ANALYSIS OF TECHNOLOGICAL RISK ASSESSMENT METHODS IN ORDER TO IDENTIFY DEFINITORY ELEMENTS FOR A NEW COMBINED/COMPLETE RISK ASSESSMENT METHOD

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Abstract: Operators worldwide are using hazardous substances in the production process and after the completion of production processes, those substances can cause major accidents with serious consequences on the health and safety of people and the environment. This paper describes some of the methods of risk analysis in plants who use hazardous substances in the production process, in order to identify a method combined-complete, to provide the data needed to calculate the effects of chemical accidents and emergency planning.

Keywords: integrated risk management, risk analysis, methods of risk assessment, hazard identification

1. INTRODUCTION

Continuous and rapid evolution of science and technology in recent years has highlighted the limitations and practical difficulties caused by the use of traditional methods for risk assessment.

Therefore, these methods are based on deterministic models, probabilistic or combined when an accident occur, are not allowing a systematic and unitary approach to risk assessment of major accidents in industrial plants [1].

Satisfying the requirements of Directive Seveso II, requires the development of new risk assessment methods that are able to satisfy the competent authorities and the public [2]:
- that the operator has taken all necessary measures to control risks;
- and allow to communicate the results of the risk assessment in a form accessible to people who are not trained in this domain.

To assist all interested/affected stakeholders by the security industrial facilities (operators, competent authorities, population etc.)., the paper presents some of the methods developed so far and studied for integration of all stages that contribute to risk assessment for these facilities.

The risks subject to man and the environment can be identified, analyzed and evaluated so that the social and economic consequences are minimal. **The integrated risk management** contains the steps of identification, prevention, reduction and control.

The most important sources of risk are:
- continued emissions from industrial activities and related activities;

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- accidental discharges of hazardous substances from industrial plants, transport systems (railways, roads, pipelines and waterways);
- natural sources, earthquakes, storms, volcano eruptions, farming;
- urbanization and infrastructure's expansion.

Risk targets are local people, the ecological systems (biodiversity) and the economic sector.

The current concept of security extends over loss prevention of products, goods and human accidents with consequences on the health of workers. Terms like safety, hazard and risk are commonly used in safety of the chemical processes [3, 4].

Security and **loss prevention** is the prevention of accidents by using *appropriate methods* to identify and eliminate the installation fault before accidents happens.

2. RISK ASSESSMENT METHODS INDUSTRIES WHERE HAZARDOUS SUBSTANCES ARE INVOLVED

There are two categories of analysis to identify and characterize the risk [5]:
- **Qualitative analysis (Hazard Operability Study);**
- **Quantitative analysis quantitative (CPQRA - Chemical Process Quantitative Risk Analysis).**

The decision on the choice of the analysis and the deepening of the work are related to probabilistic risk tolerance scale.

Techniques to identify the risks in the process and techniques for evaluating these risks - to decide how to act on them in order to eliminate or reduce them to protect the population and the environment, are often mistaken. Summarizing these two categories of techniques, we can distinguish the following general components [4, 6]:
- To identify risks: their the intrinsic presence, observation of what happens, the checklist, HAZOP method is used (Hazard & Operability Analysis) is a method for identifying operational problems associated with the design, maintenance or operation of the safety system. It is an objective process to evaluate the different parts of a given system that provides a systematic and well-documented potential hazard [7];
- Risk assessment: their intrinsic presence, previous experience, codes of practice uses the method HAZAN (Hazard Analysis) estimation method used to assess hazards to decide how to take action to eliminate or reduce the risk.

The order of application is from the qualitative identification to quantitative analysis. The main difference between these methods is presented in Table 1.

Table 1. Differences between HAZOP and HAZAN methods [8].

HAZOP	HAZAN
Identify hazards	Evaluate hazards
The preferred technique for use in each project	Selective techniques: use in particularly in systems damaged
Qualitative	Quantitative
Realized by a team	Realized by one or two experts

Called: What if?	Called:
	  - Risk analysis
	  - Risk evaluation
	  - Probabilistic risk assessment
	  - Quantitative risk assessment

2.1. HAZOP method
The purpose of the method is to analyze the safety an installation/ site and especially to discover vulnerabilities (technical, organizational, operational) to enunciate them and develop a plan for rectifying/ improvements.

Hazardous scenarios identified in the analysis will be used on the quantitative risk analysis (using the methodology of LOPA - LAYER OF PROTECTION ANALYSIS - Analysis of protective barriers, which is a quantitative method to prevent hazardous events and to reduce risks to the process units acceptable levels) and non-hazardous scenarios, a decision to establish the efficiency qualitative safety measures [9].

Discontinuous modes of operation (start, stop, production on lots, emergency stop etc.), non-process hazards, dangers and hazards based on general external unforeseen events not covered by HAZOP analysis, will be analyzed according to the methodology checklist of hazards general [10].

HAZOP study is conducted in a series of sessions by a team and they are examining the process diagrams, flow and other relevant documents (for example, cause and effect diagrams, procedure, operating manual, instructions, etc..) using a list of keywords to stimulate consideration of all possible process errors from normal operating conditions at the installation which the analysis is made for.

2.2. LOPA method (Layer of protection analysis)
Protective barriers analysis (LOPA) is a quantitative method to prevent hazardous events and risk reduction to the process units to acceptable levels.

Risk analysis is a preliminary stage and provides elements for limiting the duration of the study by considering only significant scenarios in terms of consequences.

LOPA methodology must be applied to each individual dangerous identified scenario, generated by risks associated with the process, such as: deviations due process scenarios that can be predicted, like: control system inoperative / locking / alarm, a valve wrong operation, a pump failure, etc.

LOPA is an independent methodology for risk assessment, provided the fact it requires the results of a previous risk analysis process identified by the checklist or HAZOP method.

Risks related to the probability of individual scenarios as an event initiator to develop the scenario with the worst credible consequences. For example, a column overfill results in overpressure, at column break, losing of flammable content, the formation of a cloud of steam, and in case of ignition, a explosion of a vapour cloud or flash fire, and thereby, the damage to people because of the pressure of the explosion, thermal radiation, projectiles, etc. [11].

Entire LOPA analysis will be provided in the safety report or, like support document to security management system.

Existing protective measures or those must be implemented to ensure an adequate safety level, will be set according to the frequencies and consequences shown in Table 2 [12].

Table 2. Risk matrix [12].

Frequency	The level consequences C1	The level consequences C2	The level consequences C3
$10^2 – 10^3$ [one event/year]			
$10^3 – 10^4$ [one event/year]			
$10^4 – 10^5$ [one event/year]			
$10^5 - 10^6$ [one event/year]			
$10^6 – 10^7$ [one event/year]			

Consequences on population	One or more from the establishment hospitalized for more than 24 hours; effect on health, reversible and short term.	A fatality or irreversible health effects for people on establishment; a person outside the establishment hospitalized.	More fatalities or irreversible health effects for people on establishment; a fatality or irreversible health effects to people outside the establishment.
Environmental consequences	Reversible environmental damage, requiring the intervention of internal and external forces (county).	Reversible environmental damage, requiring the intervention of regional external forces.	Massive environmental damage, possibly irreversible, requiring the intervention of national, international forces.

■	Intolerable risk.
■	ALARP risk (As Low As Reasonably Practicable) for existing establishments.
■	Acceptable risk.

According to the study made by experts the colors in Table 2 represents [12]:
- **The Red zone - Intolerable risk -** for all scenarios that the frequency of manifestation in the red zone, protective measures need to be improved to descent the level of risk.
- **The Yellow zone - ALARP risk** (As Low As Reasonably Practicable) - reduce risk to the lowest reasonably practicable level: the level of risk is considered to be "tolerable", provided that they have been reduced to the point where the reduction is disproportionate to the improvement achieved, the costs and the fact that standards internationally accepted were applied in the control and risk reduction. As long as the risk level is high, the material and financial efforts will need to be larger to reduce it. Applying this thinking to reduce the level of risk is considered as "reduced risk As Low As Reasonably Practicable" (ALARP).
- **The Green zone - Acceptable risk -** no further action is required of reducing risk.
- **Thick black line (boundary line)** is the line under that must be maintained all scenarios individual analyzed, for newly built facilities.

Since LOPA methodology does not refer to total individual risk, only the risk presented by an individual scenario, the limit values used are one or two levels of size lower than those shown above.

The consequences Accidents in column C2 and C3 are major accident in the context of SEVESO Directive (H.G. no. 804/2007).

For the evaluation a scenario using LOPA is required a previous estimate of the worst credible consequences. Normally, this is done based on experience (and not performing a detailed analysis of the consequences).

Table 3 presents a correlation for guidance between the hazardous consequences and dangerous phenomena [13].

Table 3. Correlation between the consequences level and dangerous phenomena [13].

Dangerous phenomena	Consequences level (population)	Comments
Toxic cloud	C2 - C3	It depends on the quantity and type of substance
BLEVE/ Fire Ball - Boiling liquid expanding vapor explosive	C3	
UVCE - Unlimited Vapor Cloud Explosion	C2	

VCE - Vapor Cloud Explosion	C2 - C3	Depends on the quantity
Explosion	C2 - C3	Depends on the quantity
Flash Fire	C2	
Pool Fire	C1 - C2	
Fire intensity	C1 - C2	
Tank fire	C1	
Boiling	C2	
Hazard chemical powder explosion	C1 - C2	

2.3. Technical / technological risk analysis method - MOSAR
MOSAR method (Méthode Organisée et Systémique d'Analyse de Risques – Method Organized and Risk Analysis System) was developed by a team of specialists from the "Institute National des Sciences et Techniques Nucléaires" (INSTN CEA Grenoble) [22]. It is an integrated approach that allows progressive analysis of risks an industrial site.

MOSAR method insist on hazard chaining flow between component systems of industrial plants and is specially adapted for studying the effects of simultaneous accidents or "domino" effects.

MOSAR method consists of two modules which can be used more or less independently. Module A corresponds to a macroscopic analysis of the risks of an industrial site and requires a preliminary risk analysis. Module B is used for a more detailed analysis of the scenarios identified in Module A, realized with specific instruments of safe operation. The two modules are almost the same structure [14].

Module A refers to „macroscopic analysis", as follows:
- installation representation, identifying sources of risk;
- hazards identification and accident scenario building;
- risk evaluation;
- negotiating the objectives of prevention;
- definition of safety barriers.

Module B refers to „microscopic analysis ", as follows:
- identifying risks of malfunctions;
- risk assessment through the trees of failures;
- negotiate a specific purpose prevention;
- improving of the means of prevention.

Probability assessment can be made, at the option of the analyst, qualitative, semi-quantitative or quantitative, using classical instruments (trees of failures, trees of events). MOSAR method explicitly provides for identify and assess security measures and distinguish between technical measures and usage measures (called in other methods ,,human protective measures") [15].

Risk analysis by this method is performed in several stages, respectively [15]:
a) *malfunctions identification of the investigated system* - implies the identification all the risk factors involved and identify possible scenarios for the production of technical accidents;
b) *risks evaluation* - consists of the evaluation technical consequences of accidents and their probability of production; risks are ranked in categories: negligible, acceptable and unacceptable;
c) *eliminating unacceptable risks* - involves setting methods, means and procedures intended to prevent major damage and/or neutralize their effects;
d) *control of the residual risks* and setting the measures, plans and crisis strategies.

2.4. ARAMIS method
ARAMIS (A Risk Assessment Methodology for Industries) is a European research project carried out between 2002-2004 in the 5th Programme - Framework for Research and Development (PPCD) of the European Union.

ARAMIS project objective was to elaboration a method to allow estimating risk and resolving the difficulties presented in the context of the SEVESO II Directive requirements. The methodology wanted an alternative to the strict deterministic or probabilistic risk assessment strictly used at that time in Europe [16].

The origins of the project were the consequences of the accident in December 2001 in Toulouse - France, due to the fact that the available method of risk assessment does not satisfy the requirements of Directive SEVESO II and the expectations of the population [17].

Countries using strictly deterministic approach have faced with the difficulty of public decisions based on the risk assessment scenarios that used systematically increased scenarios.

The results of deterministic estimates could be easily communicated to the public, but they presented an erroneous view of the risk. Associated evaluation methods were not only a means by which the operator of an industrial installation may prove controlling risks [18, 19].

For countries using a strictly probabilistic approach, resulting estimate was presented as a social risk, which may be difficult to communicate because it was difficult to understand from the population.

The social risk being usually based on statistical data, does not reflect local reality, nor efforts made by the industrial facility's operator to control the risks [20].

Specialists in countries that use strictly probabilistic approach scenarios considered most likely to be the most representative, and the specialists from countries which use a strictly deterministic approach, taking into consideration worst case scenarios [21].

ARAMIS project objective was to develop both, a method to estimate risk and resolve the difficulties presented in the context of the SEVESO II Directive requirements. This method should provide the results that can be used by operators of industrial installations and can be communicated to an audience of non-specialists [22]

Concepts, instruments and methods of ARAMIS project were assessed by means of some case studies that allowed their validation and identifying possible ways of improvement. ARAMIS project results have been taken over by many competent authorities from EU, and they inspired the evolution of legislative and regulatory developments, which was the premise of a European convergence in risk assessment [23, 24].

So far, the results of ARAMIS project has not been used in Romania for legislative regulations aimed at, in particular, safety reports and emergency plans [16].

ARAMIS method requires going through to six stages [25]:
   a) Identifying potential major accident scenarios;
   b) Identify the safety barriers and performance evaluation;
   c) Evaluation of the effectiveness of management and its influence on the performance of safety barriers;
   d) Identification of reference scenarios;
   e) Estimation and mapping of gravity reference scenarios;
   f) Mapping vulnerability.

2.5. QRA Method
QRA method (Quantitative risk assessment) is a method whose objective is the evaluation of the probability of damages as a consequence of a potential accident. This method was originally elaborated for nuclear and transportation, and later, it was progressively adapted to chemical particularities, especially in northern European countries [26].

The main peculiarity of the QRA method, which differs from other integrated methods, lies in the expression and representation of the results of the risk assessment. It can calculate the probability that an individual in a given location, to be a victim due to the effects of an accident, called individual risk and percentage of the population likely to be victims as a consequence of an accident and the associated frequency, called social risk [10].

It should be noted that frequently QRA method does not consider the than lethal effects on people. There are exceptions to this general rule, may be mentioned this method QRA model developed by INERIS - France (Institut National de l'Environnement Industriel et des Risques) for the quantitative assessment of the risks generated by transport of dangerous goods, model that takes into account the risk of injury. Results obtained with the method of QRA, are represented generally in the shape of the curve frequency / gravity (or curve F / N) for social risk or in the shape of the izo-risk curve for the individual risk [27].

The main steps of the QRA method are [28]:
- Selecting installations for QRA;
- Defining central undesired events (loss of isolation) and associated frequencies;
- Modeling the intensity of dangerous phenomenon;
- Modeling exposure and consequences;
- Calculation and results presentation.

Even if the QRA method has many similarities with LOPA and ARAMIS methods above, it distinguishes itself from them by the fact that it is less adapted to take into consideration site-specific safety barriers studied. Only security barriers that allow the limitation or reduction of loss of isolation can be explicitly taken into account for calculating the final probability of damage. For this reason, QRA method is less adapted to demonstrate that the controller is keeping risks under control of an industrial site, as required by the Directive SEVESO II [29].

2.6. Octave method

OCTAVE Method (Operationally Critical Threat, Asset and Vulnerability Evaluation), developed by American specialists, defines strategic assessment based on risk and technical planning, with the purpose of reaching objective's security protection. There is a model adapted to small organizations with up to 100 people and is called OCTAVE. To implement the method is required to operate a team of 3-5 experts who will be in charge with data collection, analyzed the data, developing a protection strategy and risk reduction of identified plans[5].
Activity is performed in 3 stages [29]:

STAGE 1 is dedicated to build the threat's profile on the existing values in the organization (objective) and is composed of two processes:
- 1st process - identify organizations information;
- 2nd process - setting profiles threats.

In the 1st process criteria for assessing the impact of the goods of the organization are defined, its values are inventoried and security practices at audit time.

In the 2nd process, it takes place a selection and ranking of critical values, establishing security requirements for these and identifies threats to critical values.

STAGE 2 identification of infrastructure vulnerabilities phase is dedicated to the detailed analysis of computer networks, in terms of critical values. The phase consists of examining specific ways of access (physical and logically) to network resources, and the technologies used for implementation.

STAGE 3 activities consist of two processes:
- 1st process - identify and risk's analyze;
- 2nd process - development of protection strategy and plans concerning the limitation of the risks.

Activities during the first process, identify and analyze risks, are allocated to threats impact assessment, probability of determination for evaluation criteria and estimate the probability of threats [29].

Further, during the second process of elaborate the strategy of protection and risk reduction plans, shall be carried out the following activities [28]:
- drafting of the current strategy of protection;
- choosing risk reduction concepts;
- development of risk reduction plans;
- identify changes in protection strategy.

In this presentation highlights some features of the method, which begins with the selection and differential treatment of critical values of the organization, continue with the analysis of the informational component and ends with drafting specific plans to reduce the identified risks, activities which are designed to perform cyclic and systemic [28].

2.7. MEHARI method
One method is the method used in Europe is MEHARI Method. (Méthode Harmonisée d'Analyse de Risques), developed by a French team, which addresses both analysis and risk management, assessing quantitative and qualitative risk factors.

In the method instrument's set is a base of information about risks, supported by a software application that allows calculations, simulations and optimizations [5].

Diagram risk analysis consists of the following steps [5]:
a) Natural exposure assessment, which is based on a combined grid that contains levels of exposure (exposure very low, low, medium, high) and depending on that is made the evaluation of four chapters of threats:
- accident (fire, flood, power failure, IT equipment or telephone malfunctions, accidental loss of data and files, loss of important staff, etc.);
- destruction actions (vandalism, terrorism, corruption of data and files, data theft and IT components, software misconfiguration network, industrial or state espionage etc.);
- intentioned actions (the absence or IT staff strike, departure or resignation of important officials, illegal use of licensed software);
- error (performance degradation due to non-application of periodic maintenance, unintentional deletion software due to human errors, errors in the input data etc.).

b) The evaluation of the deterrence factors and prevention (building elements, equipment, procedures, specialized personnel);
c) The evaluation of potentiality;
d) Direct impact assessment referring to:
• goods (values);
• data and information;
• infrastructure (telecommunications and systems);
• general infrastructure;
• availability of staff;
• conformity with the regulations and specific procedures.
e) Evaluation of protection factors, compensation and recovery through the following measures to reduce the risk:
• deterrence;
• prevention;
• protection;
• compensation;
• recovery.
f) Evaluation of impact reduction - at the stage of security auditing is doing the analysis of factors to reduce risk and evaluation of their levels;
g) Global assessment of risk.

The method is distinguished by the package of questionnaires that serve the audit and detailed list of scenarios, which is useful in assessing the precise impact as the organization's values [8].

This method of risk analysis takes advantage of the use of performing instruments (audit questionnaires, lists of security scenarios, knowledge base etc.) recognized in the specific literature and validated of practice.

2.8. Checklist method for risk analysis
General hazards checklist is used for guided brainstorming to identify relevant hazards specific installations/ sites.

The purpose of the methodology is to examine the safety of a facility/ site and especially to discover vulnerabilities (technical, organizational, operational) to enunciate them, and to develop a plan to rectify/ improve them [30].

General hazards are divided into [30]:

- Site-specific hazards / process;
- Event-based hazards incidental;
- External hazards.

The checklist is based on the checklist developed by TUV Rheinland (TÜV Rheinland Group, one of the leading certification association, headquartered in Köln, Germany) to implement the SEVESO sites [30].

The checklist is used to guide discussions in order to identify dangers during process, corresponding installations. A danger based on an incidental event can be treated at installation level, or at the site, if relevant, such as [30]:
- Uncontrolled disposal of the substances / hazardous waste - for the entire site;
- Failure of the system gas detection - ay the installation level;
- Failure of the system to detect substances - at installation level or sewer system for the entire site.

The criteria for a system / site to be relevant are [31]:

a) The criterion of substances dangerousness who represent a dangerous substance (or more), classified according to H.G. no. 804/2007, substances may be present or that can be produced as a result of uncontrolled processes;

b) The criterion for the amount of the dangerous substance at the site / facility represent the amount of the dangerous substance at the site / facility that can lead to a major accident:
- Existing hazardous substances on site in amounts equal to or less than 2% of the relevant amount (column no. 2 of Annex no.1 of the H.G. no. 804/2007) can be ignored if their location and processes that are involved cannot act as an initiator of a major accident near or in another area;
- The same criterion, the quantity equal to or less than 2% of the relevant amount (column no. 2 of Annex no.1 of the H.G. no. 804/2007) will be considered in the case of a continuous flow system, taking into consideration the amount given by the flow for 10 minutes, supposing this is the time for an accident intervention.

2.8.1. Hazards Identification

In order to systematically identify specific hazard installations/ sites, the first step is to select an appropriate methodology (latest generation). A systematic approach will ensure an exhaustive identification of hazards. A very important aspect of hazard identification is to consider preventive measures that will ensure reduction of the frequency of manifestation of an accident due to possible process deviations. Appropriate methodologies may be "Checklist" and "HAZOP". Selecting the method or combination of methods depends in principle on the complexity of a site / facility and is shown in Figure 1 [30].
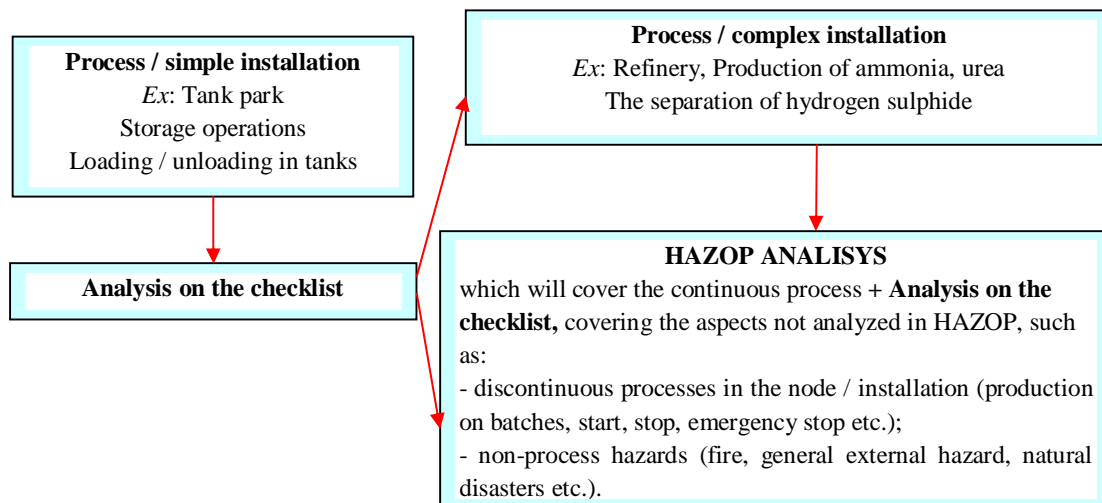
Process / simple installation
Ex: Tank park
Storage operations
Loading / unloading in tanks

Process / complex installation
Ex: Refinery, Production of ammonia, urea
The separation of hydrogen sulphide

Analysis on the checklist

HAZOP ANALISYS
which will cover the continuous process + **Analysis on the checklist,** covering the aspects not analyzed in HAZOP, such as:
- discontinuous processes in the node / installation (production on batches, start, stop, emergency stop etc.);
- non-process hazards (fire, general external hazard, natural disasters etc.).

Fig. 1. Selecting method or combination of methods [30].

CONCLUSIONS

1. Studied and presented methods were designed to assess the major hazards, designed especially sites identified under SEVESO II Directive.

2. HAZOP Method is a qualitative method that analyses the safety an installation / site and especially to discover vulnerabilities (technical, organizational, operational) to and develop a plan for rectify / improve them. For each vulnerability, it analyses the relevant causes, the theoretical consequences and existing protections. All classical deviations are covered in the analysis, which is performed by a team. Discontinuous modes of operation (start, stop, production on lots, emergency stop, etc..), non-process hazards, dangers and hazards based on general external unforeseen events not covered by HAZOP analysis, will be analyzed according to the methodology checklist of hazards general. So, the method requires using it in combination with other methods of risk assessment, and cannot cover all the hazards of the process.

3. LOPA Method is also a quantitative method to evaluate the technologies necessary to prevent hazardous events and to reduce risks to tolerable and acceptable levels. This is not sufficiently and requires the use of the results of a previous process risk analysis, by other methods such as HAZOP Method or CHECKLIST method. The method is applicable to each individual dangerous scenario, and mainly to scenarios due to process failures can be prevented such as: the malfunction of a control system, locking, alarm, pump inoperative or incorrect operation of a valve. However, the method may examine the protective barriers to prevent dangerous events and risk reduction.

4. MOSAR Method is an integrated method that allows progressive analysis of risks an industrial site and insist on hazard chaining flow between component systems of industrial installation and is specially adapted for studying the effects of simultaneous accidents or "domino effects". This method realizes the identification, probability of producing and risk assessment using classical instruments (trees of failures, trees of events). The assessment can be made, at the option of the analyst, qualitative, semi-quantitative or quantitative. The MOSAR method is composed of two modules that can be used more or less independent, depend on the analysis that we want to realize.

5. ARAMIS Method is a method of risk assessment based on the requirements of the SEVESO II Directive and can be an alternative to deterministic or probabilistic approaches to risk assessment used in Europe. Its main objective is selecting equipment in reference to the hazardous quantities which they contain, to identify and develop accident scenarios which is based on the use of a series of malfunction trees and reels of events that correspond to different types of equipment commonly used in the chemical industry. However, by using the probabilistic ARAMIS Method, the result is presented as social risk and could hardly be communicated to the population because it is difficult to understand.

6 QRA Method is a method of assessing the probability of damages caused by a possible accident which has many similarities with ARAMIS and LOPA Methods and is less adapted to consideration the safety barriers of site-specific studied. For this reason, only security barriers that allow the limitation or significant decrease of losses can be taken into account in calculating the probability of final damages.

7. OCTAVE Method defines strategic assessment based on risk and technical planning, with the purpose of reaching objective's security protection, identify and analyze risks, develop a protection strategy and risk reduction plans. After the implementation and completion of the 3-phase method, are highlighted few features such as: selection and differential treatment of critical values of the organization, the analysis of informational component, and finally drafting concrete plans to reduce identified risks. This method can be adapted for smaller organizations having up to 100 people, and to implement it is necessary to operate a team of 3-5 specialists.

8. MEHARI Method addresses both the analysis and risk management being a qualitative and quantitative method. The method is distinguished by the package of questionnaires that serve the audit and the detailed list of scenarios, this aspect is necessary to assess the impact on economic operator. This method brings the advantage of the use of advanced instruments recognized in the literature and validated practice (audit questionnaires, lists of database, security scenarios etc.).

9. ANALYSIS CHECKLIST Method analyses the safety of a facility/ site, discover vulnerabilities (technical, organizational, operational) and elaborate a plan to improve and eliminate them. The checklists will be provided entirely in the safety report, or like support document of security management system. For the protection measures outcomes in the analysis, this method establishes necessary documents and actions to be taken by the management of economic operator to each employee that is involved in the implementation of prevention activities.

10. The common goal of these methods is to organize instruments provided by classical methods in a global approach to risk estimation. They are not confined to the identification of accident scenarios and to rapid estimate their gravity and the probability, that it incorporates steps for estimating the intensity of dangerous

phenomena, identification and evaluation of security barriers and presenting the results in formats adapted to decision process.

11. The defining feature of risk assessment methods studied is the high degree of complexity. They propose, in generally specific instruments: grill, verification guide lists, generic trees (malfunction trees and event trees), informatics means, geographical information systems (GIS) and operating methods in order to achieve some estimates: the gravity, the probability, the security barriers reliability etc.

12. The use of risk assessment methods presents certain advantages and disadvantages. So, due to their complexity are difficult to implement in practice, are expensive, require a large volume of work and involves a particular specialization and expertise of analysts which carries out risk assessment

13. Itch one of the methods studied and shown not establish intervention actions/measures necessary to limit and remove the consequences of possible major accident.

14. In terms of Seveso security objectives, the analysis of risk assessment methods studied is necessary from the perspective of the way of establishment the steps of hazard identification, risk assessment and establishing measured of prevention, protection and intervention on a given location in a single combined method.

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