Promote financial instruments for liability on environment (LIFE PROFILE)

Action A.1: Update of the current state of international and EU level regarding environmental risk analysis of Annex III activities and ELD

Deliverable A.1.2: Review and mapping of risk analysis methodologies

PROmote Financial Instruments for Liabilty on Environment

Athens, January 2022

LIFE PROFILE has received funding from the LIFE Programme of the European Union and the Green Fund.

Document Information			
Grant agreement number	LIFE19 GIE/GR/001127		
Project acronym	LIFE PROFILE		
Project full title	Promote financial instruments for liability on Environment		
Project's website	https://life-profile.gr/		
Project instrument	EUROPEAN COMMISSION - European Climate, Infrastructure and Environment Executive Agency (CINEA)		
Project thematic priority	Environmental Governance and Information		
Deliverable type	Report		
Contractual date of delivery	April 2021		
Actual date of delivery	January 2022		
Deliverable title	Review and mapping of risk analysis methodologies		
Action	A.1.2 & A.1.3	Review and mapping of risk analysis methodologies	
Authors	National Technical University of Athens		
Version History	1st Version		
Issue Date / Version	Authors	Partners	
25/01/2022 / V.1	National Technical University of Athens	– Ministry of Environment and Energy, – Griffin Environmental Consulting LP	

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ABBREVIATIONS

AHI	Atmospheric Hazard Index
ALARP	As Low As Reasonably Possible
APA	Environmental Protection Agency of Portugal
ARM	Environmental Risk Analysis (initials in Spanish)
ASRP	Average Summation Risk Parameter
AWSRP	Average Weighted Summation Risk Parameter
BN	Bayesian Networks
DVAG	Dynamic Vulnerability Assessment Graph
E&S	Environmental and Social
EBRD	European Bank for Reconstruction and Development
EFRAT	Environmental Fate and Risk assessment
EHI	Environmental Hazard Index
EHI	Environmental Harm Index
EIA	Environmental Impact Assessment
EIE	Environmental Impact of Energy
EIM	Environmental Impact of Material flow
ELD	Environmental Liability Directive
EPA	Environmental Protection Agency
ETA	Event Tree Analysis
EU	European Union
FIs	Financial Intermediaries
FMEA	Failure Mode and Effect Analysis
FRAM	Functional Resonance Analysis Method
FTA	Fault Tree Analysis
GD	Green Degree
GIS	Geographical Information Systems
GMO	Genetically Modified Organism
HAZOP	Hazard and Operability Analysis
IDM	Environmental Damage Index (initials in Spanish)

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IED	Industrial Emissions Directive
IETM	Intent Environmental Toxicity Hazard
IGCs	Industrial Growth Centres
IMPEL	EU Network for the Implementation and Enforcement of Environmental Law
IPPC	Integrated Pollution Prevention and Control
ISI	Intent Safety Index
LCA	Life Cycle Assessment
LOPA	Layer of Protection Analysis
MAPAMA	Ministry of Agriculture and Fishing, Food and Environment
MEIM	Methodology of Environmental Impact Minimization
MITE	Ministry of Ecological Transition
MORA	Environmental Liability Supply Model (initials in Spanish)
MORT	Methods – Management Oversight and Risk Tree
MORT	Management Oversight and Risk Tree
NACE	Statistical classification of economic activities in the European Community
PEI	Potential Environmental Impact
PHA	Preliminary Hazard Analysis
PM	Process Mapping
REA	Resource Equivalency Analysis
SME	Small and Medium Enterprise
STAMP	System Theoretic Accident Model and Processes
SVOC	Semi Volatile Organic Compounds
SWIFT	Structured What If Analysis
TOPSIS	Technique for Order Reference by Similarity to Ideal Solution
VA	Vulnerability Assessment
VAT	Value Added Tax
VOC	Volatile Organic Compounds
WAR	Waste Reduction Algorithm

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Executive Summary

The purpose of this deliverable is to perform a review on industrial and environmental risk assessment methodologies. The knowledge built around the literature that includes published journal papers as well as environmental risk assessment tools currently used throughout the EU, both from member states and from insurance companies, that assess the risk of ecological damage from industrial accidents will be utilized in the design of the risk assessment IT tool that this project aims to create. The work presented in this deliverable will aid in the construction of a scientific base behind the risk assessment methodology not only by analyzing the methods, but also by extracting information about the criteria used in the various formulations and the type of output they create. Finally, a comparison between the methodologies will be performed and the risk criteria that each methodology and tool utilizes will be listed.

The outputs of this deliverable are inputs for other actions of this project. In the deliverable A.1.4 some of the risk criteria identified in this deliverable will be utilized so that key-activities will be determined among a number of 12 main and 418 sub-categories. Secondly, the methodologies adopted from IT Tools used in EU will inform the development of the tool methodology in B1, in the method selection section in step 1. Furthermore, the outputs of this deliverable, mainly the analysis of the mathematical models found in literature and the IT tools of other European counties, will be used in Action B3 in order to inform the design of the platform incorporating the risk assessment IT tool.

The performed literature review shows that the most commonly used tools for industrial and environmental risk assessment are tree-based methodologies, mainly bow-tie diagrams or Bayesian networks. These types of tools provide flexibility in the creation of the risk assessment tool and the produced model may include any organizational or systemic aspect of a plant's operation that might lead to an accident with the inclusion of an accident's possible consequences. There is also the capability for the use of mitigation barriers that might reduce the probability of an accident or reduce its effects. Those types of tools are robust enough to be applied in any type of industry and to combine a large amount of information and different types of data such as different types of causes and consequences.

The mapping and review of the environmental risk analysis methodologies that exist and are applied throughout Europe show a lack of consensus on a standardized way of estimating the risk, and more specifically the effect and the probability. In all of the risk analysis methodologies analysed in this report, the risk is calculated as the product of the effect and the probability. One of the points that need thorough consideration during the development of the risk assessment tool, is the selection of the reference accident scenario that will be used to calculate the financial provision. In many of the reviewed methodologies the worst-case scenario is selected, but this will most likely result in overstatement of the necessary financial provision, leading to non-cost-efficient solutions from a financial security provision perspective. Some countries adopt a different approach, such as the system for mitigating the negative impact of the maximum value in the Spanish methodology. As regards to the identified criteria that are used to assess the environmental risk across the reviewed methodologies, a strong overlap is observed, even between distinct methodologies, such as those used by the European countries and by the insurance companies in Greece.

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1. Introduction

1.1 Purpose and structure of the deliverable

The purpose of this deliverable is to perform a review of recently published literature and of tools used in European Union and by financial security providers that assess risk of accident in industrial activities with environmental consequences. The first part of this review refers to sub-action A.1.3 while the second part to sub-action A.1.2.

In the first part of the deliverable, a review of the pertinent scientific literature takes place. The goals of the literature review are to identify the process of assessing risk in industrial activities, to list all the methodologies that partake in every stage of process, to map applications on test cases, to identify how environmental risk is applied within industrial risk assessment and to finally reach conclusions on the factors that are used in the literature that influence risk and environmental damage.

The second part of this deliverable maps and reviews the existing environmental risk analysis methodologies that are used in Greece and other EU Member States, based on the existing legislation. Firstly, the Integrated Risk Assessment Method (IRAM), an environmental risk assessment methodology that facilitates the planning of inspections by the Member States, developed by IMPEL is introduced. In the following section, the implementation of the IRAM methodology by the Hellenic Ministry of the Environment is presented, in order to demonstrate the applicability of the IRAM method to different types of inspections, as well as to inform the next actions of the Life Profile project on the environmental risk analysis methodologies that exist and operate in Greece.

Consequently, existing risk analysis methodologies practiced across Europe and used for the calculation of the financial security cost, in order to assist operators to meet their environmental liabilities, are presented and analyzed. This information will be used for developing a risk analysis and assessment methodology in the next action of the project. Methodologies practiced by financial security providers are also discussed. More specifically, the European Bank for Reconstruction and Development (EBRD) Risk Categorization Framework, as well as environmental risk assessment methodologies practiced by the insurance sector in Greece are presented and reviewed.

The last section contains a list of the collected risk criteria from all available sources, which will be used for the selection of the final sample of activities that are to be investigated later in the project, and more specifically in the sub-action A.1.4. Some Annexes are included at the end, where more detailed information on the presented methodologies is provided.

1.2 Topic introduction

Risk management is a process utilized in order to reduce risk. The analyzed risk could be economic risk referred to the viability of an investment or risk of accidents and loss of life or environmental and ecological damage. In the scope of this project, industrial risk refers to the probability of a major accident taking place and environmental risk refers to the consequences of this major industrial accident that negatively impact the environment.

Generally, risk is defined as the chance of something happening that will have negative effects. In the bibliography risk is usually defined as the possibility of an unwanted event to take place and is

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calculated as risk=danger x exposure (Robu et al (2007)). In the field of toxicology, danger or hazard could mean the toxicity of a substance or the strength of radiation which is then multiplied with exposure. Exposure in turn could be expressed in terms of time or area.

The process of risk management, according to Rausand, M. (2013), depicted in Fig. 1 consists of two processes. The first is risk assessment while the second is risk control. Risk assessment consists of the following two subparts: risk analysis and risk evaluation. The purpose of risk analysis is hazard identification, risk frequency estimation and consequence severity estimation. During risk evaluation the risk is compared with the risk acceptance criteria established at the beginning of the risk management process, the different risks are categorized and sorted. During risk control, monitoring and review of the risk takes place. This pattern is varied in different sources, however the following steps are consistent: A precursor to the first step in risk management is planning, organizing the partners and stakeholders and setting the ethical boundaries of the analysis. Risk identification is the process of identifying all the risks in a system and is very important in risk analysis. The risk identification methods help identify sources of risk in systems by structuring the analysis of a system or operation and creating thorough lists with unwanted events, their causes and their consequences. The next step in risk analysis is the risk calculation. This calculation can be quantitative or qualitative. Qualitative risk assessment techniques are the techniques that calculate risk qualitatively by risk using keywords such as low risk or high risk and provide mostly an estimate of the risk. Quantitative techniques measure risk in the form of probability or frequency. They possess a more structured and rigorous mathematical background making them more accurate but at the same time more complicated, expensive and hard to use. Risk identification techniques as well as quantitative risk assessment techniques can also be used for qualitative risk assessment. This means that many complicated quantitative techniques can be simplified in order to use keywords for the risk calculation and an extra step can be added in many risk identification techniques such as HAZOP that can turn them from risk identification techniques to qualitative or semi-qualitative risk estimation techniques. The following step, which is risk evaluation, usually utilizes some form of risk matrix in order to compare the different risks, the top events and in general the results from the previous step in order to extract useful conclusions from the results of the analysis in relation to the initial scope of the research. The final step exists solely because risk management is a dynamic process. Monitoring and reviewing the results of the analysis is crucial since what was initially taken for granted could rapidly change.

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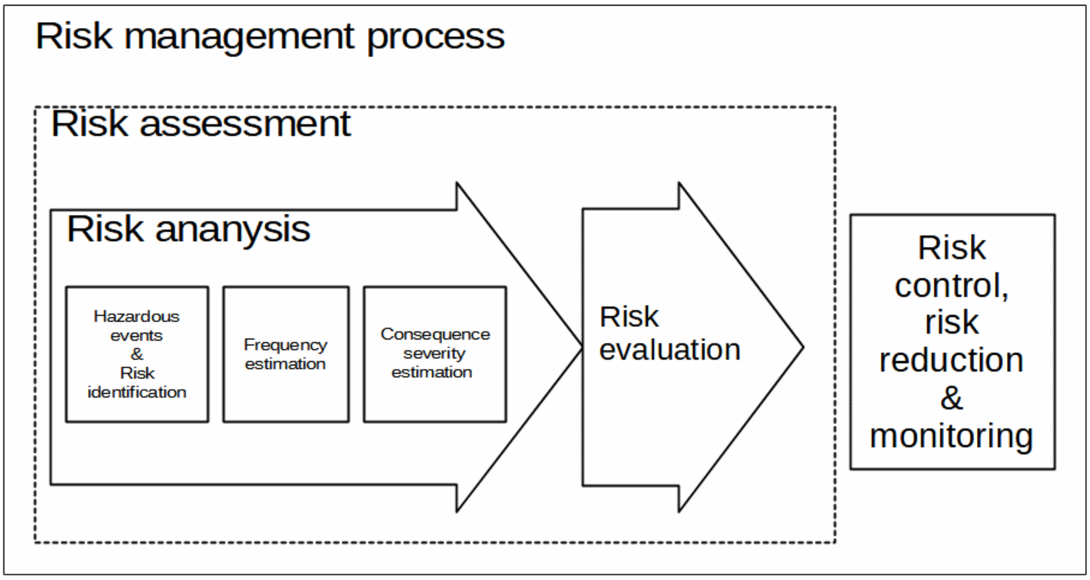

Figure 1: Simplified risk management process according to Rausand, M. (2013)

More specifically, the risk identification stage focuses initially at common sources of hazard such as:

- Sources and propagation paths of stored energy in electrical, chemical, or mechanical form
- Propagation paths of chemical materials (routing optimization)
- Toxic and corrosive liquids and gases escaping from containers
- Mechanical moving parts
- Material or system incompatibilities
- Nuclear radiation
- Electromagnetic radiation (including infra-red, ultra-violet, laser, radar, and radio frequencies)
- Collisions
- Fire and explosion
- Deterioration in long-term storage
- Noise including sub-sonic and supersonic vibrations
- Biological hazards, such as bacterial growth in such places as fuel tanks
- Human error in operating, handling, or moving near equipment of the system
- Software error or malfunction

Identification of industrial hazards is achieved by examining similar systems, reviewing previous hazard analysis and by reviewing checklists and hazards. Then the flow of energy and material throughout the system is reviewed. The presence of inherently dangerous materials is always taken into consideration as well as the interactions between systems.

Environmental risk assessment is the estimation of environmental damage as a result of one or more environmental stressors. Those stressors might be the result of industrial activity, meaning that industrial and environmental risk assessment may be interconnected in many instances. Environmental risk assessment is closely related to ecological risk assessment despite their differences to their focal points. Ecological risk assessment focuses on the assessment of risks posed by human activity onto all living organisms that make up the ecosystem as well as the disruption to their food chain. However environmental risk management focuses mainly on reduction of natural habitat, soil and sediment pollution, air pollution, aquatic pollution and marine biota disruption.

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In the scope of this work environmental risk assessment is considered to be one of the consequences of an industrial accident or misconduct that creates those environmental stressors, such as explosions, debris, toxic spills, fire that cause environmental damage. The term environmental risk assessment is not to be confused with the assessment of the risk that the environment poses to an industry or investment in the form of flooding, typhoons, earthquakes, droughts and many more, which is extremely common in the bibliography. In addition, it is important to dissociate the term environmental risk assessment from the term operational environmental impact which is the environmental impact of a plant during its regular state operation, since this work doesn't take into consideration the normal state of operation and the environmental impact of an industry at a steady state. Thus, important methodologies for the environmental impact assessment when assessing the regular state operation such as life cycle assessment (LCA), methodology of environmental impact minimization (MEIM), waste reduction algorithm (WAR), and environmental fate and risk assessment (EFRAT) which are common methodologies for the analysis and evaluation of environmental impacts of various industrial processes will not be taken into consideration. Finally, risk control which includes mitigation steps as well as monitoring and review are also not in the scope of this work since risk control is not a part of the risk assessment process.

2. Hazard Identification and Risk Analysis methodologies and techniques

2.1 Literature review methodology

The literature review mainly involved work that was published since 2015. Although the subject of the publications was revolved around risk assessment and were searched under specific keywords, among them was an apparent divergence within their subjects and their framework. More than 150 journal papers, textbooks and books were studied, however only a small amount among them, approximately 20%, was satisfactorily within the framework of this research. Next follow the results of the keyword search that prove how broad the terms industrial and environmental risk analysis are within published literature. The keyword search is described below and in table 1. The search was conducted via Google scholar using the combination of keywords described in table 1.

Initially the term *"industrial risk assessment"* was searched. The results could be categorized in the following subjects: industrial risk assessment utilized in maintenance scheduling optimization, industrial risk assessment in chemical route planning, optimized inspection planning, framework review, industrial plant reliability and vulnerability, economic industrial risk assessment and many more that are outside the scope of this analysis. This was an expected outcome due to the broad definition of the term industrial risk assessment.

The term *"industrial risk assessment"* paired with *"environmental risk assessment"* yielded the following results: environmental impact in the design phase/construction of a plant, environmental impact onto a plant such as flooding, typhoons etc. and industrial accidents with some ecological/environmental consequences. The last category was the most relevant to the scope of this analysis but was a minority The majority of the papers, approximately 70% of them, conducted an analysis on the consequences of an industrial accident that mainly focuses on loss of life, destruction of property, reduction in production, loss of revenue, the accidents range of effect and lastly some environmental factors. The results contained applications that included mainly power plants, chemical plants, pipelines and ports.

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The search continued with the term *“industrial accidents”* and *“environmental damage/environmental impact”*. In this search the concept of indexes was prevalent. Index methods are mainly used by medical research in order to assess the toxicity of a substance or its effects. In addition to that it has been widely used in environmental risk assessment in order to quantify the effect of a substance to the environment.

The terms *“environmental risk analysis/assessment”* rarely referred to an analysis of effects caused by an industrial accident, something that has been stated even in publications such as in the work of Kaikkonen et al (2021). The bibliography is divided to a large degree according to the definition of environmental risk assessment that was given above. This means that in the majority of publications researchers used the phrase *“environmental risk assessment”* in order to define the environmental impact of a plant in its regular state of operation and assess the environmental impact of the industries byproducts and waste. A large amount of publications used the term in a similar way to environmental impact analysis in order to express the risk that a plant has due to external hazards (natural disasters) such as typhoons, earthquakes, forest fires, flooding and many more. Only a minority of publications, around 20%, was within the scope of this work.

Table 1: Keyword usage

Environmental risk assessment				accident		Environmental impact
				or		or
or	and	Industrial risk assessment	and	hazards	and	Environmental damage
Ecological risk assessment				or		or
				operability		Environmental consequences

2.2 Classification and analysis of risk assessment methodologies

In this section risk assessment methods and hazard identification methods are described and categorized. During the literature review the methods and techniques that were found were categorized in the following way:

- “A” type methods are usually used in the hazard identification process. They can’t quantitatively calculate risk by themselves unless paired with other techniques. They can be utilized in order to estimate risk quantitatively but their main purpose is to assist safety engineers to locate sources of risk in a structured manner.
- “B” and “C” type methods are the essence of risk assessment. What these methods have in common is that they create graphical representations of the process or system they aim to assess and by utilizing rigorous mathematical formulations they quantitatively calculate risk. The difference between “B” and “C” techniques is that “C” techniques focus more on policy,

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while still conserving the graphical form of quantitative risk assessment. These methods are not directly related to environmental risk, however they are utilized in risk assessment and may form the backbone of environmental risk assessment methods.

- In the “D” category belong all the methods that calculate specifically the environmental risk. These methods are rarely standalone since they don’t calculate the probability of a hazardous material to be released into the environment but they only calculate the effects of the release. Thus, they only calculate consequence. As it was already stated risk is calculated by multiplying probability or frequency with consequence. Thus, a risk assessment procedure can be used for environmental risk assessment by calculating the consequence of an unwanted event by utilizing a “D” method. In the literature review many industrial risk assessment methodologies included some environmental factors to their analysis but they were hardly the focal point of the analysis since in industrial accidents the most important consequence is always loss of life, both the workers as well as of the inhabitants that populate the area near the plant, pipeline, port etc.
- “E” category is the risk matrix. Risk matrix is an extremely important classification tool used in multiple stages of risk assessment and thus couldn’t be placed in some other category. The risk matrix can be used for both risk classification and risk assessment calculation. Since it doesn’t seem to belong to a single category, it is placed in a separate one.

2.2.1 Description of the most popular methods in environmental/industrial risk assessment

A) A-type Methods

A.1) Preliminary Hazard Analysis (PHA)

PHA is technique used usually in early stages of a project and its goals are to identify all potential hazards that can lead to an accident so that countermeasures can be implemented in the design process. All possible accidental events are then categorized according to their severity and finally all required hazard controls and follow-up actions are identified. The main purpose of PHA is to identify the hazards that should later on be more thoroughly examined. PHA considers hazardous components, safety related interfaces between elements, personnel and software, diagnostics, emergency procedures, facilities, training, safeguards, alternate approaches and finally malfunctions to the systems and software.

A.2) Process mapping (PM)

Process mapping is a workflow diagram used to understand a process that helps organizations identify improvement opportunities in order to improve efficiency and reduce risk within the organization. Process mapping is an important tool mainly used for environmental risk identification (Tejaswi & Samuel (2017)) and for managing environmental management systems according to ISO 14001:2015. The first step of a process mapping is to identify the interconnections between all processes. Then to identify the activities that lead to environmental aspects and accidents that can create a significant environmental impact. After the impacts are predicted, countermeasures are created. Process mapping can create a quality management program that reduces the risk of accidents and significant environmental impact at an organizational level but not a systemic level. Thus, the results can only be qualitative.

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A.3) Structured What If Analysis (SWIFT)

This technique is mainly chosen in lieu of HAZOP or other systematic risk analysis methodologies such as bow tie, fault tree and event tree analysis. This is due to the fact that these types of analysis require extensive pre planning. This methodology creates a series of what-if questions based on information related to processes, operating conditions and operating procedures.

A.4) Hazard and Operability (HAZOP) Analysis

HAZOP focuses on deviations from the predefined as appropriate and proper operating procedures-conditions and calculates the hazard risk assessment accordingly. This analysis is always performed by a multidisciplinary team because the different scientific backgrounds lead with certainty to a more robust analysis. There are generally six objectives identified for a HAZOP study as described by Theodore et al (2012):

- To identify the areas with a significant hazard potential.
- To identify and study parts of the design that influence the probability of a hazardous incident occurring.
- To familiarize the study team with the design information available.
- To ensure that a systematic study of the areas of increased hazard potential has taken place.
- To identify pertinent design information not available to the team.
- To provide a mechanism for feedback of the study team's conclusions to the client regarding process safety and operational complexity.

HAZOP analysis functions by identifying how a process is deviating from its intended design. This deviation is expressed by a series of keywords such as too high-too low, more-less, reverse and many more. This process works well because it follows the Process Flow Diagrams (PFDs) and the Piping and Instrumentation Diagrams (P&IDs) and breaks it down into smaller workable sections with well-defined boundaries called nodes into various types of graphs (Dunjó et al (2010), Kościelny et al (2017)). Kościelny et al (2017) provide a plethora of graph methods that can be applied in a HAZOP analysis so that a quantitative result can be reached. Some of these methods are HAZOP Digraph Models (HDM), Qualitative Hazard Identifier (QHI), Dynamic Flowgraph Methodology (DFM), Sign Directed Graph (SDG) and Graph of a process (GP graph). In the work of Kościelny et al (2017) a GP graph is created, based on the HAZOP analysis that results in a series of fault trees that measure the probability for an undesirable event.

A.5) Scenario Analysis Techniques

The scenario analysis technique is the process where descriptive scenarios are created in a manner similar to sensitivity analysis where possible future developments can help identify the involved risks. This type of analysis, according to Fuentes-Bargues et. Al. (2020) includes a best-case scenario, a worst-case scenario and the most probable scenario. This is a risk identification technique effective in urban planning and environmental impact analysis.

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B) B-type Methods

B.1) Fault Tree Analysis (FTA)

Fault Tree analysis (FTA) is a deductive technique that traces an undesired event back to its causes. The failure behavior of a system is represented by a logic diagram. Boolean logic is applied in order to depict the relationship between a fault (event) and its causes. The constructed tree is then used to calculate the quantifiable failure probability (Tejaswi & Samuel (2017)). Modern FTAs can include fuzzy sets so that they can handle stochasticity where it exists, mainly in input data. Temporal fault trees combined with expert elicitation are an extension of the classical Boolean trees that model time dependent failures in dynamic systems. Bayesian networks are also utilized in order to expand the fault tree so that it can include more than two states, 0 and 1, that can better represent the state of each component (Kabir et al. (2019)). Thus, fault trees prove to be a very dependable tool in representing a system and the possible faults.

B.2) Event Tree Analysis (ETA)

In comparison to a FTA which is a deductive technique, an Event Tree Analysis (ETA) is an inductive approach. ETA tries to induce the consequences of an unwanted event. The ETA starts with the identification of the initiating events. Those events mainly include equipment failure, process malfunction and others. The probability of every potential consequence that initiates by an initiating event is calculated by the multiplication of the probabilities of the sequential events.

B.3) Bow-Tie Diagram

The bow tie diagram, also known as a butterfly diagram is the combination of a FTA and an ETA. Such a diagram includes on the left side all faults that can lead to an initiating event and for that initiating event, all possible consequences are included on the right part of the diagram. Thus, a diagram is created that includes all causes of an unwanted event followed by the prevention barriers. After the prevention barriers lies the top event (the initiating event) that is followed by all mitigation barriers and the consequences of the top event. The combination of the consequences of the different outcomes lead to the risk of each outcome and the summation of that produces the total risk of the initiating event.

B.4) System Theoretic Accident Model and Processes (STAMP)

In this technique, there are three hierarchies that act as a three-level representation of accidents. The root cause of an accident is determined by the third hierarchy level. Each other level contains constrains that allow for the accidents to occur. At the top (third level) there are constrains that enable the conditions at level two to exist, and in turn at level two there are conditions that enable the conditions at level one to exist.

B.5) Layer of Protection Analysis (LOPA)

LOPA uses rules in order to define risk as a function of frequency and consequence severity. According to Willey (2014), LOPA is a simplified risk assessment technique between a cause and consequence pair. Independent Protection Layers (IPL) are safeguards that interrupt hazardous consequences and prevents scenarios from propagating. Generally, there are seven layers applied:

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Layer 1: Process Design
Layer 2: Basic controls, process alarms, and operator supervision
Layer 3: Critical alarms, operator supervision, and manual intervention
Layer 4: Automatic action
Layer 5: Physical protection
Layer 6: Plant emergency response
Layer 7: Community emergency response

The quantified risk is calculated in the following way

$$f_i^C = IEF_i \times PFD_{i1} \times PFD_{i2} \times \ldots \times PFD_{ij} \qquad (eq. 1)$$

where:
f_i^{C} : is the frequency of the consequence occurring for scenario I
IEF_i : is the frequency of the initiating event
PFD_{ij} : is the probability of failure

B.6) Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a systematic approach that evaluates the design of a system. This type of analysis begins with a failure mode, locates its potential causes, the potential impact of the failure and its severity to the stakeholders. Then follows a probability estimation that is expressed as a frequency. The detection mode creates a hierarchy of all the potential detection measures of the failure and in combination with the ease of detection, which is also measured, the risk level is extracted. The analysis concludes whether further investigation is required and possible mitigation actions are proposed. The main focus of the method is reliability indices and failure modes such as equipment failure, incorrect operations, mechanical repairs and shutdowns.

B.7) Vulnerability assessment

Vulnerability assessment assesses a systems security and the systems capability to protect itself mainly from deliberate attacks. This type of analysis is usually used in order to detect and mitigate vulnerabilities that are related to cyber-attacks and software but can also be utilized in counter measuring physical attacks such as terrorism or sabotage. In this method risk is calculated by using the following equation.

$$R = P_A*(1 - (P_I * P_N))*C \quad (eq. 2)$$

where:
R: is the risk to the facility
P_A: is the probability of an adversary attack during a period of time
P_I: is the probability of interruption by respondents
P_N: is the probability of neutralization of the adversary
C: is the Consequence Value. A value from 0 to 1 that relates to the severity of the occurrence of the event

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B.8) Bayesian networks

This is a probabilistic graphical model where each node is a representation of a random variable. The method utilizes directed acyclic graphs such as trees that represent the sets of those variables and their dependencies (Kabir & Papadopoulos (2019)). Bayesian networks utilize the Bayes theorem which describes the probability of an event from taking place given another event has already taken place. This probability is calculated by the following equation. In that equation events A and B are nodes in the graph. B node is a parent node and A node is a child node. A could have multiple other parent nodes that represent events that at least one of them needs to occur for event A to occur.

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)} \qquad (eq.3)$$

where:
P(A|B): posterior probability of event A occurring given that event B has already occurred
P(B|A): posterior probability of event B occurring given that event A has already occurred
P(A): prior probability of event A
P(B): prior probability of event B

C) C-type Methods-Management Oversight and Risk Tree (MORT)

A MORT analysis generally occurs after an accident has taken place but can also take place in order to identify risks and evaluate safety programs. It shares the same structure as an FTA and uses Boolean logic. The result of this analysis is a logic diagram that calculates the problems regarding the management of risk. In a MORT diagram the top event is labeled as losses. Beneath the top events, there are the two possible causes, Oversights and Omissions, and Assumed Risks. Assumed risks are risks that have been identified and accepted correctly while oversights and omissions are risks that have not been managed correctly. The MORT analysis is a very useful technique because it operates in the organizational level.

MORT is a part of a larger group of risk analysis methodologies that are more appropriate at a policy level. Their main focus is at the organizational level. Some others of those techniques are Quality Assessment of Safety Analysis (QUASA), Safety Management and Organization Review Technique (SMORT), Structured Audit Technique for the Assessment of Safety Management Systems (STASAS).

Applicability of Methods A to C

Based on the work of Tejaswi & Samuel (2017) and Ericson (2015) the framework of Table 2 was enhanced and expanded. In that matrix the applicability of each technique is associated with the stage of the processes. Techniques are graded with one if they never partake in that stage of a plant's life cycle. However, they are graded with 5 if it is necessary for one of those methods to be applied in those stages. Methods graded 5 in the development phase are necessary for mapping possible hazards and creating a robust to hazards design. Methods graded 5 in the production, operation and disposal stages receive the highest grade since they are the most appropriate for that purpose, because there is a completed (physical), functional and operational process to assess. The same techniques usually don't work in a theoretical background and thus receive a lower grade, for instance Process Mapping receives the highest grade in Production, Operation and Disposal but a low grade in the development stage.

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However, techniques such as SWIFT and PHA which are created particularly for use in a preliminary stage, receive a higher grade in the development phase.

Table 2: Applicability of Methods A to C per process stage

stage	Development			Production	Operation	Disposal
	Preliminary design	Detailed design	Test			
HAZOP	2	2	2	4	4	4
SWIFT	5	5	5	4	4	4
PHA	5	5	5	4	4	4
Process Mapping	2	2	2	5	5	5
FMEA	1	1	1	5	5	5
FTA	1	1	1	5	5	5
ETA	1	1	1	5	5	5
Bow Tie	1	1	1	5	5	5
STAMP	1	1	1	4	4	4
MORT	1	1	1	4	4	4
LOPA	1	1	1	4	4	4

D) D-type Methods - Environmental Impact analysis methodologies

D.1) Environmental Hazard Index (EHI)

EHI, as described in Cave & Edwards (1997), is mainly used to assess the environmental friendliness of a chemical plant's process routes. It utilizes a method for inventory estimation and is used in conjecture the Intent Safety Index (ISI). This method estimates the maximum environmental harm which could be caused by a complete loss of material containment on a route. EHI is calculated by multiplying the effects of the chemical and the exposure of the chemical as shown in the following equation. In recent years multiple Atmospheric Hazard Index (AHI) were added in the method since EHI didn't include one when it was first created.

$$EHI = \sum_{i=1}^{n} Q_i \times SEHI_i \qquad (eq.4)$$

where:
Q: is the total inventory of the chemical in the plant
SEHI: is the Specific Environmental Hazard Index

SEHI is calculated by the Specific Water Hazard Index (SWHI) and the Specific Terrestrial Hazard Index (STHI):

$$SEHI_i = SWHI_i + STHI_i \qquad (eq.5)$$

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$$SWHI_i = \frac{PEC_{wi} \times 10^6}{LC50_i} \qquad (eq.6)$$

$$STHI_i = d\,\frac{\left[(TDI_{wx} \cdot PEC_{wi}) + \left(TDI_{fx} \cdot PEC_{si}\right)\right]}{LD50_{xi} \cdot Wt_x} \times 10^9 \qquad (eq.7)$$

where:
PEC: the Predicted Environmental Concentrations for water and soil per 1 km^2
LD50 and LC50: are acute toxicity data

D.2) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

A disadvantage of the EHI technique is that it contains no spatial patterns or geographical criteria. The TOPSIS method is a multi-criteria decision-making algorithm that can incorporate Geographical Information Systems (GIS), that can be important in disaster management. According to Ozturk & Batuk (2011, May) TOPSIS is a multi-criteria decision-making algorithm that uses Euclidean distances to find a solution that satisfies the conflicting criteria. This optimization technique has been mainly used in chemical routing design (Li et al.(2009)) and many humanitarian problems (Thakkar (2021)). The case studied by Li et al.(2009) aimed to create an environmentally friendly process that reduced the systems influences to the environment mainly by reducing the environmental impact of material flow (EIM) and the environmental impact of energy (EIE). The humanitarian application of TOPSIS in the work of Thakkar (2021) is the other side of the same coin, where the pollution on the environment caused harm in the poor population that inhabited an area near large plants. GIS is a really important computational tool that uses interpolation in order to calculate the amount of rainfall, pollution, concentration of materials and many more in geographical locations where there are no available data (Rolf & de By (2001)). Therefore, TOPSIS and other techniques that have a capacity to include a GIS formulation are used together in order to calculate, most often in the case of environmental risk assessment, the levels of pollution, be it from the normal operation of a plant or in case of accidental release of a toxic substance. The stages followed for the GIS application in the specific applications are the following: first a data base with measurements is created. Then a georeferenced list with all averages is constructed. Finally, the results of the georeference undergo spatial interpolation.

D.3) Intent Environmental Toxicity Hazard (IETH)

This is an aggregated indicator methodology, basically an index method that incorporates EHI, that mainly assesses the Operational Environmental Impact of a plant. IETH is one technique among many others that utilize several indicators such as ozone depletion potential, global warming potential and others in order to quantify the impact of the process to the environment (Gunasekera et al (2006)). Other techniques include Green Degree (GD), Potential Environmental Impact (PEI), IMPact Assessment of Chemical Toxics 2002 (IMPACT) (Sharma et al. (2011)). Although IETH is not used in disaster management, the way it calculates the environmental impact is very similar to EHI. Addressing toxicity risks can also account for accidents when evaluating the probability of the release of contaminants (Kaikkonen et al. (2021)).

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E) E-type Method-Risk Matrix

Risk Matrices are used to visualize risks in relation to the likelihood of their occurrence and the extent of the damage they might cause. Events that are both frequent and catastrophic are high risk and placed on the top right of the risk matrix while events that have low consequence and happen rarely are low risk and placed on the bottom left of the matrix. This practice takes place after the calculation of probability, in the step 3 of the entire analysis, as shown in the following diagram of **Error! Reference source not found.**. That is because the researcher has all risks available and is capable to categorize and compare the risks depending on their place on the matrix. Thus, a risk matrix is a decision-making tool that helps categorize events and their consequences. A risk matrix can also be utilized in prior stages of the research in order to identify a top event that in turn will be used in a fault tree or event tree analysis. A risk matrix is by no means a complete risk analysis methodology but a synergistic tool used alongside B.1 to B.7 and C.1 techniques.

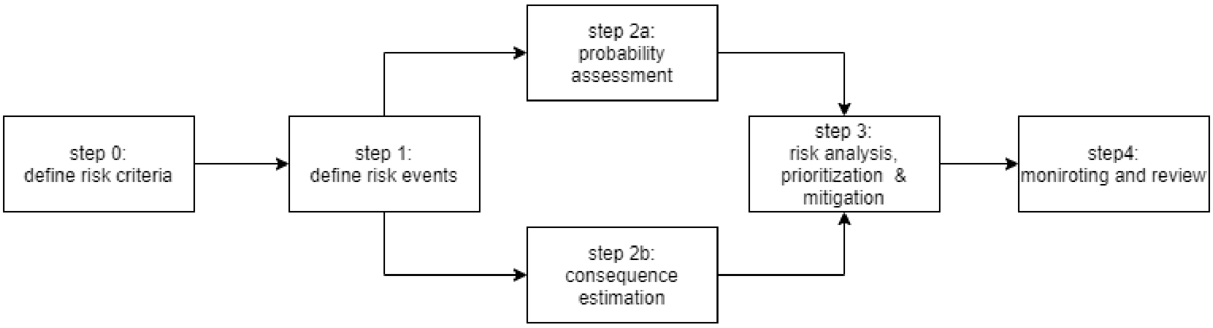

Figure 2: Complete risk management process

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2.2.2 Advantages and disadvantages of the aforementioned methods

Next follow a series of tables stating the advantages and disadvantages of risk identification and analysis methodologies.

Table 3: A-Type methods

Method	Advantages	Disadvantages
Preliminary Hazard Analysis (PHA)	Short time for completion	Very simple technically and not systematic
	Used where information is not available	Depends on the team's experience
		Qualitative analysis
Process mapping	Very versatile in combination with other techniques	Very simple technically and not systematic
		Qualitative analysis
What-If (SWIFT)	avoids lengthy discussions of areas where hazards are well understood	Relies on the team experience
	Very flexible type of analysis, for every operation, at any stage of the life-cycle	Not predicted consequences can lead to unaddressed risks
	The checklist, that is based on historical data can be very robust	Qualitative analysis only - Ranking is not based on numerical results
Hazard and Operability (HAZOP)	Both qualitative and quantitative risk analysis	Requires a multidisciplinary team, rigorous work
	In depth analysis of systems	Due to its function it can't take into consideration human error
		Sensitive to assumptions
		Focuses on single events and not combinations of events
		Overlooks risks not related to a guide-word
		Expensive and time consuming
		Mainly used in the design phase of a plant
Scenario Analysis Technique	Simple to implement	Requires a multidisciplinary team and a lot of insight to be effectively utilized

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Table 4: B-Type methods

Method	Advantages	Disadvantages
Fault Tree Analysis (FTA)	Thorough and systematic	Difficulty in expressing complicated systems
	Quantitative/probabilistic analysis	Only two states can be included, accounting for temporal effects partial functioning
	Can identify single points of failure leading to top events	Repairs and safety barriers are left out
		Can't represent well stochastic dependencies between events
Event Tree Analysis (ETA)	cross-discipline system analysis	It is limited to a single initiating event. In case of a broader analysis, more event trees must be created or a different technique must be chosen
		Events are not associated with each other, as a result, systemic problems might be missed
Bow Tie Diagram	All of the advantages of the fault tree	Difficulty in expressing complicated systems
	Includes safety barriers	Only two states can be included, accounting for temporal effects partial functioning. For more states, or if more complicated techniques need to be applied, see Kabir, Geok, Kumar, Yazdi, & Hossain, (2019)
Failure Mode and Effect Analysis (FMEA)	Efficient at discovering single points of failure	Doesn't consider combined failures
	Can optimize reliability	Doesn't consider human and software interaction
	Is very thorough	It can rank the failure modes but doesn't provide for a management plan
	Quantitative analysis	
Layer of Protection Analysis (LOPA)	Both qualitative and quantitative tools	Risk tolerance criteria must be carefully established before the process and therefore certain standards need to be adopted
	Can be used for risk identification	Heavily depends on the expertise and experience of the user
	Can be used for cost benefit analysis and with ALARP	

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Method	Advantages	Disadvantages
	Removes subjectivity	
	Can be used in multiple stages of design, construction and operation	

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Table 4: B-Type methods (continued)

Method	Advantages	Disadvantages
System Theoretic Accident Modeling and Processes (STAMP)	Can model the system process without oversimplifications	Has some subjective aspects
	Can identify links between factors	Lack of bibliography on environmental risk assessment
	Can confidently replace FMEA and FTA due to its capacity to handle complicated systems	
	Clear systematic methodology for risk analysis	
	Can be used at system level and at closer detail	
	Can detect human errors, failures of components and interactions between systems or components	
vulnerability assessment (VA)	Can be applied to shield against external attacks in an industry	Mainly used in Cyber protection and has little to no effect in risks other than security from attacks
Bayesian networks (BN)	Extremely flexible, more than one way to construct the network according to the needs	
	Can be used with uncertainty in data	
	Any type of factors or states may be included	
	Good synergy with other methods	
Management Oversight and Risk Tree (MORT)	Is systematic and can integrate, organize and structure safety into well mathematically defined relationships and measurements	Misses black swan accidents
	Its safety goal oriented structure leads to good management decisions	The resulted tree can be extremely long and complicated
	As a tree method, it is flexible	Time consuming and costly
	Old and well established technique	

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Table 5: Environmental impact methodologies, index methodologies

Method	Advantages	Disadvantages
Environmental Hazard Index (EHI)	Old and well-established technique	no spatial patterns or geographical criteria
Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)	Easy to perform	It's an optimization technique, used in the design stage
	Can include GIS in the disaster management	
Intent Environmental Toxicity Hazard (IETH)	Includes the Environmental Hazard Index (EHI) and all its advantages	no spatial patterns or geographical criteria
	Explicitly designed to deal with a catastrophic failure of a chemical process plant and its environmental consequences, the aquatic and terrestrial toxicity impact	

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2.3. Industrial and environmental risk assessment case studies

According to the research patterns and keywords stated above the following research papers were obtained. These papers are divided into two categories, publications that focus on the industrial risk assessment techniques in a variety of sectors that have increased accident severity and publications that focus on environmental risk assessment and ecological risk assessment (Table 7). These publications utilize the methodologies of risk analysis that were described above in order to analyze risk of accidents in sectors such as oil pipelines, chemical plants, ports and other.

2.3.1. Industrial risk assessment – Case studies

The first group of publications consists of those that utilize a tree method. The most common methods are bow-tie, event tree and fault tree analysis. According to Iacob & Apostolou (2015) one of the most prolific tools for industrial risk assessment is the bow-tie method. The Bow-tie method has been widely used in a variety of publications including natural gas pipelines. Fang et al (2019) create a bow-tie of their pipeline system and utilize Bayesian networks in the mapping process. Thus, a detailed mapping of the risk assessment system that combines causes and all possible consequences is created. Subagyo et al (2021) study a real-life test case that focuses on improving the safety performance of an oil pipeline in Gresik, East Java in Indonesia. In their research, the authors showed that different segments of the pipeline have different risk of accident with severe environmental consequences. After following the proposed risk management process according to (ISO 31000) the authors identify all sources of risk, evaluate it and finally propose mitigation measures. This was also achieved by creating a bow-tie diagram. Muniz et al (2018) utilize a bow-Tie risk management system for dual purpose, first to assess risk and secondly to prove to stakeholders that pipeline risks are under control. In addition to the bow-tie technique the researchers apply the HAZID method in order to identify risk sources, showcasing the synergy between hazard identification and risk analysis techniques. A fault tree was created by Le Duy et al (2016) that evaluates risk for accident in nuclear plants. In this work the authors emphasize the role common systems play in accident prevention as well as the human factor in risk assessment. Jing et al. (2017) use an event tree in order to quantitatively assess individual and societal risk in the Jiangyin Port. According to them an accident or an explosion will cause casualties, property loss and pollution to the aquatic environment in the Yangtze River. The authors create a societal risk curve that evaluates the hazard as a whole in the society. It is those author's belief that individual risk alone is not enough in an industrial risk assessment, thus there is a need to include both environmental factors as well as societal risk such as damage to property and environmental stressors.

Altabbakh et al (2014) describe how a STAMP model can be utilized in crude oil processing facilities and in oil and gas industry in general. This work presents an accident case where in a crude oil processing facility, a leakage of oil caused a series of massive explosions that destroyed the entire facility and caused several deaths and injuries. Using the STAMP technique, it was easier for the researchers to find the inadequacies of the facility and of the staff in accident prevention. The researchers concluded that the main causes of that specific accident were in fact the lackluster prevention measures, the underwhelming company culture in accident prevention and in organization that eventually resulted in human error. This was possible due to the STAMP methodology that focuses at the organizational level in comparison to techniques such as Root-Cause analysis that focus mostly at equipment and technology. A methodology that brings together techniques that operate at organizational level such as STAMP and tree techniques such as bow-tie, event and fault tree analysis is MORT. Consequently, within the scope of this work, the human factor is largely emphasized as a key criterion for accident prevention. Appicharla (2011) used a MORT method in order to analyze a railway accident and its causal factors in order to analyze future risks and propose mitigation steps. The analysis proved that the main reasons for the accident were the lack of safety barriers.

Vulnerability analysis is a method of risk analysis that mainly focuses on risk management against hacking attacks. Chen et al (2019) applied this method in chemical plants. The main focus of their work is cascading effects in risk analysis by modeling it with a Dynamic Vulnerability Assessment Graph (DVAG) model which is a form of vulnerability assessment that integrates a graph methodology in order to model the studying system. The authors also opted to contain risk for three types of loses: economic loss, casualties and environmental pollution. According to Asgari et al (2021) the risk of accident in the transportation and storage of residual hazardous materials can be managed by utilizing the Functional Resonance Analysis Method (FRAM) which is a method very similar to HAZOP as it shares the usage of keywords. The benefits of this method over other conventional risk assessment techniques is the ability of this method to handle and account for the variability of dynamic functions such as the nonlinear relationships between organizational aspects and process safety in the chemical industry.

Guzman Urbina & Aoyama (2018) suggest a risk analysis methodology that is capable of assessing risk with numerous variables and a large amount of uncertainty. Many risk analysis methodologies suffer from the large amount of uncertainties that comes up in a risk assessment project. The aforementioned work combines artificial intelligence with fuzzy logic in order to assess the risk and ensure pipeline integrity in a Colombian oil network. The fuzzy logic is used in order to turn crisp values of probability and consequence into grades of membership (fuzzy sets) and in combination with rules stated by the U.S. Department of Defense[1] for safety management, an inference system was created. Following that the centroid method of defuzzification was used in order to quantify risk.

A Bayesian network (BN) was utilized by Zhang et al (2018). Their work focuses on oil pipelines network. In their work the researchers take into consideration four types of consequences: casualties, economic loss, environmental pollution and social order influence. Every type of consequence is further expanded into four states of consequence and each consequence has its own probability value assigned to it. In the same manner are the initiating events placed into the network. The nodes of the BN are deployed after a rule created by the authors, which makes the network more organized and integrated. In their work the authors take into consideration geographical criteria where the environmental impact from natural disasters is higher in some segments than others. After the creation of the BN a sensitivity analysis takes place in order to assess the first response measures. Another model of risk analysis with BN is introduced by Yuan et al (2015). In their work the consequences of a dust explosion are studied. Their model performs probability updating and probability prediction which is possible due to the use of BN. In addition to that, a domino effect analysis is applied in order to study the escalation probability caused by the initial dust explosion.

2.3.2. Risk matrix – Case studies

Risk matrix is a very valuable tool and can be used in risk analysis and assessment in a plethora of ways. Here follow a series of publications that utilize the risk matrix to a great extent and in a non-

1 Standard Practice for System Safety, Department of Defense of the USA, Code: MIL-STD-882D, United States of America, 2000. 15.

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conventional manner creating interesting case studies. For example, Zhao et al (2010) study the risk of accident in deep coal mining. In order to deal with the uncertainties in the data and the difficulty of the decision makers to fully comprehend the enterprise capabilities the unascertained measure model was proposed in combination with entropy estimation. According to the authors this model is ideal for mine shaft risk assessment and it can combine qualitative data in a quantitative method. The next three papers concern chemical plants. Arjuna & Hasibuan (2020) use the chemical plants of Cilegon city, Indonesia. The main focus of the work is fire in chemical plants and the 15 activities in chemical plants that lead to fire. In this work hazard identification was obtained by using HAZOP and then a likelihood/consequence matrix on those 15 activities was created. In the work of Yang (2018) a risk analysis methodology was proposed that handled black swan events in the chemical industry. According to the researcher, in major accidents, regular risk assessment techniques are inapplicable. Thus, Yang proposes a model that contains a three-dimensional risk matrix that can contain all four types of events as defined by Flage and Aven (2015). These are the known-known (the event we know we know), the known-unknown (the event that we know we don't know), the unknown-known (the event we don't know we know) and the unknown-unknown (the event we don't know we don't know). Thus, the axes of this matrix are unwanted Consequences, uncertain occurrence and uncontrolled development. A big case is made about how attention to warning signs can reduce the amount of process accidents. Finally, Haddad et al (2008) proposed a risk assessment algorithm that operates via a hazard matrix. This methodology prioritizes health, safety and environmental management strategies. According to them, a risk matrix is a ranking system of the events in accordance to their rate of occurrence and their severity. The created risk matrix contains three types of information, hazards, environmental agents (radiation, coolants, etc) and exposition factors (probability factors).

2.3.3. Environmental impact assessment – Case studies

Environmental impact assessment (EIA) is the assessment of the environmental consequences of an operation, process or project. The environmental impact of an industrial accident is a part of environmental impact analysis. EIA methodologies may be applied in the case of an event that could lead to an industrial accident that have quantifiable environmental consequences. In addition to that EIA is an essential tool at the design part of a plant. One of the main causes for an industrial accident besides technology malfunction, human error and deliberate attack is an environmental impact such as floods, wildfire, typhoons, earthquakes and others. Zeleňáková & Zvijáková (2017) propose a risk analysis methodology to assess the impact of floods in European countries. The way this is achieved is by clearly establishing the methodology and principles of risk analysis in the EIA, by utilizing the different meanings of risk, by expanding the knowledge of emerging risks, by creating a new methodological approach and finally apply the results of the methodology in order to convince all stakeholders. The proposed methodology contains three parts, establishing the context, risk analysis and decision making. The first part assesses the state of the environment and of the installation. The second part assesses the risk by utilizing the following risk parameters AWSRP (average weighted summation risk parameter) and the ASRP (average summation risk parameter). The weights in the risk parameters help in establishing the importance of every risk parameter. The decision making part contains all possible countermeasures to the highest calculated risks. In this work, there are measures that are specified to flooding but there are also measures that focus mainly on organizational level such as safety requirements and many others.

The following work by Hermansyah et al (2020) performs EIA in port development. Their work is a semi-quantitative risk assessment of the external risks that may harm the development of a port platform. In addition to that a sensitivity analysis is performed in order to find the largest likelihood factors that affect the risk value of the platform. For two platforms the total risk was calculated using risk hierarchies via a risk matrix. The risk was calculated before the installation of mitigation measures and after. The resulting risk after the mitigation measures was halved. This paper clearly demonstrated how a semi-quantitative technique could overcome the lack of data without using overly complicated mathematical techniques that could be hard to understand and consequently make it harder for all stakeholders to grasp. In the pre-construction step of a plant there is the work of Gupta, Suresh, Misra, & Yunus (2002). Their objective is dual, first is the clean operation of plant and second is the safe operation of the plant. The pollution control objectives are dual. It is important for the researchers to reduce risks of environmental threats such as accidental chemical reactions, accidental release of hazardous gases and liquids. The researchers make a strong point for the safe selection of sites for industrial development. Those sites are called industrial growth centers (IGCs) and selection of those sites must be done with specific geographical and environmental criteria as well as with criteria that evolve the synergistic pollution among the plants, the risks of accidental releases and synchronous activities. Thus, the location of other industrial plants adjacent to the studied plant is an important factor for both steady operation pollution and for risk related to accidents. In this work, the researchers consider the site selection stage the single most important step of environmental protection. In IGCs small and medium size business, whose operation can be very harmful to the environment because of synchronous pollution, can benefit from synergistic mitigation measures that reduce pollution in steady state operation and in cases of accidents. In IGCs, small sites and businesses can take better care of environmental issues. The researchers also propose an integrated ecological risk assessment that in addition to mitigation via technological means, policy is also included. This is integrated risk identification, assessment, analysis, management and mitigation system is a closed loop that updates itself in all levels once a possible threat to the environment has been identified.

2.3.4. Environmental risk management – Index methodology

In this section follow a series of publications that perform environmental risk management by utilizing harm indexes. Index methodologies have been widely used in the field of medicine but have recently also been used in environmental risk analysis. In the work of Trávníček et al (2016) a risk assessment of a biogas plant takes place. The researchers study two test cases. One involves the continuous leak of a substance to the environment and the second an immediate release of the toxic substance to the water horizon. The methodology used is the following. First HAZOP was used for identifying the risks. Following that the environmental risks were screened by utilizing the Environmental Accident Index. The quantitative risk assessment was performed by PROTEUS (Netherlands). The acceptability of the risks was determined by using the Environmental Harm Index (EHI) (Scott (1998)). The EHI is calculated by using the chemical properties of the material such as the toxicity to water-living organisms, the viscosity, the amount of the material that is stored or transferred and the water solubility of the chemical. This works compares the results of the method with the ALARP (As Low As Reasonably Possible) approach and the results were similar. According to both methods the risk was at acceptable levels for both test cases. According to Porfiryev & Tulupov (2017), it would be beneficial in environmental risk analysis not just to calculate the risk of an accident by calculating the frequency and consequence of an accident but also to assess the capability of a plant to prevent an accident. Their work utilizes risk matrices for a number of industrial enterprises as well as a series of factors in

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order to rate their operation and the hazard they impose. The damage for accidental pollution is calculated with the following information: the damage from accidental release into the atmosphere, the dispersion of the impurities, a coefficient of relative danger over a trajectory, the share of the territory, an index of relative aggressiveness of the substance and the unexpected entry of toxic mass. A series of factors of influence is created in order to judge the probability of an industrial accident with great consequences to the environment. The formula that calculates the accident probability is dependent by the following factors: the maximum probability of an accident with ecological consequences, an expert estimate of the degree of influence of the accident's probability factor and the value (weight) of the factor.
Many publications described above contain criteria for the industrial risk assessment. However, all of them were located by the researchers in their work (Porfiryev & Tulupov (2017)) among some others. These factors are presented at the table below:

Table 6: Categorization of factors that increase the probability of an industrial accident according to Porfiryev & Tulupov (2017)

Group of factors	Factor's no.	Factor
Type of harmful substance	1	Hazard class of harmful substances involved in the production process
Production technology	2	Compliance with requirements, norms and rules
Provided cleaning	3	Used technology
	4	Number of accidents (emergency situations)
Quality management	5	Authority of the manager
	6	Independence, responsibility of managers
	7	Susceptibility to innovation
Personnel characteristics	8	Average level of education of employees
	9	Average length of service of employees by profession
	10	Number of violations of labor discipline for the analyzed period
	11	Number of violations of production discipline for the analyzed period
Existence of external sources of danger	12	Influence of natural phenomena (seismicity, floods, mudslides, landslides)
	13	Hazard level of nearby external man-made sources of danger
	14	Terrorism, military actions

Table 7: Summary of papers that studied industrial accidents and their causes based on a risk analysis methodology framework

Paper	Primary Method /Secondary Method	Industry
Iacob & Apostolou (2015)	bow-tie	NA
Bai, Zhang & Reniers (2019)	bow-tie/Bayesian network	natural gas pipelines
Fang et al (2019)	bow-tie	oil pipeline
Muniz et al (2018)	Bow-tie/ HAZID	oil pipeline
Le Duy et al(2016)	fault tree	nuclear plants
Jing et al. (2017)	event tree	port
Altabbakh et al (2014)	STAMP	crude oil processing facility
Appicharla (2011)	MORT	railway
Chen et al (2019)	Vulnerability analysis/ Dynamic Vulnerability Assessment Graph	chemical plants
Asgari et al (2021)	Functional Resonance Analysis Method	chemical industry/transportation
Guzman Urbina & Aoyama (2018)	artificial intelligence with fuzzy logic	oil pipeline
Zhang et al (2018)	Bayesian network	oil pipelines
Yuan et al (2015)	Bayesian network	mines
Arjuna & Hasibuan (2020)	Risk matrix	chemical plant
Zhao et al (2010)	Risk matrix	deep coal mining
Yang (2018)	three dimensional risk matrix	chemical industry
Haddad et al (2008)	hazard matrix	process accidents
Zeleňáková & Zvijáková (2017)	Risk hierarchy/Environmental impact analysis	NA
Hermansyah et al (2020)	semi-quantitative risk assessment/ Environmental impact analysis	port
Gupta et al (2002)	Environmental impact analysis	chemical plants
Trávníček (2016)	harm indexes	biogas
Porfiryev & Tulupov (2017)	harm indexes	Industrial plant

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2.4. Conclusions on literature review

In this section a large number of publications was studied. In the first part of this section all the methodologies that are utilized in industrial risk assessment and environmental risk analysis were described, as well as the structure of a complete risk management process that is shown in Figure 1. In the second part of this chapter a wide range of publications was analyzed that utilized the methodologies described in the first part of the review in case studies. Those articles used as test cases a number of industrial activities that were deemed by the researchers as hazardous with environmental, social, economic and health impact. From those publications a number of conclusions were drawn.

As it appears there is no correlation between the type of risk assessment method and the industry that the test case belongs to. The main industries that were used as test cases were oil and gas pipelines, railway, ports, nuclear plants, chemical plants/petroleum industry, mine shafts/road tunnels. In those publications there was no reference to possible benefits from choosing a specific risk assessment method over another in relation to the type of industry it involved.

A preference to certain risk assessment methods was apparent when there was a plethora of uncertainties in a system and in the data. The type of methodologies that were chosen in those cases where some type of semi-quantitative risk assessment or methods that involved the creation of fuzzy sets that eventually were defuzzified in order to perform qualitative risk assessment.

Every risk analysis reaches a point where all risks or consequences need to be categorized. The main way this is achieved, in the majority of the publications, was the risk matrix. The risk matrix can perform a hierarchical categorization of the risks and can even be used on its own for qualitative risk assessment. The risk matrix is the tool that informs the researchers which of the risks are in need of mitigation measures.

The most popular type seemed to be the tree-based methods: fault tree, event tree and bow-tie methods. The methodologies that utilized Bayesian networks proved to be also very popular in terms of recent publication numbers. Risk assessment methodologies that operate at an organizational level such as MORT were also present in the recent publications that focused on industrial accidents and risk assessment, however their number is almost negligible since the aforementioned methods such as trees and Bayesian networks could include any organizational aspect to their structure. This is the case with almost every other type of method that is not a tree or Bayesian network.

The main causes of industrial accidents from all research papers above are perfectly summarized in the work of Porfiryev & Tulupov (2017). Table 6 contains all criteria found in the performed bibliographical review among others that Porfiryev & Tulupov also found important. As shown in the same matrix there are six types of factors that increase the probability of an accident. However, researchers seem to find some factors more important than others. The most important factor that can lead to an industrial accident is by far, environmental causes such as floods, typhoons, wildfires, earthquakes, landslides and many more. Those accidents can lead in turn to accidents with severe consequences such as loss of life, environmental destruction, destruction of property and socio-economic consequences. Thus, according to these researchers, the main countermeasure is the choice of location of the plant. The second most important reason proves to be the types of harmful substances used

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and stored in the location. This explains why most test cases revolve around oil plants and chemical plants where a large amount of dangerous materials are stored and railway accidents and pipelines where dangerous materials are transferred. The third cause is the human error factor. This can happen due to violations of regulations and laws by workers, managers and owners alike, lack of experience and training, lack of concentration due to lack of organization, internal regulations and overworked workforce.

Although generic industrial risk assessment methods can be found in large numbers and applications in the literature, it is observed that there are only few instances of methods that focus explicitly on environmental risk assessment in terms of environmental impact from industrial accidents.

In order to assess the environmental consequences, the researchers use environmental stressors to assess the consequence of the risk. These include contamination of water, substrate or air by accidental release of toxic liquids or gases. All those accidental releases are assessed via index methods that mainly remain the same for the last 25 years. The sensitivity of the ecosystem to those stressors is then studied and the possible consequences are obtained. Other stressors caused by an accident are wildfires, physical stress such as explosions, accidental release of warm water which is considered thermal pollution, biological pollution by the release of raw sewage and pathogens and biological stressors such as disruption to the food chain.

In conclusion the case studies analyzed above offered a plurality of methodologies and key criteria on assessing the risk for an accident in industrial plants with environmental impact. In addition, the most prevalent risk analysis methodologies were obtained, listed and categorized. In the last three decades, where risk analysis has been established as a scientific area of research, a number of methodologies have been created. However, since many models share the same underlying principles, many similarities arise among them. This part of the review aimed to showcase all the unique methodologies of risk assessment and the strategies that are utilized in order to assess the probability of an accident with the purpose to reduce the environmental impact.

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3. Existing Environmental Impact Methodologies in Greece and EU

3.1 IMPEL's Integrated Risk Assessment Method (IRAM)

IMPEL's Integrated Risk Assessment Method (IRAM) was developed in 2012 by a group of experts within the framework of the easyTools program of the European Union's IMPEL Network (Network for the Implementation and Enforcement of Environmental Law). IMPEL's group of experts developed a new web-based tool as well, which facilitates the implementation of the methodology[2]. The IRAM methodology is based on information on the risk assessments that are used across Europe.[3]

One of the main goals of the IMPEL network is to improve the inspection activities in its member countries. Thus, they decided to develop an environmental risk assessment methodology that would assist the member states with the planning of inspections. According to the project team, the method was designed to be flexible, user friendly, applicable to all types of inspections and suited to the needs of the Industrial Emissions Directive (IED) and the Seveso Directive (Kramers, et al., 2012). The flexibility of the tool underlies in the possibility given to the user to decide on the inspection task, the risk criteria, and the setting of the steering parameters that are to be used (Kramers, et al., 2012, p. 6). The aim of the project was to develop an internet-based IT tool for environmental risk assessment that could be used by all member states, to help them plan their environmental inspections. The IRAM tool can therefore be used in different languages.

3.1.1 Determination of the risk category

The IRAM methodology is used to systematically appraise the risk, in order to prioritize the workload of an inspecting authority. The outcomes of the risk assessment could be the classification of the risk of an inspection object, its inspection frequency and the related inspection effort.

The IRAM project team reviewed the risk assessment methodologies that are used across Europe and attempted to integrate their advantages, while reducing their disadvantages. Although the methods have been tailor made to fit the exact needs of each inspecting authority and are therefore different from each other, three general types of methods for risk assessment were identified· the linear mean value method, the mean value of risk and the maximum value of risk (Kramers, et al., 2012).

In the **Linear mean value method**, the sum of all criteria (weighted or not) is divided by the number of the criteria and the results are assigned to certain risk categories and inspection frequencies. One of the main disadvantages of this method is that there are no probability factors in the calculation, making it no real risk assessment. Another significant disadvantage is the fact that the low risks from some criteria level out the high risks of other criteria, concluding to an imprecise result where the high risks are not given the appropriate attention (Kramers, et al., 2012).

[2] A description of the IRAM Tool can be found in Appendix 1.
[3] The project is based on the findings of a review of the risk assessment methods and risk criteria that were in use in IMPEL member countries at the time of the project. For the review, a questionnaire was created, which was distributed to the IMPEL National Coordinators on March 21, 2010, who were asked to fill it out and return it by April 23, 2010. More information on the findings of the questionnaire is given in Appendix 4.

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Risk = $(C1W_1 + C2W_2 + \ldots + CnW_n)/n$

The **Mean value of risk method** works like the Linear mean value method with only difference the integration of the probability factor in the calculation. The probability factors generally derive from the performance of the operator or the characteristics of the installation. Disadvantages of this method are again the levelling out of criteria with high risks, the small dispersion of the results when the number of the criteria is high, and mainly, the big influence the probability factor has on the results (Kramers, et al., 2012). The outcome of the Mean value of risk method is basically the result we would have with the Linear mean value method multiplied by the probability factor.

Risk = $(C1W_1 + C2W_2 + \ldots + CnW_n)/n * P$

The **Maximum value method** determines the inspection frequency based on the inspection frequency scores of the different inspection tasks. One of the main disadvantages of this method is that no risk assessment is made within the inspection tasks (Kramers, et al., 2012). Another disadvantage is that the result of this method will show a higher number of inspections, and that the information about the inspection frequencies of less important tasks is lost (ibid.). There are also no probability factors in the calculation, and no steering mechanisms.

Inspection frequency = Max $(IT_1, IT_2, \ldots, IT_n)$ C = impact criterion

W = weighting factor

P = probability of occurrence

Max = maximum of

IT = inspection task with fixed frequency

Source: (Kramers, et al., 2012)

3.1.2. Rule based method (IRAM)

Through the combination of the advantages of the above-mentioned methods and the mitigation of the disadvantages, the IRAM method was developed, a Rule based method.

The IRAM Method uses the "Rule", a risk rule, to prevent the highest scores of some criteria to be levelled out by the low scores of the other criteria (a basic disadvantage of the Linear mean value and the Mean value of risk methods). This risk rule defines the number of criteria with a maximum rating required for the overall environmental risk of an installation to be equal to the maximum rating of the criteria. This means that if the number of criteria with the maximum score reaches the rule value, then the overall environmental risk of an installation is the same with the maximum score of the criteria. If the rule is not met, the risk category of the inspection object is lowered by one point from the maximum score of the risk criteria. The inspection coordinator sets the “Rule” value, which basically allows him to decide how many highest scores of an inspection object are needed to impact the highest inspection frequency.

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Generally, the more impact criteria are introduced into the assessment, the greater the rule value should be. This is a way to use all the information to avoid unnecessary inspections (a basic disadvantage of the Maximum value method). An example of a risk calculation using the rule is given in Appendix 2.

IMPEL's project team define the concept of risk as follows:

> *"The Risk of an (industrial) activity in inspection planning is defined as the (potential) impact of the activity on the environment or the human health if the operator is not compliant with the regulations by law or permit conditions"*

They calculate the risk as *"a function of the severity of the consequence (the effect) and the probability this consequence will happen: Risk = Effect * Probability"* (Kramers, et al., 2012, p. 12)

According to the project team, effect is the impact of the source on the receptor, and probability depends on factors like the level of management, the level of compliance with laws, the attitude, the characteristics of the installation and others.

3.1.3 Criteria

The proposed methodology distinguishes the impact criteria, which are the criteria relating to the environmental impact of an activity, from the performance criteria of the operator of the activity. According to the easyTools Guidance, the effect is represented by the Impact Criteria, while the Operator Performance Criteria stand for the probability. They don't exclude the possibility that some probability is contained in the impact criteria (Kramers, et al., 2012, p. 12)

3.1.3.1 Impact criteria

The impact criteria can vary between inspecting objects and inspecting authorities. Impact criteria include the severity of the consequence by evaluating the vulnerability of the receptor and the destructive power of the source.

3.1.3.2 Operator performance criteria

The operator performance criteria influence the risk scores in a positive or a negative way, shifting the risk category and thus the inspection frequency, but their effect, unlike that of the impact criteria is indirective and limited. Depending on the operator performance, the impact could be neutral, additive to the impact score by one point if the performance is "good", subtractive by one point if it is "bad". In case of multiple operator performance criteria, the outcome will be the average of the performance criteria scores, in order to ensure that the shift of the inspection frequency will be no more than one unit. After the implementation of the probability factor, the impact scores become risk scores. From these risk scores the inspector can choose the most important subjects for inspection.

3.1.3.3 Criteria examples

According to the IMPEL research team, a fixed set of standard risk criteria is impossible to provide, since each inspection authority has different tasks and responsibilities. Therefore, they mention that the criteria presented in the annexes of the guide should only be seen as good examples. (Kramers, et

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al., 2012, p. 11). Two types of risk criteria examples are mentioned· risk criteria for IPPC/IED installations and for Seveso establishments. The examples are summarized in the following tables (.

Table 8, Table 9).

Table 8: Risk criteria examples (for IPPC/IED installations)

	Risk criteria examples (for IPPC[4]/IED installations) (More detailed information about the scoring of the criteria is given in Appendix 3.)	
	Impact Criteria	Operator Performance Criteria
1.	Type and kind of installation	Compliance
2.	Impacts on human health or the environment	Attitude of the operator
3.	Releases to air	Environmental management system
4.	Releases to water/off-site transport in waste water	
5.	Releases to land	
6.	Off-site transfer of waste	
7.	Input of waste	
8.	Quality of the local environment	
9.	Sensitivity of the local environment	
10.	Risk of accidents	
11.	Noise	

[4] IPPC – Integrated Pollution Prevention and Control

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Table 9: Risk criteria examples (for Seveso establishments)

	Risk criteria examples (for Seveso establishments)		
	Impact Criteria		Operator Performance Criteria
1.	Knowledge on the establishment	Taking into account major-accident hazards	Required records and documents based on Seveso II Directive
2.	Dangerous substances		Results and assessment of previous inspections
3.	Organisation of damage limitation		Attitude of the operator
4.	Neighbourhood Seveso establishments or other facilities or conditions	Taking into account the sensitivity of the local environment	
5.	Sensitive objects and conditions in the neighbourhood		
6.	Process risks, complexity of installations	Taking into account the risk of accidents	
7.	Detection systems for the prevention of accidents		
8.	Serious complaints, serious accidents and near-misses, incidents and occurrences of non-compliance in the past	Actual impacts	
9.	Control of incidents, near misses and accidents by the operator		

3.1.3.4 Weighting factors and weighting terms

Besides the "Rule", weighting terms and factors are being used as steering mechanisms in the rating of each impact and performance criterion, because it allows the inspection authority to set priorities according to political importance, modifying the risk analysis. Additional steering mechanisms are the

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risk ceiling and the so called "safety net". The risk ceiling stands for the maximum possible risk score of an impact criterion. This is a way of weighting since an impact criterion with lower maximum score than other criteria, won't influence the highest inspection frequency. The safety net will ensure that the inspection frequencies will stay within the boundaries of the national and the European legislation. It is used to limit the drop of the inspection frequency if the legal minimum inspection frequency is higher than the inspection resulting from the risk category of the assessment.

3.1.4 The Integrated Risk Assessment Method steps

The IRAM method consists of the following stages:

First, the impact and operator performance criteria are defined. Then, the weighting terms and factors are defined, taking into account the differences in importance of the selected criteria. As part of the weighting, the risk ceiling is also assigned in this step. Afterwards, the minimum number of highest scores ("the Rule") is defined. The following step is the matching of the risk categories to the inspection frequencies. This is a policy decision to be made from the inspecting authority as to how to use the outputs of IRAM. The last step before the filling in of the criteria scores is the definition of the safety net according to the legal obligations and the policy.

Taking into account all the steering mechanisms, the impact criteria scores are filled in, and they shall be varied only one step upwards or downwards, depending on the operator performance criteria of the activity. If the rule is met, the overall environmental risk category is equated with the maximum rating. If the rule is not met, the overall risk category is reduced by one step from the maximum individual score. The impact scores, combined with the operator performance scores, give the risk scores, based on which the risk categories are formed. Based on the risk categories, the inspection frequencies are assigned to each inspection object, and the inspection time needed is calculated.

3.1.5 Review

According to the workshop conclusions of IMPEL's project easyTools, the IRAM method is successful, since it is working better than most systems used in Europe ((IMPEL), 2010, p. 96). Its success lies on its simplicity and its flexibility. The method is easy to use and can be adjusted to fit the needs of different inspecting authorities. Moreover, the method was based on existing systems, which makes it similar to them and facilitates the merging of the systems that are already in use, with this method. What is critical for this method, is the selection and the clear description of the risk criteria (impact and operator performance criteria).

3.2 The Hellenic Ministry of the Environment Environmental Inspectorate methodology

The Hellenic Ministry of the Environment and Energy developed the "National Plan and Regular Environmental Inspection Programs", according to the article 20 of Law N. 4014/2011. The methodology was then accepted as joint ministerial decision (ΥΠΕΝ/ΣΕΝΕ/13582/952/2021- ΦΕΚ

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689/B/22-2-2021). The aim of this regulation is to make the environmental inspections more effective and to achieve a higher degree of compliance of the inspected facilities, projects and activities, and thus a higher degree of environmental protection. This will be achieved through systematic inspections at a specified frequency based on the environmental risk of each activity (Glitsis, et al., 2017).

The national inspection plan developed in 2017 introduces a new model for the regular and urgent environmental inspections in Greece, in which, firstly, the analysis and assessment of the environmental risk of each activity, and then the prioritization of the inspections takes place.

The model analyses the environmental risk and then determines the frequency of the environmental inspections for each project or activity, based on the Integrated Risk Assessment Method (IRAM) of IMPEL[5].

The IRAM method was applied to the 6.252 projects and activities that the register of the audited activities includes. The implementation of the methodology by the Environmental Inspectorate team is shown on the following table (Table 10), which displays the impact and operator performance criteria selected, their scoring conditions, as well as the number of projects and activities that meet each criterion. The range of the scoring of each impact criterion was 1-5, where the value 5 corresponds to the highest risk category, and the value 1 to the lowest. For the "Empirical Hierarchy" and the "Inclusion to the e-PRTR Regulation" impact criteria, a steering mechanism was used (-0,5) in order to lower their effect on the risk analysis. The operator performance criteria shall be assigned values of -1, 0 or 1 and their impact may be positive, neutral or negative correspondingly. For the operator performance criteria, it was decided not to employ weighting factors, but to weight all criteria equally. Currently there are two operator performance criteria considered. The average value of the individual performance criteria (PC), rounded to the nearest whole number, should yield the overall performance score (OPC) for each operator, which shall be assigned values of -1, 0, or 1.

$OPC = (PC_1 + PC_2)/2$,

The overall performance of the operator is then added to each individual impact criterion (ICn) to obtain the individual risk category corresponding to each impact criterion. As a result, the influence of the operator performance criteria on the risk assessment might be positive, negative, or neutral. That is, a good performance by the operator scores at -1 decreases the estimated risk by one step, but a poor performance rated at +1 raises the estimated risk by one step.

RCa = ICa + OPC
RCb = ICb + OPC
RCc = ICc + OPC
…

Finally, to calculate the overall environmental risk category, the individual risk categories (RCn) are used and the risk rule is applied. The highest value of the individual risk categories shall be taken as the environmental risk category, provided that this value is presented in at least two individual risk categories, as the value of the rule has been set at "2", given the large number of impact criteria used.

[5] More information on the IRAM method is given in chapter one of this report.

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Table 10: Scoring of the Impact and Operator Performance Criteria (Source: *(Glitsis, et al., 2017, p. 36)*

Scoring of the Impact and Operator Performance Criteria				
		Scoring condition	Score	Number of projects and activities that meet the criterion.
Impact Criteria				
ICa	Inclusion in Directive 2010/75 (IED)	A1[6], subject to IED	5	149
		A1, not subject to IED	3	857
		A2, subject to IED	3,5	321
		A2, not subject to IED	1	4925
ICb	Inclusion in Directive Seveso II	A1, subject to upper Seveso	5	29
		A1, subject to lower Seveso	4	24
		A1, not subject to Seveso	3	953
		A2, subject to upper Seveso	3,5	47
		A2, subject to lower Seveso	2,5	54
		A2, not subject to Seveso	1	5145
ICc	Within a protected area of the Natura 2000 network	A1, within Natura 2000	5	167
		A1, outside Natura 2000	3	839
		A2, within Natura 2000	3	848
		A2, outside Natura 2000	1	4398
ICd	Inclusion to the e-PRTR Regulation	A1, subject to e-PRTR	4,5	146
		A1, not subject to e-PRTR	3	860
		A2, subject to e-PRTR	3	124
		A2, not subject to e-PRTR	1	5122
ICe	Inclusion in Directive 1999/13/EC (VOC)	A1, subject to VOC	5	12
		A1, not subject to VOC	3	994
		A2, subject to VOC	3,5	37
		A2, not subject to VOC	1	5209
ICf	Empirical Hierarchy	A1, of high hierarchy	4,5	261
		A1, of medium hierarchy	3	485
		A1, of low hierarchy	2	260
		A2, of high hierarchy	3	1337
		A2, of medium hierarchy	2	2332
		A2, of low hierarchy	1	1577
Operator Performance Criteria				
PC1	Environmental compliance history	Inspection without confirmation of infringements	-1	54
		No inspection by the inspection authority	0	5979
		Inspection with confirmation of infringements	1	219
PC2	EMAS active registration	Installation registered in EMAS	-1	26
		Installation not registered in EMAS	0	6226

[6] Classifying the project /activity in subcategory A1 or A2 according to the classification of IA 37674/2016 (B' 2471) "Amendment and codification of YA 1958/2012". Classified in category A for their environmental authorization are all projects and activities likely to have significant effects on the environment.

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Regarding the urgent environmental inspections in Greece, a large number of inspections are carried out by the competent authorities every year. Due to the lack of coordination between the competent authorities, multiple inspections are often carried out on the same activities (Glitsis, et al., 2017, p. 26).

According to paragraph 14 of Article 20 of Law 4014/2011, emergency environmental inspections are conducted only in exceptional circumstances, namely:

- Examining significant environmental complaints
- Events with particular environmental impact
- In situations of non-compliance

According to paragraph 9 of the same Article, procedures for urgent environmental inspections are set out as part of this project.

In light of the foregoing provisions, the current plan establishes particular processes for emergency inspections aimed at ensuring the plan's successful execution. These processes include:

- the processing of the regular inspections prescribed by the annual program of regular inspections as a matter of priority by each audit authority. The inspections shall in any case be carried out within the year of their accession.
- the processing of the emergency environmental inspections of Category A or B projects as a second priority, provided that they do not cause the competent audit authority to be unable to carry out regular inspections. Emergency inspections in environmental incidents of particular importance are an exception.

Moreover, the current plan establishes specific procedures for handling complaints and carrying out emergency inspections. The procedures are detailed in the environmental inspection plan (Glitsis, et al., 2017, pp. 26-28).

3.2.1 Review

The Impact and Operator Performance Criteria selected by the Hellenic Ministry of the Environment and Energy are very clearly defined, which is a critical step when using the IRAM method. The selected criteria assess mainly what is measurable by European Directives, Regulations and Verifications. The criteria leave no room for a different interpretation, and their scoring is very simple and definitive, since it derives from the subcategory of the project/activity (A1 or A2) and the subsumption to the Directives (yes-no). Even the Operator Performance Criterion regarding the Environmental management system of each installation has only a negative and neutral scoring which depends on whether the installation is registered in EMAS or not. In comparison to the examples given by the IMPEL project team (

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Appendix) for this kind of criterion, other accepted environmental management systems are not taken into consideration, in order to reduce the complexity of the criterion.

The only criterion that has a more subjective nature is the “Empirical Hierarchy” criterion, where the hierarchy is given according to the inspection needs of specific groups of activities, based on the proposals of the regional services and the experience of the inspections in Greece so far. The project team considered this criterion important enough to be considered in the risk analysis, but not as important as the other criteria, and thus decided to lower its effect by using a steering mechanism of -0,5 for this criterion. It is important to note here, that it is necessary to assess the weighting factors on a regular basis according to the organization’s overall and specialized goals, and this method (IRAM) is suitable for modifications.

The result of the risk analysis with this method determines the frequency of the environmental inspections, but the minimum frequencies of the inspections of the projects/activities resulting from the application of the provisions of the applicable European and national environmental legislation are not considered. Because there can be a conflict between the result of the risk assessment and the legal requirements for inspection frequencies, the project team made an additional correction on the inspection frequencies. They have been corrected in relation to the requirements of Directive 2010/75/EU (IED), which are the following:

“The period between two on-site visits shall be based on a systematic assessment of the environmental risks of the installations concerned and shall not exceed one year for the installations posing the greatest risks and three years for the installations generating the smallest risks”. (Directive 2010/75/EU, Article 23, paragraph 4)

For the activities subject to the Directive, the minimum frequency of environmental audits has been corrected so that the time interval between two successive visits is in no case more than three years, and not more than one year for the activities which have been assessed for an overall environmental risk of 4,5 or above in the analysis based on the Hellenic Ministry of the Environment Environmental Inspectorate methodology.

3.3 Risk Analysis Methodologies practiced in other EU Member States

In order to review and map the risk analysis methodologies practiced in other EU Member States who aim to calculate the Financial Provision cost in the context of the Environmental Liability Directive (ELD), a request for information to all 27 EU Member States was sent, in particular the members of the Environmental Liability Directive Government Expert Group, with the contribution of The Hellenic Ministry of the Environment (MEE/COIEL). Answers were received from the following countries/associations: IMPEL network, Italy, Spain, Portugal, Ireland, and Malta.

The spokesperson of the IMPEL network provided a translation of the Netherlands methodology, which was prepared for the IMPEL Financial Provision study and the French legislation about mandatory financial provisions.

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According to the spokesperson of Italy, the competent authority in Italy (Ministry of Ecological Transition (MiTE)) does not use risk assessment methodologies because the Italian legislation on ELD implementation and enforcement (part Vi of the LD 152/2006) does not require mandatory provisions for the environmental liability under ELD. Mandatory financial provisions do exist under other legislations related to environmental protection, but they are available only in the Italian language.

The spokesperson of Spain gave detailed descriptions of the ARM-IDM-MORA tools in Spanish. These tools help the operators make their environmental risk analysis and determine the amount of the mandatory financial security. In addition to helping operators in the determination of the mandatory financial security, the ARM, IDM and MORA tools also include a catalogue of prevention, avoidance and remedial measures, providing operators with a comprehensive environmental risk management tool for their facilities. The three tools are cost free (only registration is required) and available in English. The Hellenic Ministry of the Environment (MEE/COIEL) provided the translated IDM and MORA user's guides. The user's guide of the ARM tool is not yet translated in English, the website of the tool is, however, publicly available in English[7].

Portugal had developed an IT tool within the scope of the Environmental Liability Regime for Communication of Environmental Damages and Imminent Threats of Damages. This tool is bilingual (PT + EN) and is publicly available[8]. Portugal's spokesperson presented the methodology that the operator should follow to calculate the cost of the financial provision.

Ireland's representative confirmed the website on financial provision for EPA licensed facilities, where information on the approach in Ireland is provided[9].

Malta's representative referred to the document 'Improving financial security in the context of the Environmental Liability Directive No 07.0203/2018/789239/SER/ENV.E.4 May 2020', where in section 2.1 is stated that: "Insurers based in, or with branches in, Malta do not offer stand-alone environmental policies for ELD or other environmental liabilities to operators with sites only in Malta".

Consequently, the environmental risk analysis methodologies of Spain, Ireland, the Netherlands and Portugal are presented and analysed below, as well as the French compulsory financial provision method.

3.3.1 Methodology of Spain

The aim of the Spanish Environmental Risk Analysis Methodology is to help operators fulfil their obligations under the European Union Environmental Liability Directive (ELD) and the relevant Spanish legislation.

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[7] The tools can be found at: https://servicio.mapama.gob.es/mora/login.action;jsessionid=5ADE19C9811D2A4C1D5C35C7DD471751.e0310050?request_locale=en (Ministry for the Ecological Transition and the Demographic Challenge, Version 1.24.0).
[8] The link for the Portuguese tool is the following: https://ra.apambiente.pt/form ((APA), 2017)
[9] https://www.epa.ie/our-services/compliance--enforcement/industry-and-waste-management/financial-provision-for-environmental-liabilities/ ((EPA), 2021)

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The Spanish methodology contains three elements: A tool for helping operators in the elaboration of their environmental risk analysis (ARM), a tool for calculating the Environmental Damage Index (IDM), which estimates the damage associated with each scenario, and the MORA Tool (Environmental Liability Supply Model), which calculates the cost of remedial (primary, complementary, compensatory) and preventive measures for natural resources (water, soil, biodiversity) that may suffer damage.

The Spanish methodology applies to existing legislation. The procedure for the determination of financial security in Spain is set out in Article 33 of Royal decree 183/2015, which amends the regulation that partly develops Law 26/2007, approved by Royal Decree 2090/2008 of 22 December. This process involves the following phases:

- First, the operator must identify the risk scenarios and their probability of occurrence (ARM Tool use)
- Next, the operator must calculate the IDM (Environmental Damage Index) for each risk scenario.
- Step three involves calculating the risk associated with each risk scenario by multiplying the probability of the scenario occurring by the IDM value.
  Risk = Probability x IDM
- In the fourth step, the scenarios with the lowest Environmental Damage Index (IDM) constituting 95% of the total risk are selected. The one with the highest IDM will be the final selected scenario.
- At the final stage, the amount of financial provision is determined as the monetary value of the environmental damage caused by the selected scenario.

  For this step, the following must be done:

  1. The operator should quantify the environmental damage caused by this scenario.
  2. The environmental damage caused by the reference scenario should be monetized, which means that the cost of the remediation project should be calculated.

  To this end, operators can use the MORA tool, a free software tool developed by the Ministry for the Ecological Transition of Spain, to help operators calculate the costs of the remediation of the natural resources impacted by a possible environmental damage (within the scope of Law 26/2007).

  - At the end, a percentage of at least 10% of the repair costs is added as prevention costs.

3.3.1.1 ARM Module for the development of the Environmental Risk Analysis

The ARM module allows operators to build the event trees on which the environmental risk analysis report must be based, as established by the UNE 150.008:2008 standard for environmental risk analysis and evaluation. The construction of the bow-tie analysis contains the identification of the sources of danger, the consideration of the typology of substances that may be involved, the identification and collection of the initiating events, the identification and management of the conditioning factors, the obtainment of accident scenarios with their associated probabilities, and, if applicable, the quantity of the pollutant emitted (Ministry for the Ecological Transition and the Demographic Challenge, Version 1.24.0). Before using the ARM module, the user should be familiar

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with the methodology that this tool supports, as well as having created a risk analysis sketch of their installation in which they have identified the various parts of which the event tree will be constructed *(MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA YEL RETODEMOGRÁFICO, n.d., p. 16).* The methodology for the risk analysis that must be followed is displayed below (Figure 3).

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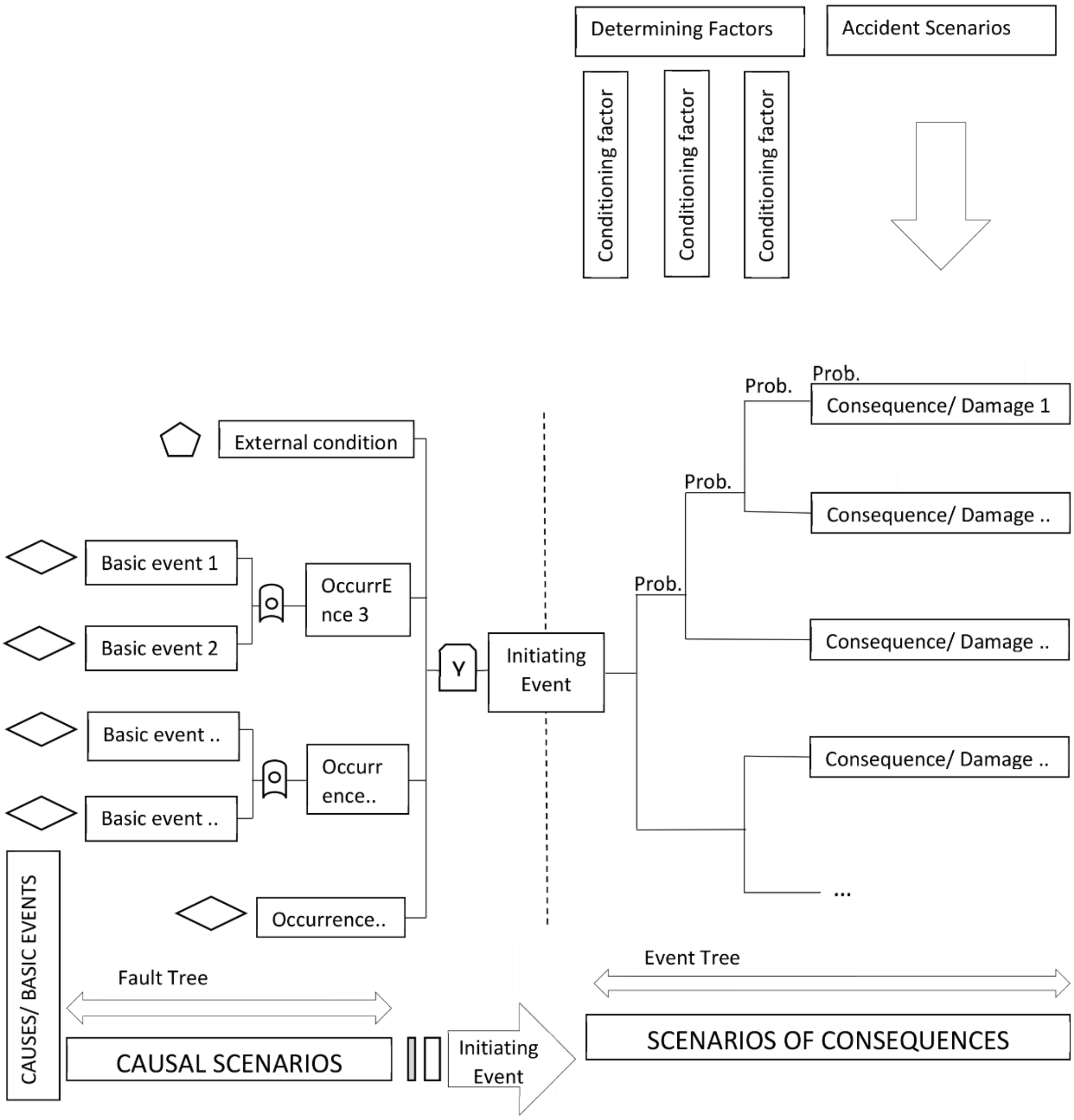

Undeveloped events

External condition: Used to indicate a condition or event that exists as part of the scenario in which the failure tree develops

Doors O: They represent the logical operation that requires the occurrence of one or more of the input events to produce the output event

Doors Y: They represent the logical operation that requires the occurrence of all input events to produce the output event.

Figure 3: General outline of the methodology for risk analysis. *(Source: (MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA YEL RETODEMOGRÁFICO, n.d., p. 16)*

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3.3.1.2 Environmental Damage Index (IDM) Estimation

The Environmental Damage Index (IDM) is used to estimate the size of the potential environmental damage associated to each accident scenario. The IDM output is a numeric value that represents the consequences of the damage. The unit of measurement does not have a direct mathematical relationship to the monetary value of the damage. It is used for the comparison between the estimated sizes of the consequences of the different scenarios, in order to select the accident scenario that will act as a base for the calculation of the financial security. The Environmental Damage Index should be calculated for as many possible accident scenarios as the facility under consideration has.

IDM is derived from the concentration of different combinations of agent-resource pairs corresponding to each accident scenario. For each agent-resource combination, the use of a set of specific variables is suggested. Table 11 lists the various agent-resource groups for which the IDM equation can be applied.[10]

As a result, any environmental damage will be assessed in accordance with the agent-resource combinations listed in Table 11, which are based on currently accessible remediation techniques. The user should choose one or more agent-resource combinations that are appropriate for the circumstance under consideration, and then estimate the IDM using the equation that is described in the Royal Decree (see below).

The IDM estimate is based on the MORA methodology's average primary remediation costs for each agent-resource combination. Because this data has been classified and converted to a non-monetary numeric value, the IDM program cannot assess the remediation costs that would result from using the Environmental Liability Supply Model (MORA). The MORA methodology necessitates the determination of the amount of possibly damaged natural resources first. For the IDM calculation, such quantification is not required and the outcome is provided through a generic estimate of the number of damaged resources for each agent-resource pair.

[10] It is important to note that in the context of IDM estimation, the habitat is defined as the collection of abiotic (such as soil) and biotic (such as flora and fauna species) components that it contains. To avoid double counting these resources, the resource "habitat" is not shown in Table I because it is assumed that it will be recovered when the resource is repaired.

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Table 11: Agent- resource groups for the application of IDM. (**Source:** IDM user guide (MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA YEL RETODEMOGRÁFICO, n.d.) (Annex III of the Royal Decree))

<table>
<tr><td colspan="3" rowspan="4"></td><th colspan="8">Resource</th></tr>
<tr><th colspan="3">Water</th><th rowspan="3">Continental shelf and seabed</th><th rowspan="3">Soil</th><th rowspan="3">Sea and estuary banks</th><th colspan="2">Species</th></tr>
<tr><th rowspan="2">Marine</th><th colspan="2">Continental</th><th rowspan="2">Plants</th><th rowspan="2">Animals</th></tr>
<tr><th>Surface</th><th>Underground</th></tr>
<tr><th rowspan="15">Agent causing the damage</th><th rowspan="7">Chemical</th><td>Halogenated VOC</td><td rowspan="5">Group 1</td><td rowspan="7">Group 2</td><td rowspan="7">Group 5</td><td></td><td rowspan="7">Group 9</td><td rowspan="5">Group 10</td><td rowspan="7">Group 11</td><td rowspan="7">Group 16</td></tr>
<tr><td>Non-halogenated VOC</td><td></td></tr>
<tr><td>Halogenated SVOC</td><td></td></tr>
<tr><td>Non-halogenated SVOC</td><td></td></tr>
<tr><td>Fuels and NVOC</td><td rowspan="3">Group 7</td></tr>
<tr><td>Inorganic substances</td><td></td><td></td></tr>
<tr><td>Explosives</td><td></td><td></td></tr>
<tr><th rowspan="3">Physical</th><td>Extraction/Disappearance</td><td></td><td>Group 3</td><td>Group 6</td><td></td><td rowspan="2">Group 3</td><td></td><td>Group 12</td><td>Group 17</td></tr>
<tr><td>Inert waste discharge</td><td></td><td></td><td></td><td>Group 8</td><td></td><td></td><td></td></tr>
<tr><td>Temperature</td><td></td><td>Group 4</td><td></td><td></td><td>Group 4</td><td></td><td>Group 13</td><td>Group 18</td></tr>
<tr><th colspan="2">Fire</th><td></td><td></td><td></td><td></td><td></td><td></td><td>Group 14</td><td>Group 19</td></tr>
<tr><th rowspan="4">Biological</th><td>GMO</td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="2">Group 15</td><td rowspan="3">Group 20</td></tr>
<tr><td>Invasive alien species</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Virus and bacteria</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Fungi and insects</td><td></td><td></td><td></td><td></td><td></td><td></td><td>Group 15</td><td></td></tr>
</table>

The variables included in the IDM were chosen based on two criteria: their likely importance in describing the number of environmental impacts and their convenience of use for model users.

The IDM estimation requires the following input data:

- Prior identification of the relevant accident scenarios.

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- Selection of the damage causing types of agents.
- Selection of the potentially affected natural resources.
- Determination of the location of the damaged caused in each accident scenario.
- Introduction of the values of the specific qualitative and quantitative variables for each agent-resource combination.

$$IDM = \sum_{i=1}^{n}[(Ecf + A * Ecu * (B * a * Ec) + p * {M_{acc}}^{q} + C * Ecr) * (1 + Ecc)] + (\mathrm{b} * Eca)$$

The variables of the IDM equation have the following meanings, as determined by the Royal Decree:

IDM, is the Spanish acronym of the Environmental Damage Index, which is calculated according to the specifications established in the environmental liability regulation (Annex III of Royal Decree 183/2015 of 13 March which modifies the regulation which partially develops Act 26/2007 of 23 October on Environment Liability, approved by Royal Decree 2090/2008 of 22 December).

Ecf, is the estimator of the remediation project's fixed cost for the combination i of the agent causing the damage and the resources potentially impacted.

A, is the multiplier of the remediation project's unit cost estimator (Ecu), which is calculated by multiplying the values of the unit cost modifiers (M_{Aj}) for each agent-resource combination *i.* Its formula is as follows:

$$A = \prod_{j=1}^{l} M_{A_j}$$

Ecu, is the estimator of the remediation project's unit cost for the agent resource combination *i.*

B, is the amount estimator's multiplier, which is calculated by multiplying the values of the amount estimator's modifiers (M_{Bj}) for each agent resource combination i. Its formula is as follows:

$$B = \prod_{j=1}^{m} M_{B_j}$$

a, represents the amount of agents involved in the damage.

Ec, reflects the relationship between the units of impacted resources and the units of agents participating in the harm.

p, is a constant that only takes a value other than zero for damage to the continental shelf or seabed.

Macc, is the amount of agents involved to the accident. In the case of damage to the continental shelf or seabed, this is measured in tonnes. This parameter is set to 0 in all other agent-resource combinations.

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q, is a constant that takes the value 1 in all agent-resource combinations, except those that entail harm to the continental shelf or seabed, in which case it takes a specific value.

C, is the multiplier of the remediation project's revision and control cost estimator (Ecr), being equal to the value of the modifier that affects the estimator of the cost of the revision and control (M_{Cj}) for each agent-resource combination. Its formula is as follows:

$$C = M_{C_j}$$

Ecr, is the estimator of the remediation project's revision and control costs for the agent-resource combination i.

For example, some of the review and control activities include: sampling and laboratory analysis of water and soil, monitoring of fauna, monitoring of afforestation, etc.

Ecc, is the estimator of the remediation project consultancy cost, expressed as a percentage of the previous estimators, for the agent-resource combination *i.*

i, refers to each of the agent-resource combinations *i* considered.

n, is the total number of agent-resource combinations that the agent considers relevant for the scenario under consideration.

b, denotes the distance *(Dist)* between the site to be recovered and the nearest accessible roadway in meters.

> In the case of scenarios that are predicted to affect multiple locations, the value of the parameter will be the sum of the distance from each site to the nearest roadway.
>
> In the case of scenarios that include harm exclusively to sea water, the continental shelf or seabed, β will be set to 0.

Eca, is the estimation of the cost of accessing the site that could be harmed by environmental damage, and its value is 6.14.

The IDM estimation module displays a screen for each agent-resource group in which the value of the coefficients indicated in the Royal Decree for this agent-resource combination are gathered and a list of the modifiers that apply to the combination is offered, once the agents causing the damage and the potentially affected resources have been identified for the accidental situation being investigated.

The user should fill out the box that corresponds to the mass (in tonnes), volume (in cubic meters), or surface (in hectares) involved in the accident and select a category for each of the modifiers.

Specifically, the coefficients provided on this screen are:

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- Estimator of the remediation project fixed cost (Ecf).
- Estimator of the remediation project unit cost (Ecu).
- Accounting relationship between affected resource and agent units involved in damage (Ec).
- Estimator of the remediation project revision and control cost (Ecr).
- Estimator of the remediation project consultancy cost (Ecc).

The IDM Tool provides the values of the estimators based on the agent-resource group of the agent resource combination.

Following the estimation of all the costs that are dependent on the agent-resource group for each of the combinations that apply to the investigated scenario, the **cost of accessing the damaged site** may be calculated. This cost is independent of the agent-resource pairing.

The IDM estimation module provides the value of the projected access cost per metre of the road that will need to be created for this purpose. The distance between the damaged site and the nearest roadway (parameter β) should be provided by the user.

Once the values of all the variables of every agent-resource combination have been given, the module returns the IDM value for the accident scenario under consideration as a result.

Subsequently, the process is being reiterated and the IDM value of the other accident scenarios is calculated.

The four types of modifiers (A, B, and C) specified in the IDM equation are shown in Figure 4 below.

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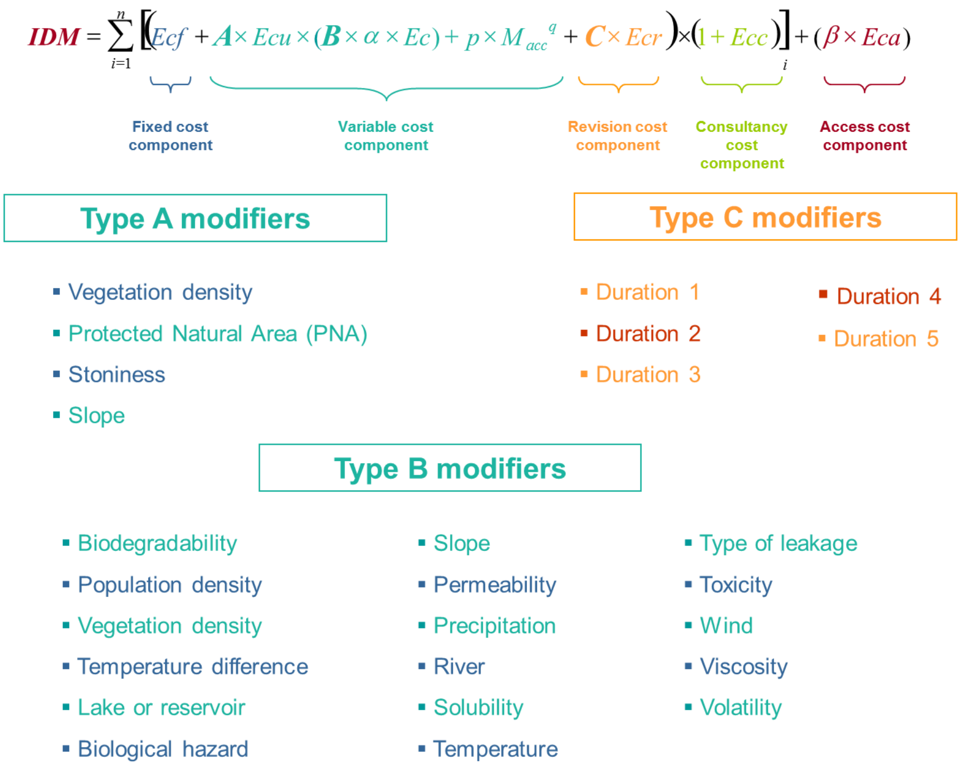

Figure 4: IDM Estimation: list of type A, B and C modifiers. (Source: IDM user guide (MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA YEL RETODEMOGRÁFICO, n.d.))

3.3.1.3 MORA Tool (Environmental Liability Supply Model)

The Environmental Liability Supply Model is a voluntary tool that provides the monetization of the primary, compensatory, and complementary remediation measures associated with a risk scenario that are necessary to restore the damaged natural resources and the services they offer to their original condition[11].

The aim of the MORA Tool is to determine the financial security as the monetary value of the environmental damage caused by the reference scenario selected through the IDM Tool. However, MORA may be used to estimate the recovery costs of any risk scenario.

For the calculation of the remediation costs associated to the environmental damage under investigation, MORA uses a mechanism to select the best available techniques based on the provisions of Law 26/2007. Three elements influence the selection of the remedial approaches:

[11] To access the tool visit: https://servicio.mapama.gob.es/mora/asistente/inicioOperador.action (Ministry for the Ecological Transition and the Demographic Challenge, Version 1.24.0)

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1. the agent that caused the damage,
2. the resource affected,
3. and the characteristics of the place where the harm occurs.

The appropriate remediation techniques were identified through a bibliographical review at both the national and international level, as well as consultations with public agencies with expertise in environmental damage remediation (Technical Commission for the Prevention and Remediation of Environmental Damage, n.d., p. 26)

A database of remediation techniques has been developed for the MORA model, where the techniques have been assigned to each combination of agent-resource (Technical Commission for the Prevention and Remediation of Environmental Damage, n.d., p. 24)

The recommendation of the remediation measures is based on the nature of the environmental damage occurred, and the decision is made through event trees that constitute the mechanism of MORA. A set of parameters is used to obtain information regarding the nature of environmental damage.

The parameters are organized into four blocks that are related to the following aspects:

1. Location of damage
2. Agent causing the damage
3. Damaged Resources and quantification of damage
4. Reversibility of damage

The event trees developed for MORA begin with the location of the damage and the damaging agent, as this information determines the possibly affected natural resources. Each agent-resource combination results in a specific event tree.

<u>Location of damage</u>
The assessment of the environmental damage begins with the positioning of the location of the damage. Hence, as a first step, the coordinates must be sent to the system that provides the assessment. The user of the MORA Tool can directly enter the coordinates, or use the cartographic viewer available to obtain, select or check the coordinates of the environmental damage.

When a point is selected, the data that characterizes the damaged region is received by the program. This information is acquired using MORA's GIS (Geographic Information System) coverage.

The data that are acquired from the location include the values of the following parameters. If the user is more informed about the area of consideration, he is able to modify the obtained data (parameters 1. -8.), given that a justification is included.

a) Accessibility (user can modify)

   This parameter can only take the values YES or NO, and indicates the ability to gain access to the affected area with the mechanical equipment required to carry out the remediation. The area is considered accessible if there is already a road that leads to it, or if the construction of

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an access road is feasible. The cost of the road construction will be assigned as an additional expense that must be taken into account in order to accomplish efficient natural resource rehabilitation.

b) Distance to the nearest access road (user can modify)

If the affected area is accessible, the distance between the location of the damaged area and the nearest road is given. The unit measure of this value is meters.

c) Protected area (user can modify)

This parameter can only take the values YES or NO. With YES meaning that the area belongs to a protected space, and NO indicating the absence of special protection figures in the impacted area. The prevention of future risks and the avoidance of collateral damage is of significant importance when selecting the remediation project in sensitive natural areas.

As a result, the level of harm on a protected natural area influences both the costs and the time required for repair.

d) Permeability (user can modify)

The permeability parameter is also divided into five groupings (Very high, High, Medium, Low, Very Low). The Permeability Map of Spain is used for obtaining this value. The remediation procedures that can be used to soil and groundwater resources depend on the degree of the permeability of the land. In essence, techniques that involve the circulation of air and water flows can be used in permeable zones.

e) Slope range (user can modify)

This parameter is classified in five ranges according to the percentage of the slope (see Table12). A digital terrain model is used to acquire the slope percentages. When deciding on a remediation measure, the slope of the affected region is critical.

Table 12: Range of slopes in the model, (Source**:** MORA user guide)

Slope Range	Slope (%)
Very high	>50
High	31-50
Medium	21-30
Low	11-20
Very low	≤10

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f) Fraction of covered capacity (user can modify)

The fraction of the total capacity represents the extent to which the soil is covered by the vertical projection of the treetops and is given in percentage.

g) Planting density (user can modify)

h) Soil type, stoniness (user can modify)

The stoniness of the soil influences the cost per hectare of forest treatments, with stony soils costing more than transit type soils.

i) Infiltration risk to the groundwater

When damage occurs in a permeable zone, there is a possible danger of chemical compounds affecting the mass of groundwater.

j) Groundwater body presence

The presence of a body of groundwater influences the possibility of physical harm from extraction.

k) Land use

l) Existing tree species

The current tree species are important for determining the density of the same individuals per unit area. Similarly, the type of vegetation is critical for defining habitat restoration.

m) Animal species present

n) Woodland age

The average age of the tree mass is a basic metric for determining how much time must pass before the remediation achieves its goal of re-establishing the basic condition.

<u>Agent causing the damage</u>

Following the damage location, the user must select the damaging agent(s)[12].

- Physical

  Physical agents are associated with the excess or lack of a substance that does not have an associated toxicity level, such as water, inert waste, soil, temperature, or magnetic fields.

  Extraction/Disappearance

  Inert waste discharge

  Temperature

[12] More detail is given in MORA methodology document (Technical Commission for the Prevention and Remediation of Environmental Damage, n.d., pp. 16-20)

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- Fire

- Biological

  GMO
  Invasive alien species
  Virus and bacteria
  Fungi and insects

- Chemical
  Chemical agents are associated with the release of a substance at a concentration that exceeds the substance's toxicity threshold in specific receptor. For the purposes of the MORA Tool, the Federal Remediation Technologies Roundtable (FRTR)[13] has been used as a reference for the characterization and identification of the chemical agents.

  Biodegradable chemicals
    - Fuels and biodegradable NVOCs
    - Biodegradable halogenated VOCs
    - Non-halogenated biodegradable VOCs
    - Biodegradable halogenated SVOCs
    - Non-halogenated biodegradable SVOCs
    - Biodegradable explosives
    - Biodegradable inorganic substances

  Non-biodegradable chemicals
    - Fuels and non-biodegradable NVOCs
    - Non-biodegradable halogenated VOCs
    - Non-biodegradable non-halogenated VOCs
    - Non-biodegradable halogenated SVOCs
    - Non-biodegradable non-halogenated SVOCs
    - Non-biodegradable explosives
    - Non-biodegradable inorganic substances

In order to successfully classify the specific agent that causes the damage into one of the given categories by MORA, a matrix is given in the User's Guide, which acts as an aid to the selection of the damaging agent in each unique case (Technical Commission for the Prevention and Remediation of Environmental Damage, n.d., p. 21)

[13] www.frtr.gov

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Table 13: Selection matrix of the agent causing the damage *(Source: MORA user guide)*

<table>
<tr><td rowspan="16">Agent causing the damage</td><td rowspan="8">The agent has an associated toxicity threshold (chemical agents</td><td rowspan="7">The agent is not an explosive substance</td><td rowspan="6">Organic agent</td><td rowspan="4">BP <325 ºC</td><td rowspan="2">BP[14] < 100 ºC</td><td>The agent contains halogenated elements</td><td>Damage by halogenated VOC</td></tr>
<tr><td>The agent does not contain halogenated elements</td><td>Damage by non-halogenated VOC</td></tr>
<tr><td rowspan="2">BP < 100 ºC</td><td>The agent contains halogenated elements</td><td>Damage by halogenated SVOC</td></tr>
<tr><td>The agent does not contain halogenated elements</td><td>Damage by non-halogenated SVOC</td></tr>
<tr><td rowspan="2">BP >325 ºC</td><td>Fuel</td><td colspan="2">Damage by fuel</td></tr>
<tr><td>Other substances</td><td colspan="2">Damage by non-volatile organic compounds (NVOCs) [CONV]</td></tr>
<tr><td>Inorganic agent</td><td colspan="4">Damage by inorganic substances</td></tr>
<tr><td>The agent is an explosive substance</td><td colspan="5">Damage by explosive substances</td></tr>
<tr><td rowspan="8">The agent does not have an associated toxicity threshold</td><td rowspan="3">Physical Agents</td><td colspan="5">Damage by extraction or disappearance of a natural resource</td></tr>
<tr><td colspan="5">Damage by inert waste discharge</td></tr>
<tr><td colspan="5">Damage by temperature increase</td></tr>
<tr><td>Fire</td><td colspan="5">Damage by fire</td></tr>
<tr><td rowspan="4">Biological Agents</td><td colspan="5">Damage by genetically modified organisms</td></tr>
<tr><td colspan="5">Damage by exotic invasive species</td></tr>
<tr><td colspan="5">Damage by virus and bacteria</td></tr>
<tr><td colspan="5">Damage by fungi and insects</td></tr>
</table>

The MORA Tool allows numerous agents to be selected at once, allowing several damaged resources to be assigned to each of the selected agents. However, each agent-resource pair will be considered independently.

[14] Boiling point

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Table 14: Basic matrix of damages considered within MORA. Source: (Technical Commission for the Prevention and Remediation of Environmental Damage, n.d., p. 23)

			Resource										
			Water								Species		
				Inland								Animals	
			Marine	Surface	Groundwater	Bed surface inland waters	Seabed	Soil	Shore of sea and estuaries	Habitat (vegetal species not threatened)	Plants threatened	Threatened	Not threatened
Damaging agent	Chemical	VOC halogenated	x	x	x			x	x	x	x	x	x
		VOC non halogenated	x	x	x			x	x	x	x	x	x
		SVOC halogenated	x	x	x			x	x	x	x	x	x
		SVOC non halogenated	x	x	x			x	x	x	x	x	x
		Fuels and y NVOC	x	x	x	x	x	x	x	x	x	x	x
		Inorganic substances		x	x	x	x	x		x	x	x	x
		Explosives		x	x	x	x	x		x	x	x	x
	Physical	Extraction/Dissapearance		x	x			x		x	x	x	x
		Inert waste				x	x	x					
		Temperature		x				x		x	x	x	x
	Fire									x	x	x	x
	Biological	GMO								x	x	x	x
		Exotic species								x	x	x	x
		Virus and bacteria										x	x
		Fungi and insects								x	x		

Damaged Resources and quantification of damage

After the selection of the damaging agents, the resources that may be harmed by the damage should be determined.

By default, the application pre-selects the resources that may be affected, based on the information obtained from the digital coverages of Spain developed by the Ministry of Agriculture and Fishing, Food and Environment (MAPAMA).

In this phase, the user may select additional resources, deselect the given ones, or both. The tool gives the user the possibility to add resources that are not shown on the page.

The **natural resources** considered by Law 26/2007 are surface water, underground water, soil, wildlife species, habitats, and shore of estuaries and sea. MORA also addresses the bed of surface waters due to the uniqueness of the procedures for their rehabilitation.

If an incident affects many resources, the model suggests taking remedial action for each of them.

Following the determination of the affected resources, the application displays the first of the agent-resource pairs, requesting some of the information that the user must submit for the monetization of the damage to begin.

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Reversibility of damage

The user should provide the amount of the resource that is affected by the damage, and inform the system whether the damage is reversible or irreversible.

The reversibility of the damage depends on:

- the damaging agent and the extend of the damage,
- the environmental features affected,
- the possibility to recover the damage within a reasonable time frame,
- and whether the remediation cost is disproportionate to the benefits.

If the damage is considered irreversible, the remediation will be carried out using only complimentary measures.

Depending on the damage, the application can request additional information, such as the volume of the discharge and the type of impact (total or partial) in cases of spillage where there is a direct relationship between the amount of agent discharged and the amount of resource damaged (Technical Commission for the Prevention and Remediation of Environmental Damage, n.d., p. 31) .

Once the quantity of the damaged resource and its reversibility state is determined, the application **provides the proposed remediation techniques**. The possibility is given to the user to accept the recommended technique or to select a different one from the drop-down list of the remediation techniques available. The user may also incorporate new remediation techniques by providing the corresponding information and justifying the choice.

Remediation measures

The remediation measures in MORA are categorized in primary, compensatory and complementary techniques. The primary and compensatory measures pertain to the reversible damages, while the irreversible damages are treated with complementary measures. MORA distinguishes reversible from irreversible damages, which means that in the case of damages that are partly reversible and partly irreversible, their parts should be considered separately.

Primary remediation

Primary remediation measures should be carried out in the area where the damage occurred and aim to return damaged natural resources to their baseline condition by recovering the same amount of resource as was lost. The primary remediation takes place when there is a technique capable of restoring the damaged resource. The restorative approaches are determined by the damaging agent and the characteristics of the resource damaged. Natural resource recovery should also be considered as a feasible remediation technique.

The following equation is used to calculate the cost of primary remediation:

$$Coste_R = Coste_f + (Coste_u \times Q) + (p \times Q^q)$$

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Where:

$Cost_R$, is the recovery cost of the resource.

$Cost_f$, is the fixed cost.

$Cost_u$, is the variable cost.

Q, is the amount of resource damaged or the amount of agent discharged. It is dependent on the agent-resource pair that is being monetized and the remediation approach to be applied.

p, is a multiply coefficient that varies based on the method of repair.

q, is an exponential coefficient that varies based on the method of repair.

After the calculation of the cost of the primary remediation, the Value Added Tax (VAT) and the percentage of contingency safety is added. The percentage of safety by contingency role is to account for the occurrence of contingencies and unforeseen events during project implementation. Its value depends on the recovery efficiency (limited=40%, demonstrated=20%) of a technique on specific agent-resource pairs.
These percentages can be modified by the user if he is better informed, and any modification must be justified.

Compensatory remediation
Compensatory remediation measures are designed to compensate for temporary losses of natural resources or natural resources services while primary or complementary remediation is carried out. Compensatory remediation entails the creation of additional units of the damaged resource, and it can take place at the location of the damage or at a different geographically related location.

Complimentary remediation
Complimentary remediation is used for the irreversible damages. The restoration activity will obtain the necessary units (more than the damage) of the same type and quality of the affected resource, but in a different location that should be geographically close to the impacted area.

Compensatory and complementary remediation measures are assumed to have the same fixed and variable costs as the primary measures that could apply, since, the repair is appraised before the harm happens, and it is impossible to determine the precise site where the remediation actions will be carried out. The only data that varies is the amount to be repaired, which is the one calculated through Resource Equivalency Analysis (REA) as physical units of compensatory and complementary remediation respectively.
The REA is a methodology for determining the additional quantity of resources or services required to compensate for the temporary (compensatory measures) or permanent (complementary) loss.
The idea behind this methodology is that the society affected by a certain damage is compensated if a remediation project is undertaken that provides the same amount of natural resources as those lost. The main contribution of this methodology is the measuring of these amounts in biophysical units. The two ways of this are resource-to-resource and service-to-service approach.

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Description of the economic model

According to Law 26/2007, priority should be given to the resource-to resource or service-to-service approach. This regulation is established and expanded upon in Annex II of Royal Decree 2090/2008, which outlines the hierarchy of equivalency approaches shown on the table below.

Table 15: Hierarchy of the equivalency approaches, (Source: (Technical Commission for the Prevention and Remediation of Environmental Damage, n.d., p. 3))

Preference	Equivalence approaches
1º	Resource-to-resource
1º	Service-to-service
2º	Value to-value
3º	Value-to-cost

In order to select the appropriate equivalence approach, one should consider the type and the quality of the natural resources or services of the natural resources that have been lost, as well as of those that can be achieved as a result of the remediation. The possibility to quantify the loss and gain of the natural resources or the services of the natural resources using the same unit of measurement should also be taken into account. Lastly, the place where the remediation will be undertaken and the cost of the remediation are very important factors as well.

The **resource-to-resource approach** calculates the cost of the damage based on the remedial project that provides the same type, quality and quantity of natural resources. The unit of measure is the resource damaged like tons, cubic meters, hectares, etc.

It is anticipated that the damaged resources will be totally restored to their baseline condition.

The examples that are used for clarification in the MORA User's guide are the following:

If 1 ton of soil is damaged, the recovery project should recover 1 ton of soil of the same type and quality.

If 1 ha of 20-year-old wild pine tree is damaged, the remediation project should recover 1 ha of 20-year-old wild pine tree.

The **service-to-service approach** calculates the cost of the damage based on the remedial project that provides the same type and quantity of services. Their quality should be the same or analogous.

The amount of damaged resource and the type of resource generated by the remediation can be different in this approach.

It is critical for this strategy to understand all of the services that the damaged resources used to provide, as well as the services that the resources obtained through the repair project will provide. Once the type and quality of the resource to be generated have been determined, the value is based on the costs of providing such resource, using the associated supply curve.

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Because it is not necessary to obtain the same type and quality of damaged resources, the cost of the remedial action to restore the natural resource may differ from the cost of delivering new services.

The example used for clarification in the MORA User's guide is the following:

If there is damage to 10 tons of soil that fixes 1 ton of CO_2 per year, we can obtain 1 ha of forest that fixes 1 ton of CO2 per year through a remediation project.

The **value-to-value approach** is a monetary evaluation based on the assumption that the social value of the damaged natural resources and their services equals the social value of the environmental benefits of other resources or services that could be provided by the remediation project.

For the societal value of the above-mentioned resources to be determined, this approach is based on the demand curve for environmental goods and services. Traditional economic models can be used to evaluate the social worth of natural assets throughout the environmental evaluation process. Using this approach, the goal is to generate resources that are equally valued by society in relation to the original damaged resources. Hence, the unit of reference is monetary.

According to Royal Decree 2080/2009, this strategy is an alternative method that should be applied when the resource-to-resource or service-to-service approaches cannot be applied for the situation.

The **value-to-cost approach** is a monetary evaluation based on the assumption that the social value of the environmental damage equals the cost of the remediation project.

This approach is used when it is not possible to evaluate the social worth of the natural resources or the services of the resources that could be generated as result of the remediation project, or if such an assessment would take an unacceptable timeframe or cost to be completed.

Budget road construction

If necessary, the building cost of an access road to the affected region should be determined as a final stage of the damage assessment using the MORA program. The equation used is the following:

$$Coste_{CC} = Coste_{u} \times Dist$$

Where:

$Cost_{CC}$, is the cost of road contract execution (€).

$Cost_{u}$, is the unit cost in Euros of construction of each meter of road in execution budget per contract (€/m).

Dist, in the distance in meters from the damaged place to the nearest access road (m).

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After calculating the cost of contract execution for the road, the Value Added Tax (VAT) and the percentage of contingency security must be added to the budget. At the end, consulting costs for the road construction are added.

3.3.2 Methodology of Ireland

The approach of Ireland to assessing and monetizing environmental liabilities is presented in the "Guidance on assessing and costing environmental liabilities", published by the Environmental Protection Agency (EPA) in 2014. The Environmental Protection Agency is the competent authority for the implementation of Environmental Liability Directive (2004/35/EC) and the corresponding Irish law in Ireland.

EPA requires environmental liability risk assessments and plans for the closure and restoration/aftercare of the operations that are compliant with the EPA requirements. These requirements are set in the guidance ((EPA), 2014, pp. 6-7). This guidance is intended for operations covered by various authorization regimes of EPA, such as the Industrial Emissions Directive (IED), the Integrated Pollution Prevention and Control (IPPC), Waste and Wastewater Discharge (WWD), and Dumping at Sea (DaS).

The guidance presents the methodologies for assessing and costing of the environmental liabilities associated with incidents, as well as with the closure and the restoration or aftercare of a facility.

3.3.2.1 Closure and restoration/aftercare

The aim of the closure and restoration/aftercare plan is to guarantee that all essential precautions are taken to avoid environmental damage and in the event that damage has occurred, to return the site to baseline condition.

When operators are authorized to provide a benchmark upon closure, a baseline report must be created. The requirements should be met in order to complete the activity's closure and restoration/aftercare phase.

Closure and restoration/ aftercare plans are prepared by the operator with the help of external expertise so that they can meet the required standards. In the case of extractive waste facilities subject to Article 14 of the Extractive Waste Directive, the plans should be prepared by independent and suitably qualified third parties.

The process of closure and restoration/aftercare includes three steps. First, the closure needs to be scoped, since the standards for closure and restoration/aftercare differ depending on the site. Depending on the situation, the restoration/aftercare may not be required after closure. Following the scoping, a plan for the closure should be made, and then, if needed a plan for the restoration or aftercare should be prepared.

With closure plan, the short-term measures required to close the business (including decommissioning and residuals management) are meant.

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With restoration/aftercare plan, the long-term measures required in case environmental liabilities continue after closure are meant. Such environmental liabilities could be, for example, associated with soil and groundwater pollution, landfills, extractive waste facilities or mines and quarries.

An authorized site may accommodate various activities, and it may contain areas that require merely a closure plan and others that require an additional closure/aftercare plan. Therefore, it could be beneficial to divide the site into clearly defined zones when developing the closure and restoration plans.

Closure plan

The closure plan should include the following as a minimum:

- activity name and address
- name of the operator
- licence/permit number
- name and address of person/organisation who prepared the plan
- classes of activity licensed/permitted and carried out
- risk category, e.g. RBME or DREAM
- scope: closure plan only or restoration/aftercare plan also
- overall closure costs
- details of any previous closure plans
- financial provision mechanism
- review period for the closure and restoration/aftercare plans

The closure plan should include an Introduction, followed by a Site evaluation, the Programmes of the closure tasks, the Criteria for a successful closure, the Validation of the closure plan, the Costing and the Review and update on the plan. The contents of each section are given in the following Table (Table 16).

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Table 16: Contents of a closure plan, (Source: ((EPA), 2014, p. 11))

Closure Plan Section	Section Contents
Closure plan summary	Summary details
1. Introduction	Site description Activities Licence/permit details Closure scenarios covered in the plan Whether restoration/aftercare plan is also required
2. Site evaluation	Operator performance Environmental pathways and sensitivity Site processes and activities Inventory of buildings, plant and equipment Inventory of raw materials, products and wastes Maximum storage capacity for raw materials, products and wastes
3. Closure tasks and programmes	Plant and equipment decontamination requirements Plant and equipment decommissioning requirements Demolition (if necessary) Waste facility closure (e.g. landfill and extractive waste facilities) Raw materials, products and waste disposal and/or recovery requirements Contaminated land treatment, removal and/or disposal Programme (Gantt chart or similar) and timeframes for delivery
4. Criteria for successful closure	A benchmark set of criteria to evaluate the success of closure
5. Closure plan validation	Environmental monitoring Closure validation audit Closure validation audit report Closure validation certificate
6. Closure plan costing	Plant and equipment decontamination costs Plant and equipment decommissioning costs Demolition costs Waste recovery or disposal costs Environmental monitoring costs Site security costs Validation costs Management and utility costs
7. Closure plan review and update	Proposed frequency of review 1. Proposed scope of review

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For the contents of each section, a detailed report with the background information required is provided in the guide ((EPA), 2014, pp. 12-13). This information is displayed in Table A1 in Appendix 6.

Restoration/aftercare plan

As mentioned above, the main situations that necessitate a restoration/aftercare plan are soil and groundwater contamination and landform changes (landfills, extractive waste facilities, mines, quarries, soil recovering facilities).

Table 17: Contents of a restoration/aftercare plan, Source: ((EPA), 2014, p. 19)

Type of Liability	Report Contents
Soil and groundwater contamination	Site investigation and risk assessment findings Remediation tasks and programme Aftercare tasks and programme Criteria for successful remediation/aftercare Validation Costing Review and update
Landform changes (landfills, extractive waste facilities, mines, quarries, soil recovery facilities)	Restoration tasks and programme Aftercare tasks and programme Criteria for successful restoration/aftercare Validation Costing Review and update

Further details for the contents of each situation are provided in the guide ((EPA), 2014, pp. 20-26), which are summarized in the Table A2 in Appendix 6.

Cost of closure and restoration/aftercare

Due to the complexities involved and the lack of knowledge of the circumstances that will apply at the time of closure, there is inherent uncertainty in monetizing closure and restoration/aftercare. As a result, a **level of contingency** should be included in the final cost. The level of uncertainty in the costing should be reflected in the rate of contingency.

The costs of site closure and restoration/aftercare may increase and vary over time. The monetization of the restoration/aftercare associated with phased activities is known as the **"cost profile"** and it should be clearly specified in the closure and restoration/aftercare plan.

Closure and restoration/aftercare expenses are assessed according to the costs at the time of the assessment. Nevertheless, because the closure and restoration/aftercare project may last many years, the future inflation should be considered after the initial monetization is carried out.

The costs of the closure and restoration/aftercare must be reviewed and updated every year. For the update of the costings, the following formula is used as a framework:

Revised Cost = (Existing Cost × WPI) + CiCC

where:

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WPI = Appropriate Wholesale Price Index [Capital Goods, Building & Construction (i.e. Materials & Wages) Index], as published by the Central Statistics Office, for the year since last calculation/revision.

CiCC = Change in compliance costs as a result of change in site conditions, law, regulations, regulatory authority charges or other significant changes.

3.3.2.2 Incidents

The consideration of the risk of damaging incidents occurring that pose environmental liabilities is made through the Environmental liability Risk Assessment (ERLA). The ELRA process has two main goals: to identify and quantify environmental liabilities based on possible unplanned events that could occur during the operational phase, and to offer a framework for encouraging continual environmental progress by managing possible environmental hazards.

The ELRA approach is an environmental risk assessment where the risk is the product of the likelihood of occurrence of an event and its consequences (risk=probability*effect). The environmental risk assessment is followed by a costing of the most likely worst-case scenario to establish the degree of the financial provision required.

The ELRA process is based on the principles of the following Irish Standards:

- I.S. ISO 31000:2009 Risk Management – Principles and Guidelines
- I.S. EN 31010:2010 Risk Management – Risk Assessment Techniques.

The first step is the scoping to establish the nature of the environmental liabilities to be covered. Next, the risk assessment takes place, which includes the following phases: risk identification, risk analysis, risk evaluation. The third step is the risk treatment, a process of mitigating hazards, for example, by eliminating the risk or reducing the likelihood or effects. The last step is the identification, quantification and costing of the worst-case scenario to determine the necessary financial provision.

In most cases, ELRAs must be produced by independent and suitably trained experts. However, appropriate operator employees should participate actively in the ERLA process so that it gets informed by site-specific expertise.

<u>Risk identification</u>

Risk identification is the first phase of the risk assessment, and is the systematic identification of probable hazards, of the sensitivity of the receiving environment, as well as the identification of the likely pathway for the activity to negatively impact the environment.

The following table (Table 18) displays the key information that is required for the risk identification process.

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*Table 18: Key information required for the risk identification process, (*Source: ((EPA), 2014, p. 30))

Parameter	Data Requirement
Site Operation	– Size and nature of the activity – Age of the activity and previous site uses – Details of licence/permit – Overview of site infrastructure – Details on storage and handling of fuel and other materials – Details on the scale and nature of all environmental emissions – Overview of abatement plant – Overview of the nature and volumes of waste generated
Operator Performance	– Environmental Management Systems – Compliance history – Enforcement history – Incidents history
Environmental Sensitivity	– Details on the underlying geology/hydrogeology, coupled with any historic soil or groundwater monitoring or known contamination – Proximity to identified surface water bodies, their Water Framework Directive status and identification of scheduled or unscheduled discharges to these water bodies from the activity – Proximity to sensitive human receptors and potential for nuisance or health impacts to these receptors – Details on the nearest EU or National protected site, natural habitat or protected species and potential pathways for the activity to impact these habitats and species

The steps of the suggested method for carrying out the risk identification are the following:

- Identify all the processes
- List the risks associated with each process
- Identify potential causes of failure of the processes

To identify the potential risks inherent in the activity, a risk management workshop should be held with the relevant staff and external specialists as needed.

EPA Guidance provides a list of generic risks for all sectors for guidance ((EPA), 2014, p. 31). Sector specific risks are also included ((EPA), 2014, p. 32). Operators could use the lists to assist them in identifying the risks of the activity, however the list is not exhaustive and some of the risks pertinent to the activity could be missing. In the risk identification all risks pertinent to the activity must be included.

Risk analysis

The second stage of the risk assessment is the risk analysis, a process of evaluating the likelihood and effects of specified risk occurrences. In order to evaluate and rank the risks in comparison to one another, risk classification tables are necessary. The following tables are provided as examples. Operators may develop unique descriptors based on case-specific numeric information ((EPA), 2014, p. 33).

Table 19: Risk classification table for the likelihood of occurrence, (Source: ((EPA), 2014))

Rating	Likelihood	
	Category	Description
1	Very Low	Very low chance of hazard occurring
2	Low	Low chance of hazard occurring
3	Medium	Medium chance of hazard occurring
4	High	High chance of hazard occurring
5	Very High	Very high chance of hazard occurring

Table 20: Risk classification table for the consequence, (Source: ((EPA), 2014))

Rating	Consequence	
	Category	Description
1	Trivial	No impact or negligible change to the environment
2	Minor	Minor impact/localised or nuisance
3	Moderate	Moderate impact to environment
4	Major	Severe impact to environment
5	Massive	Massive impact to a large area, irreversible in medium term

Risk evaluation

The last stage of the risk assessment is the risk evaluation, where the outcomes of the risk analysis are used to rate the risks in order to prioritise them for the risk treatment program. In order to present and prioritise the risks, a risk matrix may be created. The risk matrix employs the consequence and likelihood ratings, with the level of consequence forming the x-axis and the level of likelihood forming the y-axis.

Below is an example of a risk matrix displayed (Figure 5).

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	V. High	5					
Likelihood	High	4				4	
	Medium	3					
	Low	2					
	V. Low	1					
			1	2	3	4	5
			Trivial	Minor	Moderate	Major	Massive
					Consequence		

Figure 5: Risk matrix example (Source: *((EPA), 2014, p. 35))*

Risk treatment

The risk treatment is a process to mitigate risks by removing the risk or minimising its likelihood or its consequences. A person (risk owner) should be held responsible for the implementation of the risk mitigation strategies and each risk mitigation measure should have a timetable for deployment.

Costing

The determination of the necessary degree of financial provision is based on the plausible worst-case scenario. "The plausible worst-case scenario refers to the plausible event that poses the maximum environmental liability, i.e. consequence, during the period to be covered by the financial provision." ((EPA), 2014, p. 38). This means that the plausible worst-case scenario is indicated by the risk with the highest consequence rating.

Operators must perform a comprehensive quantification and cost analysis for the plausible worst-case scenario. The types and quantity of the materials lost, the pathways involved, the nature and the extent of the impact, and lastly, the control and remediation measures required, should be included in the description of the worst-case scenario, in order to monetize its damage.

A justification must be supplied for each cost item used by the operator. This reasoning must be based on actual, current cost estimates for the activity, and the sources of the costs must be provided.

EPA anticipates that the ELRA minimum cost for EPA-authorised operations will be 1,000,000€ with higher amounts for activities with higher risks.

Figure 6 below depicts the approach used in Ireland for assessing and costing environmental liabilities.

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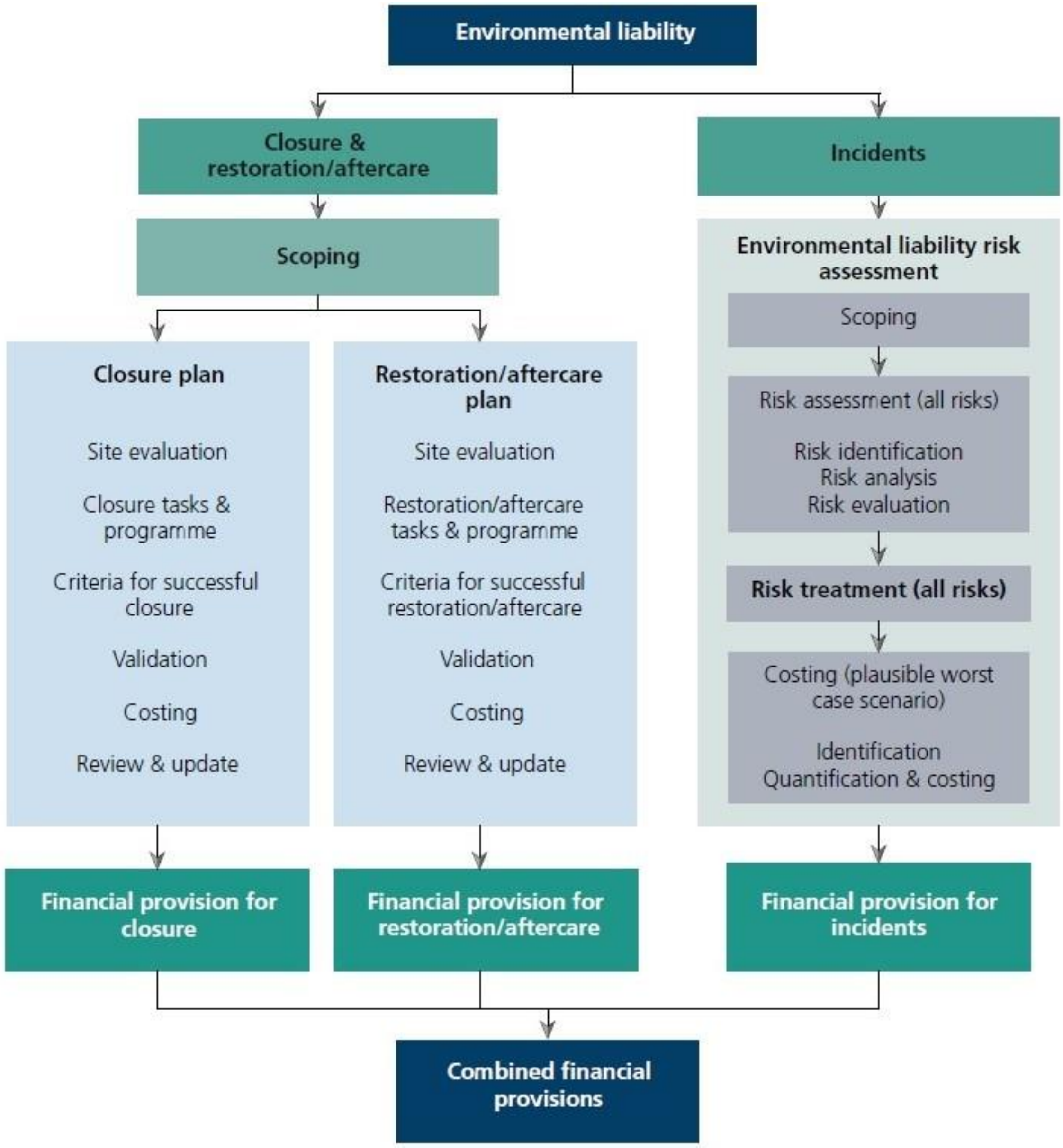

Figure 6: Assessing and costing environmental liabilities, (Source: ((EPA), 2014, p. 3))

3.3.3 The Netherlands Methodology

Information regarding the approach of the Netherlands is provided in Phase III of the Final Report about financial provision made by IMPEL (Bradley, et al., 2018). There is a chapter with the translation of the Netherlands methodology available (Bradley, et al., 2018, pp. 22-37).[15]

The methodology was created by consultants on behalf of the Dutch Ministry of Infrastructure and Water Management, in order to assist local competent authorities in determining the level of financial security required to pay the expenses of environmental damage repair. It was developed to cover Seveso and IED Annex 1 Section 4 (chemical industry) installations. Unlike Spain and Ireland methodologies, the Netherlands methodology does not yet apply to existing legislation.

In the model it is assumed that the companies under investigation have a current and valid permit, and that they are in compliance with their environmental responsibilities. The model is oriented on effects rather than risks, and the starting scenario is the possibility of company closure due to an incident. The amount of financial security depends on the environmental costs for waste disposal and remediation of contaminated soil and water, that arise for a company (with a valid permit) due to an environmental incident. Three separate calculations for waste, soil and groundwater, water and surface water constitute the amount of the financial guarantee.

There are minimal administrative burdens in the application of this methodology, since the required information is already provided as part of the company permit.

The information required is limited and is given through a combination of fixed and variable inputs. The variable inputs are the following:

- Type and environmental behaviour of substance
- Quantity of substance/discharge
- Capacity of largest containment system
- Presence of soil protection measures
- Proximity to surface water
- Environmental Damage Index (as determined by the Proteus III Tool[16], a Dutch Environmental Risk Analysis tool for water damage)

The fixed inputs comprise the costs of remediation measures

It should be noted that the model calculates only the primary remediation measures of waste, water and soil, and that additional calculations would be required to include remediation techniques such as

[15] The original is available at: https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/rapporten/2016/11/22/financiele-zekerheidstelling-voor-milieuschade-bij-majeure-risicobedrijven/Financi%C3%ABle+zekerheidstelling+voor+milieuschade+bij+majeure+risicobedrijven.pd

[16] Link to the PROTEUS Tool: https://www.helpdeskwater.nl/onderwerpen/applicatiesmodellen/applicaties-per/vergunningverlening/vergunningverlening/proteus/

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those recommended by the Spanish and Irish methodologies, like restoration of damaged habitats and species, and or compensatory and complementary measures in general.

As mentioned above, the determination of the amount of the financial guarantee is based on the remediation cost of waste, soil and water. Given is the information required for each step:

1. Waste
   - Amount and type of substance
2. Soil
   - Soil dependency dust
   - Soil permeability dust
   - Soil protection measures
   - Composition of soil
   - Surface of containment system
3. Water
   - Location with respect to surface water
   - Detrimental effect of substance to water
   - Protective measures, Soil permeability of substance
   - Surface containment system
   - Output of the PROTEUS III Tool

For each step, a flowchart that displays the method of the monetization of the damage is given (Figure 7-9):

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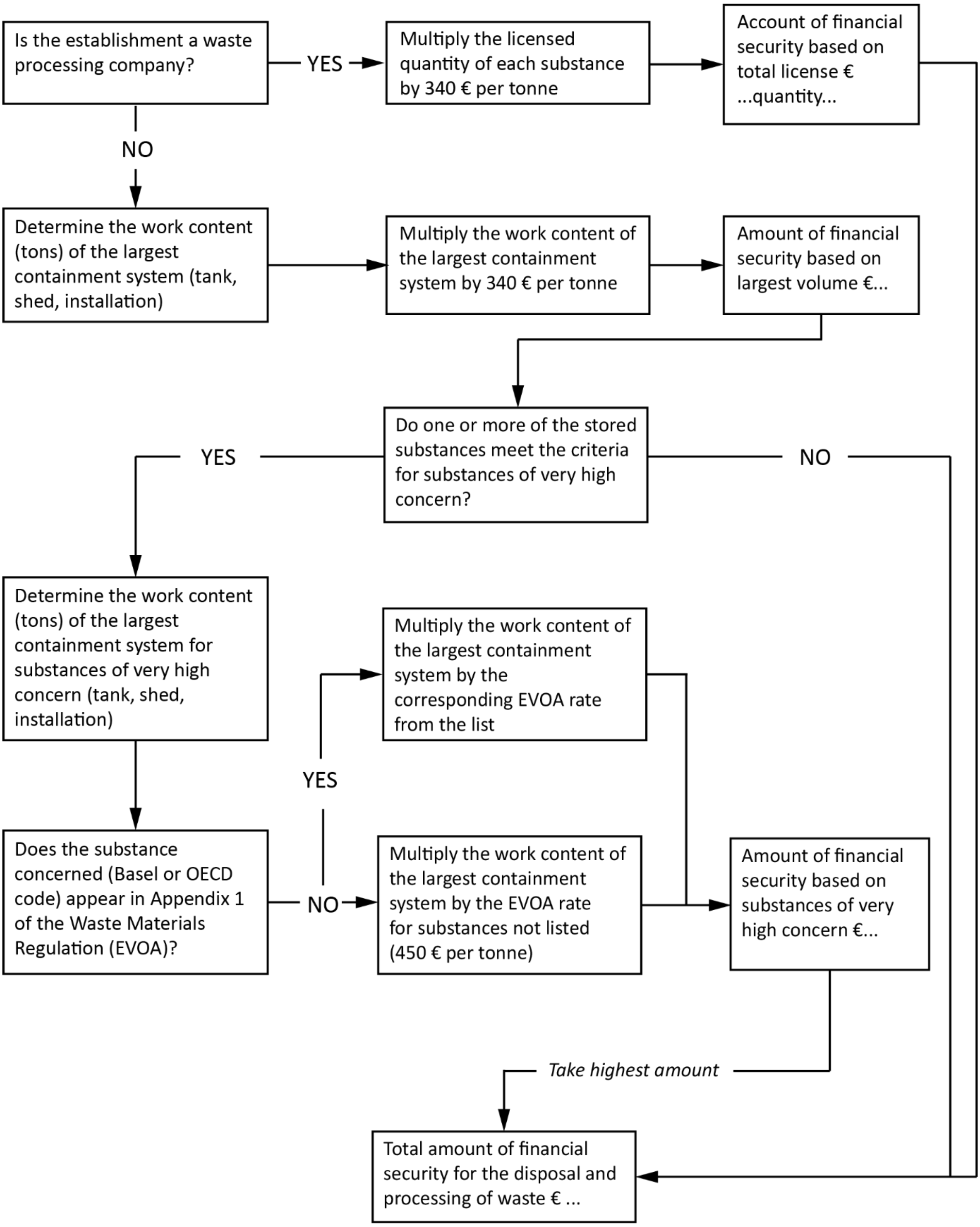

Figure 7: Step 1: Determine the costs for the removal and processing of waste (Bradley, et al., 2018, pp. 99-102):

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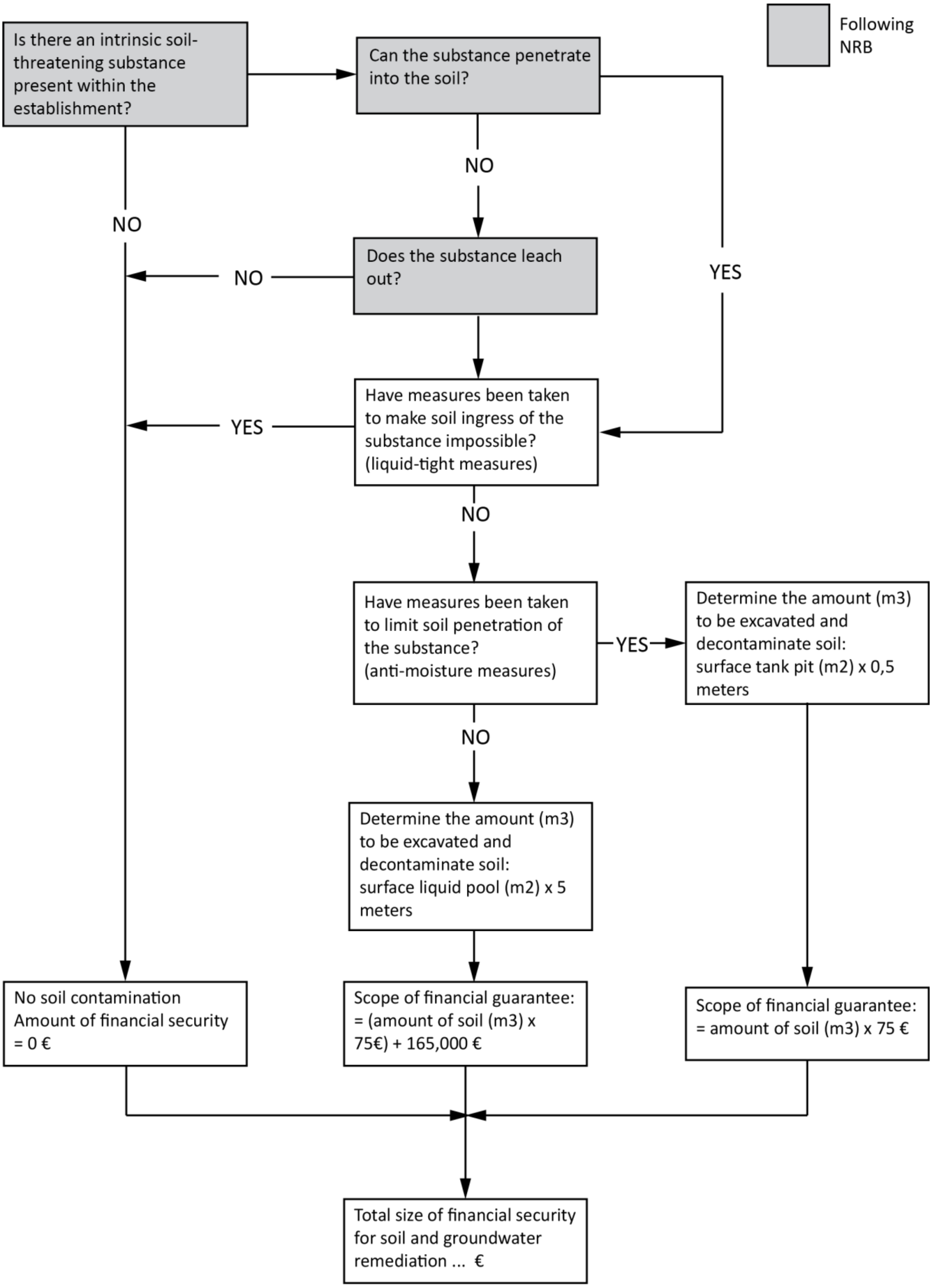

*Figure 8: Step 2: Determine the costs for **soil and groundwater** remediation* (Bradley, et al., 2018, pp. 99-102):

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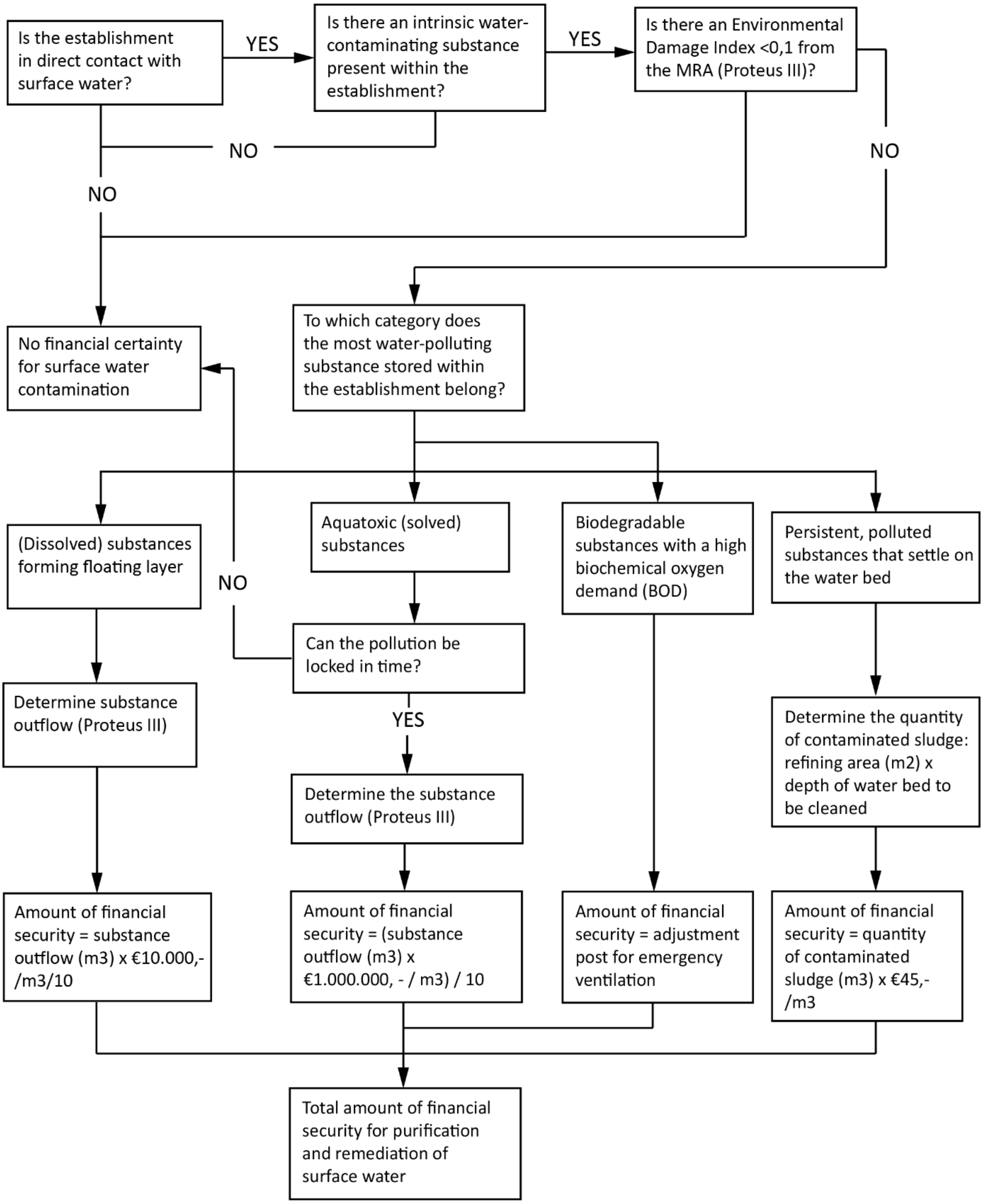

Figure 9: Step 3: Determine the costs for the purification and remediation of ***surface water*** (Bradley, et al., 2018, pp. 99-102):

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The Netherlands methodology consists of YES-NO flowcharts for the calculation of the costs for the removal and processing of waste, the remediation of soil and groundwater, and the remediation and purification of surface water. The data needed for the method to give an output, are at their majority already supplied as part of the Netherlands permission and regulation procedure. One of the data that is not already known, is the Environmental Damage Index from the Proteus Tool, a Dutch risk assessment tool for water contamination.

3.3.4 The methodology of Portugal

Within the scope of the Environmental Liability Directive, Portugal has developed an IT tool, which facilitates the communication of the environmental damages and imminent threats of damages between the operators, other interested parties and APA, the Environmental Protection Agency of Portugal[17]. According to the Portugal's spokesperson, Portugal has not established a tool for evaluating and quantifying in monetary terms the possible impact of an environmental damage that could be primarily caused by an industrial activity. To determine the amount of a financial guarantee to be established, the operator should assess the costs of damage prevention and repair procedures for which he may be held liable. The expenses must be estimated based on the risk of the activity itself, and the operator follows the methodology stated below[18]:

1. Characterization of the industrial site, the surrounding environment and the occupational activity, including all activities involving hazards to protected species and natural habitats, to water and soil, and evaluate the history of emissions, events or incidents that have occurred.
2. Identification of possible dangers such as triggering events and accident scenarios that might harm protected natural species and habitats, surface water bodies, artificial or heavily modified groundwater and marine waters, and soil in the immediate vicinity, and the services provided by these natural resources.
3. The third step is to determine how severe the consequences are, i.e., the environmental damage associated with the risk scenarios predicted, by evaluating the impacted resources and services, i.e., the extent, depth, persistence, and duration of the effect or loss of services.
4. Determination of the necessary and suitable preventative and corrective measures.
5. Estimation of the cost of the measures outlined in the previous step, based on the worst-case scenario for the resources covered.

Environmental liability was introduced into the country's legislation with the publication of Executive Order No. 147/2008 of July 29, as amended by Executive Order No. 245/2009 of September 22 and by Executive Order No. 29-A/2011 of March 1. The Environmental Liability statute defines specific obligations for the covered operators. Portugal's Environmental Protection Agency (APA), has prepared this guide due to the difficulties found during its application phase (Portugal & Quality, 2011, p. 8). The purpose of this Guide is to enlighten all interested parties on the application of environmental liability legislation, clarifying some ideas, identifying its scope, developing technical elements of its enforcement, and emphasizing the responsibilities of the relevant operators.

[17] This tool is bilingual (PT+EN) and is available at: https://ra.apambiente.pt/form ((APA), 2017).
[18] More detailed information is given in the "Guide for the Assessment of Imminent Threats and Environmental Damages"[18], published by the Environmental Protection Agency of Portugal in 2011 (Portugal & Quality, 2011).

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This Guide's explanation and suggestions are not legally binding. They are solely meant to aid the operator and the relevant authorities in their evaluation and actions in cases of environmental damage or imminent threat of environmental damage (Portugal & Quality, 2011). In the Guide, an individual approach to each of the covered environmental issues (protected species and natural habitats, water bodies and soil) is presented, in order to make these issues easier to understand.

Regarding the remediation measures that the operator must undertake, the Guide includes a list of the minimum elements that the remediation plan must include (Portugal & Quality, 2011, p. 58), refers to the operator the **resource equivalency methods** (see p.38 of this report) for determining the type and amount of remediation measures needed to fully compensate for losses caused by an occurrence, taking into account chemical, physical, biological, and sometimes social and economic environmental harm and the remediation alternatives (Portugal & Quality, 2011, p. 63). A table with the main soil and groundwater decontamination techniques is provided for assistance (Portugal & Quality, 2011, pp. 66-67).

3.3.5 French methodology for the calculation of financial provisions

The Decree of 31 May 2012 contains the methods for determining and updating the amount of financial guarantees for securing classified installations and additional guarantees in case of implementation of pollution management measures for soil and groundwater (MINISTÈRE DE L'ÉCOLOGIE, Samedi 23 juin 2012). The calculation of the financial securities reference amount for the safety of the installations is referred to Article R.516-1, and formulas for the following values are being used:

1. The amount of the financial security (M)
2. The index of the discounted cost
3. Measures for the management of hazardous products and waste (M_e)
4. Elimination of the risk of fire or explosion, by emptying and inerting of underground fuel tanks, M_I
5. Prohibitions or limitations of the access to the site
6. Monitoring the effects of the installation on the environment (M_s)
7. Site security or any other equivalent device (M_G)

A detailed description of the formulas is following (MINISTÈRE DE L'ÉCOLOGIE, Samedi 23 juin 2012):

The amount of the financial security (M)

The total amount of the financial security is equal to:

$$M = S_c \, [M_e + \alpha \, (M_i + M_c + M_s + M_g)]$$

Where,

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S_c: weighting coefficient taking into consideration the costs related to the management of the site. This coefficient is equal to 1.10.

M_e: amount, determining the first financial security amount, related to the measures for the management of hazardous products and waste, which exist on the site of the installation. This amount is determined on the basis of the following:

- Nature and maximum quantity of hazardous products held by the operator.
- Nature and estimated quantity of waste produced by the installation. The quantity retained is equal to:
  - the maximum storable amount on the site under the Prefecture
  - in the absence of the above, the maximum quantity that can be stored on the site estimated by the operator.

α: index of the discounted cost.

M_i: amount related to the neutralization of underground tanks presenting a risk of explosion or fire after draining.

M_c (cost 2012): amount related to the limitation of access to the site. This amount includes the installation of a fence around the site and signs prohibiting access at each entrance to the site and on the fence every 50 meters.

M_s (cost 2012): amount related to the monitoring of the effects of the installation on the environment. This cost covers the implementation of piezometers controls and cost analysis of groundwater near the area, as well as a diagnosis of soil pollution.

M_g (cost 2012): amount related to site security or any other equivalent device.

The index of the discounted cost

It is defined as: $\alpha = \frac{Index}{Index_0} \times \frac{(1+TVA_R)}{(1+TVA_0)}$

Where,

Index: TP01 index used to establish the reference amount of financial security set in the Prefecture.

$Index_0$: TP01 index of January 2011, is: 667.7.

TVA_R: VAT rates applicable according to the Prefecture, which determines the reference amount of the financial security.

TVA_0: VAT rate applicable in January 2011, is: 19.6%.

Measures for the management of hazardous products and waste (M_e)

M_e: amount related to the measures for the management of hazardous products and waste

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Me = Q1·(CTR·d1 + C1) + Q2·(CTR·d2 + C2) + Q3·(CTR·d3 + C3)

Hazardous products and waste can be classified into three categories:

Q_1 (in tonnes or in liters): total quantity of hazardous products and waste to be eliminated

Q_2 (in tonnes or liters): total quantity of non-hazardous waste to be eliminated

Q_3 (in tonnes or in liters): for waste treatment facilities, total quantity of inert waste to be eliminated.

C_{TR}: transportation cost of hazardous products or waste for disposal.

d_{T1}, d_{T2}, d_1, d_2, d_3: distances between the site of the classified installation and the treatment or elimination centers allowing, the management of quantities Q_{Ti}, Q_1, Q_2 and Q_3, respectively.

C_1: cost of operations until the elimination of hazardous products or waste

C_2: cost of operations until the elimination of non-hazardous waste.

C_3: cost of operations until the elimination of inert waste.

Unit costs (TTC): the costs C_1, C_2, C_3, C_{TR} are determined by the Prefect after the proposal of the operator

In case of flat-rate quotes from one or more enterprises including the costs of management until their disposal, in this case the operator can suggest to the Prefect to use these flat-rate quotes instead of the M_e calculation formula.

For hazardous products and waste that can be sold or removed from the site free of charge, taking into account the history of their management, their characteristics and their storage conditions and monitoring, the unit cost can be calculated as equal to 0.

Elimination of the risk of fire or explosion, by emptying and inerting of underground fuel tanks, M_I

$$M_I = \sum_{number\ of\ tanks} C_N + P_B * V$$

M_I: amount related to the neutralization of underground tanks

C_N: fixed cost related to the preparation and cleaning of the tank. This cost is equal to € 2,200.

P_B: cost per m^3 of inert liquid fill (concrete) 130 € / m^3.

V: volume of the tank expressed in m^3.

N_C: number of tanks to be treated.

Prohibitions or limitations of the access to the site

$$M_C = P * C_c + n_P * P_p$$

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M_c: amount related to the limitation of access to the site. This amount includes the installation of a fence around the site and signs prohibiting access at each entrance to the site and on the fence every 50 meters.

P (in meters): the perimeter of the occupied area for the installation and its related equipment.

C_C: the cost of linear closing is 50 € / m.

n_P: the number of access restriction signs. It is equal to: $n_p = Number\ of\ access\ points + \frac{perimeter}{50}$

P_P: the cost of a sign is € 15.

Monitoring the effects of the installation on the environment (M_s)

$$M_s = N_p * (C_p * h + C) + C_D$$

M_s: amount related to the monitoring of the effects of the installation on the environment. This cost covers the implementation of piezometers controls and cost analysis of groundwater near the area, as well as a diagnosis of soil pollution.

N_P: number of piezometers that should be installed.

C_P: the unit cost of a piezometer, i.e. € 300 per meter

h: the depth of the piezometers

C: control and interpretation cost of the results of the water quality

C_D: diagnostic cost of the pollution for the determined soils

Site security or any other equivalent device (M_G)

$$M_G = C_G * H_G * N_G * 6$$

M_G: amount related to site security for a period of 6 months

C_G: The average hourly cost of security is 40 € (incl. VAT) / h.

H_G: The number of hours needed for security per month

N_G: Required number of guards

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3.4 Comparison of the methodologies

The methodology of Spain is quite cost effective for the operators, since they incur no costs related to the creation and maintenance of the tools. Additionally, the ability to import data using the GIS interface is especially useful and cost-effective for the operators. In terms of efficiency, the Spanish method has the advantages of a digital instrument. The reports are generated automatically by the tool and include all of the inputs as well as suitable remedial techniques and their anticipated costs. Also, in a situation with multiple risk scenarios, possible iterations could be managed more easily. Many inputs, such as the damaging agent, the damaged resource, and the remedial methods, are easily selected using drop down menus or tick boxes in the ARM-IDM-MORA Tools. Despite the fixed drop-down menus, there is flexibility in adding other inputs, with condition of clarifying the different choices. What's more, unlike the Irish methodology, the valuation is not expected to be provided by the operator, but is based on a resource equivalency analysis. Using a consistent strategy will probably result in even and comparable results between the operators.

The Netherlands methodology has the advantage that the data needed to enter into the model will mostly already be supplied as part of the Netherlands permission and regulation procedure. Therefore, operators can expect a low input cost of required information. This methodology is paper based, which means that despite its simplicity, it will probably be more time consuming than a spreadsheet would. One of the basic disadvantages of the Netherlands methodology is the fact that it is limited to primary remediation of soil, waste and waterbodies, which means that additional cost calculations would be needed if complementary and compensatory remediation measures are to be included (or remediation costs related to air pollution). Moreover, the outputs of the Netherlands approach do not have as wide applicability as the other methodologies, since it doesn't cover all ELD Annex III operators like the rest methodologies.

The methodologies of Ireland and Portugal don't have a tool for the process, and the reports need to be prepared by the operators. The guides are comprehensive and easy to follow, but the cost of obtaining the information required will probably be higher for them in comparison to the operators using the Spanish tools. Another possible drawback of these methodologies is the lack of control upon the choices of the operator, resulting to an uneven playing field, which might not work as well for the countries with mandatory financial provision (Czech Republic, Ireland, Portugal, Slovakia and Spain (Fogleman, et al., 2020, p. 124)). Furthermore, the costing of the financial provision is based for both methodologies on the worst-case scenario, possibly resulting to an overpriced financial guarantee for the majority of the incidents. It is important to note here that Portugal uses the resource equivalency analysis valuation approach like Spain.

The tables below provide an overview of the key steps and features of the mentioned methodologies for better understanding and for promoting comparisons between them.

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Table 21: Comparison of the methodologies (1/2)

	EU Member States Methodologies						
	Spain		Ireland		The Netherlands	Portugal	France
Identification of Accidents Scenarios and establishment of their Probability of occurrence	Fault tree analysis Development of the specific consequences for each Accident Scenario	ARM Tool (Module for the development of the Environmental Risk Analysis)	Key information required for the risk identification process: Site Operation Operator Performance Environmental Sensitivity	Non-exhaustive lists of risks	The rationale behind the model is based on effects rather than risks. Three components determine the amount of the financial security: – Waste – Soil – Water The surface waters calculation uses the output of a Dutch Environmental Risk Analysis tool (PROTEUS III)	Key information required: Characterization of the industrial site Identification of possible dangers	Not provided
Environmental Risk Analysis **(Risk = Probability x Effect)** Risk identification/estimation	Risk = Probability x IDM (Environmental Damage Index)		Risk = Likelihood x Consequence Likelihood 1. Very Low 2. Low 3. Medium 4. High 5. Very High Consequence 1. Trivial 2. Minor 3. Moderate 4. Major 5. Massive Risk matrix for risk evaluation	ELRA (Environmental Liability Risk Assessment)		Determination of the severity of the consequences by evaluating the impacted resources and services, i.e., the extent, depth, persistence, and duration of the effect or loss of services	Not provided

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	EU Member States Methodologies						
	Spain		Ireland		The Netherlands	Portugal	France
Scenario Selected	Select scenarios associated with less environmental IDM that group 95 % of the total risk. Final selected scenario: highest IDM	IDM Tool (Environmental Damage Index)	Worst-case scenario selected based on the consequence only. (Maximum Environmental Liability) A number of risks may need to be grouped to represent a plausible worst-case scenario.			The worst-case scenario for the resources covered is selected.	Not provided
Costing	Each agent-resource combination results in a specific event tree in which, based on the values adopted by the relevant **parameters**, both the type of measure to be applied and the remediation technique to be performed are obtained. Then the resource equivalency analysis valuation approach is used.	MORA Tool (Environmental Liability Supply Model)	Costs provided by the operator.	EPA (Environmental Protection Agency) published unit costs for assistance.	The total amount of the financial security is determined by adding up the calculated costs per Component.	The operator determines the necessary and suitable preventative and corrective measures and then estimates the costs of the measures using the resource equivalency analysis valuation approach.	The Decree of 31 May 2012 contains the methods for determining and updating the amount of financial guarantees

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Table 22: Comparison of the methodologies (2/2) (partly based on the table of Bradley, et al. (2018, p.12))

Environmental Resources considered	EU Member States Methodologies				
	Spain	Ireland	The Netherlands	Portugal	France
Soil	√	√	√	√	√
Groundwater	√	√	√	√	√
Surface water	√	√	√	√	
Habitats	√	√		√	
Species	√	√		√	
Air		√			
Environmental Liabilities	Incidents and Accidents	Incidents Closure and Restoration/Aftercare	Incidents that cause company closure (bankruptcy) Seveso companies and companies that fall under Annex I category 4 of the EU Industrial Emissions Directive (IED)	Environmental damages and Imminent threats of environmental damage	For securing classified installations in case of implementation of pollution management measures for soil and groundwater
Methodology Availability	Web-based Tool available Free	Paper-based Guidance available Free	Tool available Free	Paper-based Guidance available Free	Not provided

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3.5 The EBRD (European Bank for Reconstruction and Development) Risk Categorisation Framework

The EBRD's purpose is to achieve sustainable development through its funding arrangements. To that aim, the EBRD requires Financial Intermediaries (FIs) to implement Environmental and Social (E&S) risk management policies and processes that are consistent with EBRD requirements.

The environmental and social Performance Requirements adopted by EBRD are the following ((EBRD), 2019, p. 6):

1. Assessment and Management of Environmental and Social Risks and Impacts
2. Labour and Working Conditions
3. Resource Efficiency and Pollution, Prevention and Control
4. Health, Safety and Security
5. Land Acquisition, Restrictions on Land Use and Involuntary Resettlement
6. Biodiversity Conservation and Sustainable Management of Living Natural Resources
7. Indigenous Peoples
8. Cultural Heritage
9. Financial Intermediaries
10. Information Disclosure and Stakeholder Engagement

To facilitate the implementation of the required Environmental and Social (E&S) risk management procedures for corporate loans, SME loans and equity investments, EBRD developed the E&S Risk Management Toolkit for Financial Intermediaries[19]. The toolkit combines current EBRD resources (like the "EBRD Environmental and Social Risk Categorisation List" ((EBRD), 2014)) to assist the user in screening transactions for environmental and social risks and in assessing the efficacy and sufficiency of the client company E&S risk management systems.

If the Financial Institution does not perform appropriate environmental and social due diligence on clients, they may face financial, legal, and/or reputational problems. The institution's risk exposure will be reduced through the toolkit, since it determines whether the clients are ecologically sound and sustainable in the long run.
The actual exposure of a bank to financial, legal and reputational risks will be determined by the inherent environmental and social risk level related to particular business activities, the nature and size of the transaction, as well as the financial and managerial capacity of the client to effectively manage environmental and social issues. All these factors are taken into account in the toolkit[20].

[19] https://www.ebrd.com/who-we-are/our-values/environmental-emanual-toolkit.html

[20] A summary of the environmental and social issues and risks associated with the industry into consideration can be found here: https://www.ebrd.com/who-we-are/our-values/environmental-emanual-risk.html

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Description of the Toolkit

There are seven sections of the toolkit that should be filled out. Each section should be completed in order.

In the first section, the user fills in her/his User Details:

- Name of user
- FI (Financial Intermediary) name
- Branch name (if applicable)
- Position/Role
- Email address
- Contact number

The second section is about the Environmental and Social Risk Assessment. Firstly, the user fills in the name of the costumer, the costumer ID and the date of the assessment. Afterwards, the user can select the appropriate information from the following drop-down lists:

Transaction country

- All the countries alphabetically (It should be noted that the country of transaction does not influence the generated inherent risk rating)

Transaction type

- Corporate loan
- SME loan
- Equity_active
- Equity_passive

Length of loan

- Long (>3yr)
- Medium (1-3yr)
- Short (<3yr)

Industry Category Subcategory	All the Industries, their Categories and Subcategories that can be found in the "EBRD Environmental and Social Risk Categorisation List" ((EBRD), 2014), a guide to the typical level of inherent environmental and social risk related to particular business activities.

After this information is given, the tool generates the NACE code of the company, the E&S risk rating of the sector, and the overall E&S risk, which is the product of the sector risk rating and the length of the loan.

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An E&S risk matrix that shows how the overall risk rating is generated, is also provided (Figure 10).

Length of Loan ↑			
Long (>3yr)	Medium	High	High
Medium (1-3yr)	Low	Medium	High
Short (<1yr)	Low	Medium	Medium
	Low	Medium	High

Sector Risk Score →

Figure 10: E&S Risk Matrix, (Source: ((EBRD), 2019))

In the third section of the toolkit, the Legal Compliance Check takes place. Answers of YES/NO are given to questions regarding the Regulatory Compliance and the Contaminated Land Issues.

The fourth section comprises of a questionnaire about the Commitment, the Capacity and the Track Record of the client. This section facilitates the assessment of the effectiveness and the adequacy of the E&S risk management systems of the user's clients. An evaluation of the client's commitment, capacity and track record to manage these issues takes place.

Depending on the outcome of section 2 (E&S risk rating), the user might not need to complete this questionnaire. In this circumstance, the E&S risk rating should be "Low". In the case of a "Medium" risk rating, the questionnaire should be completed as a means to decide whether an operational site visit is to be conducted. For "High" risk ratings, the operational site visit is mandatory, and does not depend on the outcome of the questionnaire.

For every question, the user selects one of the given answers that has one of these values:

- Best Practice
- Good Practice
- Satisfactory
- Deficient,

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and the questions are the following:

Commitment

1. What Environmental and Social (E&S) Policy commitments does the client have in place?
2. What is the commitment level of Senior Management to Environmental and Social (E&S) Issues?
3. How does the client engage with stakeholders on Environmental and Social (E&S) Issues?
4. What is the level of commitment to the Environmental and Social (E&S) Performance of Third Parties (e.g. a client, supplier and/or principal contractor which has an active and substantial role which is material to business operations)?

Capacity

1. How comprehensive is the client's Environmental and Social Management System (ESMS)?
2. What organisational capacity exists to manage Environmental and Social (E&S) issues?
3. Are staff appropriately trained on relevant Environmental and Social (E&S) issues?
4. How does the client manage the Environmental and Social (E&S) Capacity of Third Parties (e.g. a client, supplier and/or principal contractor which has an active and substantial role which is material to business operations)?

Track Record

1. Does the client demonstrate Good Corporate Citizenship?
2. What is the client's track record with regards to Occupational Health and Safety (OH&S)?
3. How does the client report on Environmental and Social (E&S) issues?
4. To what extent does the client manage labour relations?
5. To what extent does the client actively manage community investment activities?

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The output of the questionnaire is given in a chart (Figure 11), where the customer score is compared with the best practice score and the benchmark score (in case of corporate loan).

Figure 11: Summary Chart, (Source: ((EBRD), 2019))

The fifth section of the toolkit is a checklist of the site visit. It gives the user an idea of what to look for while the operational site visit takes place.

During the operational site visit, the user will be on the lookout for concerns about safety, the environment, health, labour, and the community. Except from the site investigation, this will also include what is being monitored and recorded by the management of the company. The user should ensure that policies and processes are in place to guarantee that risks are recognized and controlled. The facility should also get checked for measures to protect people and the environment from any remaining risk. The assessor should write comments where she/he identifies an issue.

The sixth section gives the user the opportunity to summarize the key findings from the Environmental and Social assessment of the client company. The user is expected to form her/his own opinion about the E&S Risk rating and justify her/his risk rating assessment. Then, the user can make recommendations for the credit committee and give feedback.

In the final section, the Environmental and Social Due Diligence Report is generated, where all the information from the previous section is collected and the results of the E&S risk assessment are given.

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3.6 Environmental risk assessment methodologies practiced by the insurance sector

In order to review and map the environmental risk assessment methodologies practiced by the insurance sector, open interviews/conversations with the relevant executives of the interested insurance companies were made with the contribution of the Hellenic Association of Insurance Companies (HAIC). The demand for environmental liability insurance in Greece is low, hence not many insurance companies offer a product for environmental liabilities in Greece. According to GRIFFIN, it is estimated that 7-8 insurance companies are providing environmental liability contracts in Greece. Three insurance companies accepted the invitation to be interviewed for the purposes of this sub-action, namely Interamerican and two more companies that wish to remain anonymous.

The interview/discussion was driven by the following questions, but a lot of flexibility was given to the discussion, in order to clearly understand the approach of each insurance company.

1. What procedure is followed and at what individual stages does the insurance sector analyse the environmental risk assessment?
2. a) Is your company applying a specific methodology for environmental risk assessment? b) Is the methodology implemented using absolute criteria and conditions by the evaluator or is it provided with relevant and on a case-by-case flexibility according to his/her estimates?
3. In case of a positive answer to question 1., it is appropriate to further clarify the specific technical criteria and characteristics of the applicable environmental risk assessment methodology based on the following sub-questions:
   - What risk criteria are used?
   - In addition to the above, are additional criteria considered?
   - What scoring system or methods is being used?
   - Are weighting factors used and how are they determined? Are there criteria with more weight than others, or are they all equal?
   - How does the relevant mathematical algorithm work computationally?
   - How is the environmental risk assessment result used to complete the intended classification?
4. Is a computational tool used to assess the risks?
5. Is a specific technical procedure used to estimate the cost of repairing a potential damage? If so, how is the scenario to be costed selected and how is the aforementioned cost computed?
6. Has the operational application of the methodology been evaluated? If so, what were the results obtained?
7. How is the environmental risk assessment updated?

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3.6.1 1st interviewed insurance company

This company offers products for the accidental pollution, where no special risk evaluation takes place, and for the environmental liability under the ELD (Environmental Liability Directive), where a more specialized risk assessment is made.

For the environmental liability insurance offered by this company, the type of activity shall be firstly taken into account, in relation to the risk of fire. According to the interviewed executive of the company, fire has been shown to be the largest risk the company runs in the largest range of activity. The evaluation of fire risk is done through access to internal engineering reports. In-house engineers visit the clients' facilities and make specific observations about potential sources of related risk. Recommendations are made and then the company's willingness to take the proposed measures and to what extent, is taken into consideration.

Next, the flooding risk and generally the risk posed from natural phenomena is being assessed. For the flooding and natural phenomena risk, such as tropical cyclones, tsunami, lightning, earthquake, etc.) a tool is used, which indicates the potential intensity of the phenomena. The tool is a geolocation database developed in-house. Below is a screenshot of an exemplary geological, meteorological, hydrological and climate exposure risk assessment that takes place in the Argos tool.

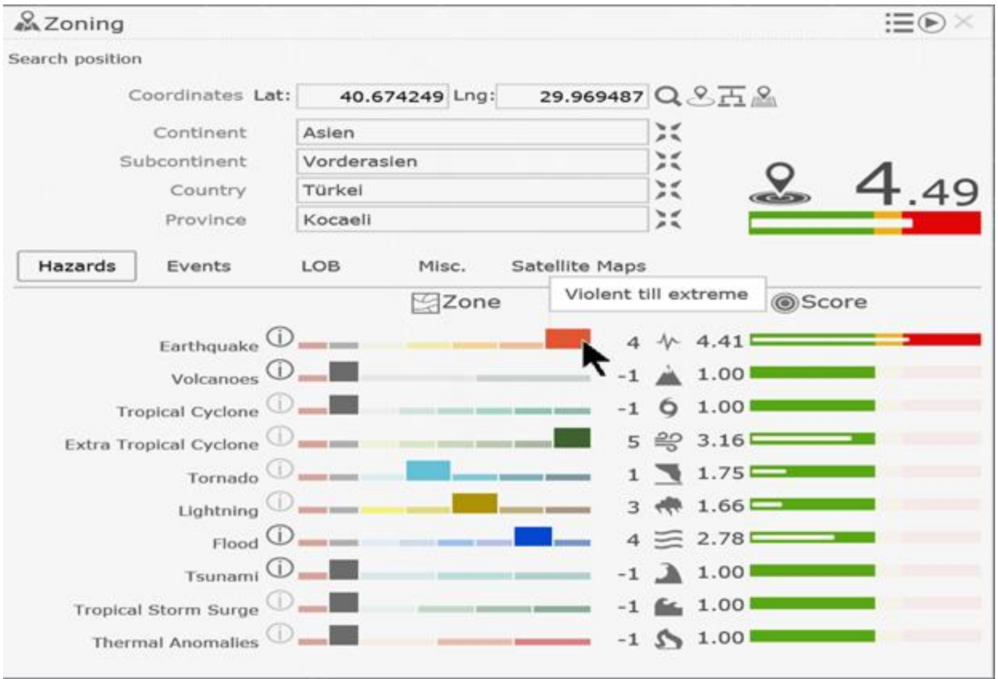

Figure 12: Screenshot of the Argos Tool, (Source: Interview with 1st insurance company)

For the risk assessment posed from natural phenomena, only the geographical location is considered, and the activity of the facility is irrelevant.

The facilities per se are considered during the environmental risk assessment, when storage of hazardous materials takes places. In this instance, the storage methods are taken into consideration. The access to detailed information about the facility/activity plays an important role in the understanding of the risk from the perspective of the insurance company. If, for example, the company

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covers the same client for other issues, such as property, for the same activity, and have visits of the engineer on a regular basis, they can have access to a range of information without the need to employ another engineer to undertake an inspection.

Another basic factor that influences the proposal of the insurance cover, is the scale of the facility/activity. The age of the establishment/activity is also taken into consideration, especially when there is an existing pollution. When this is the case, an environmental specialist takes samples from the subsoil and evaluates the damage. Based on the results the insurance company proceeds to decide whether to provide full insurance or introduce exceptions.

Questionnaire/Risk criteria

In order for the above-mentioned environmental risk analysis to take place, specific information is needed. The required information is provided through a questionnaire that is given to the client to fill in.

Firstly, the information of the intermediary is given (name, tax number and registration number). Subsequently, general information about the insured party is asked, like the name, contact details, address, tax identification number, as well as the business activity, the date of establishment, the turnover, the number of the employees and the NACE code. Contact details of the engineering head or the responsible environmental officer are also required. The questionnaire consists of six main chapters, and detailed information is asked for the following subjects:

1. Activities/Products (handling of special substances)
2. Production Sites (information about the site and the internal environmental organization)
3. Subjects of Protection (soil, groundwater, surface water, biodiversity)
4. Surroundings
5. Special Environmental risks (e.g. disposal of toxic gases or volatile substances, fire/explosion risk)
6. Risk Modules (water pollutant substances, installations liable to notification and authorization, sewage works and effects on waterbodies, subject to SEVESO-II-Directive)

After the completion of the questionnaire, the attachment of the following documents is requested:

1. Copy of Company Establishment and Operation License
2. Copy of Environmental Impact Survey
3. Decision of Approval of Environmental Conditions

Cost evaluation

There are invoicing tools for the calculation of the insurance premium which are based on the type of the activity. For example, the chemical industry has higher risk than the food industry. Mitigating and aggravating factors influence the output, which is at the discretion of the underwriter. To estimate the insurance premium, the severity of the damage is taken into consideration, and not the cost of repairing the potential damage.

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Summary

The approach followed by this company to estimate the environmental risk of a facility/activity is collecting the relevant information from the Questionnaire, the internal engineering reports, and the Argos tool, and consequently analysing the attained information using the experience of the underwriter and the in-house developed invoicing tools to propose a competing insurance price with minimal risks. The operational application of this approach has not been evaluated, since no environmental liability incidents have yet occurred. The environmental risk assessment is evaluated once a year, since the contracts are annual.

3.6.2 2nd interviewed insurance company

The evaluation process of this company is based on information given by the client, on research processed by the company, and when it is required, on on-site inspections from experts. The attained information supplies the in-house developed rating tool, which, combined with the knowledge of the underwriter, gives the desired insurance premium with minimum risk and competitive price.

The relevant information from the client is obtained through the filling in of a questionnaire, and through the delivering of all applicable official documents, such as the Approval Decision of Environmental Conditions, the environmental impact study and the waste register.

In order to acquire as much information about the prospective client as possible, the insurance company conducts its own research, which mainly consists of searches on google earth, to obtain information about the elevation profiles and the site adjacencies, searches on the Natura website to have an image of possible adjacent protected areas, and web searches for incidents in the region. There are specific areas that might have accumulation issues from a liability exposure (i.e. an event can cause a number of claims).

Questionnaire

The questionnaire is integrated in the application for an insurance cover. It starts with the general information of the applicant, such as name, legal address, a detailed description of the operations, a list of subsidiary companies requesting coverage, prior year's turnover and present year's estimate, as well as damage history and claims against the applicant. The applicant can choose coverage for the following three sections, which constitute the rest of the questionnaire:

1. Locations, where information about the following is obtained:
   Business operation description,
   Facility site plan,
   Site history,
   Surroundings,
   Duration of occupancy,
   Description of the facilities,
   Description of the storage areas,
   History of environmental surveys, audits or investigations,

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History of pollution events,
Existing soil or groundwater contamination,
Ongoing remediation projects,
Environmental lawsuits,
Types and quantities of raw materials, air permit, ways of waste management

2. Transportation Operations
   How many transfers take place, what's the arrival point, what quantities are being transported, waste description(codes), type of packaging

3. Contract Works
   Profile of operations,
   Total professional staff personnel of applicant,
   Current liability coverage information,
   Safety

Cost evaluation

This company has an in-house rating tool for the calculation of the premium price. The platform is filled by the responsible member of the company, and the cost is generated. The basic parameters that influence the cost are the information on the occupancy, the answers on the requested limits of liability, the deductible amount and the details on the operation.

The rating tool has been developed by the company regarding many countries taking into consideration the local jurisdictions. The contracts are usually annual, so the rating is re-underwritten every year.

3.6.3 3rd interviewed insurance company (Interamerican)

Interamerican has created a specialized line of products under the name "Green Line" with variations of environmental insurance cover depending on the various requirements (especially for the case of mandatory insurance) of its clients (business operators), with specialised general and special terms. Its insurance policies are in full compliance with the applicable legislation of Greece and differentiate according to the business activity that falls under the individual current legislation. For the businesses not subject to mandatory legislation, some additional covers are available, which are not provided to those types of contracts subject to environmental legislation.

According to the company executive, environmental liability is a special risk with many difficulties, and the experience around it is limited compared to the insurance experience of fire, earthquake and flood. Other challenges around environmental liability insurance are (a) the lack of insurance culture among Greek businesses, which still consider insurance as a cost that could be avoided and (b) the weakness of the structures of the state to persuade and control the businesses to comply with the legislation.

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The approach

The company requests a range of information from the perspective client to assess the risk of covering his/her business.

The first step involves the completion of the application from the prospective client. In the application, the details of the contracting and the insured party need to be filled in at first (name, tax identification number, tax office, date of birth, gender, ID, contact details). Next, the duration of the insurance, the business location, business activity and the acceptable insurance cover limit are requested.

The second step involves the completion of the questionnaire. There are two questionnaires for environmental liability insurance available· one for business premises and one for the collection-transportation of hazardous or non-hazardous waste or raw materials and products.

The questionnaire for the business premises contains three sections:

1. General operation of the business,
   where the type of the business is requested, as well as years of operation in the insured location, number of employees, construction year of the buildings and the installation year of the machinery, other insurance covers, etc.
2. Location of the business,
   where detailed information regarding the location and its surroundings is requested
3. Environmental operation of the business,
   where the classification of the business with regard to environmental impact (A1, A2, B) and with regard to the degree of nuisance (high, medium, low), the subsumption to a special regulatory regime (IPPC, REACH, SEVESO), the hazardous waste storage permit and the business operations of environmental interest are asked for. In this section, details of the following are also requested:
   - Management of raw materials in the manufacturing process
   - Produced product management
   - Hazardous waste management
   - Environmental history of the business, such as pollution incidents, complaints, fines, certification to a standard of environmental management.

The questionnaire for the collection-transportation of hazardous or non-hazardous waste or raw materials and products firstly requires information about the general operation of the business, where the type of the business is requested, together with the details of the covered company's vehicles and information on the properties of the materials transported. Subsequently, information regarding the way of packing is requested, together with the list of the hazardous or non-hazardous waste or raw materials and products. The last section regards the environmental history of the business.

Following the completion of the questionnaire(s), a full business license file is requested. The required accompanying information for business premises is summarized below:

- ΑΕΠΟ (Approval Decision of Environmental Conditions)
- Approved environmental impact study
- Electronic Waste Register No. (H.M.A.)

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- Installation and operation licence
- Fire protection certificate
- 4 representative photos of the installation

Accompanying data necessary for businesses collecting-transporting of hazardous or non-hazardous waste or raw materials and products:

- License of the company
- Approved Waste Management Plan
- Registration and authorization ADR for each insured vehicle
- 1 representative photograph of each insured vehicle
- Certificate of waste registration (Law 4042/2012)

If questions arise after the processing of the given information, the company asks for a pre-insurance inspection.

Interamerican does not use a computer tool/model to assess the environmental risk, however it follows a parametrized approach to assess environmental risk and premium calculation, on the basis of the questionnaire responses on the topics summarized above. The data acquired from the questionnaire and the relevant official documents are examined by the responsible executive of the company, and are evaluated based on his/her experience, and the collective experience of the company. The applicant's business is assessed beyond the questionnaire, if necessary. They take into consideration multiple factors, such as the economic situation of the business, the history of fines and charges, the production process and the waste storing methods. Additionally, an internet search is undertaken, where additional information regarding the region of the business location is obtained. Lastly, not only the activity, but also the operator performance of the applicant is taken into consideration during the environmental risk assessment.

<u>Cost evaluation</u>

There is no specific technical procedure used to estimate the cost of re-instating a potential damage, since there is no history of impairment for damage costing/ estimation of restoration costs, but rather an empirical approach used to estimate these costs. There is no experience in the part of the compensation process, because the company has not encountered an environmental damage event to date.

Regarding the evaluation of the operational application of the approach, three things need to be considered, according to the interviewee:

1. The level of risk exposure of the operation under evaluation, on the basis of assessed parameters (questionnaire + accompanying parameters named above).
2. The degree of compliance with the regulatory procedures required by the current insurance legislation.

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Approach update

Regarding the update of the environmental risk assessment, the risk is reassessed before the renewal of the annual contract.

During the update of the data, the company focuses on the following:

- if the production process has changed,
- whether the licensing documents have changed,
- whether there any imputations or any nuisances,
- if the production activity has increased

3.6.4 Review

The methodologies followed by the interviewed insurance companies vary, but they are similar in their core. The three companies base their environmental risk assessments on the information obtained from the respective questionnaires, from the relevant official documents, and from in-house research, whether this is done remotely through in-house developed tools, through the internet, or on-site with the contribution of specialized engineers. The optimum insurance premium is then proposed by the underwriter, after analysing the attained information with the assistance of in-house developed rating tools or following specific guidelines. None of the insurance companies explicitly calculates the cost of repairing a potential environmental damage as part of the process. All companies rely on the experience of the underwriter on assessing the environmental risk. In the case of Interamerican, the human error is minimized through the use of a strict internal audit process and obligation for guidelines in the evaluation method. All companies follow a strong auding process. The objective of the auding process is to ensure correct rating and the adherance of implementation to all guidelines. In the cases of the first two interviewed companies, the use of a rating tool allows a harmonised aproach and cosistency to the market. Further, the evaluation of a portfolio performance is derived from an actuarial study, which is based on large sample basis and not on a per account evaluation. The environmental risk assessments of all three companies are re-evaluated in every renewal of the contracts, which are usually annual. The operational applications of none of the outlined approaches have been evaluated thoroughly, since few cases of environmental liability have occurred in Greece the last years.

The environmental risk criteria that are found in the three questionnaires are correlated, and they could be summarized as follows:

1. Type of activity/ operation
2. Products (handling of special substances)
3. Location
4. Site and surroundings
5. Scale of the establishment
6. Age of the establishment
7. Storage of hazardous materials, storage methods

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8. Waste management methods
9. Management of raw materials in the manufacturing process
10. Produced product management
11. Special environment risks
12. Existing contamination
13. Environmental history of the business, such as pollution incidents, complaints, fines, certification to a standard of environmental management
14. Compliance to regulation (official documents)

It can be observed that criteria relevant to the severity of a possible incident, or impact criteria as they are defined by IMPEL in the IRAM methodology, and criteria relevant to the operator performance are used, such as compliance to regulation, attitude of the operator, and environmental management systems.

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4. Identification of key criteria for the selection of the final sample of activities to be investigated)

The following table (Table 23) is a list of all reported key criteria obtained during the research phase of this sub action, that will be used for the selection of the final sample of activities to be investigated at a later stage of the project. The selection of the activities to be investigated will take place in the sub action A.1.4, based on the final key criteria that will be selected in A.1.4. The following list will be used as a starting point for selecting and determining the final key criteria.

The key-criteria that are contained in the list were collected from various sources:

- From the research of IMPEL on the risk assessment methods for regulating the inspection frequency in IMPEL member countries ((IMPEL), 2010),
- from the IRAM Methodology Guide (Kramers, et al., 2012),
- from the EBRD Environmental and Social Risk Categorization List ((EBRD), 2014),
- from the technical summary of the LIFE-PROFILE project and more specifically from the details of the proposed Actions (Anon., 2020, p. 48),
- and from the "National Plan and Regular Environmental Inspection Programs" developed by The Hellenic Ministry of the Environment and Energy (Glitsis, et al., 2017).

Since the criteria that were found didn't have the same degree of particularity, the more specific criteria were assigned to the more general of the same type.

Table 23: Key criteria

	Risk criteria collection	**Parameters Values**
1.	**The number of licensed operations of this category in Greece**	
2.	**The number of licensed operations of this category in EU**	
3.	**The availability of a financial security product currently in the market for this category**	
4.	**The range of environmental risk within each category**	
	Environmental Risk Level (EBRD)	High-Medium-Low
5.	**A representation of categories subject to regulation such as REACH or SEVESO**	
	Regulatory fields:	
	IED/IPPC Installation	Yes/No
	Seveso establishment	Yes/No If Yes: Upper tier

	Risk criteria collection	Parameters Values
		Lower tier
	Large Combustion Plants Directive	
	VOC Directive	
	Landfill waste Directive	
	Extractive waste Directive	
	Directive establishing a scheme for greenhouse gas emission allowance trading within the Community	
	Urban sewage treatment plant	
	Biodiversity, Natura 2000	
	PRTR Installation	
	The inclusion of the project/activity in Regulation EC/166/2006.	
6.	**Risk location**	
	Proximity to sensitive areas	
	Quality/sensitivity of the local environment	
	Projects which have impact on NATURA 2000 area	
7.	**Activities of significant importance to the national economy**	
	Turnover	
8.	**Environmental risk classification of plant**	A, B Category (Greek classification)
	The classification of the project/activity in subcategory A1 or A2 according to the classification of YA 37674/2016 (B΄2471).	
9.	**Size of the installation** (In terms of quantity of substance and/or surface area) Installed power capacity	Example from Portuguese risk assessment method to determine inspection frequency: Size 1. < 1 ha 2. 1 ≤ Surface Area < 10 ha 3. 10 ≤ Surface Area < 20 ha 4. 20 ≤ Surface Area < 50 ha 5. ≥ 50 ha

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	Risk criteria collection	Parameters Values
10.	**Process complexity of the installation**	
11.	**Type and number of substances emitted (Load of enterprise on the environment)**	
12.	**Hazardous substances & Waste management**	Hazardous Non- hazardous
	Storage of hazardous materials, storage methods	
13.	**Off-site transfer of waste**	Yes/No Hazardous Non-hazardous Amount?
14.	**Operator performance**	
	Legal performance	Compliance with limit values
	Effect-reducing measures	
	Detection systems for the prevention of accidents	
	Complaints made by the public	
	Pollution incidents	
15.	**Facilities Activities where a major industrial accident has occurred (within the past 4 years)**	
	Frequency of production accidents	
16.	**Seasonal character of activity of an enterprise**	
17.	**Branches of industry**	

The criteria with the yellow indication were collected from the technical summary of the project and more specifically from the details of the proposed Actions (Anon., 2020, p. 48).

The criteria with the green indication were collected from the "National Plan and Regular Environmental Inspection Programs" developed by The Hellenic Ministry of the Environment and Energy (Glitsis, et al., 2017).

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5. Conclusions on the European Tools for risk estimation

The methodologies for the regulation of the inspection frequencies and the methodologies for the calculation of the financial provision cost have different aims, but they both appraise the risk. All of the risk analysis methodologies analysed in this report calculate the risk as the product of the effect and the probability (risk=effect*probability). However, each methodology has its own definition and way of estimation for the effect and the probability, hence, a lack of consensus on a standardised way of estimating effect and probability is evident. For the IMPEL methodology, the effect is represented by the impact criteria and the probability by the operator performance criteria. For the Spanish methodology, the effect is represented by the Environmental Damage Index (IDM), while the probability derives from a sum of event trees chosen by the operator in the ARM tool. As for the Irish methodology, a simple risk matrix of Likelihood (probability) and Consequence (effect) is employed.

Studying the Guide of the IRAM methodology, the disadvantages of the Maximum value method are made clear: valuable information might get lost in the process and highest frequencies than needed might be calculated (Kramers, et al., 2012). Analogous to the Maximum value method used to regulate the inspection frequencies is the selection of the worst-case scenario for the costing of the financial guarantee (Irish and Portuguese methodology), which will most probably result to an overpriced financial guarantee for the majority of the incidents. The selection of the reference scenario for the estimation of the financial provision cost is a critical step that needs thorough consideration. Since IMPEL has developed a smart, flexible and easy to use way to regulate the inspection frequencies, its possible application to the selection of the reference scenario could be considered. The way the accident scenario is selected in the Spanish methodology is also of great interest. A selection process is used, where, the final accident scenario derives from a pre-selected list of the scenarios constituting 95% of the total risk. This way the maximum value problem is mitigated, since the scenario that will act as a base for the calculation of the financial security is the slightly better case than the worst-case scenario.

The methodology of Spain seems to be the most appropriate for a country with a mandatory financial provision, since it has a consistent strategy for the cost valuation, is cost effective, the tool is easy to use and facilitates the modification of the data. The methodology of the Netherlands has not as wide applicability as the other methodologies, and the Irish and Portuguese methodologies are not so cost effective for the operators, since the reports need to be prepared by them, which, unlike the Spanish methodology, may result in an uneven playing field, which also hinders the equal treatment between the different installations.

The insurance sector methodologies are mostly qualitative or semi-qualitative and heavily reliant on empirical methods and expert judgement. The main focus of the insurance sector is the calculation of the insurance premium rather than explicitly assessing the environmental risk and all the relevant accident scenarios to calculate the costs of repairing a potential environmental damage. Consequently, a large gap between the methodologies used by the European countries and those used by the insurance companies in Greece is observed. Nonetheless, the environmental risk criteria that the interviewed insurance companies use, coincide to a large degree with the risk criteria used for the regulation of the inspection frequencies and those used for the calculation of the financial provision.

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7. Appendices

7.1 Appendix 1: Description of the IRAM web-based Tool

The IRAM Tool facilitates the implementation of the IRAM Methodology from the member states. Firstly, the user needs to register by filling in her/his name, surname, e-mail address, language and user identification. By completing the registration, a password is generated for the user, and send to her/his e-mail address. The registered user can login with his user ID and password, and have access to the tool.

There are three types of registered users˙ the *administrator*, the *inspection coordinator* and the *inspector*.

The *administrator* role is given to two individuals from the project team, the project leader of the "easyTools" Project and the secretary of IMPEL. The administrator has the overall control of the program, which means he is responsible for giving the inspection coordinator role to nominated users, deleting registered users and holding contact with the programmers.

The *inspection coordinator* is nominated by the pertinent authority and set by one of the two administrators. This role involves the coordination of the inspectors of his administration and the creation of risk assessment forms for the inspection tasks. He can choose which inspectors will be under his coordination by ticking the box corresponding to each inspector's ID. Regarding the creation of the forms, he has to develop one form for each inspection task. The first step involves choosing one of the two available risk assessment methods˙ the Integrated Risk Assessment Method (IRAM) or the Linear Mean Value Method. The next step is the determination of the impact criteria, their respecting score graduation (min. and max. score) and the operator performance criteria. For this task, the inspection coordinator can use the examples given in the easyTools guidance book (Kramers, et al., 2012, pp. 43-51) or develop new criteria. He can add the criteria by clicking the "+" button beneath the boxes of the impact criteria and the operator performance criteria. Considering that the IRAM method is chosen in the first step, the inspector coordinator has to set the values of the steering mechanisms like the "Rule" (minimum number of highest score), the risk ceiling (maximum score), the "safety net" (highest/lowest risk category), weighting terms and factors, and inspection weight. These values are then mandatory for the inspectors under his coordination. The forms created by the inspector coordinator are stored in a folder named "Integrated Risk Assessment for Inspection Planning". The inspector coordinator can modify the existing forms in the folder. Additionally, under the menu "Inspection Task" a collection of these forms is to be found.

The *inspector* is responsible for the filling in of the data into the forms. She/He can find the folder containing the forms under the menu "Forms". The data that are filled from the inspector are the following:

1. Identification number and name of the inspection object.
2. Date of the last inspection.
3. Address of the inspection object.

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4. Values for the “safety net” by checking the regulatory demands for the inspection task.
5. Scores of all the impact criteria according to the range set by the inspector coordinator, and by taking into consideration the description of each score, which is also set by him.
6. Scores of the operator performance criteria with a range between -1 and 1, also by taking into consideration the description of the scores set by the inspector coordinator.

The tool will then calculate the following parameters:

1. Highest score
2. Number of highest risk scores
3. Risk category
4. Maximum inspection effort (100%)
5. Sum of inspection profile
6. Inspection effort (in percentage)
7. Inspection category
8. Sum of risk profile and
9. Mean of risk profile

Because the assignment of frequencies to risk categories may differ in the member states, the inspection frequency is not calculated.

All data can be downloaded by clicking the buttons “Download XLM” or “Download CVS”. The tool will also develop a PDF file if the “Print” button is pushed. The names of the downloaded files are generated based on the identification of the inspection object and date of the assessment.

There is also the possibility to upload the XML files into the IRAM tool, by using the “Upload XML” button, in order to make changes in the scores or the steering values, and recalculate the outcomes.

The IRAM tool gives the possibility to interested users to make a risk assessment without registration. The menu “Integrated risk assessment” on the start page can be used for this. The user can go through the same steps with the inspector coordinator, and choose the method for the risk assessment, add the criteria and the steering values. After entering the data as the inspector would, the user can click the button “Calculation of the integrated risk assessment”, and all the parameters mentioned above will be calculated. The data can be downloaded, printed, and uploaded in the same way as for registered users.

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7.2 Appendix 2: Example of a risk calculation using the Rule (IRAM Method)

The table below displays an example of how the risk rule moderates the unnecessary inspection frequencies by defining a requirement to be met to assign the highest risk score to an activity. The risk rule of the displayed example is the value 2, which means that at least two criteria should have the maximum risk score (5), for the activity to be assigned to the maximum risk category. As we can see, the activity B meets the requirement (rule), since two of its criteria have the highest risk score, and therefore, its risk category is the highest. The activity A doesn't meet the rule, so its risk category is reduced by one value.

Activity	Risk categories of the impact criteria					Risk category (risk rule: 2)	Time span between inspections
	RC1	RC2	RC3	RC4	RC5		
A	4	3	**5**	4	1	4	3 years
B	**5**	4	**5**	1	1	**5**	1 year

(Source: (Glitsis, et al., 2017, p. 17))

17.3. Appendix 3: Risk criteria examples (for IPPC[21]/IED installations) (as given by the IMPEL project team)

[21] IPPC – Integrated Pollution Prevention and Control

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	Impact Criteria	Score: 0	Score: 1	Score: 2	Score: 3	Score: 4	Score: 5
1.	Type and kind of installation	Non-IPPC installation without need of an environmental permit	Non-IPPC installation without need of an environmental permit but object of environmental regulations	Non-IPPC installation that needs an environmental permit	IPPC installation; Non-IPPC installation as relevant part of a lower tier Seveso establishment	IPPC installation as relevant part of an upper tier Seveso establishment or with obligatory environmental impact assessment	IPPC installation as relevant part of an upper tier Seveso establishment and with obligatory environmental impact assessment
2.	Impacts on human health or the environment	No environmental complaints, environmental accidents or incidents in the last 5 years	At least one minor environmental complaint, minor environmental accident or incident in the last 5 years	More than two minor environmental complaints, minor environmental accidents or incidents in the last 5 years	At least one relevant environmental complaint, relevant environmental accident or incident in the last 5 years	One important or more than two relevant environmental complaints, environmental accidents or incidents in the last 5 years	One important or more than two relevant environmental complaints, environmental accidents or incidents in the last 2 years
3.	Releases to air	Activity is not mentioned in Annex 1 of the EPRTR Regulation and there are no releases to air	Activity is mentioned in Annex 1 of the EPRTR Regulation but no threshold of Annex 2, column 1a, is exceeded and there are no other releases to air	Activity is or is not mentioned in Annex 1 of the EPRTR Regulation, no threshold of Annex 2, column 1a, is exceeded but there are other releases to air	Activity is mentioned in Annex 1 of the EPRTR Regulation and the sum of the releases to air - normalised to the thresholds* of Annex 2, column 1a - is >1	Activity is mentioned in Annex 1 of the EPRTR Regulation and the sum of the releases to air - normalised to the thresholds* of Annex 2, column 1a - is >5	Activity is mentioned in Annex 1 of the EPRTR Regulation and the sum of the releases to air - normalised to the thresholds* of Annex 2, column 1a - is >10 * Ratio of release to threshold value

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	Impact Criteria	Score: 0	Score: 1	Score: 2	Score: 3	Score: 4	Score: 5
4.	Releases to water/off-site transportation in waste water	Activity is not mentioned in Annex 1 of the EPRTR Regulation and there are no releases to water or off-site transports in waste water	Activity is mentioned in Annex 1 of the EPRTR Regulation but no threshold of Annex 2, column 1b, is exceeded and there are no other releases to water or off-site transports in waste water	Activity is or is not mentioned in Annex 1 of the EPRTR Regulation, no threshold of Annex 2, column 1b, is exceeded but there are other releases to water or off-site transports in waste water	Activity is mentioned in Annex 1 of the EPRTR Regulation and the sum of the releases to water or off-site transports in waste water - normalised to the thresholds* of Annex 2, column 1b - is >1	Activity is mentioned in Annex 1 of the EPRTR Regulation and the sum of the releases to water or off-site transports in waste water - normalised to the thresholds* of Annex 2, column 1b - is >5	Activity is mentioned in Annex 1 of the EPRTR Regulation and the sum of the releases to water or off-site transports in waste water - normalised to the thresholds* of Annex 2, column 1b - is >10 * Ratio of release or off-site transport to threshold value
5.	Releases to land	Activity is not mentioned in Annex 1 of the EPRTR Regulation and there are no releases to land	Activity is mentioned in Annex 1 of the EPRTR Regulation but no threshold of Annex 2, column 1c, is exceeded and there are no other releases to land	Activity is or is not mentioned in Annex 1 of the EPRTR Regulation, no threshold of Annex 2, column 1c, is exceeded but there are other releases to land	Activity is mentioned in Annex 1 of the EPRTR Regulation and the sum of the releases to land - normalised to the thresholds* of Annex 2, column 1c - is >1	Activity is mentioned in Annex 1 of the EPRTR Regulation and the sum of the releases to land - normalised to the thresholds* of Annex 2, column 1c - is >5	Activity is mentioned in Annex 1 of the EPRTR Regulation and the sum of the releases to land - normalised to the thresholds* of Annex 2, column 1c - is >10 * Ratio of release to threshold value

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	Impact Criteria	Score: 0	Score: 1	Score: 2	Score: 3	Score: 4	Score: 5
6.	Off-site transfer of waste	No activity specific waste	Non-hazardous waste <2,000 t/y or hazardous waste <2 t/y	Non-hazardous waste >2,000 t/y or hazardous waste >2 t/y	Non-hazardous waste >20,000 t/y or hazardous waste >5,000 t/y	Non-hazardous waste >50,000 t/y or hazardous waste >10,000 t/y	Non-hazardous waste >100,000 t/y or hazardous waste >20,000 t/y
7.	Input of waste	No waste input	Non-hazardous waste <2,000 t/y and hazardous waste <2 t/y	Non-hazardous waste >2,000 t/y or hazardous waste >2 t/y	Non-hazardous waste >50,000 t/y or hazardous waste >1,000 t/y	Non-hazardous waste >100,000 t/y or hazardous waste >5,000 t/y	Non-hazardous waste >250,000 t/y or hazardous waste >10,000 t/y
8.	Quality of the local environment	There is no contribution by the installation and therefore no influence on the environmental quality		There is contribution by the installation but the environmental quality is better than the ambient standard	There is contribution by the installation and the environmental quality is kept at the ambient standard	There is contribution by the installation to the violation of environmental quality standards by less than 3%	There is contribution by the installation to the violation of environmental quality standards by more than 3%
9.	Sensitivity of the local environment	No sensitive areas in the surroundings or distance is >10 km	Sensitive areas outside the influence sphere of emissions or distance is <10 km	Sensitive areas within the influence sphere of emissions or distance is <5 km	Sensitive areas within the influence sphere of mayor accidents or distance is <1,5 km	Sensitive areas close to facility premises, the distance is <100 m	Facility lies within a sensitive area or in the direct vicinity
10.	Risk of accidents	No (categories of) dangerous substances covered by Annex I of the Seveso-II Directive	Sum of (categories of) dangerous substances covered by Annex I of the Seveso-II Directive - normalised to the	Sum of (categories of) dangerous substances covered by Annex I of the Seveso-II Directive - normalised to the thresholds of Column 2*) - is >2	Sum of (categories of) dangerous substances covered by Annex I of the Seveso-II Directive - normalised to the thresholds of Column 2*) - is >4 or	Sum of (categories of) dangerous substances covered by Annex I of the Seveso-II Directive - normalised to the thresholds of Column 3*) - is >1	Sum of (categories of) dangerous substances covered by Annex I of the Seveso-II Directive - normalised to the thresholds of Column 2*) - is >50

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	Impact Criteria	Score: 0	Score: 1	Score: 2	Score: 3	Score: 4	Score: 5
			thresholds of Column 2*) - is >1		- normalised to the thresholds of Column 3 - is >0.75		*) Ratio of managed amount to threshold value
11.	Noise	No relevant emissions	Noise emissions are more than 5 dB(A) below limit value	Noise emissions are more than 1 to 5 dB(A) below limit value	Noise emissions are plus or minus 1 dB(A) around limit value	Noise emissions exceed limit value by 1 to 5 dB(A)	Noise emissions exceed limit value by more than 5 dB(A)*) *) This can't only be handled by routine inspection, action is needed

IPPC – Integrated Pollution Prevention and Control

EPRTR Regulation – European Pollutant Release and Transfer Register

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	Operator Performance Criteria	Score: -1	Score: 0	Score: 1
1.	Compliance	No relevant non compliances of the installation with the permit conditions or violation of the operator duties	One relevant non compliance of the installation with the permit conditions or violation of the operator duties	More than one relevant non compliance or one important non compliance with the permit conditions or violation of the operator duties
2.	Attitude of the operator	Operator reacts immediately after recognising a condition of relevant non-compliance	Operator reacts after receiving a warning letter form the competent authority	Operator reacts only after repeated warning letters or after a formal administrative decree of the competent authority
3.	Environmental management system	Site is registered under EMAS and the operator is working successfully with this environmental management system	Site is not registered under EMAS but the operator is working successfully with an accepted environmental management system	Site is not registered under EMAS and the operator is not working with an accepted environmental management system

EMAS Register – Verified Environmental Management

https://webgate.ec.europa.eu/emas2/public/registration/list

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7.3 Appendix 4: Risk assessment methods for regulating the inspection frequency in IMPEL member countries

The IMPEL project "Development of an easy and flexible risk assessment tool as a part of the planning of environmental inspections linked to European environmental law and the RMCEI" (easyTools project) was based on the findings of a review of the risk assessment methods and risk criteria that were in use in IMPEL member countries at the time of the project. For the review, a questionnaire was created, which was distributed to the IMPEL National Coordinators on March 21, 2010, who were asked to fill it out and return it by April 23, 2010.

The following questions were sent out to the IMPEL member countries: ((IMPEL), 2010, p. 4)

1. Do you use a risk assessment approach when planning inspections?
   If yes continue with question 2, if no continue with question 9.
2. For which statutory tasks of your organisation do you use the risk assessment approach?
3. Specify the methodology of your risk assessment(s) by answering the following questions:
   What risk criteria do you use?
   What scoring systems do you use?
   Do you use weighting factors and how are they determined?
   How does your mathematical algorithm (the way your system calculates) work?
   How do you use the output of your risk assessment in terms of ranking and classification?
4. Do you use a software tool for performing the risk assessment?
   If yes, is this tool accessible by internet? Is it possible to receive a copy?
5. Have you already evaluated the risk assessment methodology in practice?
   If yes, what was the outcome?
6. How is the risk assessment updated?
7. Is the risk assessment methodology set by law?
8. When you assess risk, what form do input and output data have? (Database, 1 big excel sheet, 1 excel sheet for each facility...)
9. Do you prefer a tool developed on the basis of general software (e.g. MS Office, MS Excel) or a tool developed on the basis of more specialized software (e.g. Visual C++ or other programming software)? If you prefer a tool developed on the basis of more specialized software, what architecture of the tool would suit you better (for your IT needs)?
10. Do you have any issues, concerning risk assessment that you would like to share with us that could be interesting for this project?

IMPELs group of experts received answers from Italy (Lombardi), Ireland, Germany (Munster, Hessen, Hamburg, Detmold, Schleswig-Holstein, Cologne, Bremen, Rheinland-Pfalz), Spain (Extremadura, Basque Country, Madrid), Poland, Portugal, Macedonia, Romania, Latvia, Turkey, France, Slovakia, Denmark, Slovenia, Finland and Greece. The answers given by each country are available in the "Risk Assessment in Inspection Planning-A European Perspective-Report on the Results of the questionnaire" by the IMPEL Project easyTools ((IMPEL), 2010).

The respondents use a risk assessment approach to plan the inspections for a range of statutory tasks, the most prevalent of which are IPPC and SEVESO. Each country has its own distinctive risk assessment method, and when common criteria are utilized, they are applied in a different manner. The scoring

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systems also differ, and according to the research team, more in-depth study would be required to reach a conclusion on the scoring systems in use ((IMPEL), 2010, p. 9). Almost all scoring systems in use award points ranging from 1 to 5 (or 10) for each criterion based on comparisons to predefined thresholds. Weighting factors are rarely used, and when they are, they also differ. Five respondents stated that their risk assessment systems include weighting variables, although it is unclear how they are derived. Some examples are the following ((IMPEL), 2010, p. 6):

- The weighting factor depends on the inspector's experience.
- The weighting elements are determined by the relevance of the criterion.
- The weighting variables were developed based on past inspection experience.
- The weighting factors are determined by national priorities.

Several ways are used to calculate the risk score. Some of the systems make use of the "if" function (comparison), while other approaches employ summing and mean values, as well as multiplication with weighting factors when appropriate. Finally, the risk value is compared to threshold values for risk classification (high, medium, low).

The results of the risk assessment methods are primarily used to prioritise the inspections. This prioritization sets the number and type of inspections to be performed within a certain time frame. They are also used to calculate the amount of resources required.

According to the answers obtained from the questionnaire, the following aspects are important to consider while developing a risk assessment tool ((IMPEL), 2010, p. 8) :

1. *The tool should be easy to use and flexible*
2. *The tool should produce a schedule with the inspections and the inspectors, taking into account non routine inspections.*
3. *The risk approach should be linked to the objectives to get a complete approach for an efficient and effective inspection.*
4. *It should be possible to update the tool in an easy way.*
5. *It should be able to link to systems that are already in use.*
6. *There can be a conflict between the outcome of a risk assessment and the national legal requirements on inspection frequencies.*
7. *The risk criteria should be made as simple and effective as possible*
8. *The output of the IT Tool developed under easyTools Project should be a list of controlled installations and activities ranked on the basis of their risk score.*
9. *Gathering the information for risk assessment should be easily achieved.*
10. *More information about IT Tool developed under easyTools Project and training opportunities on using the tool should be available in the future.*
11. *Weighting indicators is a subject which needs to be reviewed regularly according to the general/specific objectives of the organisation.*
12. *It should be possible to execute a risk assessment on different levels of planning within an organisation.*
13. *The project should deliver an overview of criteria and calculation methods in the different IMPEL member countries.*
14. *A risk assessment approach has to be straightforward and quick to operate. An assessment requiring too much detail leads to low acceptance by the inspector and to low quality data input to finish the assessment.*

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Most inspectorates use the method of addition of the scored criteria, which are multiplied by the probability in some cases. As mentioned before, important information may be lost due to the usage of mean values. Another method is the use of the highest value to determine the inspection frequency. The combination of the two methods resulted in the IMPEL's Integrated Risk Assessment Method (IRAM), which, according to the workshop conclusions, is working better than most of the systems ((IMPEL), 2010, p. 96). The critical point of IRAM lies in a clear description of the impact criteria.

The examples of Denmark, France and Germany

The table below shows three characteristic examples of risk assessment methods for regulating the inspection frequency (Denmark, France, Germany). Denmark uses a risk matrix based on subjective assessment of the criteria and no mathematical ranking system. France uses the maximum value method, and Germany (Cologne) uses the mean value method for the risk criteria and the highest value method for the size criteria.

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	Denmark	France	Germany (Cologne)
Risk criteria	Individual caseworker assessment of the risk posed.	National priorities - Waste facilities (with certain threshold for each type: dangerous waste facilities, non-dangerous waste stockings, non-dangerous waste incineration) - Measured Air emissions (SOx, NOx, dust, Cl, Cd+Hg, …) - Measured Water emissions (COD, hydrocarbs, As+Cr+Cu+Sn+Mn+Ti+Zn, Cd+Hg+Ni+Pb) with different threshold depending on where they reject (wastewater treatment plant, river, lake) - Manure spreading (with tonnage threshold) - Porks and poultry Farming (with tonnage of Nitrogen threshold) - Polluted sites that have specific problems. High stakes (among those who are not already above, following ones are High stakes) - IPPC - CO2 quotas - Large Combustion Plants - Incinerators - COV emitting plants (threshold on tonnage)	For IPPC-installations Risk criteria: - Basic environmental relevance (kind of IPPC installation) - Distance to sensitive objects/areas - Number of substances released into the air - Number of substances continuously measured - Waste water relevance - Quantity of hazardous/non-hazardous waste - Compliance with regulations - Readiness of the operator to comply - Number of neighbourhood complaints - EMAS or EN ISO 14001 certification prolongs the inspection cycle

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	Denmark	France	Germany (Cologne)
		Wastewater treatment plant treating industrial wastewater	
Mathematical algorithm	No mathematical ranking system	The mathematical calculation is a “max” and not a sum.	For the risk criteria the points are added and the mean value over all is calculated. For size criteria the highest value is taken into account. Certification leads to a lower risk category.
Classification	Categorization of instruments as described in the national guideline concerning differentiated inspection practices.	Facility categories <u>Declared facilities:</u> They can start their activities as soon as they have declared they will. They rarely get inspected (mainly upon complaint, or when a national order is given to check in every region a certain number of {dry cleaners / printers /…}).	The risk mean values of the installations are allocated to three risk categories: high, medium and low, leading to an inspection frequency of every 1, 2 or 3 years.

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	Denmark	France	Germany (Cologne)
		<u>Registered facilities:</u> They have a simple procedure to fulfil before they can start their activities. <u>Authorised facilities:</u> They need to get a proper authorisation (which usually takes approx. 1 year). - National priorities get inspected every year - High stake get inspected every 3 years - Other get inspected every 10 years	
Software tool	Geoenviron product	Software GIDIC	Microsoft Excel; the tool is available on Basecamp, on the ECENA website and on www.dunsche.eu.
Risk assessment methodology evaluation	No	No	An evaluation was planned for 2011.

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7.4 Appendix 5: EU Member States: Request for information mapping

EU Member States	Contacted	Received Information	Information from net-searching	Tool (for Inspection frequencies or Financial provision cost)
Austria	√			
Belgium	√			
Bulgaria	√			
Croatia	√			
Cyprus	√			
Czechia	√			
Denmark	√			http://www.geoenviron.eu/
Estonia	√			
Finland	√			
France	√	√		http://www.synapse-info.com/spip.php?article52
Germany	√			http://www.dunsche.eu/
Greece	-	-		
Hungary	√			
Ireland	√	√	√	
Italy	√	√		
Latvia	√			
Lithuania	√			
Luxembourg	√			
Malta	√			
Netherlands	√	√		
Poland	√			
Portugal	√	√	√	https://ra.apambiente.pt/form
Romania	√			
Slovakia	√			

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EU Member States	Contacted	Received Information	Information from net-searching	Tool (for Inspection frequencies or Financial provision cost)
Slovenia	√			
Spain	√	√		ARM, IDM, MORA https://servicio.mapama.gob.es/mora/login.action
Sweden	√			

7.5 Appendix 6: Ireland methodology- Detailed reports

Detailed reports with the background information required for the contents of each section of the Ireland methodology is provided in the guide ((EPA), 2014, pp. 12-13). This information is displayed in the Tables A1 and A2 below.

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Table A1: Detailed report with the background information required for a closure plan

Closure Plan Section	Section Contents	Background Information
1. Introduction	Site description	general description of the activity and site
	Activities	the classes of activities licensed and operational at the site
	Licence/permit details	date of issue of first authorisation and any subsequent revisions details of any closure requirements specified in the EPA authorisation details of any relevant requirements of planning permissions or other authorisations.
	Closure scenarios covered in the plan	date of commencement of operations
	Whether restoration/aftercare plan is also required	
2. Site evaluation	Operator performance	Any EMS for the activity Compliance history

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Closure Plan Section	Section Contents	Background Information
		Enforcement history Incident history; Complaint history Any relevant results of monitoring and/or site investigations carried out, which may include baseline monitoring/conditions that existed prior to the commencement of site operations (where available).
	Environmental pathways and sensitivity	Details on the underlying geology/hydrogeology Proximity to surface water bodies, their classification and status Proximity to sensitive receptors, including humans Details on the nearest natural habitat, SAC, SPA, NHA List of all emission and discharge points, including the quantities of materials (solid/liquid/gas) emitted Neighbouring developments, etc.
	Site processes and activities	Overview of the processes and activities undertaken at the site Detailed maps of the site and building layouts (to an appropriate scale) The different process areas, e.g. incoming raw materials, production units, dispatch area, waste handling/storage areas, water/waste water treatment areas.
		List of all buildings and major plant and equipment

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Closure Plan Section	Section Contents	Background Information
	Inventory of buildings, plant and equipment	Details of any hazardous or potentially polluting components and construction materials, e.g. PCBs, asbestos List of all bunded, secured and protected areas Details of any tests on bunds, pressure tanks, pipelines, etc.
	Inventory of raw materials, products and wastes	A comprehensive list of all raw materials, products and waste, including non-hazardous and hazardous materials The quantities of each item identified in the inventory.
	Maximum storage capacity for raw materials, products and wastes	Maximum storage capacity for raw materials, products and wastes and maximum storage amount in practice.
3. Closure tasks and programmes	Plant and equipment decontamination requirements	
	Plant and equipment decommissioning requirements	
	Demolition (if necessary)	

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Closure Plan Section	Section Contents	Background Information
	Waste facility closure (e.g. landfill and extractive waste facilities)	
	Raw materials, products and waste disposal and/or recovery requirements	
	Contaminated land treatment, removal and/or disposal	Baseline/existing conditions; Proposed remediation methods and their current status, including details of any agreements reached with the EPA Monitoring proposals
	Programme (Gantt chart or similar) and timeframes for delivery	With all key activities included
4. Criteria for successful closure	A benchmark set of criteria to evaluate the success of closure	Examples of benchmark criteria: – Plant safely decontaminated using standard procedures and authorised contractors – Wastes handled, packaged, stored and disposed or recovered in a manner that complies with regulatory requirements – Relevant records relating to waste and materials management retained throughout the closure process

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Closure Plan Section	Section Contents	Background Information
		– No soil or groundwater contamination at the site verified using monitoring data and a soil and groundwater assessment at the time of closure (if required) – Hazard and/or risk of environmental pollution addressed and the EPA is satisfied that the site is returned to a satisfactory state – Sufficient funds available to cover the full cost of closure – Environmental management system in place and actively implemented during the closure period.
5. Closure plan validation	Environmental monitoring	*The monitoring and validation process and the resulting certification relate solely to the physical closure of the activity and the formal acceptance of closure and ultimate surrender of a licence/ permit is a separate process that must be formally agreed with the EPA.
	Closure validation audit	
	Closure validation audit report	
	Closure validation certificate	
6. Closure plan costing	Plant and equipment decontamination costs	*Operators must determine the costs themselves from previous experience, relevant suppliers and contractors or from recognised experts who are familiar with such costs

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Closure Plan Section	Section Contents	Background Information
	Plant and equipment decommissioning costs	*EPA has prepared unit costs ((EPA), 2014)to assist in the validation of site-specific costings.
	Demolition costs	
	Waste recovery or disposal costs	
	Environmental monitoring costs	
	Site security costs	
	Validation costs	
	Management and utility costs	
7. Closure plan review and update	Proposed frequency of review	*typically once a year

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Further details for the contents of each situation are provided in the guide ((EPA), 2014, pp. 20-26), which are summarized in the Table A2 below:

Table A2: Detailed report with the background information required for a restoration/aftercare plan

Type of Liability	Report Contents	Details
Soil and groundwater contamination	Site investigation and risk assessment findings Remediation tasks and programme	The remediation proposals should include a suitably scoped and researched contaminated land and groundwater risk assessment including recommendations and a programme of measures.
	Costing	The following items should be costed: – Site investigation works (e.g. drilling and groundwater well installation) in order to delineate the extent and magnitude of contamination – Environmental risk assessment in order to determine whether risk is posed to environmental receptors and to devise an appropriate remediation strategy – Implementation of a remediation programme such as excavation, treatment, environmental verification testing and/or design and installation of in-situ treatment systems – Maintenance and monitoring costs associated with the site remediation, e.g. costs of maintenance of the treatment plant associated with a pump and treat system or the costs of groundwater monitoring associated with a monitored natural attenuation (MNA) programme – Staff resourcing – Site security (e.g. CCTV, inspections/patrols, fencing).

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Landform changes (landfills, extractive waste facilities, mines, quarries, soil recovery facilities)	Restoration tasks and programme	The process for the development of a site restoration proposal will involve the following main steps: – Details of proposed measures, land end uses and the considerations required to achieve these measures – Details of the engineering methods and technologies, including justifications, to be employed as part of the restoration process – A programme for the phased restoration of the site over a defined period of time.
	Costing	The following items should be costed: – Restoration measures, e.g. backfilling, seeding and landscaping – Maintenance of surface water drainage systems – Ongoing pollution control measures, e.g. landfill gas extraction and flaring/ utilisation, landfill leachate extraction and treatment/disposal – Maintenance of access to monitoring locations; – monitoring (e.g. surface water, groundwater, air, gas, leachate, stability) – Servicing and calibration of monitoring equipment (e.g. continuous water quality monitors) – Landscape maintenance; – staff resourcing – Site security (e.g. CCTV, inspections/patrols, fencing).

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	Aftercare tasks and programme	Examples of aftercare measures include: – Maintenance of surface water drainage systems – Operation of contaminated soil and groundwater pump and treat systems – Ongoing landfill gas extraction and flaring/utilisation – Ongoing landfill leachate extraction and treatment/disposal – Monitoring (e.g. surface water, groundwater, air, gas, leachate, stability) – Maintenance of access to monitoring locations – Servicing and calibration of monitoring equipment (e.g. continuous water quality monitors) – Landscape maintenance of grass cover and planting – Staff resourcing – Site security (e.g. CCTV, inspections/patrols, fencing).
	Criteria for successful remediation/aftercare	
	Validation	
	Review and update	*typically once a year

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