MOVING TOWARDS AN INTERNATIONAL COMMON APPROACH TO SAFETY CASE DEVELOPMENT

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ABSTRACT

The main purpose of the paper is to address a comparison between the main International Regulations related to the Safety Case development for offshore fixed and floating installations. In particular the comparison concerns the regulations in force in the United Kingdom, in Norway and United States. The comparison will particularly focus on Floating Production, Storage and Offloading units.
The paper will discuss the way the methodologies and techniques today available to perform Risk Analyses can be applied in order to fulfil the request of each regulation, and how the different approaches to Safety Case development can be compared or merged in a more general methodology.
Specific applications of these results will be given in relation to the safety assessment of the turret system and the loading and offloading operations of FPSOs.

1 - EXISTING REGULATIONS: THE STATE OF THE ART

In spite of growing efforts and investments towards offshore exploration aiming at increasing oil production from underwater reservoirs, still now only a few Countries involved in those activities have stated proper regulations concerning safety assessment and management. Among the already “regulated” areas, it is worth remarking USA, Norway, UK, and (in quick progress) also Australia.
Nevertheless, the coexistence of different regulations all over the world often causes the operators to approach differently the same problem, forcing the companies to customise their policies according to the area of action.
Nowadays a common effort is arising, in order to optimise safety matters (dealing with different aspects of the same problem, such as worker, environment and property/production) within a world-wide unitary view which would require the same effort and commitment for each geographical site of operation.
Historically speaking a fundamental impulse in this direction came from the Piper Alpha disaster (dated July 1988). Before that time only very few and incomplete regulations addressing safety issues did exist, scarcely or partially covering the global range of the offshore oil activities. After the accident Norway, UK and USA (through the API, author of the well known Recommended Practices) started the compilation of careful regulations which became model and reference point of the Governments of the other Countries.
Following the public enquiry promoted by Lord Cullen in UK after Piper Alpha disaster, which gave further impulse to the trend, in 1991 the Norwegian Petroleum Directorate replaced the existing

guidelines for risk evaluation with the Regulations for Risk Analysis, till nowadays valuable within the Norwegian Continental Shelf. In 1992 in UK a fundamental offshore-activity-regulating document was licensed, called Safety Case Legislation. The document is now under revision and the updated version will be issued in the progress of 1999. In 1993, the API recommended Practices of a Safety and Environmental Management Program were published in USA (API RP 75, May 1993), followed by other API publications (such as API RP 14 J), always concerning the offshore installation safety.
All the regulations are based on goal setting rather than prescriptive requirements, and they require the use of risk based techniques (qualitative and quantitative) to prove the safety level of the installation and its operation.
<u>Analyses of existing regulations lead to remark what here follows:</u>
in Norway regulations aim to establish and to keep acceptable levels of safety within the offshore oil activity on the basis of mandatory development and management of internal check systems to be promoted and guaranteed by the operator, after being given any temporary exploration permit (NPD, 1991). The word safety means and involves any means effective for the protection of people, environment and investments, where fundamental milestones are the careful description of the safety tasks and the global safety evaluation procedure, upon which any safety concept has always to be studied and developed;
in UK the operator on fixed installations is supposed to produce a project safety case, a pre-operative safety case and an abandonment safety case, to be presented at least 6 months before the operation startpoint, while the operator on mobile installations is supposed to produce a vessel safety case as well (prepared by the owner) to be judged by the HSE at least 3 months before starting the operations in British waters. In case of combined operations, the request has to be fulfilled of reaching the accomplishment of the existing safety case, in order to guarantee the adequacy of the conjunct safety standards which have been set. Periodical update regulation has been stated, concerning any further technological and operative change or re-organisation;
in USA the offshore activity has commonly to refer to the US Coast Guard Regulations, to the API Recommended Practices and to the Code of Federal Regulations, where the most important points are contained inside the 33 CFR sub N-OCS Regulations, the Policy Letter n. 13-92, the OPA ‘90 Regulation, where within the Outer Continental Shelf at the Chapter 143.120 (belonging to the 33 CFR Regulations) it is outlined that, before the start point of any OCS floating installation construction, both the owner and the operator have to submit what required to the US Coast Guard. In case of unusual project contents, any alternative project composition is encouraged, since the judgement takes into consideration the equivalent acceptable safety standard. Both the check and the inspection are to be performed by the Minerals Management Service (MMS) and by the US Coast Guard (USCG). FPSOs must undergo the issue of biennial certificates of inspection (COI), while non-US FPSOs (registered overseas) operating in US waters have to accomplish 133 CFR 159.
Generally speaking, it can be said that, while British regulations mainly aim at the reduction of the risk level concerning the personnel (through the concepts of temporary refuge and ALARP), Norwegian and USA regulations show appreciable interest with respect to any kind of risk, and have been developed with respect to a wider purpose (while USA regulations do not provide indications concerning the risk acceptability, the Norwegian ones quantitatively evaluate the risk level affecting personnel, oil spill, material damage, production delay and/or interruption). In Norway, moreover, it is up to the operator to guarantee the safe installation management (through the Internal Check Principle), while in USA and UK the law directly requires the adequate performance of the Safety Management Systems. British regulations consider floating production installations as fixed installations, thus appointing the operator (and not the owner) as the responsible of the safety case preparation and submitting-updating stages. In USA any floating production installation is considered as a tanker, even in case of FPSO destination; moreover, any Contractor has to be selected also according to the presented safety documentation anytime, on the occasion of any undertaking on contract.
As far as applicability is concerned, for the British Regulations the primary task concerns the design of fixed installations and the operations concerning both fixed and mobile installations (where the operator can propose different acceptability criteria for material changes requiring the revision of safety cases), while Norwegian Regulations have to be applied -in a wider way- to any offshore activity.
The most crucial matter keeps being the risk acceptability one, together with the quantitative risk assessment (QRA), directly involving the operator or the owner of the offshore installation, depending on the active regulation standard.

2 - TOWARDS A COMMON REGULATION: OPEN POINTS

As discussed previously, the current existing regulations on Safety Cases / Risk Assessment of fixed and floating offshore platforms are endorsed by few specific countries, i.e. UK, Norway, North America and Australia. The other countries do not have compelling regulations which the operators have to comply to, even if safety issues have to be addressed as well. Usually, in those countries, the operators need only to be compliant with existing structural and operational requirements.
With the current level of technological complexity, this state should no more be accepted, and the operators themselves are well aware of the necessity of constructing and operating their platforms by satisfying specific safety criteria. An approach in line with the existing regulations, and capable to improve system safety, should therefore be well accepted.
From the previous discussion it raises that the Quantitative Risk Assessment is the most commonly suggested tool to evaluate and reduce the risk level, even if the ongoing revision of the UK Safety Case by HSE is going towards a most specific and dedicated use of this technique, and the use of other methods for safety assessment is suggested as well.
Thanks to the experience gained in the current decade, the application of the QRA to **fixed platforms** has obtained a good level of standardisation (at least in the country subjected to Safety Cases regimes), and the critical systems and hazards are well known and studied. For the **floating units** the situation is different because, even if their function is the same as the fixed platforms, their shape and characteristics are closer to oil tankers. Presently, different regulations are applicable to *platforms and ships*, respectively certification and classification, and different regulatory bodies are involved in the assessment process. For example, it was seen before that for the UK Safety Case regime the FPSO is considered as a platform and therefore submitted to Local Authority regimes, while for the US it is considered as a ship, therefore complying mainly with IMO (International Maritime Organisation) regulations. The role of local and international authorities needs therefore to be clearly stated and Risk Analysis has to be well addressed in order to cope with this diversity.
Another important question to be evaluated is the transfer of the FPSO from one field to another one, that is one of the advantages the floating units have with respect to fixed installations. In this case the problem of *compatibility among different regimes* raises. Obviously, closer are the regulations or the approaches which come to be selected, easier is the conversion.
Finally, when attempting to uniform Safety Case regimes among different Countries, the problem of *responsibility* raises. It is in fact necessary to decide who states the methodology of analysis and the acceptance criteria and who approves them.
An open point, not clearly addressed by the existing regulations, is then represented by the risk analysis of operations. In particular, loading / offloading activities, which are specific to the FPSO systems. The existing “Close Proximity Study” (by HSE / HSC 1997) addresses partially this problem, by analysing collision problems between FPSOs and shuttle tankers. Extension of the study to include other risks associated to the operations is necessary and future standards are required. It is for this reason that the Authors strongly believe in the necessity of addressing Risk Analysis studies also to operations, in order to have a global picture of the risk associated to the exercise of the FPSOs.
In order to start to answer these difficult and ticklish questions, attention will be addressed to FPSO systems and the following paragraph will present a methodological approach as compatible as possible with the different existing regimes. The approach, based on risk assessment, is also suggested for fields not regulated by Safety Cases regimes, where it can be applied at different levels of detail in order to enable the operators to fit their specific needs.
Focus is then put on Risk Analysis addressing technical solutions as well as operational activities, and case studies showing a qualitative approach able to provide prompt insights in safety problems are then here presented.

3 - METHODOLOGICAL APPROACH

The traditional Quantitative Risk Assessment /QRA) usually starts with a formal qualitative risk analysis in order to identify hazards and ends within the quantification of the various components of risks, where input data are available. The approach is based on the application of classical techniques, such as

Failure Mode Effect and Criticality Analysis - FMECA, Preliminary Hazard Analysis - PHA, Fault Tree Analysis - FTA, Event Tree Analysis - ETA and Cause Consequence Analysis. By applying them the analyst is thus able:

- to identify hazards and the related *accident initiating events* and *accidental sequences*
- to classify these sequences into *frequency categories,* and finally
- to determine the related *consequences* with respect to the workers, the population, the environments and the industrial production.

The accident initiating events can be identified both by field experience and by provisional tools. Expert judgement and/or accidentology analysis are widely applied together with Failure Modes and Effects Analysis or alternative Hazard Identification techniques. They are performed on detailed system descriptions (at the level of Piping and Instrumentation Diagrams - P&ID) and/or where the detailed design of a system is not yet available, upon functional system descriptions. The identified initiating events which have a similar impact upon the plant are grouped into classes each one represented by Reference Initiating Events (RIE).

The event sequences that may derive from each class are determined by the application of ET analysis to the RIE. Generally, the number of sequences can be very large, as to take into account the totality of the classes and the uncertainty concerning safety system intervention, evolution of phenomena and so on. Each sequence is classified into a frequency category by using a mixed deterministic/probabilistic evaluation approach. The probabilistic approach involves assessing the initiating event frequency and the use of systems fault tree analysis to determine event tree branching probabilities. Where no data are available or where the system design is not sufficiently evolved to perform fault tree analysis, a set of rules and/or expert judgements is used to support the classification into frequency categories.

Consequences of each sequence are assessed by scoring calculations using conservative estimations of phenomena (releases, fires, explosions, dispersion) and are expressed in terms of damage categories. The purpose of the sequence analysis is double: on one hand to calculate the risk, on the other hand to identify the reference accidents that need in depth analysis in order to improve system design, operational procedures, and maintenance planning.

According to the considerations made in the previous sections, a similar approach to assess the safety for FPSO units does not seem up to date because a comprehensive study becomes too expensive and time consuming, and therefore unable to quickly follow system changes and relocations.

The Safety Case, in fact, should be a «living document that needs to be updated to take account of changing activities, technologies and other circumstances» (HSE, 1992). Starting from these considerations, it appears clear that the selection of an appropriate methodological approach plays a fundamental role in achieving exhaustive and updated results:

- “Exhaustive results” means to guarantee that all the hazards have been identified and studied in order to prevent or mitigate the related accidental sequences, considering system design, maintenance and management. Management becomes crucial in the case of FPSO units due to their similarity with transportation systems: they are generally characterised by a changing working environment requiring high variability and safety of operative procedures.
- “Updated results” means to be able to follow the changes in system configuration and, in particular for FPSOs, to easily adapt the safety considerations when the unit is relocated.

As stated above a formalised approach to risk analysis could be a good basis to structure the safety case, but the application of a methodological approach requires that at least the following two needs are fulfilled:

- the necessity of having an integrated methodology able to support risk analysis at different levels of detail;
- the use of the results and significant data obtained during the design phase for risk monitoring during the operative phase.

The first requirement is related to the complexity of the problem: a detailed study, as described before, for all the realistic accidental sequences also taking into account both design and operations is very expensive; in addition it is almost impossible to correctly update it when the unit is relocated. Viceversa an integrated approach based upon both qualitative and quantitative estimation can offer a good opportunity to realise the “living” assessment; a general approach including different levels of detail matches better the approach of northern countries (UK, Norway, USA) that usually apply the QRA in design, but are interested in simplified techniques in order to extend the approach to operations and to consider relocable units, with the needs of other countries that are approaching the overall problem just nowadays.

The second requirement, i.e. the outcomes of risk analysis on operations, is particularly important when moving to consider the operational aspects. Although traditional applications of QRA during system design offers good improvements on the design itself, rarely it contributes to the definition of operational procedures (this is particularly true for maritime industry and more in general for transportation systems). A good approach to risk assessment has to provide prompt insights to improve operational procedures and to validate them.

In this context, the Authors' opinion is that an advanced approach has to be organised in order to integrate an accurate study for specific problems, as provided by the Quantitative Risk Assessment, with quicker approaches able to treat safety issues from a qualitative and comprehensive point of view. In other words, it is necessary to give a better prominence to the qualitative steps of the Risk Assessment that in the QRA are only considered as "preliminaries", and to extend them to operation assessment in order to provide some outputs in the earlier step of the assessment as prompt contributions to safety.

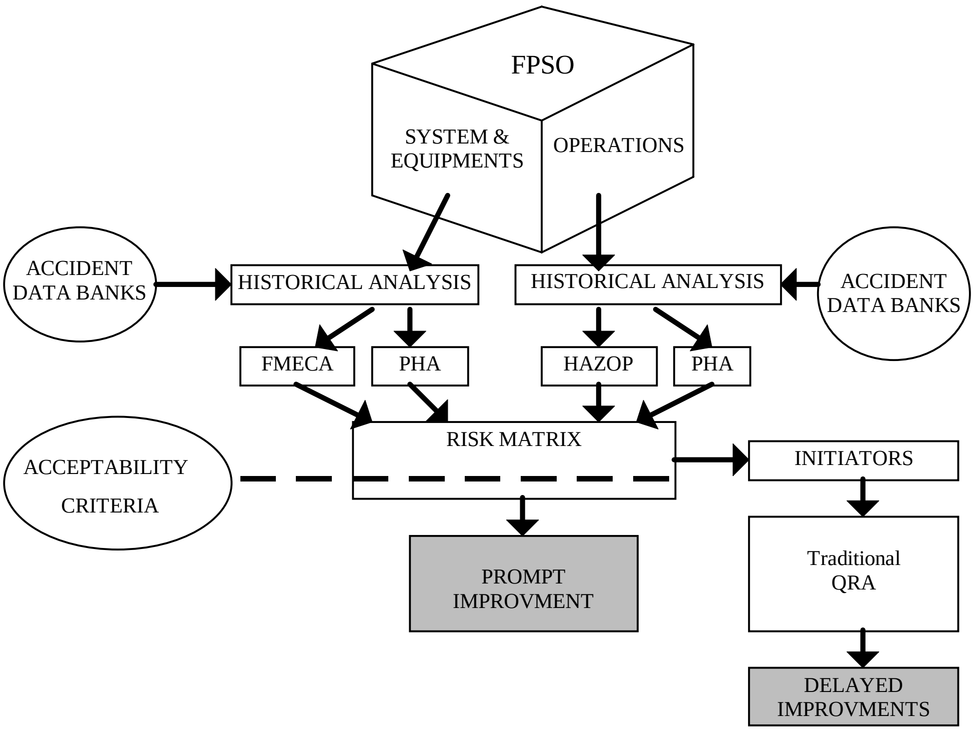

Figure 1. The proposed methodological approach

According to the scheme in Figure 1, since the beginning the analysis should include systems, equipment and operations too.

Historical analysis and expert judgement provide a guide to identify hazards and to estimate failure and accident frequencies, although in qualitative terms. It should be noted that Data Banks supporting this part of the analysis already keep into account operational phases in a certain detail (i.e. WOAD by DNV, E&P Forum DB).

The system/equipment analysis proceeds by PHA for equipment (helicopters, towboats, etc.) and FMECA for systems (turret, X-mas tree, process systems, etc.) while operations and processes will be analysed by PHA in terms of activities and by traditional HAZOP studies.

PHA can be successfully applied in fact to the investigation of system operations focusing the analyses on "activities" and "procedure steps" instead of the usual "equipment" or "system functions" as shown in Figure 2 (Vivalda and Merlier, 1998). An example of this approach is summarised in the following section in order to show how it can provide important suggestions for a safe organisation of system operations.

SYSTEM OPERATION kk

Activity	Deviation	Causes	Operation Effects	System Effects	Freq.	Damage	Risk	Detection	Prev./Correct. Measures
...	...	...	...	...	f_1	d_1	$f_1 \times d_1$		

Figure 2.

All these qualitative investigations can be enhanced by the introduction of a qualitative estimation of risk for each failure mode, action, process deviation. This estimation can be very useful in order to "filter" by a Risk Matrix all the events leading to unsafe situations and to separate the events that can be easily addressed by prompt preventive or mitigative actions, from those requiring more detailed investigations (initiators for the traditional QRA).

The qualitative Risk estimation can be performed by the introduction in the analysis techniques (PHA, FMECA, HAZOP) of qualitative estimations for event frequencies and the related magnitudo of damage. A categorization of them in four classes each (i.e., Unexpected, Rare, Expected, Frequent for frequencies and Negligible, Marginal, Critical, Catastrophic for damage) and the construction of the related Risk Matrix containing the Risk acceptability criteria (Carpignano, Priotti, Romagnoli, 1998) can already provide a screening tool able to select critical components and processes and to address safety prompt improvements.

4 - STUDY CASES

The current paragraph presents two case studies developed in previous works (Vivalda and Merlier, 1998; Carpignano, Priotti, Romagnoli, 1998), where the use of qualitative investigations was applied respectively to the systems / equipment and to the offloading operation of reference FPSOs.
Concerning the investigation of systems and equipment, we can mention the study (Carpignano et al., 1998) performed for the FPSO Firenze installed by AGIP in the south of Italy (Aquila field). The investigation was oriented to assess the safety and the reliability of the production system which is located between the subsea wellheads and the FPSO unit.
Analysis was started by an historical investigation by WOAD, E&P Forum DBs, but due to the poor statistic on FPSO accident some extrapolation was performed by applying data deriving from different kinds of units. This search led the analysts to better understand field problems. In the mean time, several data for qualitative estimations of failure/accident frequencies were found. In particular the investigation has been performed upon the production operating phase, although data concerning different working conditions have been considered (drilling, idle, operating production, construction, support, transfer, other → operation mode) in order to provide a general overview. Frequencies have been qualitatively estimated for the main initiating events: failure in anchor systems, risers and pipelines, blowouts, crane accidents and falling loads, collisions, oil spill / release, natural events.
The second step of the analysis was performed using qualitative techniques. FMECA was applyed to wellhead while the production lines and the turret were studied by HAZOP, from the process point of

view. In both cases a qualitative estimation for frequencies and magnitude of damage has been considered (Figure 3) using the qualitative levels described in Table 1.

Frequency (F):	***Magnitude of damage (D):***
1) Not expected during the life of the unit	*1) Not relevant*
2) Expected one or a few times	*2) Damage to the unit*
3) Expected some times	*3) Injuries or heavy damage to the unit*
4) Expected several times	*4) Loss of life for personel or unit distruction*

Table 1

FMECA: Wellhead

Equipment	Fail. Mode	Local Effect	System Effect	Freq.	Damage	Risk	Detection	Prev./Mitig. Action
...	...	...	...	f_1	d_1	f_1 x d_1		

HAZOP: Turret System & Oil Production

Process	Deviation	Local Effect	System Effect	Freq.	Damage	Risk	Detection	Prev./Mitig. Action
...	...	...	...	f_1	d_1	f_1 x d_1		

Figure 3. The tables adopted to perform FMECA and HAZOP

Qualitative estimation of risk, by the simple product F x D led to categorize component failures and processes according to their criticality. Risk acceptability criteria have been selected using the Matrix shown in Figure 4. The cell background color represents the qualitative risk level R = F x D. Events characterized by a high Risk value (R > 6) will be studied as accident initiators by quantitative techniques (traditional QRA), while the others will be addressed by qualitative investigations only, and directly used to improve system and operation safety.

Frequency (F)				
4: Frequent				
3: Expected		Control system failures (5 events)	Failure in production control (4 initiators)	
2: Rare		Anchoring, failures in production control, rupture of lines (17 events)	Anchoring failures, production control failures, rupture of lines (7 events)	Anchoring failures, structural failures, production control failures (7 initiators)
1: Unexpected		Anchoring and processing failures (2 events)	Processing failures (1 event)	Anchoring failures, **rupture of production lines**, control failures (5 events)
	1: Negligible	2: Marginal	3: Critical	4: Catastrophic

Magnitude of damage (D)

Figure 4. Risk matrix for the accidental events related to the FPSO turret.

The second case study refers to the analysis of oil offloading operations from the considered FPSO. Aim of the study was to apply qualitative risk analysis and comparison criteria, which, in line with the current regulation, would support the designers and the operators of a specific installation and field to select the safer and most profitable practice for oil discharge.
Currently, three main methods are in use to export hydrocarbons to the terminals, i.e. direct discharge through export vessel, Surface Single Point Mooring system (SSPM) and sub-sea pipelines. The first two ones are characterised by the use of a shuttle tanker, which offloads the FPSO or the SSPM at predefined times. The third involves direct discharge through a pipeline connection to undersea or inland storage terminals. Each practice presents its own economic, technological and safety advantages and drawbacks. Moreover, the selection of one rather than the others during the design of a new installation depends on several ***influencing factors***, such as: meteocean conditions, distance from the shore, water depth, personnel skills, FPSO mooring system and local traffic.
In the case study the following three configurations were addressed:

1. tandem transfer by mean of a shuttle tanker not equipped with DP system, thrusters and un-assisted by tugs;
2. alongside transfer with two tugs assisting the shuttle tanker and supply vessel;
3. single buoy mooring with flexible riser carrying the hydrocarbons to the surface.

The method applied to compare the different solutions made use of Preliminary Hazard Analysis, criticality matrix and comparison criteria, which guided the users during the decision processes.
The *probability* of occurrence of the identified hazards and the seriousness of the consequences were qualitatively evaluated by referring to predefined levels. Five levels for both probabilities and consequences are defined (Tables 2 and 3). *Consequences* on people, the environment and property/production were considered. The combination of these two figures (probability and consequences) provides the risk figure associated to the identified hazards.

PROBABILITY	DESCRIPTION
A - HIGH	It is expected that the event will occur several times *during the unit's life time*
B - MODERATE	It is probable that the event will occur few times *during the unit's life time*
C - LOW	It is possible that the event will occur once *during the unit's life time*
D - NEGLIGIBLE	It is improbable that the event will occur once *during the unit's life time*
E - REMOTE	It is extremely improbable that the event will occur once *during the unit's life time*

Table 2. Probability of occurrence

SEVERITY	DESCRIPTION
I - CATASTROPHIC	• Large number of fatalities and/or total loss of the unit; • Major oil pollution with difficult control of situation and/or difficult cleaning of affected areas; • More than 1 year loss of total production.
II - CRITICAL	• Fatalities among personnel and threat to the integrity of the unit; • Significant oil pollution demanding urgent measures for situation control and/or cleaning of affected areas; • Between 6 months and 1 year loss of production.
III - SEVERE	• Serious personnel injuries and/or major damage to the unit; • A few tonnes of oil pollution. Situation manageable; • Between 2 and 6 months loss of production.
IV - MINOR	• Light personnel injuries and/or minor damage to the unit; • A few barrels of oil pollution; • Between 1 week and 2 months loss of production.
V - NON-CRITICAL	• No hazard or risk to personnel and no damages to the unit; • No oil spill; • Less than 1 week loss of production.

Table 3. Seriousness of consequences

A criticality matrix was defined combining probabilities and seriousness of consequences (see Table 4). This matrix was used to classify the hazards rising from the activities associated to each offloading configuration according to their risk levels. Three main regions were identified for risk acceptance:

(1) Non acceptable region
(2) Intermediate (acceptable only if As Low As Reasonably Practicable - ALARP)
(3) Acceptable

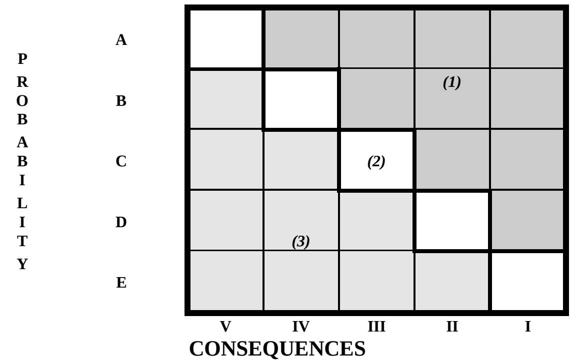

Table 4. Criticality Matrix

The PHA was carried out in two steps. The first one refers mainly to the analysis of the activities closely connected to the offloading practice, without explicit consideration of external influencing factors. The second step consists of a revision and reassessment of the PHA Tables, by the inclusion of external aggravation factors, such as geographical location, weather and sea conditions. The current application of the PHA approach presents two novelties with respect to the classical method. Firstly, activities rather than technical characteristics, are addressed. Secondly, external factors are included in order to customise the analysis to the specific environment where the FPSO is located.
The comparison was then carried out according to the following criteria:

- ***Number of hazards falling within the unacceptable and intermediate regions of the criticality matrix***.
- ***Hazardous escalation of the accident(s)***.
- ***Existence of beneficial preventive/corrective measures***.
  Aggravating factors, *i.e. geographical location, weather and sea conditions.*
- ***Technological implications***.
- ***Economic factors***.

As it can be deduced from their description, comparison criteria are not independent, and their dependencies need to be clearly identified and addressed in the assessment phase.
Table 5 briefly summarises the main results of the study.

Comparison criteria	**Results**
Number of hazards falling within the unacceptable and intermediate region	Prevalence in alongside method
Hazardous escalation of the accident	Oil leakage ➢ common to the three methods Collision with FPSO, personnel accident, fire ➢ prevalent for alongside method Reduced for mooring buoy Collision more frequent for alongside transfer due to the highest proximity
Existence of beneficial preventive/corrective measures	More beneficial for tandem and mooring buoy
Aggravating factors, i.e. geographical location, weather and sea conditions	High influence of wave height, current and wind for alongside transfer High influence of wind and current on mooring buoy Fishtailing problems with tandem method
Technological implications	Mooring buoy more complicated

Economic factors	Mooring buoy more expensive Alongside method cheaper

Table 5.

The results in the table are generic on purpose, but at least they show how a systematic qualitative approach could support the decision taking stages, involving safety issues and economic concerns.
Both the cases highlight the flexibility of the proposed approach to study problems completely different in nature, and its ability to identify critical features or to support decision making, by simply relying upon qualitative assessments.

5 - CONCLUSION AND NEW DISCLOSURES

The paper has presented an integrated approach for risk analysis focusing firstly on qualitative analysis and operational issues, in order to satisfy three main necessities:

1. The need of the countries already endorsing Safety Case regimes, now calling for more flexible tools for risk analysis able to use the existing results of already developed Quantitative Risk Assessment to assess new constructions;
2. The requirement of the Countries just entering into the “Safety Case philosophy”, which need flexible and profitable tools, able to easily show the added value of preventive risk studies;
3. The general need of the offshore community to evaluate, together with the structural and design features, the operational issues, mainly for those technological solutions involving fixed and transport activities, such as the FPSO existing systems.

The suggested approach seems to be a valid tool to guide system safety improvements and better organise operational procedures with limited time consuming and reduced investments. Its potentiality is supported by the encouraging results obtained by its application to the two different case studies, involving both subsystems and equipment and operations.

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