calculated as aforementioned. Table 4 shows, based on the \(y_w\) values, the risk events \((P_w)\), ranked against its negative impact on the financial and economical state of oil and gas production enterprises for each group (subgroup) of risk factors.

Obtained results of risk events ranking against group of economic risk factors are represented graphically in Figure 1. Represented linear accumulative chart shows the overall and partial negative impact of factors (from 1 to 0) on the financial and economical state of oil and gas production enterprises for every risk event analyzed.
Let’s simple average the high values (1) and the low (0) values in order to determine the difference or contrast. Mathematically, the calculation of an effect is expressed as follows:

\[
Effect = \frac{\sum y_1}{s_{neg.eff.}} - \frac{\sum y_0}{s_{pos.eff.}},
\]

(4)

Where, the “s”s refer to the number of data points, have been collected at each level. The “y”s refer to the associated responses. We have picked these values from the matrices. For \(q_1\) (three-factor experiments), the effect is:

\[
Effect_{q_1} = \frac{y_1 + y_4 + y_5 + y_7}{4} - \frac{y_2 + y_3 + y_6 + y_8}{4},
\]

(5)

Results of the calculations, previously made, are represented in Table 5.

**Table 5. Determination of Qi effects for all factors**

| Effects of | Groups (subgroup) of risk factors |
|-----------|-----------------------------------|
|           | I group | II group | III group | IV group | V group | VI group |
| 1.3-1.8 Factors | 1.2.1-1.2.6 Factors |
| \(q_1\) | 0.101911 | 0.338696 | 0.336781 | 0.346095 | 0.036816 | 0.594930 | 0.065470 |
| \(q_2\) | 0.178960 | 0.040633 | 0.057013 | 0.604390 | 0.018159 | 0.238489 | 0.439069 |
| \(q_3\) | 0.252722 | 0.228525 | 0.021191 | 0.049515 | 0.006219 | 0.166580 | 0.276842 |
| \(q_4\) | 0.009862 | 0.293973 | 0.102170 | - | 0.130348 | - | 0.201646 |
| \(q_5\) | 0.437436 | 0.025907 | 0.009839 | - | 0.409204 | - | 0.022073 |
| \(q_6\) | 0.019108 | 0.072266 | 0.473007 | - | 0.399254 | - | - |

Source: Own.

We use a 5% (0.05) significance level in our research. So, if the risk factor negative impact on the financial and economical state of oil and gas production enterprises is less when 5% (0.05), we have to exclude (screen) that factor at the stage of model construction. In comparison to the overall spread of results, it seems that the following factors have very little effect on financial and economical state of oil and gas production enterprises; among them are: 1) low-quality protection against lightning, possibility of equipment self-ignition (4.3 factor in Table 1, see Appendix); 2) inefficient staff retraining system (2.5 factor); 3) defects in equipment repair and maintenance system (1.6 factor); 4) the considerable density of equipment location on the territory of the production site - domino effect (4.2 factor); 5) modification of techniques and production conditions of well stock as the result of field development closing stage (1.8 factor); 6) inappropriate skill level of management, engineering and operational personnel (factor 2.3); 7) Sputnyk automatic pad metering station - saline deposit (1.2.5 factor); 8) low level of expenses connected with increase of "environmental friendliness of production" (4.1 factor); 9) breakdowns of plunger oil-well sucker-rod pump due to paraffin deposit (1.2.2 factor); 10) irrelevance of information (3.2.3 factor); 11) low cost and availability of alternative sources of energy. The impact (or "negative effect") of other factors are much larger than that of above-listed factors.
6. Limitation of study

Although the research has reached its aims, there were some unavoidable limitations. The risk magnitude of risk factors (risk index) was calculated purely based on experts’ judgment. Therefore, the accuracy level of the conducted risk assessment is not as high as it could be.

Among other things, experimental research creates artificial situations that partially don’t represent real-life situations. This is largely due to fact that all risk factors can be volatile between 0 and 1. However, in our simulation experiment, each factor had only two levels (a low - “0” and a high - “1”). The negative impact of a particular risk factor can be reduced in real-life situations, and the value of risk level will come within a range of 0 to 1.

7. Conclusion

As a result of the research performed, we may reveal the following outcomes. There are some difficulties of oil and gas production enterprises management in terms of conducting business by it under the conditions of risk and uncertainty. The lack of complex experimental studies of special risks of domestic oil and gas companies has determined necessity for coordinated expert estimation of such risk factors in our earlier academic papers. Doing a screening design is useful when a higher level or a more complex design may be required at a later stage. In order to construct the adequate model of assessment of risk of oil and gas production enterprises activity, developed on the basis of fuzzy logic, it has been suggested to exclude (screen) at the stage of model construction eleven risk factors (of thirty-five ones identified), which impact on the financial and economical state of analyzed companies is insignificant (less than 5%).

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### Appendix

**Table 1. Specific Risks and Risk Factors of Oil and Gas Production Enterprises**

| No of risk group | Risk Group                     | Risk Factors                                                                                                                                                                                                 |
|------------------|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1                | Production and technological risk | 1.2. Machinery breakdowns by the causes of its occurrence:  
1.2.1 Underground equipment (plunger oil-well sucker-rod pump) - sucker rod;  
1.2.2. Underground equipment (plunger oil-well sucker-rod pump) - paraffin deposit;  
1.2.3. Underground equipment (plunger oil-well sucker-rod pump, electric submersible pump) - imperfect design;  
1.2.4. Underground equipment (plunger oil-well sucker-rod pump, electric submersible pump) - distortion;  
1.2.5. Sputnyk automatic pad metering station - saline deposit;  
1.2.6. Crude oil pipeline leakage, loss of containment - internal corrosion.  
1.3. Insufficient level of technologies  
1.4. Equipment obsolescence  
1.5. High level of depreciation of equipment  
1.6. Defects in equipment repair and maintenance system  
1.7. Substantial quantity of depleted reserves and reserves difficult to be recovered  
1.8. Modification of techniques and production conditions of well stock as the result of field development closing stage |
| 2                | Human as a risk factor           | 2.1. Non-compliance with standards and technical documentation as to the industrial machinery operations  
2.2. Inefficient functioning of work safety service and occupational safety  
2.3. Inappropriate skill level of management, engineering and operational personnel  
2.4. Incompetency of heads of production and non-production departments  
2.5. Inefficient staff retraining system  
2.6. Inefficient employee incentive system |
| 3                | Information risk                 | 3.2. Inefficient automatic control system:  
3.2.1. Time required for preparation of necessary information;  
3.2.2. Time lag of obtaining of necessary information;  
3.2.3. Irrelevance of information  
4.1. Low level of expenses connected with increase of "environmental friendliness of production"  
4.2. The considerable density of equipment location on the territory of the production site - domino effect  
4.3. Low-quality lightning-discharge protection, possibility of equipment self-ignition  
4.4. Violation of parameters of technological processes performance  
4.5. Essential man-induced impact on environment  
4.6. Absence of scientific-based environmental risk management system at oil and gas production enterprises |
| 4                | Environmental risk               | 5.1. The actual geological and physical properties of the productive formations differ from the predicted ones (not confirmed numerical characteristics of deposits) |
| 5                | Geological risk                  |                                                                                                                                                                                                          |
TABLE 1. SPECIFIC RISKS AND RISK FACTORS OF OIL AND GAS PRODUCTION ENTERPRISES

| No of risk group | Risk Group | Risk Factors |
|------------------|------------|--------------|
| 1                |            | 5.2. The risk of loss caused by inaccurate determination of reserves and oil recovery factor of the deposits |
|                  |            | 5.3. Mistakes during the reservoir and production engineering (equipment, operation conditions, etc.) |
| 6                | Economic risk | 6.1. Cutting of oil and gas prices |
|                  |            | 6.2. Unstable tax legislation concerning subsoil users |
|                  |            | 6.3. Non-differentiation of fee rate for use of mineral resources depending on oil extraction conditions |
|                  |            | 6.4. Unsatisfactory investment climate in Ukraine |
|                  |            | 6.5. Low cost and availability of alternative sources of energy |

Source: Gryniuk (2016b).

TABLE 4. RANKING OF RISK EVENTS BASED ON ITS NEGATIVE IMPACT ON THE FINANCIAL AND ECONOMICAL STATE OF OIL AND GAS PRODUCTION ENTERPRISES FOR GROUPS (SUBGROUPS) OF RISK FACTORS

| No. | 1. Factors of production and technological risk | 2. Human as a risk factor | 3. Information risk factors | 4. Environmental risk factor | 5. Geological risk factor | 6. Economic risk factor |
|-----|-----------------------------------------------|--------------------------|-----------------------------|-----------------------------|--------------------------|------------------------|
|     | 1.3-1.8 Factors (see tab.1) | 1.2.1-1.2.6 Factors of 1.2 Subgroup | | | | |
| Pw | yw | Pw | yw | Pw | yw | Pw | yw | Pw | yw | Pw | yw | Pw | yw | Pw | yw | Pw | yw |
| 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 |

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| No. | 1. Factors of production and technological risk | 2. Human as a risk factor | 3. Information risk factors | 4. Environmental risk factors | 5. Geological risk factors | 6. Economic risk factors |
|-----|---------------------------------------------|--------------------------|---------------------------|-----------------------------|--------------------------|------------------------|
| 1   |                                            |                          |                           |                             |                          |                        |

Table 4. Ranking of risk events based on its negative impact on the financial and economical state of oil and gas production enterprises for groups (subgroups) of risk factors

Source: Developed by the Author based on pilot experiment.
Source: Own.