Guideline for the definition of Performance Indicators for Safety Management Systems

(DRAFT)

INTRODUCTION

The prevention of incidents and mitigation of consequences are a must in the policies of the European Gas Transmission Companies. Both these aspects are covered by the company management systems, which even if different in Europe, present generally the same fundamental structure (Plan, Do, Check and Act).

In particular in the Safety Management System (SMS) it is possible to identify two main areas which are strongly integrated with each other:

- the Pipeline Integrity Management policies designed to prevent the incidents;
- the Emergency Response Plans designed to manage anomalous situations and incident scenarios;

The description of the principles and the architecture philosophy followed by the Gas Transmission Industry for the SMS are described in a document issued by the International Gas Union (Ref. 1).
In this SMS all the resources and activities, which guarantee the safety and the environmental protection of natural gas transmission systems, are organised into processes (see Figure 1): two main processes, seven auxiliary processes and one general process.

The two main processes shall enable the natural gas pipeline Operator to perform his primary tasks:

- Equipment (design and construction);
- Operation-Maintenance (including emergency management).

The horizontal processes, auxiliary to the main ones, are:

- Training
- Purchasing
- Communication
- Standard Technology and Regulations Watch
- Safety
- Environment
- Quality

Finally a global process guarantees the system's coherency by managing the loop. This global process involves: policy, planning, implementation and operation, inspection and corrective action, management review (Figure 1).

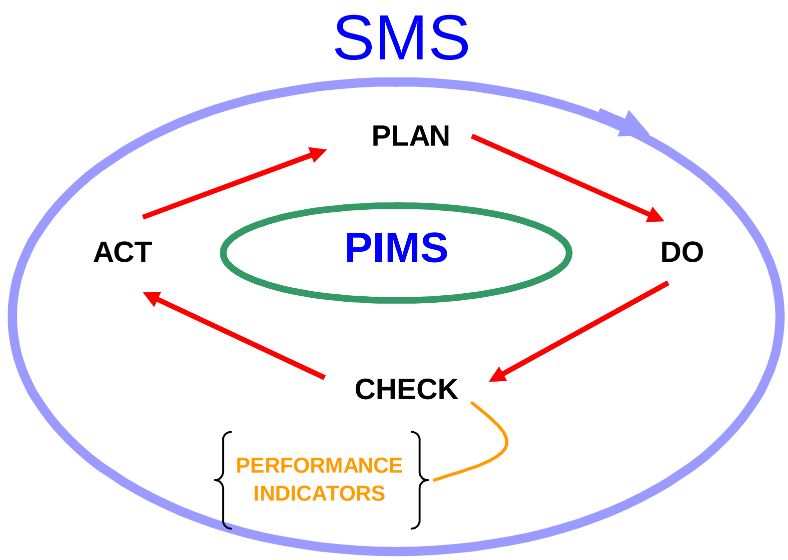


Figure 1

In this global process an important role is played by the Performance Indicators that shall support the Operator in measuring and monitoring the implementation of environmental and safety policies on a regular basis in order to plan the achievement of safety objectives.

The purpose of this guide is, according to the principles described in Ref. 1, to establish a general methodology to support the Operator in defining the Performance Indicators to measure the effectiveness of the technical policies adopted and thus the achievement of the safety targets defined in the SMS, tailored to each Company's needs.

The guide will focus mainly on the development of a performance indicator framework that can identify the key factors which can influence the causes and likelihood of failure and the severity of consequences.

This guide shall be applied to on shore pipelines covering processed, non-toxic and non-corrosive natural gas with a maximum operating pressure (MOP) over 16 bar and related equipment (insulating devices, disconnecting devices, pressure reduction devices, simple interconnections).
The delivery points, complex interconnections, storage facilities, terminals and compressor stations are not included in the scope.

The three main steps in the guide are:

- definition of the operator needs: the Performance Information;
- identification of relevant Performance Elements;
- selection of the most appropriate Performance Indicators.

Some other important references will be used in this guide for setting up the methodology:

- MARCOGAZ document about Performance Indicators (Ref. 2);
- the EGIG Report (Ref.3).
- the Arthur D. Little study ordered by DG Environment (Ref. 4);
- EN 1594 drafted by CEN/TC234 (Ref. 5).
- EN/TS 15173-15174

STEPS FOR DEFINING PERFORMANCE INDICATORS

The main steps that should be followed by the Operator in order to establish a set of performance indicators for evaluating the safety performances in a gas transmission Company, focusing on the basic elements, as described in Ref.1, shall be established and maintained through procedures on a regular basis. These procedures shall provide for:

- both qualitative and quantitative measures, appropriate to the needs of the organisation;
- monitoring of the extent to which the organisation's SMS objective are met;
- proactive measures of performance that monitor compliance with the SMS management programme, operational criteria and applicable legislation and regulatory requirements;
- reactive measures of performance to monitor incidents and other historical evidence of deficient SMS performance;
- recording of data and results of monitoring and measurement sufficient to facilitate subsequent corrective and preventive action analysis.

Performance indicators may also be needed to demonstrate that other expected benefits occur as well; namely, increased efficiency, improved communications and a closer working government/industry relationship.

Definition of the Operator needs: the Performance Information

During this phase the Operator has to clearly define why the Performance Information has to be carried out.

They could be addressed to compare performance with expected outcomes established in the policy targets or for measuring the effectiveness of technical actions adopted and used for the audit and system review of a SMS or for specific evaluation by the company top management about the efficient resource allocation in specific projects.

They could be used for communication with the public, the authorities or the stakeholders in order to provide information about the safety assured by the transmission system grid.

In this phase the Operator shall define what are the most appropriate Performance Information according to its needs; for instance the monitoring could focus on:

- the global safety performance of SMS;
- the performance of each element of SMS;
- the safety performance of a specific process (design and construction, maintenance, emergency)
- the safety performance of SMS for specific threats;
- the effectiveness of a single or of a set of preventive and mitigation measures;
- the effectiveness of new technologies adopted in the Company;
- the performance of a specific pipeline or pipeline section.

Each Performance Information can be evaluated by one or more performance indicators. The Operator shall define the most appropriate set of them.

Identification of the Performance Elements

In order to select the most appropriate Performance Indicators for the specific Performance Information the Operator shall identify all those technical actions and measures that can influence the monitored performance.

In general terms these elements are called Performance Elements.

In case of pipeline failure these elements mainly correspond to the prevention measures acting for defending the pipeline or for mitigating the possible consequences.

A useful approach for supporting the Operator in the identification of the Performance Elements for a SMS starts therefore from the identification of potential failure causes and related consequences (Ref. 2).

Identification of potential failure causes

In order to identify the potential failure causes the Operator should mainly use the internal knowledge of the network, the information gathered in similar networks managed by other operators, the international databases and the international bibliography review.

The definition of failure cause can be different according to the Operator needs: it can be based on the release of gas, on the damages without gas release, on the availability of a system and so on.

The likelihood of occurrence of each of the individual pipeline failure causes shall be judged and evaluated, case by case, with the aim to achieve the appropriate overall safety and integrity level of the pipeline system.

Surely one of the most important reference for analysing the safety in the European gas transmission in Europe can be the EGIG report (Ref. 3) that covers more than thirty years of management of pipelines (from 1970) and eleven of the most relevant European Gas Transmission Companies.

Therefore this reference can be utilised as a starting point for giving a complete overview about some of potential pipeline failure causes that can lead to an incident with unintentional gas release. Other references could be used by the Operator if more significant for the pursued aim.

From the EGIG report the failure causes can be classified into 5 sub-groups:

1. external interference (third party damage);
2. corrosion (external, internal, SCC/HCC/others);
3. construction defects/material defects;
4. ground movement (landslide, erosion, flood, mining);
5. other (design errors, e.g. overload, overpressure, temperature, welding on pipeline in operation, e.g. hot-tapping by error, maintenance, lightening impact).

It should be noted that not all mentioned failure causes are applicable to the whole pipeline system or to the specific pipeline under analysis, because some failure causes are irrelevant for the particular pipeline situation or present a very low failure frequency.

A case by case approach is therefore recommended.

Identification of realistic incident scenario

In order to identify the realistic incident scenario the Operator should make reference to:

- Internal incident databases;
- European Gas Company incident databases;
- Experience gathered in the application of its own Emergency Response Plan;
- Experimental activities carried out in the Gas Industry.

From incident databases or specific experience the Operator could identify the possible incident scenarios to be taken into consideration. For instance some of them can be:

- Gas dispersion;
- Fire;
- Explosion;
- Interruption of supply.

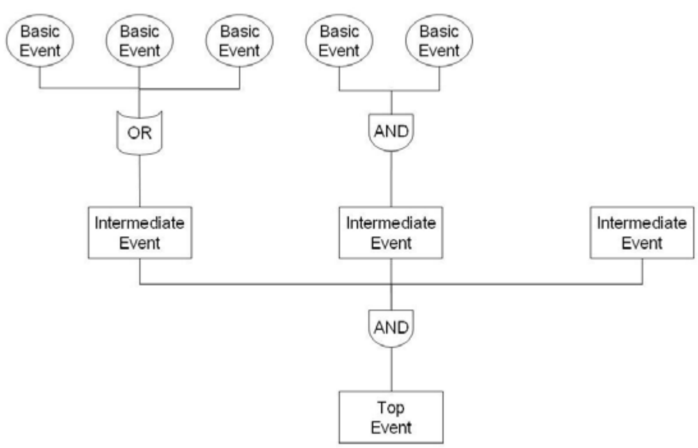
Definition of Performance Elements

Once the relevant failure and consequence scenarios have been defined it is necessary to carry out a detailed analysis for identifying the prevention and mitigation measures adopted in design, construction, operation and maintenance acting on those scenarios.

These measures can be pro-active (e.g. intelligent pigging) or reactive (e.g. increasing wall thickness) and can be wholly under the control of the pipeline operator/owner or obligations under the responsibility of National Authorities (e.g. land use planning).

These measures operate as a barrier against the different possible threats for the pipeline and should drive the operator in defining the most appropriate indicators for measuring the performances of its policies.

The Operator can use different tools in order to carry out this analysis. Among the different existing approaches, two of the more effective and flexible tools for describing the safety matters in terms of failure and consequences are the Fault Tree Analysis (FTA) and the Event Tree Analysis (ETA).



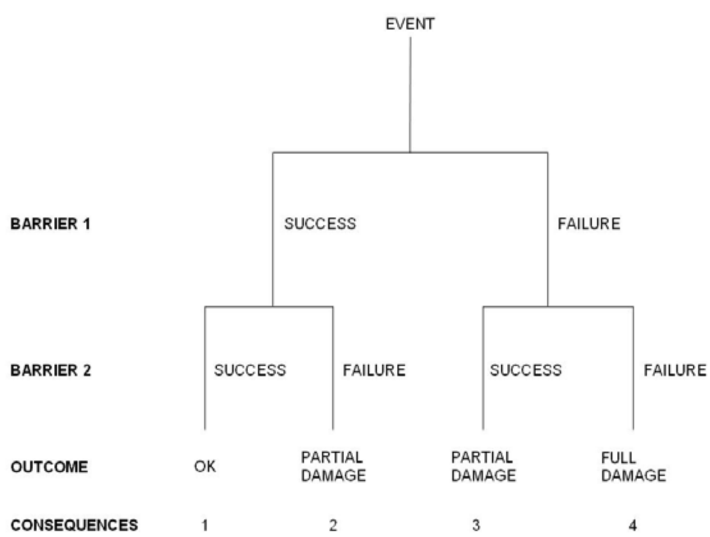
A Fault Tree consists of system and component events connected by logic symbols known as gates. Gates are the building block of fault trees as they define the causal relations between events. The following rules provide a framework for constructing fault trees:

The following rules provide a framework for constructing Fault Trees:

- Define the bounds of the system to be analysed and the level of complexity to which failures will be resolved.
- Identify the TOP EVENTS of the system to be analysed. The TOP EVENTS of the system represent those events relevant for the safety evaluations required.
- Using a top-down approach identify all the immediate causes of the TOP EVENTS.
- Define the immediate causes of the new system events. It is important that intermediate system events are not missed out when defining the immediate causes. In this way the levels of the fault tree progress systematically from major system events, through intermediate levels of complexity, to the basic events representing component failures at the roots of the fault tree.
- Continue this process of defining the immediate causes of system events until all the roots of the fault tree are terminated by primary events.
- Identify all the distinct causes for an event.

The Operator can use this tool for showing CAUSES of a TOP EVENTS (e.g. Pipeline Failure) and preventative measures (barriers). If these measures fail, the Fault Tree results in a TOP EVENT (e.g. Pipeline Failure).

Every Fault Tree should be defined according to the general needs of the Operator and focusing on all the elements relevant for the specific analysis.



An Event Tree is a graphical representation of the logic model that identifies and quantifies the possible outcomes following an initiating event. Event tree analysis provides an inductive approach to the assessment as they are constructed using forward logic.

Fault trees use a deductive approach as they are constructed by defining TOP events and then use backward logic to define causes.

In contrast to the Fault Tree, an Event Tree starts from a TOP EVENT (e.g. Pipeline Failure) and shows CONSEQUENCES of that TOP EVENT. Again preventative and mitigation measures react as barriers to stop the incident process and avoid damage to people or infrastructures.

Mainly for safety matters the pipeline damage corresponds with unintentional gas leakage, but for particular evaluation the Operator can use a more suitable definition (for instance number of hits due to external interference without gas leakage).

The Operator should define all the elements relevant for the specific Fault Tree and Event Tree Analyses according to his needs.

Both trees – the Fault Tree and the Event Tree – can be combined to a so called Bow Tie model with the Fault Tree on the top, the TOP EVENT in the centre and the Event Tree on the bottom of the Bow Tie. The basic idea of the Bow Tie model is shown in Fig. 2 using Pipeline Failure as the TOP EVENT:

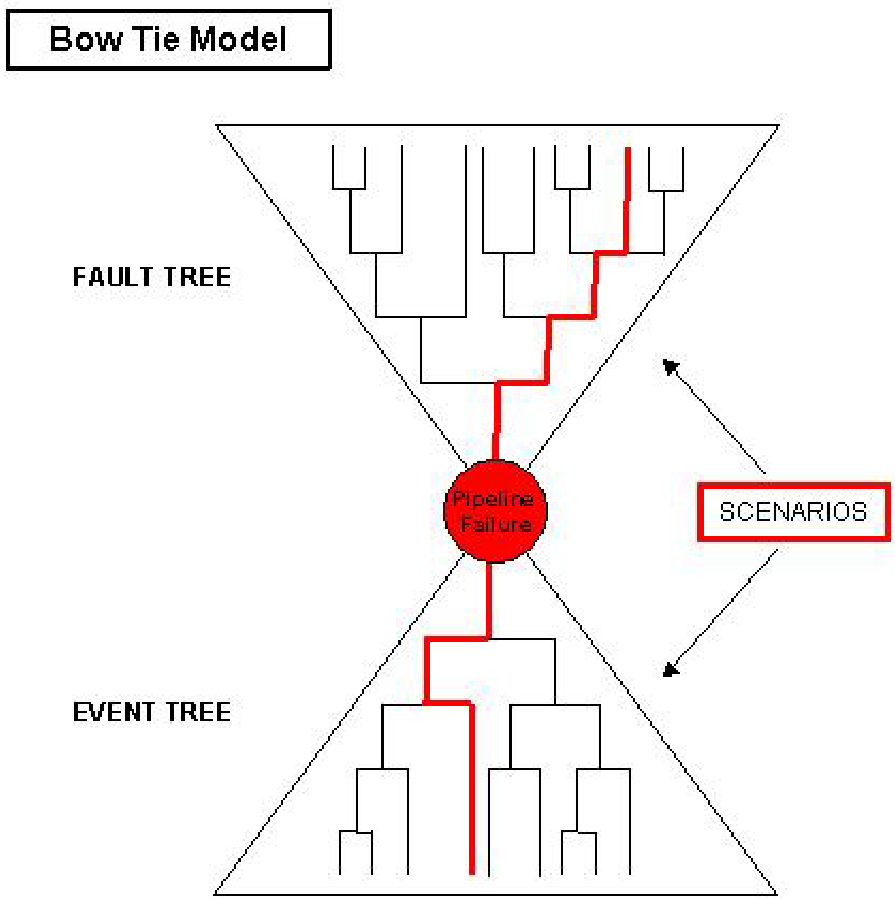


Figure 2: Bow Tie model with Fault Tree and Event Tree.

The combination of Fault and Event Trees can describe the relationships, dependencies and the roles of each of the preventative measures in the scenario analysed.

A scenario in fact will be a logical combination of threats showing also the barriers to prevent the continuation of the scenario into an incident. Barriers may be active or passive measures to protect the pipeline in the Fault Tree or prevent damage in the Event Tree. Different components of the branches are connected by logic symbols (and & or connections) known as gates. Gates are the building blocks of fault trees as they define the causal relations between events.

Figure 3 gives an example of the elements (barriers) that can be considered for the definition of the Fault Tree Analysis for the failure cause "External Interference":

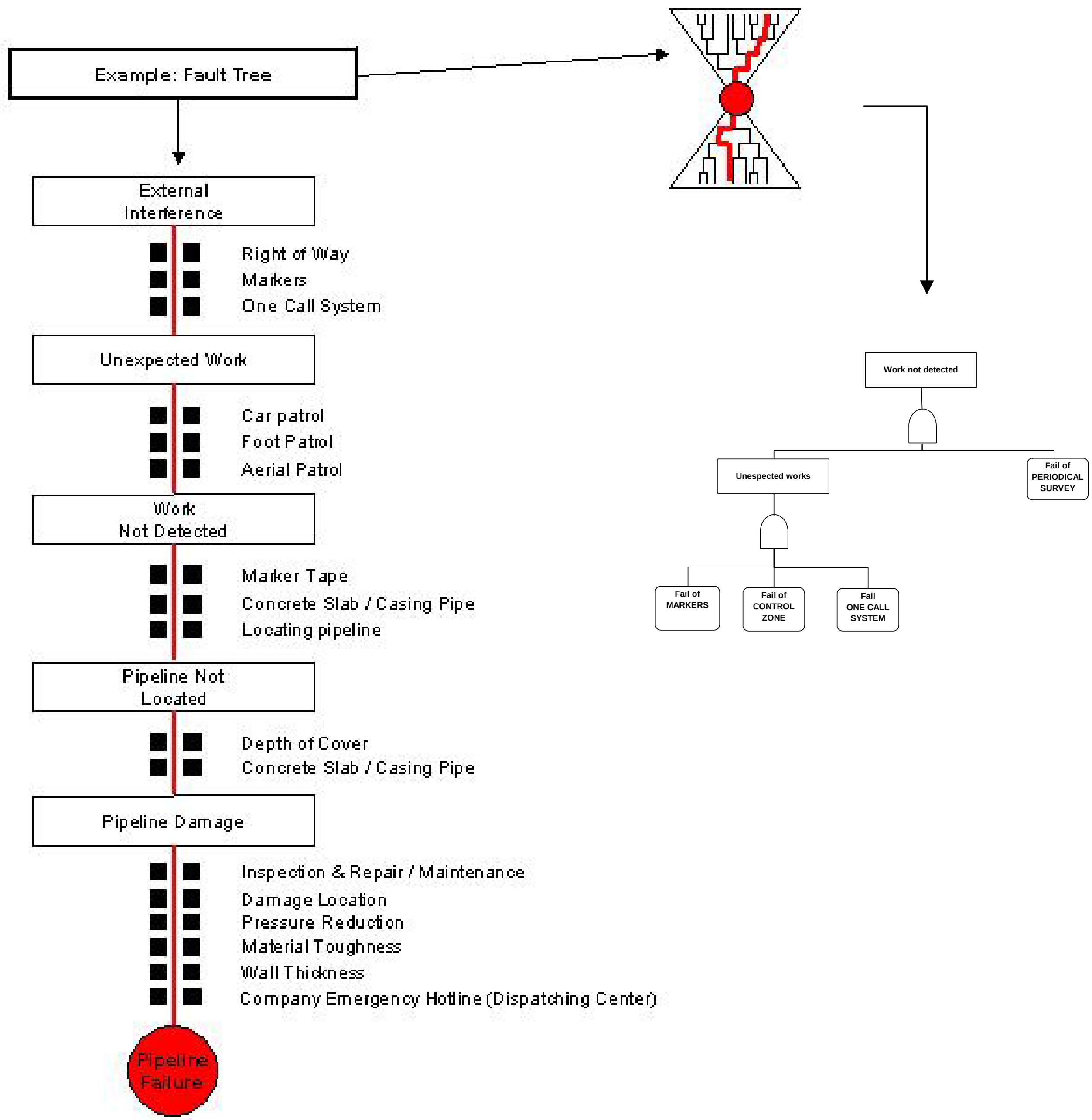
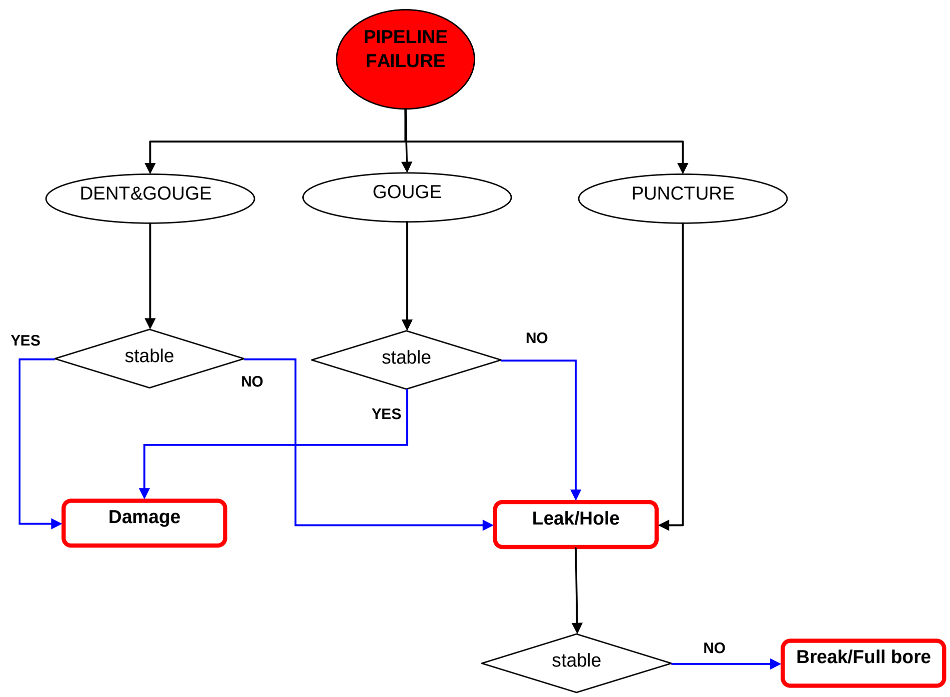


Figure 3: Fault Tree with the TOP EVENT Pipeline Failure caused by External Interference

In case the proactive and reactive measures (barriers = small black boxes) adopted by the Operator fail, the intermediate events will result in pipeline failure (bottom of Fig. 3).

The Operator, according to his needs, could decide to perform a detailed analysis of the kind of a pipeline failure since different damages generally have different impacts (e.g. the consequence in case of small leak or full bore) on safety for people and environmental protection.

In the figure below an example of failure due to external interference is shown.



Starting from pipeline failure in the Fault Tree, the Event Tree Analysis for that example may result in the scenario shown in Fig. 4:

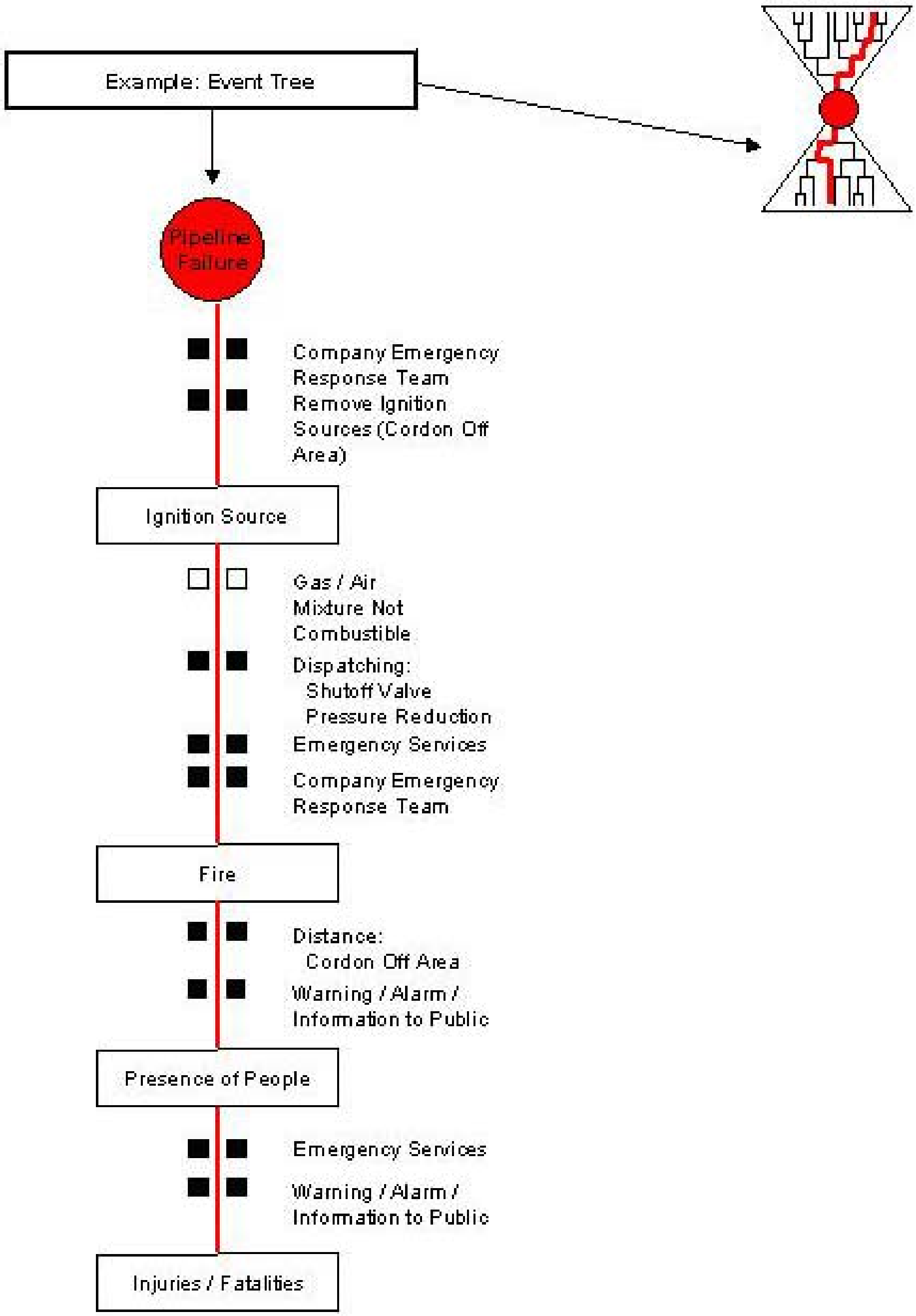
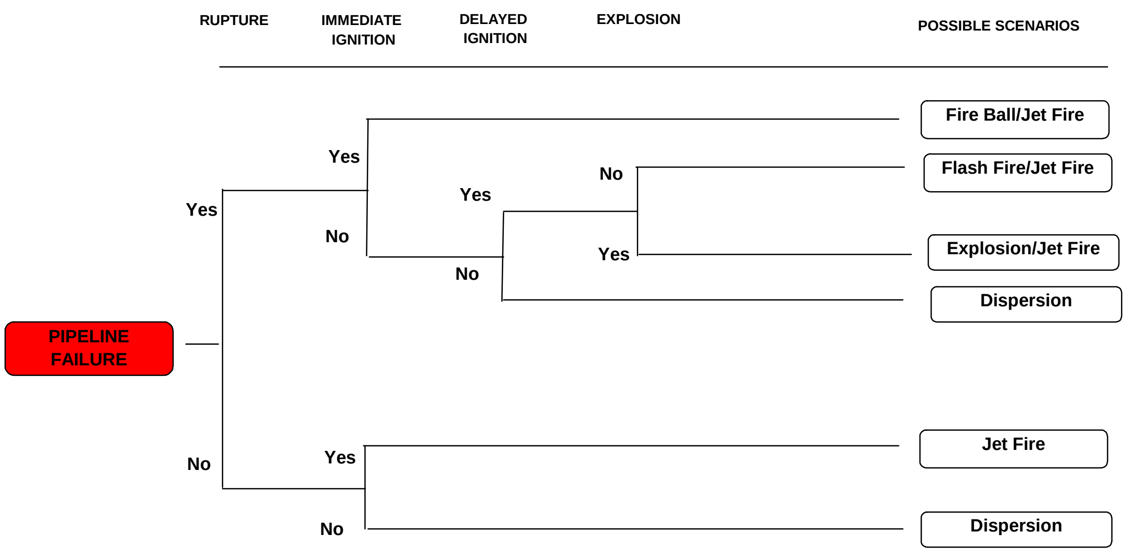


Figure 4: Event Tree with the consequence of injuries or fatalities.

Again the preventive and reactive measures (barriers) work to stop the progress of the incident process.
Event Trees can also be used where the outcome of events lead to different consequences as shown in the example below.



The Operator could decide to focus on different consequence scenarios, measuring the performance of the relevant barriers.

Selection of the most appropriate performance indicators

Selection of performance indicators will depend on the expected outcomes of the company's safety management policy and shall reflect the selected safety control activities (Ref. 4).

The definition of the most appropriate performance indicators could use the analyses carried out by the Operator described in the previous step and can be addressed to evaluate the effectiveness of a single measure or a global safety of a Top Event (Figure 4).

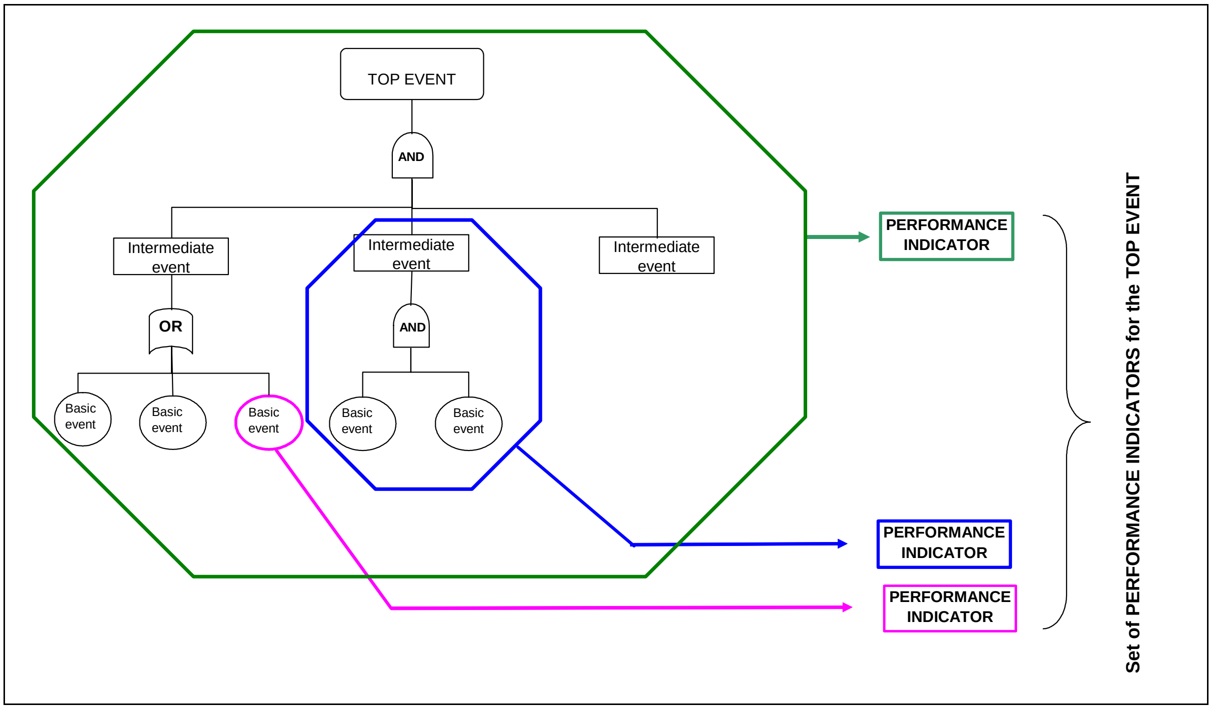


Figure 5– Example of P.I definition from a Fault Tree

Some performance indicators provide a direct measure of safety. Example may include:

- Global failure rate;
- Failure rate due to different treat scenarios
- Global likelihood/number of casualties;
- Likelihood/number of casualties per treat scenario.
- Percentage of delivery points involved in interruptions (on the total number of Delivery Points)
- Average interruption time at the incident point (hours/incident)
- Average interruption time at the delivery point (hours/delivery point involved)

Other performance measures provide indirect measures from which safety can be inferred. Examples may include:

- right-of way encroachments;
- intelligent pig vs. repairs;
- emergency training course for personnel;
- intensification of survey frequencies.

Both direct and indirect Performance Indicators can be appropriate for the kind of use necessary to the operator.

A combination of different Performance Indicators will be necessary and therefore the Operator should define the appropriate solution for its purposes accordingly. The transparency of the method used and its complete integration within the architecture of the Safety Management System adopted is necessary.

The Performance Indicators can be evaluated in terms of “absolute” values, in terms of trends the time, or comparing them with reference values.

The Performance Indicators can be identified according to different approaches such as:

- the probabilistic approach (e.g. failure rate over time);
- the binary approach (which can be an inspection declaration or an expert judgement).

The Operator can decide to use one or both of them, taking into account its needs.

Performance Indicators based on a probabilistic approach

Example of probabilistic Performance Indicators is the failure frequency (event/km-year) trend, as calculated by EGIG (Ref. 5):

ff = failure number/ pipeline exposure [event/km-year]

For instance in the EGIG Report the calculations refer to the whole period from 1970-2001 and a shorter moving period (5 year moving average). The Operator could decide to use a different period for the moving average.

These Performance Indicators can be suitable for measuring the effectiveness of:

- the whole Safety Management System (see Figure 6 as example);
- the set of preventive measures acting on a specific failure cause (see Figure 7 as example);
- the single preventive (or mitigate) measures (see Figure 8 as example).

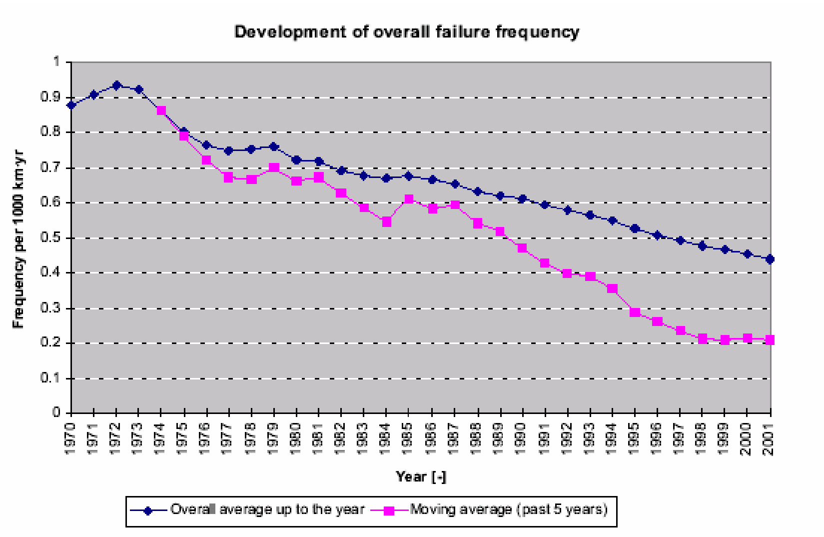


Figure 6 – EGIG: Failure Frequency in the period 1970-2001

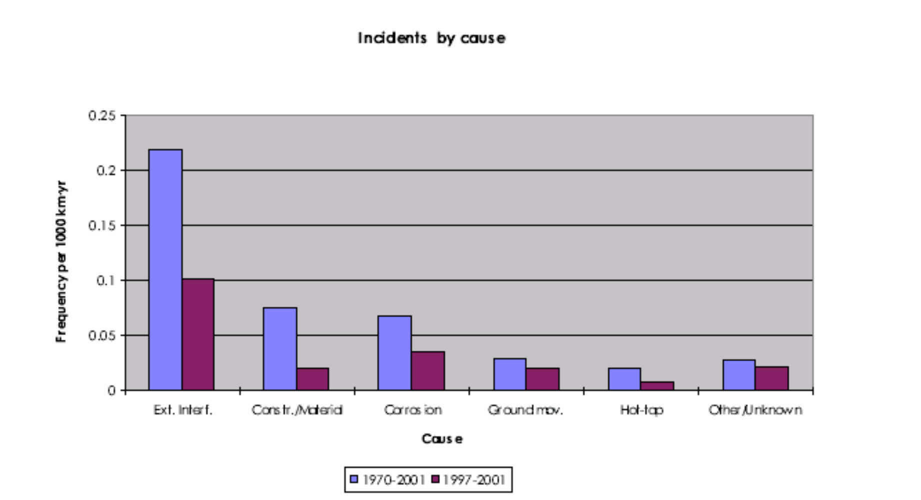


Figure 7 – EGIG: Failure frequency per damage cause

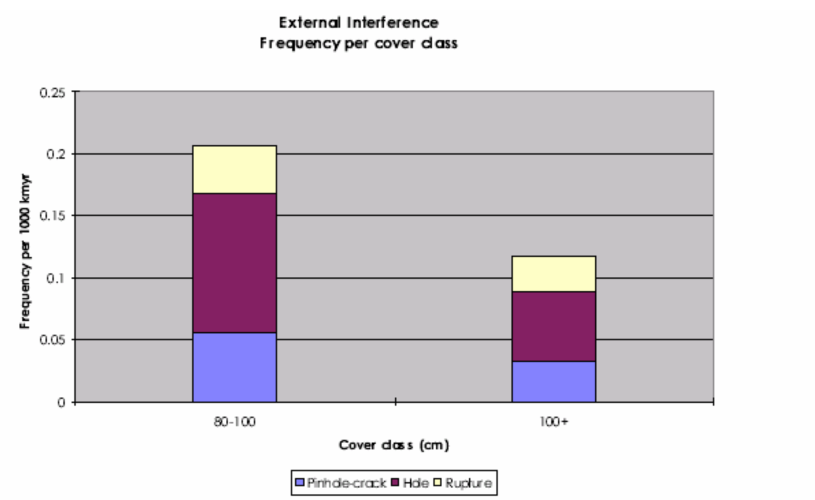


Figure 8 – EGIG: the influence of the depth of cover

Of course an Operator shall clearly define the performance indicator fit for its purposes: for instance EGIG has adopted a failure frequency definition based on "unintentional gas release", but the Operator could adopt a different definition more tailored to the specific needs (for instance the frequency mechanical contact with the pipeline without gas release in the case of measuring the performance of external interference preventive measures).

Other examples of Performance Indicators applicable for PIMS can be:

- For evaluating the intelligent pigging policies: length inspected/year and repairs;

- For evaluating the equipment maintenance: Number of failures/year, Mean Time Between Failure, availability

- For evaluating the cathodic protection system: number of operational faults/year.

Similar Performance Indicators can be taken into account for evaluating the global effectiveness of the Emergency Response Plan. These Performance Indicators could evaluate the ratio between the pipeline exposure and, for instance,:

- number of ignition;
- number of causalities;

Performance Indicators based on a binary approach

The performance is measured by an true/false criteria with respect to a reference value.

For this approach it is not necessary to have a specific database at one's disposal but it must have a definable threshold reference value based on best practices, international standards, internal knowledge or national law.

When the criteria is met the Operator can consider the preventive (or mitigate) measure carried out to have been effective (true).

For instance this may consist of an inspection declaration for the design, construction and testing phases.

Evaluation through the procedure "Expert Judgement" or/and the application of acknowledge standards are also considered "Performance Indicators" in the area concerned.
A typical example of such a Performance Indicator is the welding inspection policy.

Each single measure can be also evaluated by comparing the relevant parameter adopted by the Company with the CEN requirements or the national law requirements.

An example is the adoption of a depth of cover equal or greater than the minimum requirement as defined in EN 1594 (Ref. 5) or in the national laws.

Other similar examples could be the material toughness or wall thickness specifications.

These kinds of Performance Indicators generally are more suitable for monitoring the safety in a specific pipeline than in a complex network where the same kind of measure can be applied in a wide range of situations; nevertheless the Operator can apply this approach also in a general manners.

An example of such an application can be the adoption of a quality control on the material used: when clearly stated in the technical procedures of the Company, it can be considered as a measure for preventing material failure also in a general evaluation of the performance of whole SMS.

Some of the "Performance Indicators" may be combined because they are closely related to each other, e.g. the "Performance Indicator" defence by design (material toughness) is linked to the Performance Indicators for internal corrosion, material defects etc.

All aspects concerning operation, maintenance and overall system management shall be documented through transparent company procedures and management principles together with a system for audit and review.

CONCLUSION

Pipelines are the safest mode of transportation for hazardous substances. In the European Gas Transmission Industry a powerful tool applied for getting this result has been the Safety Management System (SMS) that covers, by transparent and complete rules and technical policies, the prevention of the possible damages and the management of the anomalous and incident scenarios.

In the SMS two main parts are strongly connected: the Pipeline Integrity Management designed for the prevention of damage and the Emergency Response Plan which assures prompt reaction to “undesired” situations.

The SMS of the European Companies may have different architectures and applications but they are developed using common principles (e.g. Plan, Do, Check and Act).

In order to apply these principles an important supportive tool is the evaluation of safety measure effectiveness to understand if the technical choices made go in the “right and desired” direction according to the Company Policy statement and the goals and targets set by the Top Management.

In addition often the Companies are asked to demonstrate the safety performance of specific pipeline to national and local Authorities or to the public.

The present guide provides a possible path that can lead the Operator to establish the most efficient solutions to face the different goals to be managed.

The safety measure can be evaluated by the definition and the calculation of appropriate performance indicators: the Operator shall define the set of these indicators fit for the purposes according to the architecture of the adopted SMS.

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