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The Usage of Tree Analysis in the Context of a Strategic Approach Concerning Incidents of Oil Marine Pollution: Introduction of the Event-Decision Network

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ABSTRACT

In this paper, we present the development of a tree analysis approach for the strategic level of handling and confronting oil pollution incidents-matters. We describe its basic structure (levels of factors) and the way it can formulate the local oil pollution. The paper is concluded with the presentation of an indicative example.

KEY WORDS: oil spills, strategic planning & tree analysis.

INTRODUCTION

It is a well-known fact that satisfactory confrontation of a critical situation such as the appearance and action of oil spills, requires an *a priori* integrated strategic plan. Thus, it is required that there would be a realistic and updated general action plan available and ready for usage. The aim of this effort is to provide a detailed separation of duties and obligations, so that in case of an emergency an anti-pollution operation can be organized quickly and effectively. Strategic planning for cases of confronting marine pollution must be in a position to respond to questions like "…in which area are spills likely to appear within a specific period of time?" or "…which areas are sensitive and in need of more protection from oil spills?"

Over the last fifteen years, a significant shift in interest has been recorded in relation to the way that issues of oil marine pollution are being handled. The relative initial thinking (at least up to the mid 1980s) was limited to complete and rapid confrontation towards oil spills. Therefore, every pollution incident was examined aiming solely to the greatest possible reduction of the upcoming damages caused by it.

Towards the end of the 1980s it seemed that the simple reaction coming from the appearance of oil spills was not enough to truly protect the marine environment and its corresponding economies of scale. Under these conditions the tactic of prevention began to dominate the scene for handling situations, which could lead to marine pollution. In this way, focus was placed on programmed procedures that could avert certain unfavorable circumstances before they even appeared.

In recent years (in particular after 1991) an additional trend has been recorded relating to integration of the manner of assessment and reaction towards issues relating to marine pollution from oil spills. This is being done as a part of a wider environmental policy with totality as it's main characteristic. Thus, the problem of the appearance of spills is no longer an isolated risk but it is perceived as a part of a systematic mechanism of procedures and structures with an ecological and environmental focus.

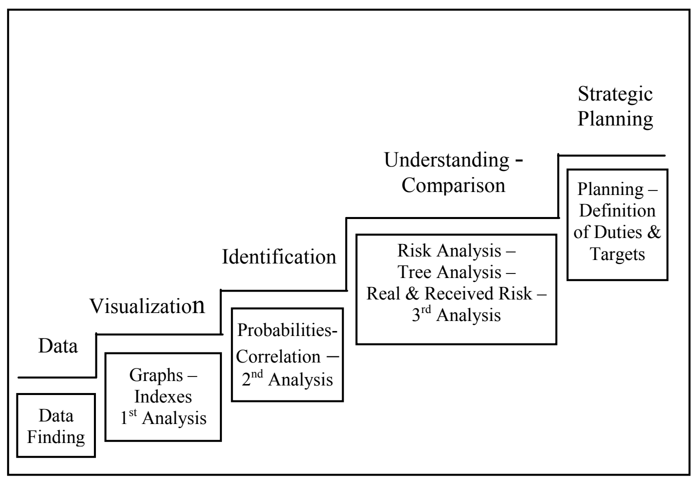

Fig. 1: Scale of Development for the Strategic Level of Oil Confronting Operations.

Figure 1 depicts the technical steps required for the formation of an integrated perception for the strategic level of operations that confront oil marine pollution. In addition, this could be considered as a *terminus a quo* and a consequent intellectual basis for the application of an efficient tree analysis.

The structure of this paper is as follows: the next section provides the outlook of an extensive relative bibliographic research (tree analysis) while the following one introduces in some detail, the event-decision network and its basic structure (stages). Then, it integrates a fully exploitable example of a selected oil spill incident and the paper is concluded with some brief conclusions and comments from the implementation of the event-decision network.

TREE ANALYSIS (BIBLIOGRAPHIC RESEARCH)

Of great interest are the findings of a bibliographic research in relation to various predetermined (tree) methods for assessing the "importance" of incidents and naval accidents threatening human life and the quality of the marine environment. These results are shortly discussed below:

(i) The IMO Formal Safety Assessment method (Karidis & Vasilakos, 2000). This applies to a series of procedures that have already been deemed to be reliable by the IMO. In brief these procedures are:

1. Risk identification
2. Risk evaluation (this stage includes the risk contribution tree)
3. Selection of risk mitigation measures
4. Cost Benefit Analysis and
5. Proposals for decision-making.

(ii) Another effort that covers the main causes and contributing parameters for the appearance of spills from a different point-of-view is as follows (Harrald et al., 1997):

Step 1: Gathers all possible measures for reducing risk,
Step 2: Forms general groups for the risk reduction measures depending on proposed actions, etc.,
Step 3: Corrects and reassesses possible risk reduction measures,
Step 4: Forms general groups for the risk reduction measures depending on proposed performance, etc.,
Step 5: Structures various protection measures in relation to the main scenario,
Step 6: Correlates performance of measures with system parameters,
Step 7: Formulates the risk mitigation measures performance, and
Step 8: Generates results through the evaluation of the proposed measures.

(iii) The proposal for network (tree) analysis that has been spotted for the combined study of accidents and oil spills is of interest (Novack et al., 1997). The main steps are as follows:

- Inaugural event,
- Planning & possibilities,
- Execution,
- Monitoring & avoidance,
- Initial limitation (physical barrier),
- Initial identification,
- Initial restoration,
- Risk limitation,
- Secondary limitation and
- Final restoration

(iv) Finally a proposal was identified that uses the following main categories of information to analyze oil pollution – from shipping accidents and operations (Gregory et al., 1997):

- Sources of oil marine pollution,
- Procedures implemented at the time of the polluting incident,
- Direct causes,
- Contributing factors, and
- Main cause.

The event-decision network is called upon to support the study (assessment, prevention and dealing with) of oil pollution from a different perspective. The concept was based on the existing need for an immediate and broad view of the appearance and consequences of oil spills on the environment of the affected areas. Thus, the existence of a standard methodology for a realistic presentation of predefined parameters contributing to sea pollution (classification/regression trees) forms the basis for the beginning of a rational effort to study of spills at all relevant levels (Edelstein, 1999). Therefore, the event-decision network is in position to present the wider qualitative and quantitative view of oil pollution into each area under examination. Consequently, the competent agents will be able to formulate a realistic and global impression for the local oil pollution with practically one glance to the introduced network. This is achieved by integrating all recorded polluting incidents in a general and preformatted structure of certain basic stages that are in a position to cover all possible versions and variations of spill appearance and actions.

In this case, in brief, instead of the network being adjusted according to the properties and features of each incident, the incidents are the ones that enrich the predetermined paths of the event-decision network. Thus the preconditions are met aiming to a continuous enhancement of data, which will result in increasing confidence of the upcoming results. In fact, the entire process becomes even more attractive if it is considered that all pre-selected figures of the event-decision network are placed at a strategic level and initially cover all possible scenarios of the progress of an oil spill incident. Therefore, the entire process is based on general, flexible and easily accessible data that can give the real aspect of everyday practice on issues relating to sea pollution.

In fact, the basic stages of the network are more or less equivalent to the nodes of a generic tree approach. These are related to (i) the classification and regression of all recorded events for a more complete examination, as well as (ii) to the existence or not of human reaction (even due to external circumstances), concerning the progress and outcome of a certain adopted scenario. Thus, these are the points indicating the type and direction of selected actions in relation to the description and differentiation of the results of an initial incident. Moreover, reaching to the limits of each basic stage, it is possible to assess all proposed proactive antipollution measures aiming to the qualitative protection of the sea and coastal environment.

In accordance with the following figure, the event-decision network comprises of the following basic stages:

- Initial Direction (Order) of Actions (I),
- Field of Actions (II),
- Monitoring - Performance & Proactive Process for Unwanted Results (III),
- Main Causes (IV),
- Direct Causes (V),
- Type of Vessel Involved (VI),
- Occurrence of the Problem -Overcoming of 1st Physical Barrier (VII),
- Extent of Problem - Amount of Leakage (VIII),
- Initial Monitoring & Limitation of Problem-Pollution (IX),
- Assessed Targets (X),
- Coordinated Control - Antipollution Actions (XI) and
- Outcome - Consequences of Network (XII).

Hence, it is of immediate interest to provide a first view of the partial interfaces as well as of the general shape that the event-decision network tends to obtain. Figure 2 shows exactly this basic structure with some additional graphic information about the bypass procedure (calculation of a newly - introduced magnitude called "pollution potential"). This magnitude is out of the scope of the present paper. It is quite obvious from Figure 2 that the event-decision network attempts to “cover” all possible variations that could be encountered through the progress of an oil pollution incident.

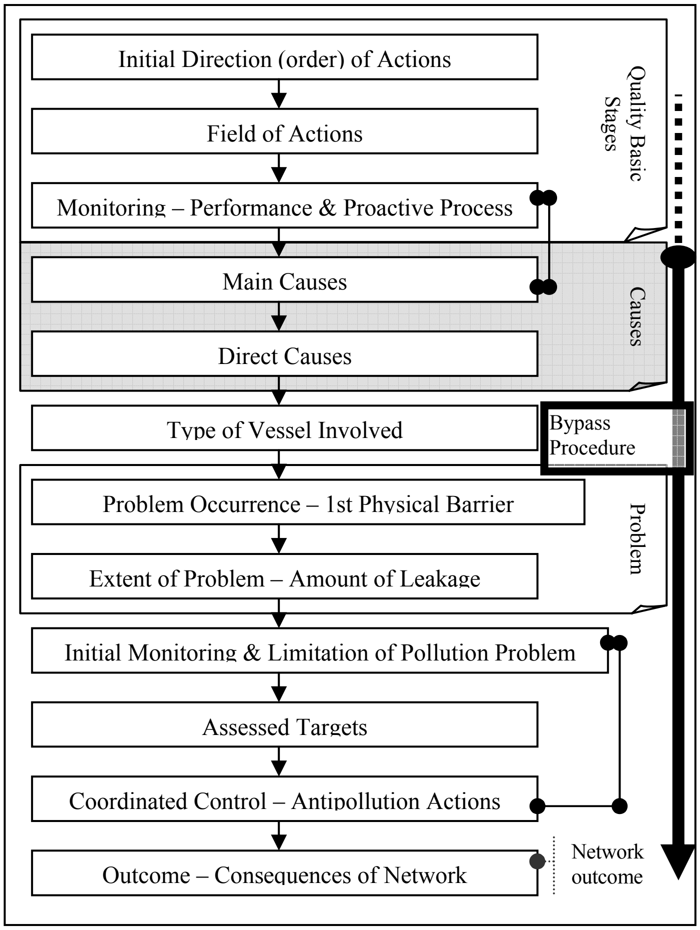

Fig. 2: Basic Stages of the Event-Decision Network (& Bypass Process)

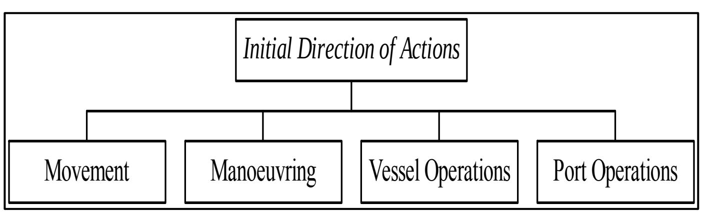

Fig. 3: Layout of 1st Stage with all of its Predetermined Options

Initial Direction (Order) of Actions: this stage has to deal with the order or operation regarded as the beginning of the event sequence that forms all oil pollution incidents. Actually, at this step the so-called "accident error" is not taken into account, since there are processes provided for all procedures on board. Figure 3 shows the layout of this stage with all of its predetermined options.

As Figure 3 presents, the Initial Direction (Order) of Actions provides in total, the following options:

- Movement,
- Manoeuvring,
- Ship Operations and
- Port Operations.

Field of Actions: this is the type, (or the “activities”) of the area where the examined oil spill occurs. In fact, this stage provides a rather more qualitative approach to oil pollution, than a simple spatial distribution.

The stage of the Field of Actions provides in total the following options:

- Open Sea,
- Sheltered Waters,
- Port & Roads and
- “Activities”: areas that are known for the bunkering or the loading / unloading of vessels.

Monitoring -Performance & Proactive Process: this basic stage may be characterized as a purely qualitative intervention to the flow of pollution. In brief, the event-decision network assumes that the processes provided for performing operations on board each vessel are understood and followed. From this point of view, if everything is done to the letter, then the network assumes that it is safe to terminate the development of the event and skips the entire remaining tree structure. Therefore, in order to develop the event-decision network beyond this stage, something should have gone wrong. Thus, it should be understood that the course of the event-decision network (and the subsequent calculation of the pollution potential) requires 100% failure of this basic stage.

Main Causes: this is the stage indicating the main categories of causes leading to the occurrence of sea pollution coming from marine transport procedures. Figure 4 shows the layout of this basic node with all of its predetermined options.

It is of crucial importance to rationally and accurately assess the main cause of the spotted spill. If this is not possible (it is not a trivial task), then a multiple and simultaneous deployment of various branches of the event-decision network is being carried out. As Figure 5 depicts, the Main Causes provide in total the following options:

- Human Factor,
- Vessel,
- Environmental Conditions and
- Other.

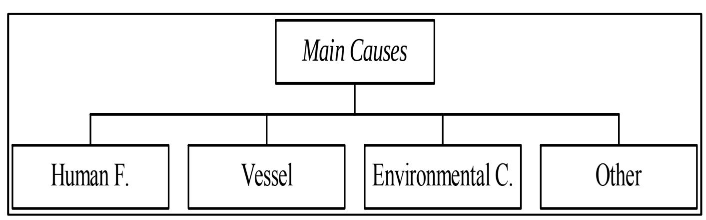

Fig. 4: Layout of the Options for the Main Causes

Direct causes: this is the node where the actual causes contributing to sea pollution are allocated. It is only natural that the options of this stage are strictly related to the course followed by the event-decision network (mainly at the Main causes stage). Therefore, if the "source" of the pollution is attributed to a human factor, the options expected at the present step are different from the ones that are emerging when the spill is due to a ship failure. If more than one direct cause are being attributed to the evolution of a spill incident, then the multiple and simultaneous development of various branches under Direct Causes stands here too. Naturally, the number of causes that may be recorded in such an effort is huge. This would only mean a significant lack of flexibility for the model. However in the context of this network several homogeneous causes were classified in larger and operable groups.

In case that the Direct Causes are in relation to human factor, they provide the following options:

- Underestimation etc.,
- Lack of skills – Training etc.,
- Insufficient Maintenance,
- Misjudgment,
- Unjustified Negligence and
- Organization Problems -Processes.

In case that Direct Causes are in relation to the ship factor, they provide the following options:

- Hull Failure·
- Electrical and Engineering problems and
- Electronic - Communication equipment.

In case that Direct Causes are in relation to the environmental conditions, they provide the following options:

- Geo-morphology,
- Adverse Conditions and
- Visibility.

In case that Direct Causes are in relation to the other causes branch, they provide the following options:

- Port Equipment,
- Act of War and
- Miscellaneous.

Type of Vessel (over 100 GRT): this is the stage where the event-decision network integrates the type (and condition) of the ship provoking the oil leakage into the sea.

The Type of the Vessel stage contains the following options:

- Tanker- Loaded,
- Tanker- Ballasted,
- Passenger Ship (powerful Greek industry),
- Cargo Vessel and
- Others.

Occurrence of Problem - Overcoming the 1st Physical Barrier: this is in fact, the approach of the event-decision network that has to do with the manner of appearance and perception of the problem, which finally leads to the leakage. Therefore, this stage presents the combination of the first incident (accident at sea or operational malfunction) with the last recorded incident certifying the detection of oil pollution. In the context of this work, the last incident may be limited to hull rupture for accidents at sea and to a corresponding leak or discard for operational oil spills.

This stage contains the following options:

- Grounding / Stranding – Rupture,
- Collision / Ramming – Rupture,
- Explosion/ Fire – Rupture,
- Hull Failure – Rupture,
- Others – Rupture,
- Intentional Discard,
- Tank Overflow – Leakage and
- Oil Transportation System Malfunction – Leakage.

Extent of Problem - Amount of leakage: at this stage, the quantitative separation of pollution is carried out depending on the amount of oil ending up into the sea. As already mentioned, in the context of this work, the study of relevant incidents must greatly depend on the quantity of oil in the marine environment since, under the same surroundings, the more massive the spill, the greater environmental value and significance it obtains. Therefore, in the event-decision network, the inclusion of the size of the spill in representative quantity categories is carried out using as limits the 149 tons, the 2,999 tons, over the 3,000 tons and the unknown fraction (Devanney & Stewart, 1974).

Initial Monitoring & Limitation of Problem – Pollution: this is a purely qualitative stage of the event-decision network that has been included mainly for purposes of consistency and completeness of the method. In brief, the network assumes that there is a coordinated group of actions which are in position to form this node, but at the same time it is common practice that these particular actions are carried out (100%) upon appearance of sea pollution. The possible actions included in the node under review are monitoring, assessment and possible positioning of restricting barriers around the source of pollution.

Assessed Targets (Local Activities): this is the stage of the event-decision network where the types of areas, which are confirmed, to have been affected by spills are co-assessed. This particular approach has the advantage of overcoming in any case the limits of the first hit-approach, since it is able to take into account multiple crisis situations within a predetermined period.

At this stage the following alternative types of targets may be selected:

- Urban / Tourist areas,
- Coastal Industrial Zones,
- Sensitive Areas,
- Commercial Areas and
- None.

Coordinated Control – Antipollution Actions: this is the second and more substantial reference of the event-decision network to model the anti-pollution actions. At this stage, the network incorporates in the entire process some qualitative pollution characteristics, which significantly affect both the efficiency and the type of the adopted antipollution action.

The parameters of the layout of the predetermined options for the Coordinated Control - Antipollution Action Step are as follows:

- Non Controllable - Non Persistent Pollution,
- Controllable - Persistent Pollution,

•Non controllable - Persistent Pollution and
•Controllable - Non Persistent Pollution

Outcome - Consequences of Network: this is the final stage of the recorded pollution flow on the event-decision network. Of course, it should be noted that the outcome of the network is a particularly important step of the methodology, since it reflects in some degree the entire significance of each spill.

The twelfth stage of the event-decision network focused its attention on the cleaning up cost (or more accurately on a relevant financial figure deriving from it) as one of the factors that can more or less describe the dynamic presented by each case (pollution flow). Moreover, it is true on a global scale that the more hazardous and important is a case of pollution the larger and more expensive confrontation operation will be finally organized. Of course, the mass media by shaping public opinion frequently play a role in this development, pushing in one or other direction accordingly.

In order to strengthen and justify the specific approach, the last stage of the network was enriched with the variable of the type of coastline, that is the selected targets affected by marine pollution in each case. Moreover one cannot evaluate the operation organized in order to combat pollution if he or she does not know the magnitude of the specific problem. At this point, the initial equation for the event-decision network end (XII) can be given in monetary units (EURO). This can be seen in Eq. 1.

$$\text{Network end}\,[€] = \text{perimeter}\,[\text{km}] \times \text{unitary clean up cost}\,[€/\text{km}] \quad (1)$$

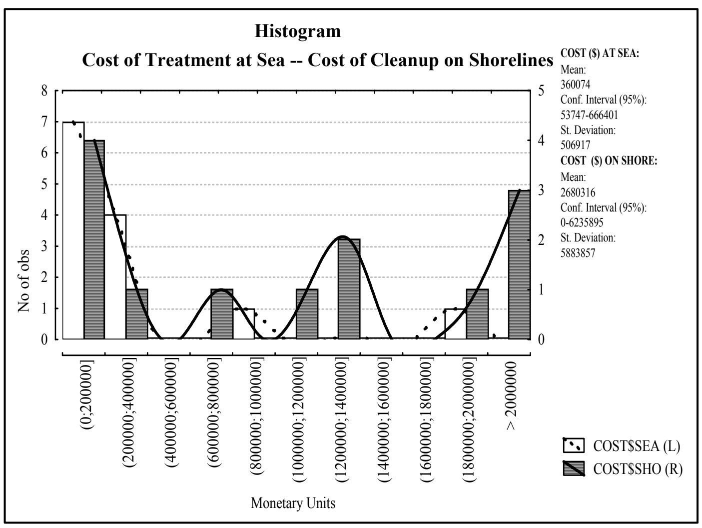

Fig. 5: Correlation of Clean-Up Costs for Sea and Coastlines (1960-1994)

Thus, the aim of this effort is to achieve a de-escalation of the impact of various extraneous factors, such as the pressure exerted by the mass media on the course and form of an anti-pollution operation. Figures 5 & 6 provide additional confirmation for the paper's preference to the initial interest in confronting marine pollution along the perimeter of the target, in other words along their coastlines. Thus figure 5 depicts the recorded fluctuation of the two–fold clean–up cost in monetary units for the time period from 1960-1994 (Etkin, 1995). From the existing data, it emerges that handling of spills near or on the coastline is the common and preferred practice of dealing with oil marine pollution.

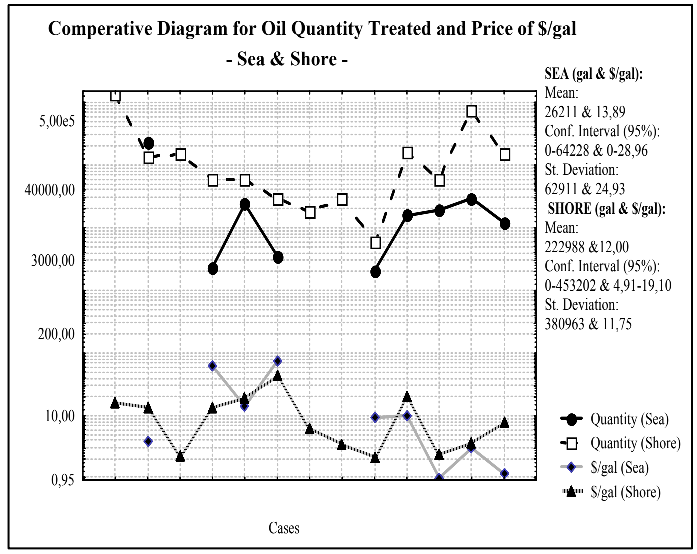

Fig. 6: Correlation of the Unitary Cost and the Quantity of Oil

Figure 6 shows that larger quantities of leaked oil were confronted on the coastline than into the sea. This difference adds up to about one order of magnitude justifying the previous remark (Etkin, 1995).

Then, the paper is focused on the appropriate use of the calculated perimeter (coastline) of the suffering targets. It is well known that coastlines are characterized by various different parameters such as their type, their gradient, their wave profile etc., so they eventually behave in a different manner towards the duration and degree of oil pollution on them (stranding coefficient). Hence, the active length of the perimeter (coastline) was defined as the product of the stranding coefficient of pollution for each type of shore times the real length of each affected coastline (Eq. 2).

$$\text{Active Length}\,[\text{km}] = \text{stranding coefficient} \times \text{real length}\,[\text{km}] \quad (2)$$

Table 1 presents the values of the pollution-stranding coefficient depending on the type of coastline and its wave profile [Gundlach & Reed, 1986].

Table 1. Stranding Coefficient for Oil Marine Pollution

Type of coastline / wave profile	Stranding coefficient
Rocky, stony & sandy/ Open coastline + exposed to tides	0,05
Rocky / sheltered	0,23
Stony / sheltered	0,13
Sandy/ sheltered	0,09
Marshy / sandy, etc. / stagnant water	1

Eq. 3 evolves from Eq. 1 and it gives an approximation for calculating the developed outcome of the event-decision network.

$$\text{Network end}\,[€] = \text{active length}\,[\text{km}] \times \text{unitary clean up cost}\,[€/\text{km}] \quad (3)$$

<u>Remark:</u> In the case where not Assessed Targets are affected from oil marine pollution, then the network end will also be calculated in monetary units so as it is shown in Eq. 4.

$$\text{Network end}\,[€] = \text{oil quantity (tons)} \times \text{unitary oil cost}\,[€/\text{ton}] \quad (4)$$

Thus at this point, the paper is ready to describe the manner in which the total network end will be given in the context of analyzing oil pollution (pollution path – Eq. 5)

$$\text{XII}\,[€] = \sum_i \left[\text{active length [km]} \times \text{unitary clean up cost [€/km]}\right] \quad (5)$$

Where:

i is the active length category index, which has to do with the type of each examined coastline.

Therefore, the choices for the last stage of the event-decision network are as follows (in 2001 prices):

- Without serious impact [< 10000] €,
- With average impact [1000-750000] € and
- With severe impact [> 750000] €.

CASE STUDY

Through the next example, [Psaraftis et al, 1999] the paper shows the way that the event-decision network codifies the data sequence and formulates the desired pollution tree path. Thereby, these are the twelve codified steps of the selected example:

- The order of the ship's captain for evasive manoeuvres,
- At the time the vessel was at a distance of less than 20 nautical miles from the nearest coastline,
- Something went wrong,
- The error was due to human factors,
- More specifically the pollution was attributed to ascertained and unjustified indifference of one or more of the crewmembers,
- The incident involved a tanker in ballast condition,
- The pollution involved discharging oil into sea,
- The magnitude of pollution was around 3 tons of bilge (which falls within the lowest quantitative category),
- ❖ In the context of the bypass procedure, the calculation of the statistical venturousness compromises numerically the 7th & 8th stages of the event-decision network. Nevertheless, this magnitude is out of the scope of this paper.
- Initial monitoring of the development of the event is carried out by the competent authorities,
- It is ascertained that urban / tourist targets are affected as well as certain nearby sensitive areas,
- The pollution clean-up operation is deemed acceptable and incorporated in the context of confrontation of non-persistent oil products, and
- On the basis of the existing data the entire event is classified as one without serious impact.

Figure 7 depicts the application (pollution path) of the above example in the limited form of the event-decision network. This procedure (formulation of the polluting flow) can also occur gradually - over a given time horizon - with the sole condition that all new entries cannot be used until their input is considered to be completed from a network point-of-view.

Likewise, in Figure 8 the same example is given but in the fully developed form of the event-decision network. The statistical venturousness has to do with a significant deviation of the network (it may combine two main stages into one), but further comments on it are outside the scope of this paper.

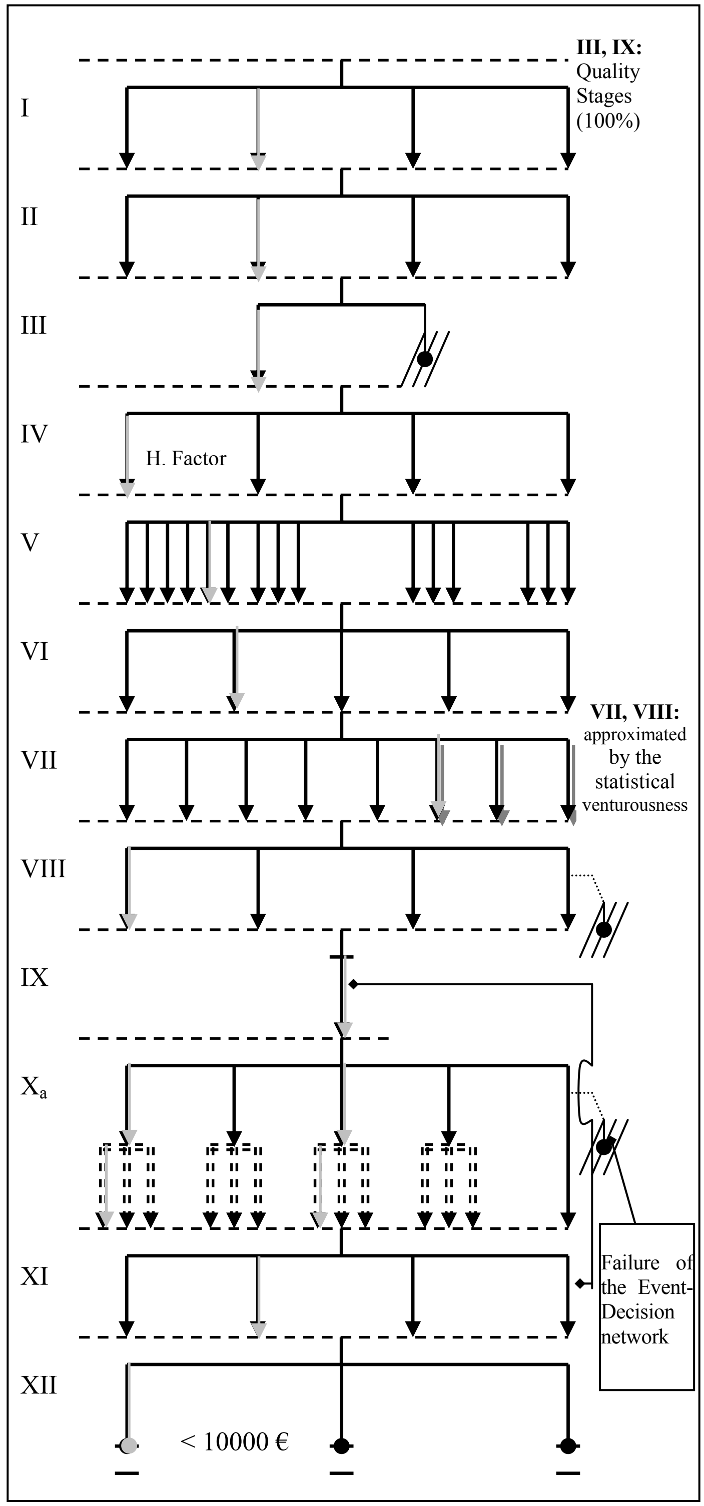

Fig. 7: A Pollution Path of the event-decision Network ("limited form").

CONCLUSIONS

This paper presents an original approach to oil spill issues from a strategic point-of-view. To the best knowledge of its authors, it is the first time that a complete pre-defined structure (tree-analysis) is being formulated, in order to cover a spill incident from the initial event up to it's impact and upcoming consequences. The introduced event-decision network is in a position to produce various pollution paths and therefore provide a general and direct description of the oil pollution framework of the area under consideration.

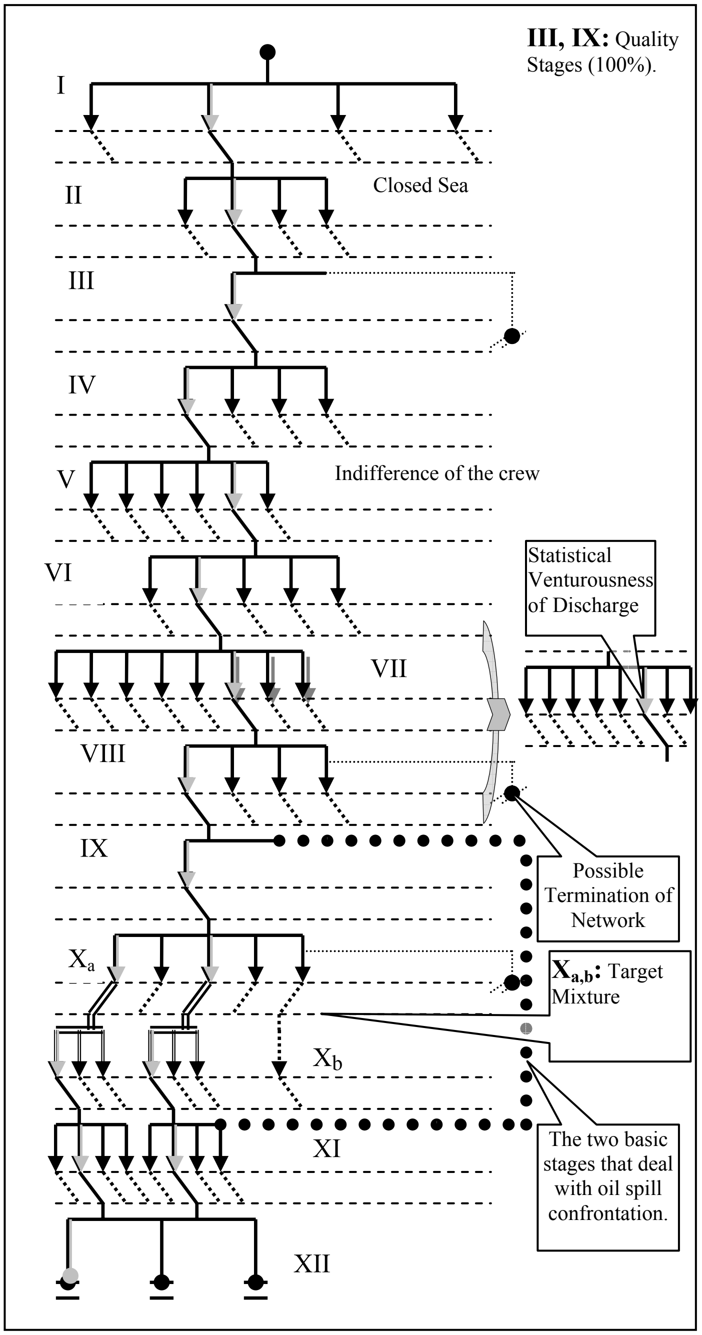

Fig. 8: A Pollution Path of the event-decision Network (developed form).

The main features needed for a successful deployment of the event-decision network are the following ones:

- The main and direct causes, which led to the problem,
- The manner in which it arose and the true magnitude of pollution,
- The mixture of the identity of the targets affected and
- The indicative economic scale of the outcome of the oil spill incident.

Closing this paper is stressed out that developing such a strategic network is a task with high potential. Moreover, it needs continuous monitoring and provision to come up with an adequately pruned tree in order to maintain it's flexibility and dynamics. In the context of oil pollution confrontation, the event-decision network is in a position to provide valuable assistance aiming to the efficient protection of the coastal and marine environment

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