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# Hazard identification and risk assessment methods used in the oil and gas industry

## Metody identyfikacji zagrożeń i ocen ryzyka używane w przemyśle naftowym i gazowniczym

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ABSTRACT: The article discusses the preparation and implementation of a complete comprehensive safety assessment of a hazardous production facility, such as environmental risk management, the risks of designing and operating enterprises, taking into account the human factor, engineering psychology, the development of labour protection management systems and other risks. When assessing risks when implementing various processes, for example, the transport support of offshore fields, it makes sense to prepare a comprehensive safety assessment of the individual operational structures. In this case, bow tie analysis is used to examine risk by demonstrating a range of possible causes and effects. The method should be applied in a situation where it is difficult to perform a complete fault tree analysis or where the research is more focused on creating barriers or controls for each failure path. The methodology for this analysis is the same as preparing and implementing an HSE for whole enterprise. The possibility to apply the Pareto principle to estimate technogenic risk parameters of composite systems was studied. According to the Pareto principle there are a few important parameters among many unimportant ones. Hence, the main success is achieved not by the many actions, but the few. This is applicable to a wide range of research areas, including manufacturing, economical and physical ones. In a bow tie diagram, some calculations may be applied for example, in a situation where the paths are independent and the probability of certain outcomes is known. Such a quantitative assessment is necessary to ensure the effectiveness of control.

Key words: degree of risk, risk assessment, Pareto principle, bow tie analysis, dangerous events, unfavourable consequences.

STRESZCZENIE: Artykuł omawia przygotowanie i realizację pełnej, kompleksowej oceny bezpieczeństwa potencjalnie niebezpiecznej instalacji produkcyjnej, obejmujące zarządzanie ryzykiem środowiskowym, ryzyko związane z projektowaniem i prowadzeniem przedsiębiorstw, uwzględniając czynnik ludzki, psychologię inżynierii, rozwój systemów zarządzania ochroną pracy oraz inne rodzaje ryzyka. Przy ocenie ryzyka jako części realizacji różnych procesów, na przykład wsparcia transportowego na złożach morskich, istotne jest przygotowanie wszechstronnej oceny bezpieczeństwa poszczególnych obiektów eksploatacyjnych. W tym przypadku stosowana jest analiza *„bow tie”*, aby zbadać ryzyko poprzez wykazanie zakresu możliwych przyczyn i skutków. Metodę tę należy stosować w sytuacji, gdy trudno jest wykonać kompletną analizę drzewa błędów lub gdy badania są bardziej skoncentrowane na tworzeniu barier lub czynników kontrolnych dla każdej ścieżki awarii. Metodologia tej analizy jest taka sama jak w przypadku przygotowania i wdrażania analizy HSE dla całego przedsiębiorstwa. Zbadano możliwość zastosowania zasady Pareta, aby oszacować parametry ryzyka technologicznego dla systemów złożonych. Zgodnie z zasadą Pareta istnieje kilka parametrów ważnych i wiele nieważnych. Tak więc główny sukces osiągany jest nie poprzez wiele działań, ale przez niewiele. Ma to zastosowanie w wielu obszarach badawczych, w tym w produkcji, ekonomii i fizyce. Na wykresie *„bow tie”* niektóre obliczenia można zastosować na przykład w sytuacji, gdy ścieżki są niezależne, a prawdopodobieństwo wystąpienia określonych wyników jest znane. Taka ocena ilościowa jest potrzebna, aby zapewnić skuteczność kontroli.

Słowa kluczowe: stopień ryzyka, ocena ryzyka, zasada Pareta, analiza bow tie, zdarzenia niebezpieczne, niekorzystne konsekwencje.

### Introduction

The main objective of risk identification and assessment is to use risk as a basis for prioritising actions and managing an inspection program in which the equipment being checked is ranked according to the degree of risk.

In almost every situation, once a risk has been identified, there are alternative ways to reduce it. On the other hand,

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all major business losses are the result of not understanding risks or their managing (Zubareva et al., 2005; Artyukhov, 2009).

The purpose of this article is to assess the risks of complications and accidents based on the results of monitoring the technical condition of potentially hazardous oil and gas industry facilities, statistical data on accidents, injuries, accidents and man-made emergencies (Ispanbetov, 2014; Markova and Shangareev, 2015; Starikov and Khlestkova, 2015).

At present, the oil and gas industry of the Republic of Azerbaijan is one of the most important areas. Oil and gas resources are the basis of energy security and the key to the development of the Azerbaijan economy. A significant part of the gross national product is created by products of the oil industry, which provides state and private revenues.

This article discusses two methods for determining risks to ensure safe work, in particular, in the oil and gas industry.

First of all, some basic definitions are given in accordance with ISO 17776-2012:

- risk – the totality of the probability or probability of the occurrence of an event and the occurrence of the risk consequences;
- risk analysis – the process of systematic processing of information to identify threats and assess risks;
- risk assessment is the process of analysing and measuring risk.

Risks lead to the following consequences:

- injury or death;
- significant financial losses;
- environmental disasters or other negative social consequences.

Unfortunate events negatively affect the reputation of a company internationally and nationally (Lomachenko, 2020).

## Risk identification and assessment procedures (HAZOP, HAZID) (Bokovnya, 2003; Nazarov and Kalist, 2007):

- (HAZOP) – reliability and operational analysis to ensure the safe design, operation and reliability of company assets at all stages of their life cycle;
- (HAZID) – detection of hazards by investigation or identification of hazards;
- analysis of results and impact modeling;
- calculation and modeling of hydrodynamic processes (CFD);
- analysis of the hazard of toxic gases, including tests for the presence of hydrogen sulphide;
- risk analysis of low-temperature processes;
- qualitative and quantitative risk assessment (HRA);
- study of the availability, reliability and performance of equipment;
- reasonable adequacy assessment (ALARP);
- integral assessment of the safety level (SIL);
- Protection Level Assurance Analysis (LOPA);
- emergency evacuation and rescue analysis (EEPA).

## Pre-Emergency Response Planning:

- analysis of reliability of emergency systems (ESSA);
- research of falling objects;
- noise analysis;
- analysis of the bow tie diagram.

## Technogenic risk assessment

Let us consider the possibility of using the Pareto distribution to assess technogenic risk parameters for complex systems.

The principle of the Pareto law (Aliyev, 2017; Goldstein and Romanov, 2018) states that a few factors are important, while many are insignificant. Therefore, not all actions result in the main success, but only a small part. It occurs in the study of various phenomena, in particular, social, economic and physical.

The Pareto distribution law is closely related to the ratio of 80 : 20 (Figure 1).

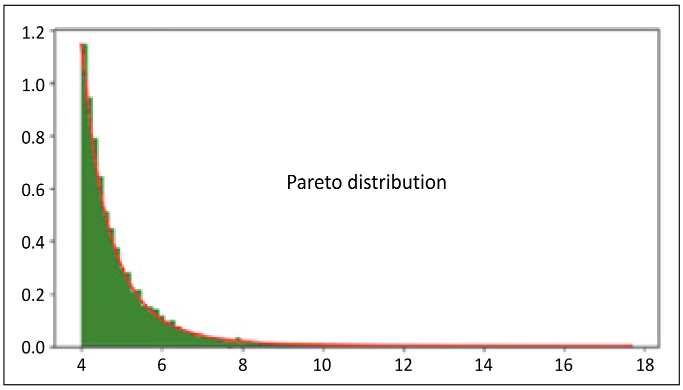


**Figure 1.** Pareto distribution
**Rysunek 1.** Rozkład Pareta

For example, "20% of the population owns 80% of the capital", "20% of the work produces 80% of the results", "80% of the work is done by 20% of employees", etc.

The distribution density of the Pareto law is determined by the following expression according to the chart shown in Figure 2.

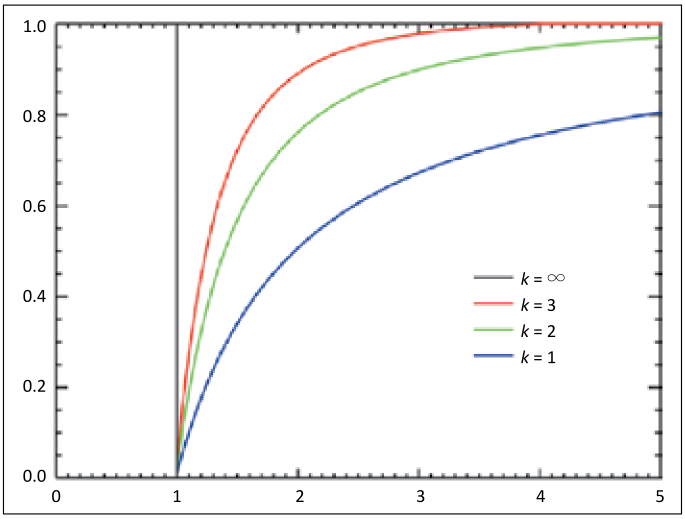


**Figure 2.** Chart of the distribution density of a random variable $X$ according to the Pareto law for $\lambda = 1$ and $k = 1$, $k = 2$, $k = 3$, $k = \infty$

**Rysunek 2.** Wykres rozkładu gęstości zmiennej losowej $X$ zgodnie z prawem Pareta dla $\lambda = 1$ oraz $k = 1$, $k = 2$, $k = 3$, $k = \infty$

$$p(x) = \frac{k\lambda^k}{x^{k+1}} \tag{1}$$

The distribution function of the Pareto law is determined by the following expression, according to the chart shown in figure 3.

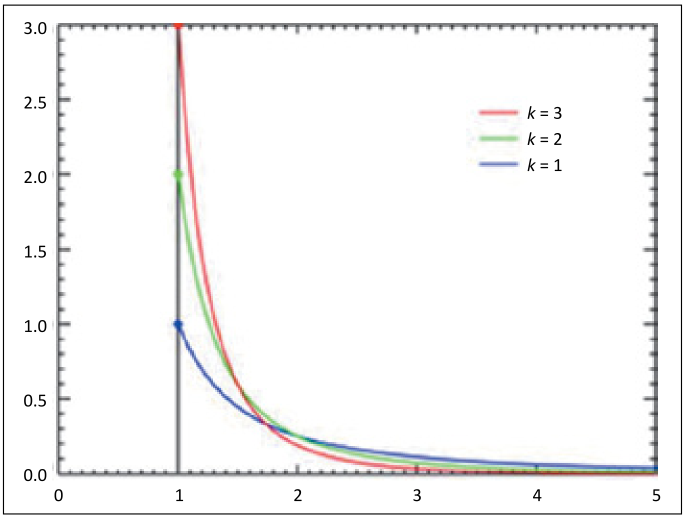


**Figure 3.** Chart of the distribution function of a random variable $X$ according to the Pareto law for $\lambda = 1$ and $k = 1$, $k = 2$, $k = 3$

**Rysunek 3.** Wykres funkcji rozkładu zmiennej losowej $X$ zgodnie z prawem Pareta dla $\lambda = 1$ oraz $k = 1$, $k = 2$, $k = 3$

$$f(x) = 1 - \left(\frac{\lambda}{x}\right)^k \tag{2}$$

Here $k$ and $\lambda$ are distribution parameters.

A Pareto chart is a type that contains both bars and a line chart, where the individual values are represented by bars in descending order and the grand total is represented by a line.

The left vertical arrow is the frequency of occurrence, but it could alternatively be a financial or other important unit of measure.

The right vertical axis is the cumulative percentage of total cases, total cost, or specific unit of measure. Because the values are in descending order, the cumulative function is a concave function.

The given procedure is useful for preparing and implementing a fully comprehensive safety assessment for a hazardous production facility, namely:

- development of labour protection management systems;
- environmental risk management;
- risks of design and operation of enterprises, taking into account the human factor, engineering psychology;
- business risk assessment;
- project risk management;
- knowledge management in the enterprise;
- security management.

## Risk assessment in the implementation of various processes

When assessing the risks within the implementation of various processes, for example, the development, production and transport support of offshore fields, it makes sense to prepare a comprehensive safety evaluation of individual operational structures.

The preparation of a comprehensive safety assessment report requires a structured formal risk management process that includes the following key steps:

- identification of potential threats and consequences;
- assessment of potential outcomes (results) and the probabilities of their occurrence;
- determining control means to prevent or minimise the probabilities of occurrence of hazards and consequences;
- determination of corrective measures to reduce the impact, and search for additional possible risk reduction measures. In its simplest form, this process includes:
- definition of the threat by analysis or identification of hazards (HAZID);
- assessing the risk associated with the hazards using a risk matrix versus acceptable risk criteria;
- identification of available control methods (barriers) to prevent the occurrence of risks or minimise their consequences;
- additional analysis and assessment of risks at a level proportional to risks;
- identification and analysis of possible additional measures to reduce the risk.

The main risks are associated with major accidents, which can lead to:
- several deaths;
- significant loss of assets;
- massive environmental or socio-cultural impacts;
- international negative impact on the company's reputation.

To identify major risks, we apply a comprehensive risk analysis using the butterfly diagram method (Bowties) (Shchekotilova and Zabelin, 2020; Bykov et al., 2021; Nayanov and Khamidullina, 2022).

The assessment of the large risks requires a comprehensive risk analysis using the bow tie diagram method to identify barriers (Shchekotilova and Zabelin, 2020; Bykov et al., 2021; Nayanov and Khamidullina, 2022), control measures and recovery.

Bow tie analysis is a schematic method for describing and analysing the path of a hazardous event from causes to effects. This method combines investigating the causes of an event using a fault tree and analysing the results using an event tree. However, the focus of the bow tie method is on barriers between causes and hazardous events as well as hazardous events and consequences.

Bow tie diagrams can be based on identified faults and event trees, but are more often built directly during the brainstorming process (Figure 4).

Bow tie analysis is used to examine risk by demonstrating a range of possible causes and effects. The method should be applied in a situation where it is difficult to perform a complete fault tree analysis or where the research is more focused on creating barriers or controls for each failure path.

This method can be useful in a situation where there are well-established independent paths to failure.

Bow tie analysis is often easier to understand than event tree or fault tree analysis and can therefore be useful for sharing information when using more complex methods (Akbarova, 2019; Raimov et al., 2020).

The input data of the method are information about the causes and consequences of hazardous events, risks, barriers and controls that can prevent, reduce or stimulate them.

In a bow tie diagram, some calculations may be applied – for example, in a situation where the paths are independent and the probability of certain outcomes is known. Such a quantitative assessment is necessary to ensure the effectiveness of control. However, it should be noted that in many cases pathways and barriers are interdependent and controls may be related to the chosen assessment method, so the effectiveness of controls is uncertain. The result of the method is a simple diagram showing the main hazard event pathways and barriers created to prevent or mitigate undesired consequences and/or aggravate and accelerate expected outcomes.

### *Advantages of the method:*

- provides a visual, simple and clear graphical representation of the problem;
- focuses on controls aimed at preventing and/or reducing the consequences of hazardous events and assessing their effectiveness;
- can be applied to beneficial effects;
- does not require the involvement of highly qualified specialists.

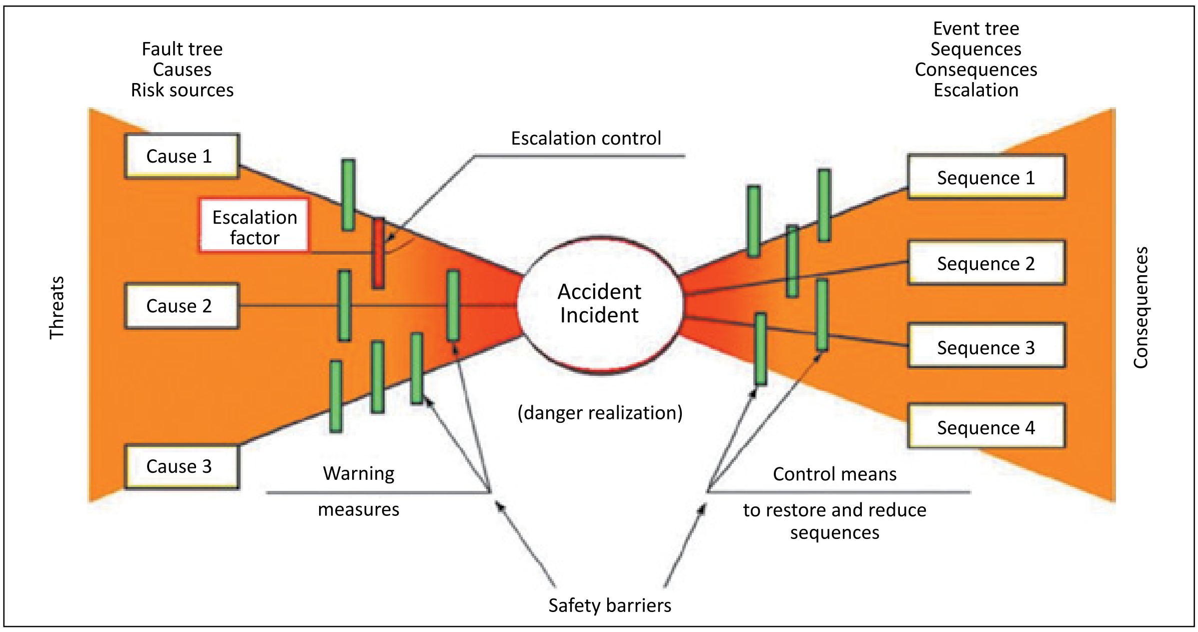


**Figure. 4.** Generalized scheme of the bow tie analysis

**Rysunek 4.** Zgeneralizowany schemat analizy *„bow tie"*

*Disadvantages of the method:*

- The method does not reveal a combination of causes that occur simultaneously and lead to results representing the left side of the diagram);
- The method can oversimplify complex situations, especially when quantified.

The work led to the conclusion that the controls in the area (health, labour protection, safety and environment) are sufficient to ensure the safe operation of the facility and, therefore, the hazardous production facility complies with the requirements and its safe operation should be continued.

## Results

1. The risks facing oil and gas industry enterprises are determined by the purposes of this production and assessment of the state of industrial injuries are necessary for the successful functioning of any labour protection system and the accident-free operation of oil and gas enterprises.
2. It has been shown that the means of control are sufficient to ensure the safe operation of the facility.
3. Risk analysis and assessment is currently applied practically in the oil and gas industries.

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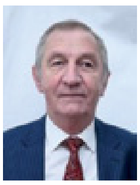


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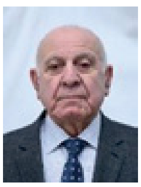


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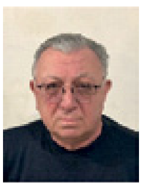


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