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Spill accident modeling: a critical survey of the event-decision network in the context of IMO's formal safety assessment

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Abstract

In this paper, we present the relationship between an oil spill-assessing approach, namely the event-decision network (EDN) and the formal safety assessment (FSA) of the International Maritime Organization (IMO). We focus on various points at which the Network incorporates basic features of the FSA in order to formulate a state-of-the-art, original strategic tool. In keeping with a safety–friendly effort, we developed the EDN, which implements a scenario-driven, generic tree framework. Moreover, the IMO, under the umbrella of decision-making, has introduced FSA, which is a systematic methodology for enhanced maritime safety by using risk and cost/benefit criteria. It is of interest to describe the introduced spill-scenario analysis/simulation and to pinpoint its interconnections with the aforementioned official instrument. Among other things, the goal of such a task is the enhancement of marine safety and the subsequent protection of seas from oil spills.

Keywords: Oil spills; Risk assessment; Strategic planning; Human factor; Tree analysis

1. Introduction

In the last three or four decades, much has been written about oil marine pollution and the many dangers deriving from it. For many years, the seas all over the world have been viewed as the main dumping site for oil products and residuals, resulting in numerous threats to the marine environment. Oceans have been mistreated by all players involved and from all possible angles. Oil pollution from vessels has often been in the spotlight of the mass media and public opinion in the aftermath of accidents.

Extensive changes to the international regulatory regime resulting from the grounding of the *Exxon Valdez* (1989), the *Erika* spill (1999), and the *Prestige* spill (2002) have recently influenced public opinion. Modern technologies (television, satellites, the internet, etc.) have rendered oil spill imagery accessible to everyone. The sight of seabirds afloat in oil, along with the accompanying "endless discussions about the millions of tax dollars spent in clean-up operations" have reached practically every individual in the countries inflicted, Barker [1]. As shown in Table 1, however, more than 70% of the oil that ends up in the sea emanates from sources other than maritime transport, such as land-based activities and industrial wastes, Ventikos [2]. Nevertheless, much of the recent attention is focused on oil marine transport, mainly due to its cargo potential and the various possible consequences.

The framework of oil cleanup operations is similar to that followed in numerous other applications and is divided into three hierarchical levels: the strategic, the tactical, and the operational, Antony [3]. The event-decision network (EDN) belongs to the category of strategic tools that support and justify the decision-making process. It incorporates all existing knowledge and experience, using the form of multiple aggregated scenarios and event-driven flows. In this manner, it can reveal a generic picture of local oil pollution and host a qualitative/quantitative analysis, covering the spectrum of causes and consequences ascribed to oil spills. The EDN attempts to fill the gap between data acquisition and strategic planning with a safety–friendly and original tree approach.

Abbreviations: IMO, International Maritime Organization; UNEP, United Nations Environment Programme; ITOPF, International Tanker Owners Pollution Federation; FSA, formal safety assessment; HRA, human reliability analysis; RID, regulatory impact diagram; EDN, event-decision network; EPC, error producing condition(s); HE, human error(s); HEP, human error probability

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The International Maritime Organization (IMO) is the body responsible for dealing with all issues concerning the maritime community on a worldwide scale. Its primary duty is to secure—through numerous regulations and initiatives—the best possible level of marine safety for all stakeholders by reducing fatalities, injuries, oil spills, etc. The development of the Formal Safety Assessment (FSA) methodology is part of this effort. It consists of a number of pre-determined tasks, which formulate and elaborate all necessary steps for the successful conclusion of the specific method. Recommendations resulting from a FSA can be used at all hierarchical levels and to cover an adequate range of cognitive topics for IMO [4].

This paper is structured as follows: Section 2 contains definitions of selected marine safety terms. Section 3 presents oil pollution statistics in order to draw a realistic picture of the amount of oil pollution generated by marine vessels. Section 4 provides an introduction to the EDN and the FSA is briefly described in Section 5. Section 6 outlines the key points of the EDN and Section 7 closes the paper with a discussion on the findings.

2. Basic terminology

The development of safety-oriented methodologies, e.g., FSA, is generally characterized by the implementation of commonly used terms. The following definitions were selected in the broad context of marine safety, IMO [4], Ventikos [2].

Hazard	A potential to threaten human life, health, property, or the environment
Initiating event	The first of a sequence of events leading to a hazardous situation or an accident
Error-producing condition	Factors that can have a negative effect on human performance
Human error	A departure from acceptable or desirable practice on the part of an individual or group of individuals that can result in unacceptable or undesirable results
Human error recovery	The potential for the error to be recovered, either by the individual or by another person, before the undesired consequences occur
Human error consequence	The undesired consequences of human error
Human reliability	The probability that a person: (1) correctly performs some system-required activity in a required time period (if time is a limiting factor) and (2) performs no extraneous activity that can degrade the system
Incident	An unintended event that can lead to an undesirable outcome such as an accident
Accident	An unintended event involving fatality, injury, ship loss or damage, other property loss or damage, or environmental damage
Accident category	A designation of accidents reported in statistical tables according to their nature, e.g., fire, collision, etc
Consequence	The outcome of an accident
Frequency	The number of occurrences per unit time (e.g., per year)
Risk	The combination of the frequency and the severity of the consequence (traditional approach)
Individual/societal risk	The risk to an individual in isolation/the risk to society of a major accident.
Risk assessment	The identification of the distribution of risk
Risk control measure	A means of controlling single elements of risk
Fault tree	A logic diagram showing the causal relationship between events that occur and can lead to the occurrence of a higher level event
Event tree	A logic diagram used to analyze the effects of an accident, a failure, or an unintended event

Table 1
"Sources" of oil pollution into the sea

Recorded "sources"	Distribution (%)
Industrial waste, urban runoffs, etc.	60.7
Refineries/terminals	1.2
Natural sources	10.3
Tanker operations	6.6
Tanker accidents	4.7
Other shipping	14.4
Offshore production	2.1
Total	100

3. Oil pollution from vessels

Oil spills from ship accidents and ship operations reflect significant components of oil marine pollution. Possible "sources" of this specific category of oil pollution are tanker accidents, tanker operations, other shipping (including non-tanker accidents and operations, and dry-docking) and in some cases, refineries/terminals. Table 1 presents the estimated contribution of recorded "sources" of oil pollution into the sea, United Nations Environment Programme (UNEP) [5].

Table 1 proves that, despite the publicity given to oil tanker accidents, it is the land-based activities (including industry, sewage, tourism, and dumping) that contribute the most to sea pollution from oil. Actually, estimations can be made for the quantities of oil that are finally conveyed into the sea from these "sources". An acceptable range of values varies from 1,700,000 to 8,800,000 tons per year, with a value of about 2,500,000 tons of oil per year (with 1,480,000 tons coming from land spills) the most common one in several relative studies, UNEP [5], Clark [6].

As long as maritime traffic takes place, oil spill accidents will occur. Moreover, a spill response plan should not focus exclusively either on operational pollution or on pollution generated by accidents. Such a plan must provide for a combined spill countermeasures plan, capable of protecting the marine environment. Its implementation should therefore yield to the most efficient solution, taking into account all existing situations.

Table 2 depicts the distribution of causal factors (operations and accidents) for spills from oil tankers, International Tanker Owners Pollution Federation (ITOPF) [7]. It is apparent from the table that most tanker spills result from routine operations, which normally occur either in ports or at oil terminals. The majority of these operational spills are small, with some 92% of them generating quantities less than 7 tons each. On the other hand, accidents (such as collisions and groundings) usually turn into much larger oil spills, with about 20% of them involving quantities more than 700 tons of oil each, ITOPF [7].

It must also be noted that important steps towards oil pollution mitigation have been recorded over time as a result of the implementation of stricter regulations and modern technologies. For example, the number of tanker spills of more than 700 tons has declined from an average of 24.1 spills per year for 1970–1979, to an average of 8.8 spills per year for 1980–1989, and 7.3 spills per year for 1990–1999, ITOPF [7]. The same reduction tendency has been noted for operational oil spillage. In particular, oil pollution from tanker operations has decreased from 700,000 tons of oil in 1981 to about 158,000 tons in 1989 (mainly due to cargo-specific systems and segregated ballast tanks). For the same time period, the oil pollution from dry-docking has been reduced from 30,000 to 4,000 tons, Clark [6].

4. The EDN: introduction and structural features

As already mentioned, the EDN has been developed to support the survey of oil pollution from a strategic perspective, based on a generic event/scenario analysis. This system can present a broad qualitative and quantitative view of vessel-generated oil pollution in each area under examination. Its main goal is to integrate all recorded polluting incidents/accidents in a pre-formatted structure that covers all possible versions and variations of spill appearance and reactions. This means that, instead of the network being adjusted for the properties and features of each accident, it is the incidents themselves that enrich EDN's pre-determined paths through an *OR*/*AND* node-oriented framework. This way, the entire process is based on general and easily accessible data about sea pollution. The basic stages of EDN are equivalent to the nodes of a generic tree approach, in a risk contribution tree-like template (a combination of an event and fault tree approach). More specifically, these stages are related to:

- the classification and regression of all recorded causes and events of accidents;
- the existence of human actions that influence the error-producing conditions and the evolution of an event chain.

The EDN consists of the following basic stages with *AND* vertical connections, Ventikos [2], Ventikos et al. [8]:

(I) initial course of actions (initiating event);
(II) field of actions;
(III) monitoring—performance and proactive process for unwanted results;
(IV) main causes [including the category of human error (HE), causal analysis in a fault tree template];
(V) direct causes [refers to error producing condition(s) (EPC), causal analysis in a fault tree template];
(VI) type of vessel involved;
(VII) occurrence of problem—overcoming the first physical barrier (including consequences of human error and accident categories);

Table 2
Causal distribution of spills for oil tankers (1974–2000).

	<7 tons	7–700 tons	>700 tons	Total
Operations				
Loading/discharging	2763	297	17	3077
Bunkering	541	25	0	566
Other operations	1165	47	0	1212
Accidents				
Collisions	159	246	86	491
Groundings	221	196	106	523
Hull failures	561	77	43	681
Fires/explosions	149	16	19	184
Other/unknown	2217	163	35	2415
Total	7776	1067	306	9149

(VIII) extent of problem—amount of leakage (quantitative aspect in an event tree template);
(IX) initial monitoring and limitation of problem-pollution;
(X) assessed targets (combining individual risk and societal risk approaches);
(XI) coordinated control—counter-pollution actions (risk control measures);
(XII) outcome—consequences of EDN (quantitative aspect in an event tree template).

As is shown in the 12-step list, EDN attempts to provide for all possible variations that could be encountered throughout the entire extent of an oil spill chain; i.e., from its starting point to its consequences.

Initial course of actions: This stage represents the initial order or action of the event sequence. Its disjunctive branches can be movement, maneuvering, ship operations, or port operations.

Field of actions: This stage refers to the type or the "activities" of areas where oil spills occur. Its options provide for open sea, sheltered waters, ports and roads, or "activities", e.g., bunkering area, etc.

Monitoring—performance and proactive process: This stage is characterized as a qualitative one; the progress of EDN presupposes that processes provided for performing operations on board vessels either fail or are not followed, at a rate of 100%.

Main causes: This stage indicates the main categories of causes that lead to the occurrence of oil pollution from maritime transport. EDN provides the possibility of multiple and simultaneous deployment of its branches, if a combination of main causes is detected. Fig. 1 shows the layout of this structure with all its pre-determined *OR* options. These are human factors, vessels (e.g., main engine problem), environmental conditions, or other (not included in the previous groups).

Direct causes: This stage allocates the actual causes of oil spills generated by maritime transport procedures. Its options are strictly related to the branch selected at the Main Causes stage. Therefore, if the cause of the pollution is the human factor, then the options expected at this step will be different from the ones that emerge when the spill is related to ship failure. It includes numerous types of causes, such as underestimation, lack of skills, training issues, negligence, etc. for the human factor; hull failure, electrical and engine problems, etc. for the vessel; adverse (weather) conditions, visibility, etc. for environmental conditions; and port equipment, act of war, etc. for other causes.

Type of vessel: This is the stage at which the EDN integrates the type of ship involved in oil leakage. It includes loaded tankers, tankers in ballast, passenger vessels, cargo vessels, or other types of vessels.

Occurrence of problem—overcoming the first physical barrier: This stage presents the combination of the recorded problem along with the way oil containment failed. Therefore, EDN provides either for grounding/stranding—hull rupture; collision/ramming—hull rupture; explosion/fire—hull rupture; hull failure—hull rupture; other—hull rupture; intentional discharge; tank overflow—leakage; bunkering system malfunction—leakage; or oil loading/unloading system malfunction—leakage.

Extent of problem—amount of leakage: This stage covers the amount of spilled oil. The Event Decision Network uses the categories of less than 149, 150–2999, and more than 3000 tons in order to classify the size of oil spills in a flexible manner, Devanney and Stewart [9].

Initial monitoring and limitation of problem—pollution: This is a purely qualitative stage of the Event Decision Network (EDN). It is assumed that necessary actions (e.g., SOPEP, spill monitoring and tracking, etc.) are normally carried out.

Assessed targets (local activities): In this stage, EDN provides for the areas affected by oil pollution through a number of disjunctive branches. These are urban/tourist areas, coastal industrial zones, sensitive areas, commercial areas, and none (sea area).

Coordinated control—counter pollution actions: This is the substantial reference of EDN to approach the anti-pollution actions. It refers to non-controllable—non-persistent pollution; controllable—persistent pollution; non-controllable—persistent pollution; or controllable—non-persistent pollution.

Outcome—consequences of network: This is the terminal node (leaf) of EDN. It incorporates an enhanced cleanup cost figure that can describe the dynamics at play for each developed pollution flow. So EDN anticipates with an event-tree structure for a monetary outcome of up to €10,000, between €10,001 and 750,000, or finally, more than €750,000 (in 2001 prices). Indicatively, the corresponding monetary "result" for an aggregated pollution scenario is given by Eq. (1).

$$\text{XII}[€] = \sum_i [\text{active length[km]} \times \text{unitary clean up cost}[€/\text{km}]] \quad (1)$$

where i is the category index for the shore types affected in a developed pollution flow and *active length* is the

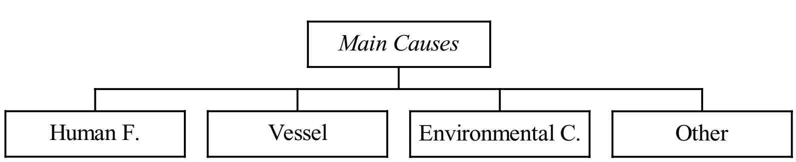

Fig. 1. Layout of the provided disjunctive options for main causes.

respective calculated coast length, according to their stranding attributes.

In closing, it is briefly noted that the EDN provides a sophisticated approach—called pollution potential—to the risk assessment of each pollution flow. Eq. (2) depicts this tree-modulated way, which is based on Bayesian theory, in order to describe elegantly the significance of each group event sequence leading to oil marine pollution, Ventikos [2], Ventikos et al. [8].

$$\text{P.P.} = \left\{ (p_{\text{MC}}/\text{fa}) \times \sum_i p_{\text{DC}_i} \times \sum_k \text{SV}_k \times \sum_l p_{\text{AT}_l} \times \sum_n \left(p_{\text{OT}} \times \text{outcome} \begin{cases} \text{AT}, & \text{AT} > 1 \\ 1, & \text{AT} \leq 1 \end{cases} \right)_n \right\} x \quad (2)$$

Pollution potential (P.P.) is given under the form of an expected value revealing the risk of structured flows, where p is probability, MC is main cause, fa is field of actions, DC is direct causes, SV is joint study of EDN stages 7 and 8, AT is assessed targets, and OT is outcome. Moreover, this formula overcomes the traditional definition of risk and it handles all flows with risk aversion derived from the power at the outcome stage. This is based on the number of assessed targets affected in the context of each flow.

5. IMO's formal safety assessment (FSA): introduction and structural features

FSA is a structured and systematic methodology aimed at enhancing maritime safety (protection of life, the marine environment, and property) by using risk and cost/benefit criteria, IMO [4]. It can be used to help in the evaluating new or existing safety regulations, improved practices, etc. This can be done by achieving a balance between various technical, operational, and cost issues, including subjects such as the human element and innovative technologies.

Through FSA, decision-makers will be able to apprehend the effect of proposed regulatory or procedural changes in terms of benefits (e.g., expected reduction of fatalities or pollution) and of related costs incurred for the industry either as a whole or for individual parties. Thus, FSA is regarded as necessary for proposals that may have far-reaching implications in terms of societal or marine community practices. A corresponding study may also be useful in case there is an acknowledged need for risk reduction and the required changes are unpredictable.

The process begins with defining the problem along with its respective boundary conditions or constraints. This task should be consistent with operational experience and current requirements and it should take into account all standing aspects (e.g., ship and accident category, onboard systems or functions, etc.). The FSA consists of the following steps, IMO [4], Karidis and Vasilakos [10]:

1. identification of hazards;
2. risk assessment;
3. risk control options;
4. cost benefit assessment; and
5. recommendations for decision-making.

Before initiating the actual detailed application of FSA, an introductory implementation of the method is suggested, e.g., for the corresponding vessel type or hazard category, in order to ensure that all necessary aspects are incorporated. A generic pre-model should therefore be developed to describe the functions and features that are common among the reviewed players. This generic approach should not be viewed as an analysis targeting an individual vessel/procedure, but rather as a collection of systems (organizational, management, operational, human, electronic, and hardware) to identify the target functions.

At this point it must be noted that the human element is one of the most important contributory aspects both to cause (up to 50% for tankers and 80% for the ensemble of the commercial fleet) and avoidance of accidents, IMO [4], Ventikos and Psaraftis [11]. Hence, human issues are being systematically treated within the FSA framework, associating them directly with the occurrence of accidents and their primal causes.

The most appropriate technique for incorporating the human factor is Human Reliability Analysis (HRA), which consists of the following stages, IMO [4]:

1. identification of key tasks;
2. analysis of key tasks;
3. identification of human error (HE);
4. analysis of HE; and
5. quantification of human reliability.

HRA was originally developed and implemented for the nuclear industry. The application of this methodology in other industries, such as the maritime one where the human element is more likely to influence the system performance, requires that all techniques used should be suitably adapted. HRA can be performed on a qualitative or quantitative basis depending on the FSA's level of detail and its broad scope. If a quantitative analysis (including expert judgment) is in order, then human error probability (HEP) can be derived to fit into relative system-models, such as fault or event trees.

FSA step 1—identification of hazards, IMO [4]: The purpose of step 1 is to identify hazards and consequently generate a prioritized list of hazards. The approaches used for hazard identification implement both creative and analytical techniques (e.g., expert judgment, HRA, statistical analysis, etc.). The hazards should be screened and prioritized in order to discard possible scenarios of minor significance using various ranking methods, e.g., risk matrix.

FSA step 2—risk assessment, IMO [4]: The purpose of step 2 is to identify risk distribution and assess the respective factors that influence risk level. This is achieved by implementing risk contribution trees and by developing regulatory impact diagrams (RIDs) that link the regulatory and policy regime to the event chain.

FSA step 3—risk control options, IMO [4]: The purpose of step 3 is to propose efficient and feasible risk control options regarding the level of aggregated risk, frequency, outcome severity, and uncertainty of pollution accidents. This can be done either by relating how a measure can alleviate risk (risk attributes), or by tracking where in the "initiating event to failure" sequence, risk control can be inducted.

FSA step 4—cost benefit assessment, IMO [4]: The purpose of step 4 is to identify benefits (reductions in fatalities, oil pollution, etc.) and costs (including training, new technologies, etc.) associated with the introduction of risk control options from step 3. The key point of step 4 is the estimation of cost effectiveness for each option in terms of net cost per unitary risk reduction.

FSA step 5—recommendations for decision-making, IMO [4]: The purpose of step 5 is to make recommendations for the decision-making bodies (e.g., IMO) aimed at keeping risk as low as reasonably practicable (ALARP).

6. The EDN in the critical context of FSA's guidelines: framework and attributes

The principal aim of the efficient development of the EDN was to follow the outline of corresponding intentions and initiatives from IMO. As a result, a comprehensive view on the matter indicates the direct incorporation of various FSA features in its structure and choices. This section presents a key sample of these points of relevance focusing on the pollution-oriented functionality of EDN.

The framework of the EDN initially refers to the generic model introduced at the preliminary phase of FSA. More specifically, its pre-determined options predict the ship's "hardware" (e.g., electrical system), the ship's "software" (e.g., crew), the management infrastructure and personnel (e.g., maintenance, fleet operations, etc.), and the outer environmental context (e.g., weather conditions). These systems are dynamically affected by each other, IMO [4].

The EDN can embody the above four components, mainly in stages IV, V, and VI exploiting accident causes (human factor, weather, etc.) and vessel type/condition (e.g., loaded tanker, passenger, etc.). The original risk approach of EDN (pollution potential) takes into account these components through selected stages and their branches (e.g., lack of training, visibility, etc.), in exploratory statistical terms (expected values), Ventikos [2], Ventikos et al. [8].

The EDN deals with numerous aspects of FSA's step 1, "identification of hazards". In particular, the structure of the specific approach belongs to the standard spectrum of techniques (fault and event trees, hazard operability and failure mode, and effect analysis) relating to a coarse analysis of causes and outcomes for all accident categories, IMO [4]. Hence, EDN with its 12-node tree-proposal promotes event/fault tree solutions, in the context of proactive reactions and countermeasures to oil spills from maritime transport. It operates under the umbrella of an original scenario-causal chain, in terms of a generic event/fault tree, Ventikos [2], Ventikos et al. [8]. "Scenarios are typically the sequence of events from the initiating event up to the consequence, through the intermediate stages of the scenario development", IMO [4]. This way, EDN is able to cover the whole range of causes of ship-generated pollution (e.g., determine its multi-level causes) and, at the same time, retain its basic descriptive, relational, and analytical characteristics.

The EDN also performs as a sub-base for ranking of the identified hazards. The implementation of the specific tree approach creates the necessary conditions for their appropriate screening. This effort uses either risk matrices (suggested for individual risk), or frequency towards number of undesirable consequences diagrams (suggested for societal risk) in order to reach its aim, Ventikos [2], IMO [4].

EDN comprises critical features of FSA's step 2, "risk assessment". The calculation of pollution potential for each developed flow is a substantial analysis of risk. The specific risk formula is in a position to evaluate the significance of the recorded pollution paths pointing to a comparative framework. Stages IV, V, VII, VIII, optionally X, and XII of EDN formulate a quantifiable structure, following the outline and context of FSA's risk contribution trees, Ventikos [2], Ventikos et al. [8]. Thus, it demonstrates oil spill causal combinations, probing the progress of spill events and their consequences through pre-determined event/fault tree choices. EDN can also support, in the high level sense, FSA's component, RID. Stages IV and V can actually be a qualitative part of a RID, a modeling route for the multi-fold influence framework of an event. Apart from the two aforementioned stages (direct and organizational), this FSA instrument needs a regulatory and a policy level to conclude its structure. RID perceives risk profile as a dependant of human factor, organizational aspects, market hardware, and regulations, allowing one to achieve a complete picture of the specific problem, IMO [4].

In the context of FSA's step 3, "risk control options", EDN presents interesting features. Its cumulative scenario identity provides for certain structural points at which risk control measures can be introduced in various ways. All the stages of EDN, except the terminal one (leaf), are therefore developed as nodes of controllable interference for preventing oil spills or mitigating their consequences. Possible control options can include training, technological innovations, communication aspects, emergency procedures, continuous maintenance schedules, etc., Ventikos [2].

Supplementary to the above, it must be noted that the human element is carefully integrated into EDN branches, e.g., its causal stages IV and V. Therefore in the outline of HRA, this methodology can produce—through its quantitative approach—numerous Human Error Probabilities

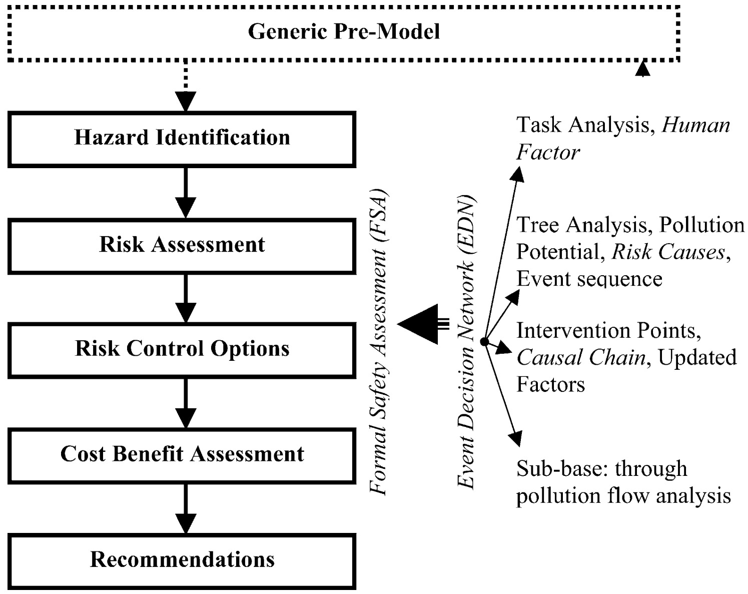

Fig. 2. Relevance feature diagram for EDN and FSA.

(HEPs) indicating human involvement in oil spill occurrence and spreading. Moreover, several of EDN's stages (I, III, IV, V, IX, and XI) take into account the recorded diversification of human conduct. This is done by accepting multiple human-related causes in one pollution path, interpreting the initial order with relative criteria, or combining anti-pollution operations with human efficiency, Ventikos [2], Ventikos et al. [8].

The up-to-date EDN does not incorporate separate features of the remaining two steps of FSA. Even so, it can still support various aspects of the decision-making process on issues concerning oil spillage from maritime transport, mostly through its structured pollution flows. Hence, it can pinpoint its hazards, formulate accurate risk assessment schemes, and introduce possible control measures in order to assist in the strategic planning for oil spills generated by ships.

Fig. 2 depicts the recorded basic overlaps between FSA (including HRA) and EDN. More specifically, it shows the aforementioned points, where EDN can be considered either as an application, an extension, or even a supplementary procedure related to the five basic steps of FSA. It is noted that EDN's structural and methodological conformation to FSA standards forms for the first time (to the best knowledge of the authors of this paper) an outline for a respective pollution-oriented survey on the strategic level of oil spill prevention/confrontation. Fig. 2 therefore explores schematically the correspondence of EDN (on the right; human-related attributes are presented in italics) with FSA's structure shown on the left of the figure.

7. Discussion

Oil pollution from maritime transport is a continuous and unpredictable threat to the quality of the marine environment. Many initiatives have been taken and even more regulations have been implemented aiming at the IMO Proclamation for Clean Seas. As result, there has been a significant reduction in oil spillage generated by ships and relative "sources". However, certain vessel types (e.g., tankers) are still important pollution players, mainly due to their potential for massive and catastrophic spills.

The IMO is the body responsible for handling all aspects of safe shipping on a worldwide scale, including protection of seas from oil pollution. FSA is actually its effort to codify all marine safety issues in a systematic manner. On the other hand, the EDN represents a structured method for a complete strategic approach—through tree scenario development under conditions of uncertainty—to matters of oil pollution from ships. Thus, EDN has adopted certain FSA attributes and techniques in order to produce a fully compatible process in keeping with IMO directives.

One of the key features of EDN is the extensive coverage that it provides of cumulative local spill paths. Its pre-determined framework is planned to incorporate all possible variations from the initiating event up to the consequences of an oil spill. This is one of the main advantages of the specific methodology, since it is in a position to describe and take into account all dynamics at play. For instance, EDN integrates all three levels of task analysis: the high level that describes a broad overview of main functions, the detailed level that deepens in the aforementioned task, and the extended level that focuses on understanding its rationale, e.g., the decisions/actions that are taken.

Moreover, EDN provides for an event-oriented risk assessment that can realistically simulate all selected aspects that lead to oil spillage from maritime transport. In this approach, EDN manages to integrate human factors into its structure as part of an advanced survey related to causal analysis for oil pollution from ships. The incorporation of "local activities" and the capability of assigning responsibilities to shore personnel are examples of this qualitative approach.

The ultimate goal of EDN is to present a promising strategic approach that is capable of handling issues of marine safety, such as oil pollution. The structure of EDN can incorporate all spill events in a defined area formulating cumulative pollution flows and depicting the local pollution patterns. In this way, it will contribute along with other similar efforts, towards a safe and clean marine environment.

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