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AGAINST MARINE
POLLUTION

Methodology for risks and incidents in EPSs developed

Final Version of December/2019

Deliverable Number D.3.1.1.

Index

Glossary

Hazard is a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. Comment: […] In technical settings, hazards are described quantitatively by the likely frequency of occurrence of different intensities for different areas, as determined from historical data or scientific analysis. (UNISDR, 2009).

Hazard map refers to a map describing the spatial distribution and the most relevant features of the hazard under investigation.

Hazardous event refers to a particular situation that produce a hazard.

Exposureis referred topeople, property, systems, or other elements present in hazard zones that are thereby subject to potential losses. (UNISDR, 2009).

Exposure map is a map showing the spatial distribution of all relevant elements that need to be protected, such as infrastructures, naturally protected areas, economic resources etc. Each element at risk should be individually reported in a specific map

Multi-risk assessments determine the total risk from several hazards either occurring at the same time or shortly following each other, because they are dependent from one another or because they are caused by the same triggering event or hazard; or merely threatening the same elements at risk (vulnerable/ exposed elements) without chronological coincidence (EU, 2010).

Operational vulnerability map is a map providing all the information related to the general logistical and operational resources in order to generate detailed information for onsite oil spill responders.

Risk is a combination of the consequences of an event (hazard) and the associated likelihood/probability of its occurrence. (ISO 31010).

Risk assessment is the overall process of risk identification, risk analysis, and risk evaluation. (ISO 31010).

Risk identification is ‘the process of finding, recognizing and describing risks. (ISO 31010)

Risk analysis is the process to comprehend the nature of risk and to determine the level of risk (ISO 31010).

Risk evaluation is the process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable. (ISO 31010).

Risk map is a map that portrays levels of risk across a geographical area. Such maps can focus on one risk only or include different types of risks.

Tactical vulnerability map is a map describing the spatial distribution of the intrinsic sensitivity todamagefor each detected element at risk.

Single-risk assessments determine the singular risk (i.e. likelihood and consequences) of one particular hazard (e.g. flood) or one particular type of hazard (e.g. flooding) occurring in a particular geographic area during a given period of time (EU, 2010).

Strategical vulnerability map is a map describing the priority of the vulnerable sites and resources, identified in the tactical vulnerability map for each detected element at risk.

Vulnerabilityis the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. (UNISDR, 2009).

1. General Introduction: Purpose and structure of the document

PEPSEA project intends to develop an adequate and timely Response System for cases of incidental sea pollution by oil spilling in enclosed parts of sea (bays/channels/lagoons), namely EPSs. The Response System should include approaches and equipment in three different phases: before (prevention, mitigation, detection, early warning), during (interventions) and after incident (remediation, monitoring) (source Action Plan Pepsea).

The Contingency Plan as a Response System for the cross-border area is expected to decrease the risk in EPSs in Adriatic Sea. The project addresses a twofold challenge:

- The lack of a shared and accepted strategy for response to incidental sea pollution by oil and dangerous substances;
- The lack of comprehensive studies of fuel impact on marine environment especially in some specific area of the Adriatic coasts and the inadequate capacity of regional authorities (regional centres designed to address the problem) and their limited resources to implement an adequate response to oil spilling risk.

The PEPSEA project define as first step for achievement of the overall objective the Definition of a shared Methodological Approach included in this document and intended as a Guide for Response Risk associated with oil spilling in the Adriatic Sea, with attention to the Enclosed Parts of the Sea (EPS).

Environmental risks posed by oil spills in Enclosed Part of the Sea (EPSs) and in general within the semi-enclosed basins is expected to be pronounced than those in the open ocean due to potential deposition along long segments of the coastlines. As a prototype semi-enclosed sea, the Adriatic coastsare considered sensitive and vulnerable to pollution events in general, and specifically to potential oil spills from ships or offloading terminals, main activities loading on the countries involved.

Due to the relatively small size of some pilot areas selected in PEPSEA Project, the exploration and the survey activities, as propaedeutic steps of Contingency Plan developing, can differ substantially. In addition, some of the EPS selected are exposed to increased environmental vulnerability in the case of an accidental oil spill with a high potential risk for cross border pollution transport (Delta of Po) due to the prevailing winds and the near surface sea currents.

Lastly, due to the close distances between the two coasts of Adriatic Sea, in many cases cross border transport needs to be considered related with the cross-border transport of the oil slicks, towards the coasts of the immediately adjacent areas. In that cases attribution of responsibility and legal accountability for transboundary transport of marine pollution should be considered. The non-clarity of the shared cross-border responsibility, during the last 20-30 years have demonstrated to have a detrimental effect [Kindt, 1986] reason that lead this project to have a particular attention to the transnational policy and interconnection of bodies to be involved avoiding overlapping of competences.

For the above reported reasons, the document is drawn up to provide:

- The Contingency Plan Methodology for Single-Risk Assessment (associated to oil sea pollution) including approaches (techniques/equipment's) needed for Hazard Analyses - Vulnerability and Risk Evaluation. The rationale behind the present Guide is to provide a working document that starting from identification of safety events (pre-risk), incidents (during) and possible impacts (outcomes after incidents) can orient the partners in the next activities (3.2, 3.3 and 3.4) and allow them to better identify the barriers to avoid undesirable events and to better design of the right mitigation actions. An overview of the rationale is given in the Boy-tie Diagram.

- The description of the EPSs areas: being the selected Pilot sites very different in terms of morphological features, a short description of each site is providing and guides for additional or minimum actions for implementing Response System are also reported.

- Some peculiarities in terms of sharing transborder responsibilities as useful recommendations for a Common Response System for whole Adriatic Area.

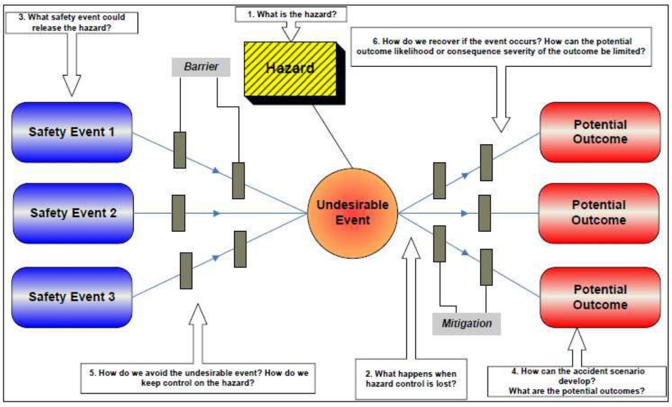

Figure1 *- Bow-Tie diagram (Chakib, 2018).*

2. Main goal of the Contingency Plan (CP)

Determine the structure for the management of response operation in compliance with the regulatory framework and commensurate with the marine pollution risk (oil spill) of the designed organization or available facilities

3. Structure/main components of CP

1) **Risk Assessment**

To identify measures to reduce and manage the risk of spill and its consequences

2) **Strategic Policy**

In order to adopt the defined response strategy, the policy decision strategy should be clarified, based on local, national and international requirements.

3) Operational Procedures (not addressed)
4) Information Directory (no addressed)

4. Preliminary analysis

- An inventory and assessment of existing plans in all countries involved (existing, regional and local plans), an assessment of the effectiveness of these plans, including the identification of gaps and other inadequacies that could be remedied.
- Identification of the portions of existing plans that can be adequate and can be incorporated in the General Plan for PEPSEA Project.
- Identification of potential sub-areas within the project boundaries that may require special attention (definition of Sub-Area of most concern).
- Review of data and information from past incidents (e.g., after-action reports, lessons learned, unresolved issues). This review aims to identify specific problems that the PEPSEA Plan should address.
- Identification of sensitive areas, including environmental, cultural and economic resources.
- Identification of jurisdictional overlaps/conflicts.
- Identification of high-risk facilities and critical infrastructure.
- Identification of key qualified personnel in each country and local agency that should be to participate n the PEPSEA Contingency Plan.
- Assessment of the consequences of not developing ad adequate Plan.
- Consideration of the expansion the Response Plans beyond their current geographic area of PEPSEA project.

5. Risk Assessment

ISO 31010 defined the Risk (R) as the combination of the associated likelihood of a hazard occurrence and its consequences, expressed in terms of human, economic, environmental and political/social impacts. The likelihood of occurrence of a hazard of a certain intensity is defined "probability of occurrence" if it can be quantified. The likelihood of occurrence of a hazard of a certain intensity is defined "probability of occurrence" when it can be quantified.

According to the situation under investigation, the Risk can be computed using different algebraic expression. In the situations where the impacts are independent of the probability of occurrence of the hazard, such as earthquakes or storms, it can be computed applying Equation 1:

(1)

When the condition explained in the previous paragraph is not satisfy, the risk should be calculated as a functional relation of Hazard (H), Exposure (E) and Vulnerability (V) (Equation 2):

(2)

The functional components are defined by UNISDR, (2009) as

- H is "*a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. Comment: […] In technical settings, hazards are described quantitatively by the likely frequency of occurrence of different intensities for different areas, as determined from historical data or scientific analysis*"
- V comprises "*the characteristics and circumstances of a community, system or asset that make t susceptible to the damaging effects of a hazard*".
- E describes "*People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses*"

Before to go forward into Risk elements computation, explained in depth in the successive sections, the risk to be analysed should be identified and examined in order to understand its nature, its relationship with other risks that could be occurred and the method to be adopted to face it. Consequently, two risk types can be distinguished (Risk Assessment and Mapping Guidelines for Disaster Management, 2010):

- Single risk, generated from one particular hazard (e.g. flood) or one particular type of hazard (e.g. flooding) occurring in a particular geographic area during a given period of time
- Multiple risk, caused from several hazards, taking into account possible hazards and vulnerability interactions:
    a. occurring at the same time or shortly following each other, because they are dependent of one another or because they are caused by the same triggering event or hazard;
    b. threatening the same elements at risk (vulnerable/ exposed elements) without chronological coincidence.

In the case of oil spill, the risk belongs to the first category "single risk", and consequently the single risk assessment approach has been considered. It is composed by the following step:

- Hazard analysis
- Vulnerability analysis
- Risk evaluation

Each phase is explained more in depth in the following sections.

5.1 Hazard analysis

Hazard analysis is aimed to identify all the hazardous events that could lead to hazard (identification of Safety Scenery of the Bow-Tay diagram). Thus, for example, in the analysed case, oil spilling is representative of the hazard (Single Risk), while the events that generate it are hazardous events, such as ship collision or explosion.

- Potential spill hazardous events could include, but not limited to, the following examples:
- Small operational/maintenance spills due to minor incidents
- Loss of well control leading to a blowout
- Ruptured flow lines, pipelines, risers, subsea equipment due to earthquake
- Loss of containment due to tank storage failure
- Loss of containment during offloading/transfers/bunkering
- Loss of containment from ship collision
- Loss of containment from ship grounding
- Loss of containment due to explosion
- Others

One or more methodologies for hazardous events identification could be used:

- Data Driven Methodologies
  - Data Monitoring
  - Company audits
  - Staff surveys
  - Hazard reports
  - Others

- Qualitative Methodologies
  - Discussions
  - Interviews
  - Brainstorming

- Specific tools and techniques
  - Hazard and Operability (HAZOP) Study
  - Checklist
  - Failure Modes and Effects Analysis (FMEA)

- Structured What-if (SWIFT)
- Dynamic Methods

Once the hazard identification is performed, the characterization of the hazardous events should be undertaken to define oil spill scenarios.

In order to characterize the hazardous event, a first approach could be based on available databases in which is possible to detect specific features.

1. Database REMPEC (http://www.rempec.org/tools.asp?pgeVisit=New) (open data), which includes the following information:
    a. Accident Date
    b. Accident Location
    c. Accident Type
    d. Vessel Name
    e. Vessel Type
    f. Cargo Type
    g. Release Status
    h. Product Released
    i. Form of Release
    j. Pollutant Name
    k. Release Quantity

2. Database ITOPF (https://www.itopf.org/knowledge-resources/data-statistics/statistics/) (open data), which involves:
    a. Accident Date
    b. Vessel Name
    c. Accident Location
    d. Spill size
    e. Global oil spill trend
    f. Tanker spills from 1970 to 2018
    g. Large oil spills
    h. Causes of large oil spills

For all specific area, for which data on International Repository are not available, it is recommended to be collect data through:

a. Harbour Master offices or other maritime offices with peripheral administrative competences designed by the Ministry of Infrastructure and Transport (according to national legislative framework)
b. Department with competences in Protected Areas or ICMZ (See CAMPs or PAP/RAC Coastal Area management Programme (CAMP: http://www.papthecoastcentre.org/index.php?lang=en)
c. Different studies within Mediterranean Action Plan of the United Nations Environmental Programme (UNEP-MAP)
d. Municipalities with competences on minor ports/bays/EPSs
e. Counties (Prefectures) with competences at local level.

Further relevant information for collecting data on hazard identification/characterisation phase are reported in the section IV.

Additionally, the identified hazardous events could be characterized by several parameters, which are useful for determining the consequences of different spill scenarios.

- **Likelihood**

Likelihoodrefers to the chance an event might occur. It can be determined:

- historical data (databases)
- mathematically

At this regard, should be highlighted that for those areas for which not historical data are available, the mathematic models are considered the unique solution for characterising the hazard.

The actions for calculation Likelihood are as following:

I. Release volume and discharge rate

Severity and consequences of oil spills and its potential outcome depend on the amount of spilled product. Release volume depend on the capacity of the tanks where they are contained.

- Identify of the types of ships handled

Table 1 *- Volume classes of oil (ref. ISPRA)*

Volume	Volume (m^3)	Description

classes		
1	50	Fuel tanks for ship up to 500 GWT Containers, tanks for coastal boats
2	50-500	Fuel tanks for ship between 5000 and 3500 GWT, small oil tanker transport vessels
3	500-10 000	Fuel tanks for ship between 3500 and 25000 GWT, oil tanker transport vessels
4	10 000-250 000	Tanks of oil tankers
5	> 250 000	Large oil tankers or oil wells[1]

II. Oil type and the behaviour of spilled oil

- Identify the oil types contained and potentially spilled
    - Density
    - Viscosity
    - Tendency to evaporation
    - Pour point

[1] The hypothesis reported is referred for those ports that have industrial character (example Split Port)

***Table 2** - Oil types and behaviour (ref. ISPRA)*

Group	Density or specific gravity and relative API	Description
1	< 0.8 (°API > 45)	Hydrocarbons with low density and viscosity. The *pour point* is far below room temperature and the tendency to distillation is high. These are light hydrocarbons and fluids with a high tendency to evaporate.
2	0.8-0.85 (°API 35-45)	Hydrocarbons with medium-low density. Viscosity and *pour point* they are also generally low. Only in some cases, the product is semi-solid at room temperature. The tendency to distillation is medium-high. These are light hydrocarbons, often fluid, with a moderate tendency to evaporate.
3	0.85-0.95 (°API 17.5-35)	Medium density hydrocarbons. The viscosity and the *pour point* are also generally medium. Only in some cases, the product is semi-solid at room temperature. The tendency to distillation is medium-low. These are medium density hydrocarbons, often fluid, with a low tendency to evaporate. In some cases, they can sink if sediment or other heavy material is trapped inside.
4	> 0.95 (°API < 17.5	Hydrocarbons with high density and viscosity. The *pour point* has values comparable or higher than the room temperature. The tendency to distillation is low. These are heavy and low-flow hydrocarbons, with little tendency to evaporate. They can often sink, especially if sediment or other heavy material is trapped inside.

III. Event location, distance from the coast, and prevailing conditions

In this paragraph, the following consideration should be made:

- The more the distance from the coast the more the time needed for interventions to minimize the impacts.
- The more the distance from the coast the more the residence time of the product in water and consequently the action time of weathering processes which reduce the quantity of hydrocarbons that reach the coast.
- The more the distance from the coast the more the coastline potentially affected.

Therefore, the first steps to be considered are:

- Identify the location and the related distance from the coast of potential oil spill scenarios.
- Identify the morphological landform and features of the coastal area.

In order to proceed with the identification is necessary implementation of:

- Maps of the extension of the area included in the scope of the Plan indicating the distance from the coast (see Annex 1).
-

***Table 3** - Distance class and related time for interventions (ref. ISPRA)*

Distance Class	Distance from the coast	Time for interventions
1	D > 50 miles	One week[2]
2	10 miles < D < 50 miles	Some days
3	5 miles < D < 10 miles	One day
5	D < 5miles	Few hours

The distance from the coast should be related with the type of oil spilled to evaluate the severity of the oil spill scenarios. The distance could be a positive factor if the spilled hydrocarbons belong to group 1 and 2 of the ITOPF classification, so the weathering processes lead to a significant reduction in residual quantities in the sea within a week from their release. The distance is unfavourable when the spilled

[2] The distance of the option 1 is referred to the trans-border hazard characterization, therefore not available for Detailed Contingency Plan in the specific Pilot-Site Area.

hydrocarbons belonging to groups 3 and 4 (denser and more viscous) because most of the spilled quantities persist in the sea and could impact wider stretches of coast and high intrinsic value areas even far from the point of release.

IV. Context data collection (on port/pilot area)

- Port technical characteristics
  - General Conditions
    - Type of physical harbour configuration
    - Location (Longitude, Latitude)
    - Wind conditions (Prevailing, Dominant)
    - Storm frequency in deep water or theoretical gales (Length, Max. wave height, Max. wavelength, Significant wav
    - Tides (Maximum tidal range, Height of MLWS compared with port zero, Heightof MHWS compared with port zero)
    - Breakwaters (Name, length, and characteristics)
    - Tidal locks (Name and characteristics)
    - Entrance
      - Entrance channel (Direction, Width, Length, Depth at MIWS, Sea bottom characteristics)
      - Entrance mouth (Direction, Width, Length, Depth at MIWS, Sea bottom characteristics, Max. controlled current)
      - Tugboat use (compulsory, optional)
  - Portsurfaces
    - Water surface area (outer waters).
      - Anchorage area
    - Water surface area (inner waters)
      - Basins surface area
        - Quay and berths (Type of berth, Type of use - commercial, fishing, marina, etc. -, Water surface, Length, Depth, Width
      - Land surface area
        - Port facilities surface
        - Roads surface
        - Railways surface
        - Other surfaces
- Companies that provide pilotage, tugboat and mooring port services for vessels.
  - Vessel pilotage companies and Tugboat companies
    - Location (quay, berth, area, etc.)

- Dangerous or polluting substances at port base of operations for its own operations or production processes
  - Typeofsubstance (diesel, propane, oxygen, nitrogen, motor oils, etc.)
    - Use of the substance (Amount of substance, Type of storage
- Maximum and minimum number of people in the port base of operations
  - Number and classification of people present in each time slot
- Risks at the port base of operations
- Port base of operations emergency plans (Plan name and risks covered by the plan)

- Port facilities/Terminals
  - Name of port facility / terminal.
    - Location (quay, berth, area, etc.)
    - Facility/Terminal description
    - Facility surface areas
      - Total surface
      - Buildings surface
        - Use of the building
        - Firefighting means available to the building
      - Storage surface
        - Open storage surfaces
        - Roofed warehouses storage surfaces
        - Closed warehouses storage surfaces
        - Tanks storage surfaces and volume
        - Silos storage surfaces and volume
    - Road surface
    - Railways surface
    - Another surface
  - Types of cargoes manipulated by the facility/terminal (solid bulk, liquid bulk, conventional general cargo, containerized cargo, ro-ro cargo, cars, frozen cargo, etc.)
  - Dangerous goods manipulated by the facility/terminal
  - Dangerous or polluting goods stored at the facility/terminal, and type of its storage (permanent, temporary, etc.)
  - Dangerous or polluting substances at Facility/ Terminal for its own operations or production processes.
    - Typeofsubstance (diesel, propane, oxygen, nitrogen, motor coils, etc).
    - Use ofthe substance (Amountof substance, Typeof storage)

    - Handling equipment: cranes, tractors, forklifts, conveyor belts, wheel loaders, crabs, special equipment, etc., and their characteristics
    - Traffic statistics per year
        - Goods
        - Passengers
    - Maximum and minimum people number in the port facility/terminal
        - Number and classification of people present in each time slot
    - Risksat the port facility/terminal
    - Portfacility/terminal emergency plans
        - Planname and risks covered by the plan
- Companies authorised to operate in the port without occupying surfaces in it
    - Name ofthe company
        - Description of the authorised operations.
            - Maximum number of people operating in the port
            - Other information about the company
    - Main annual statistics of the Port
        - By type of goods [liquid bulk, dry bulk, general goods, containerised) and by type of operation (loading, unloading, in transiting the port)
        - By type of dangerous or polluting goods (liquid bulk, dry bulk, general goods, containerised) and by type of operation (loading, unloading, in transit in the port, in transit on board) and IMO class of the goods
        - By type of passenger (cruise, ferry, local traffic) and by type of operation (embarking, disembarking, in transit in the port).

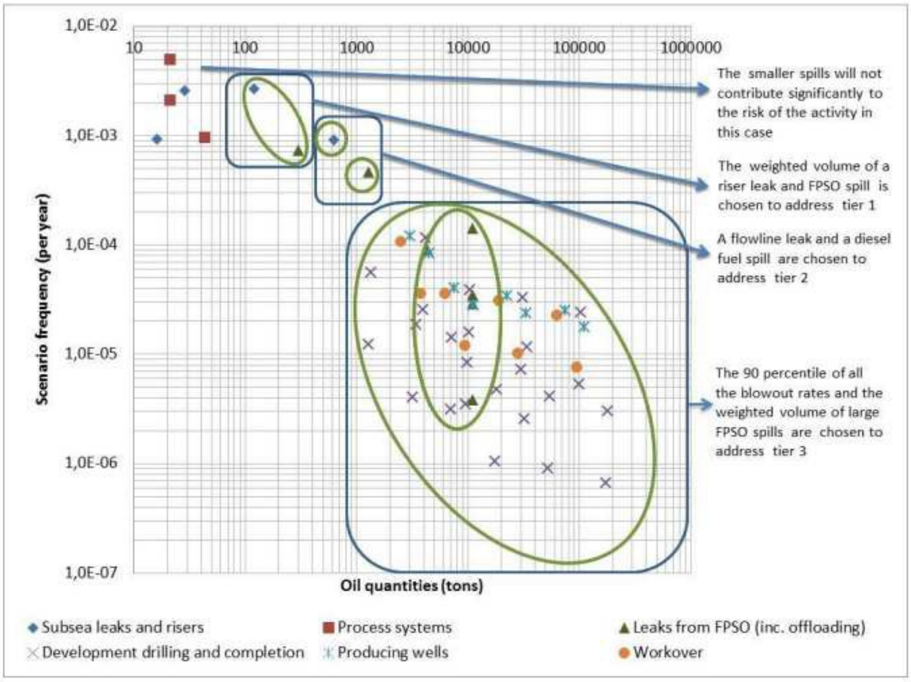

Figure 2 *- Likelihood analysis (Nissen-Lie et al., 2014)*

- **Computer Modelling**

After characterizing the hazardous events, computer modelling of oil spills in different sea condition should be conducted to estimate, for example, thephysical changes, potential paths, travel times, areal distribution and associated volumes of spilled oils.

This phase could be carried out by applying a model able to simulate hydrocarbons fate and trajectories, such as for example MEDSLIK (http://medslik-ii.org/index.html) or SIMAP (http://asascience.com/software/simap/). To achieve this goal, some parameters are needed to be collected, such as:

- Salinity
- Speed and directions of currents

- Speed and directions of wind
- Sea surface height
- Others

These parameters can be gathered from i.e. Daily Oceanographic and meteorological data for Mediterranean Sea(http://medforecast.bo.ingv.it/) (open data).

For those areas for which repository data are not available the specific instruments need to be installed on sites.

- Salinity: analytical analyses – refractometer (also optical), Conductivity Meter, multiparametric probes
- Speed and direction of wind – Installation of anemometric stations
- Speed and directions of currents (Acoustic Doppler Current Profiler (ADCP)
- Sea surface height wave array, together with the ADCP, both by Teledyne RD (this later are Teledyne RDI's Workhorse Waves Array is an innovative, cost-effective upgrade that allows you to take your Teledyne RDI ADCP to the next level)

The procedures for creating a hazard map for Contingency Plan is given in the Annex 1.

In addition to the previous database, some additional documents present in the scientific literature should be considered for computer modelling. Same examples are reported here below:

- Report and Results of the oceanographic investigations in the Adriatic Sea (1974–1976). 239 pp. [Available from CNR - Istituto Talassografico di Trieste, viale Romolo Gessi 2, I-34123 Trieste, Italy.] Hydrographic Institute of the Yugoslav Navy, 1982
- Oceanographic data of the cruises made by ships Vila Velebita in 1913 and Hvar in 1948. [Available on magnetic tape from CNR di Istituto Ricerche sulla Pesca Marittima, largo Fiera della Pesca 1, I-60125 Ancona, Italy.]Institut za Oceanografiju i Ribarstvo—Split, 1985.
- Other scientific literature

5.2. Vulnerability analysis

The information related to hazard characterization is useful to define an oil spill scenario and to analyse its consequences. For each identified scenario, the potential environmental and socio-economic consequences should be determined. This phase is commonly called "Vulnerability analysis" and it mainly consists of the following phases:

- Identification of elements at risk (exposure)
- Identification of vulnerability factors/ impacts (physical, economic, environmental, social/political)

- Assessment of likely impacts

In case of an oil spilling, the elements at risk to be taken into account are:

- Shoreline type and its general environmental
- Ecosystems, habitat, species and key natural resources
- Socio-economic (including cultural heritage) features

Each element at risk is subjected to a specific level of damage according to intrinsic features, able to influence their response to oil spill. Following, the characteristics to be taken into account are summarized for each element at risk:

- Coastline
    - shoreline type (grain size, slope) since it determines the capacity of oil penetration and/or burial on the shore, and movement
    - exposure to wave (and tidal energy) which determines the natural persistence time of oil on the shoreline
    - general biological productivity and sensitivity
- marine eco-environment
    - protected areas and important areas of biodiversity
    - types of coastal habitats/ecosystems
    - endangered sensitive species
- economic resources
    - non-living resources that may be directly damaged by oiling
    - managed areas that may suffer economically, e.g. through interruption of use if oiled
    - areas that may be valuable in the event of a spill for access or staging activities

Information regarding the spatial distribution of protected areas and the presence of species can be extracted from the UNEP-WCMC World Database of protected Areas (WDPA), while information related to the biodiversity can be obtained through the IBAT tool. Even the endangered species (unaccounted for by the ESI) must be identified and localized, as well as the coastal areas of interest for the marine flora and fauna. Moreover, endangered sensitive species may include:

- birds (seabird, shorebird, wading bird, migratory species, etc.);
- marine mammals (whale, dolphin, sea lion, seal, walrus, manatee, etc.);
- terrestrial mammals (which may be affected by contact with beached oil or by feeding on contaminated water species, e.g. beaver, mink, bears, wolves);
- fish (nursery areas, coastal species, commercial pelagic species, etc.);
- invertebrates (crustaceans, lobster, shrimp, endangered insects, etc.);

- reptile/amphibians associated to water (turtle, alligators, frogs, etc.).

Regarding the third element at risk, not all the possible socio-economics resources should be detected but just that ones that could potentially suffer because of a hypothetical oil-spill. Information related to them can be obtained by fieldwork activities, EUROSTAT data, etc.

Those activities could be grouped in different categories:

- subsistence, artisanal and commercial fishing, and fishing villages;
- aquaculture;
- water intakes (salt marsh plant, desalinization plant, aquaculture and salt production, industrial use);
- tourism and recreation areas (hotels, restaurants, marinas, beaches, recreational fishing, diving, etc.);
- port (including the activities and infrastructures);
- industrial activities (relying on maritime transport);
- infrastructures related to oil exploration, production and transport activities;
- cultural sites (archaeological, historical, religious, etc.).

In order to better define the above-mentioned element at risks, the following techniques could be considered.

- Defining bottom sediments
  - Bathymetric and geodetic survey of the bay using integral measurement system: a) multi-beam, b) IMU (inertial measurement unit) and c) RTK-GPS (real-time kinematic-GPS)
  - Aerial photogrammetry of the coastal belt up to 200 m from the coastline;
  - Aerial photogrammetry using thermal camera
  - Aerial photogrammetry of coastal area 200 m from coastline using multispectral camera (spectral resolution up to 5 bands)
- Defining bottom sea
  - Production of the bottom of the bay hardness model;
  - Sampling the surface sediments (min 10 sites) in the bay depending of the hardness and morphology of the bottom. Collecting one, referent site outside the bay as control point. Sampling the sedimentary column.
  - Classification of sediments based on the samples of hardness of the bottom of the bay and morphometric criteria using OBIA - Object-Based Image Analysis
  - Overview of the benthic communities on the 3 transects
  - Mapping of the Posidonia oceanic habitat

Models validation should be performed with in-situ analyses.

- Sediment analysis
    - Granulometric analysis of sediments
    - Concentration analysis of toxic metals (Hg, Cd, Pb, Cu, Zn, Cr, Sn, Ni, Co) in sediment
    - Redox potential and pH in sediment (minimum 3 columns)
    - Radionuclides activities (137Cs, 238U, 226Ra, 232Th, 40K) in sediment
    - Polycyclic aromatic hydrocarbons (PAH) in sediment
    - Concentration of the organic matter in sediment
    - Concentration of the organotin compounds (tributyltin-TBT, dibutyltin-DBT and monobutyltin - MBT) in surface sediment
    - Microbiological analysis of the sediment
- Water analysis
    - Physical chemical parameters (pH, temperature, salinity, dissolved oxygen, turbidity, redox) in a water column
    - Concentrations of toxic metals (Hg, Cd, Pb, Cu, Zn, Cr, Sn, Ni, Co) in water
    - Polycyclic aromatic hydrocarbons (PAH) in water
    - Concentration of organic matter in water
    - Concentrations of nutrient salts in water
    - Sanitary sea quality
    - Zooplankton
    - Phytoplankton

Subsequently, once the elements at risk have been identified and detected, the intrinsic vulnerability due to their features should be assigned, and then they should be classified in order to define the priority sites. All information related to the features to be considered and the corresponding vulnerability values are described in depth in Annex 1.

Does not exist a unique method to achieve this goal, since the procedure is strongly affected by the area under investigation. Surely, it is not advisable just using the automated computer-aided methods, since it should consider also the consensus of the main stakeholders involved in the contingency planning process. Moreover, the specific general ranking should vary according to the season considered.

The most accredited methods to rank the vulnerability are:

- mathematical modelling of the vulnerability, using multiple indices
- aggregating the vulnerability information into one index
- using a map-based approach to simplify and rank the vulnerability information.

It is suggested to implement the third method.Therefore, the Geographical Information Systems (GIS) is recommended to perform this step.

The procedures for creating Exposure and vulnerability maps for Contingency Plan is given in the Annex 1.

6. Risk Evaluation: Potential Outcome evaluation

After the spill scenarios are defined and analysed, it should make a final selection that represents the full range of response challenges and risks against which response strategies and a tiered capability can be defined. Predictions of oil trajectory and fate, together with an evaluation of the potential vulnerable resources at risk of impact from oiling, provide an estimate of the risk associated with a spill scenario. A common method used to facilitate and refine the final selection of planning scenarios is a risk assessment matrix (RAM). It is used as a visualisation tool to plot the likelihood and consequence outcomes from each of the spill scenarios, facilitating different scenarios comparison. The matrix provides a view of the overall risk profile and a comparison of the risk associated with each potential spill scenario. Overall risk reduction is achieved with effective prevention and mitigation measures. Reducing the likelihood of a spill occurring through prevention is the primary aim, but in spite of best intentions, a residual risk always remains. Nevertheless, RAM does not provide quantitative information related to the risk and, consequently, it is suggested to apply the procedure explained in Annex 1 to generate a risk map.

Safety Risk	Severity				
Likelihood	Catastrophic	Hazardous	Major	Minor	Negligible
Frequent					
Occasional					
Remote					
Improbable					
Extremely improbable					

The procedures for creating a Risk map for Contingency Plan is given in the Annex 1.

7. Response strategy development

After a range of oil spill scenarios are selected, consideration shifts to the development of appropriate response strategies, which are comprised of available response techniques and which adequately mitigate the impact and consequences of each scenario.

The identification of sensitive resources and priority protection sites, as determined by the sensitivity mapping, provides the site-specific information to develop strategies that best meet the objectives of sensitive area protection and the minimization of damage.

- Identify the appropriate response strategies according to each oil spill scenario
- Surveillance and tracking
- Containment and recovery
- Dispersant application
- In-situ burning
- Alternative technologies (e.g. bioremediation, herding agents, etc.)
- Monitoring and evaluation
- Shoreline protection
- Shoreline assessment
- Shoreline clean-up
- Others

7.1. Determination of response capability

Once suitable response strategies are assessed, the focus turns into identifying the appropriate equipment, personnel and logistics resources needed to implement the strategies and ensuring their availability within the necessary time frame.

Using the tiered response approach, the provision of resources should be flexible and adaptable enough to handle not only the low-impact spill scenarios but also the integration of additional regional and global resources in order to address more complex spills, such as the worst credible case scenarios or an escalating response.

For each response technique, it must determine:

- what resources are needed
- how much of those resources are required?
- how quickly those resources are needed and for how long

Regulatory requirements such as recovery or containment capacity, storage capacity, or response timelines may also heavily influence the arrangements and resource needs, and compliance with these requirements may need to be demonstrated within the contingency plan.

- Identify oil spill resources (type/amount/availability), for example:
    - Equipment
        - Boom
        - Dispersant spray equipment
        - Wildlife response equipment
        - Skimmers and pumps
        - Oil spill response vessels
        - Computer modelling
        - Temporary oil storage facilities (fastanks, dracones, inflatable barges, etc.)
        - Aircraft for remote sensing observation and dispersant spraying
        - Light equipment (pressure washers, lighting, generators, shovels, buckets, etc.)
        - Vessels of opportunity (VOO)
        - Heavy equipment (excavators, cranes, etc.)
        - General communication and computer equipment (phones, radios, etc.)
        - Communications equipment (satellite phones, air-to-ground radio, etc.)
- Personnel involved in the emergency:
    - Subject matter experts
    - Spill response contractors
    - Trained field responders
    - Government agencies
    - Trained vessel captains and crew
    - Trained pilots and crew
    - Vessel captains and crew
    - Labourers
    - Administrative staff
    - Security

- Volunteers
- Logistics and supply:
  - Dispersants
  - Computer modelling
  - Satellite imagery
  - Sorbent materials
  - Spare parts
  - Personal protective equipment
  - Temporary storage facilities
  - Staging areas
  - Medical aid
  - Land transport services
  - Catering and housekeeping
  - Accommodation
  - Sanitary facilities
  - Command centres
  - Aircraft for visual observation and transport of resources
  - Waste transport, treatment and disposal services
  - IT (information technology) services

7.2. Tiered provision of resources

The scale of tiered capability for each response technique will be contingent on how many resources are needed, how quickly they will be needed, and how rapidly they can be accessed and deployed. This, in turn, will greatly depend on the availability of local and regional resources and the distance, time and logistical challenges associated with mobilization and deployment.

The previous oil spill resources should be identified in accordance with the level of the risk (high, medium, low), which in turn correspond to the three emergencies covered by the Italian Regulatory:

- Medium gravity (first stage)
- Serious (second stage)
- Hazardous (third stage)

Local emergency

National emergency

8. Cross-border Dimension of Risk Assessment

Generally, the risk of cross border transport is especially acute from spills originating in deep water platforms located in the open sea due the time required to reach the coast. The vulnerability analyses in case of working in semi enclosed sea or basin located in the coastal track areas belonging to adjacent countries, thus multiple authorities with competences on the different coastal track, add to the Risk Analyses up to here proposed an additional peculiar aspects: risks deriving from cross border transport of pollution. Due to the relatively large distance from the two coasts (more than 100 km), the oil can spread across large areas and will typically take long time (2–3 weeks to reach a coast). Consequently, the risk for cross border transport of a slick originating from any of the pilot sites is very real. The relatively long period until the oil reaches the coast is in principle important for allocating and deploying resources to contain the slick and to mitigate the damage caused by oil pollution.

This emphasizes the importance of multinational cooperation in developing contingency and response plans and procedures among regions that address the same risks. It also highlights the importance of mutual responsibility to protect the marine environment since no country will be immune from potentially causing and subsequently suffering from the damaging effects of cross border pollution transport.

In order to address this aspect, it is necessary that, in addition to the previous phases, several simulations should be planned for continuous monitoring of uncontrolled spills from different areas in open sea in different seasons (at least two seasons). This step can help to define the right competences and responsibilities as reported in the subsequent paragraphs (8). An example of the research methodology for the simulation of the cross-border oil pollution transport is given in “The Risk of Potential Cross Border Transport of Oil Spills in the Semi-Enclosed Eastern Mediterranean. By Steve Brenner (in Oil and Gas Wells- Ed. InTech Open, June 2019: DOI: http://dx.doi.org/10.5772/intechopen.86205).

9. Strategic Policy

This step includes mapping of Bodies and Entities in each country for the development of a common Contingency Plan based on Local, National and International Legislation framework.

The activities to be implemented are the following:

Identify the Bodies to be involved in the Development and Application of the Contingency Plan:

- National government agencies
- Local government agencies
- Port authorities
- Coastal authorities
- Emergency services
- Oil companies
- Contractors
- Environmental organisations,
- Local communities and associations

In addition, the following authorities/stakeholders should be included in the Response System:

- Ship owner and insurers;
- Cargo owners
- Local authorities
- National and International environmental authorities
- Media
- End users (citizens)

The Policy Strategy include the following actions:

- Identify the Lead organisation in case of transborder competences
- Define the Regulatory framework and jurisdiction
- Define the Geographical area of the Plan and the specific competencies for each area
- Define the Interaction with other existing Plans and define scaling of a tiered response
- Outline the role of the shipowner

In accordance with the tiered response and according to the Italian legislation framework, the following figure show the Bodies involved in case of emergencies.

Emergency level	Plans and authorities
LOCAL EMERGENCIES - Medium gravity (first stage) - Serious (second stage)	POL – LOCAL OPERATIONAL PLAN
	OPERATIONAL EMERGENCY RESPONSE PLAN TO PROTECT THE SEA AND COASTAL AREAS FROM ACCIDENTAL POLLUTION BY HYDROCARBONS AND OTHER HARMFUL SUBSTANCES (MATTM)
	MAIN AUTHORITIES INTERESTED IN COORDINATION Capo/I Compartimento/i Direttore/i Marittimo/i MATTM/ DGPNM
NATIONAL EMERGENCIES - Hazardous (third stage)	NATIONAL EMERGENCY RESPONSE PLAN TO PROTECT AGAINST POLLUTION FROM HYDROCARBONS AND OTHER HARMFUL SUBSTANCES CAUSED BY MARINE ACCIDENTS–DCPM 4.11.2010 (DipartimentoProtezionecivile)
	MAIN AUTHORITIES INTERESTED IN COORDINATION Dipartimento Protezione Civile

10. Description of Pilot sites and peculiarities to be considered in the CP

The Contingency Plan of PEPSEA project will be developed by meticulous survey analyses of the following pilot-sites:

Sali bay – Croatia.

Sali port/bay is located along the Croatian coast, one of the most indented in the Adriatic as well as in the Mediterranean (with the mainland coastline of 1.777 km) and with 1.246 islands, islets, and rocks (with additional 4.398 km of coastline; Duplančić Leder et al., 2004). The rows of island chains are parallel to the coastline and this is known worldwide as a Dalmatian type coast (Fairbridge, 1968).

Sali is in one of these rows of island chain and have the same geomorphological features of the whole seaward edge known as Karst Plateau (McKinney, 2007).

Figure 3 *- a) The Croatia Coast. b) and c) Zoom in the Sali bay.*

The peculiarities of this area have a threefold importance for the project scope:

a. It is difficult for the area to collect historical data aimed to identify and characterize the risk or to simulate possible Safety Scenario (see next paragraphs). The lack of reliable quantitative data requires specific survey analyses site-specific for oil spills dispersion that become vital for providing enough input data for a risk/hazard predictive modelling.

b. In a socio-economic perspective, the area presents limited risk probability due to the limited traffic and very clear control competencies exerted by the local authorities. It is not expected an increase of traffic vessels in such extent that can seriously expose to oil pollution risk the whole area. Nevertheless, the seasonal touristic human pressure, albeit limited, need to be monitored and included in the Detailed Contingency Plan (DCP) for this Pilot Area.

c. By an environment point of view, the area, strongly confined within a row of island chains, can emphasise the risk. In the worst case (albeit with very low probability), the occurring incident, the area is expected to be even more vulnerable to pollution, especially in terms of ecosystems, habitat, species and key natural resources. The lack of financial resources and limited human resources to adopt a response system can facilitate the prediction of outcome responses in case of lack of mitigation measures, therefore the effectiveness of the CDP

For the above-mentioned reasons, the Sali area can serve as a test case for investigating the risks associated with widespread dispersion of oil spill within a rich habitat flanked by a limited resources/skill enabling adoption of mitigation measures.

Sibenic Port – Croatia

Šibenik Port is located near the near the homonymous historic city in Croatia, located in central Dalmatia. It is situated on the estuary of the Krka River that with its 75km long flow and 360m of total fall, creates a unique natural reserve. The approach channel of the port is navigable by ships up to 50,000 tonnes deadweight. The port itself has depths up to 40 m. The area extends southeast from the island of Pašman and Kornati archipelagos to the cape Ploča and represents the continuation of the navigation ways from Middle and Pašman Channel through the sea of Murter towards the ports of Šibenik area.

From the sea of Murter towards southeast, navigation is possible through the channels of Žirje, Kakan, Kaprije, Zmajan, Zlarin and Šibenik, and from the cape Ploče you can sail towards Split area.

Figure 4 *- a) Port of Sibenik, b) and c) Zoom of the Port area ad Phote of main quays.*

From the open sea this area is accessible through passage of Samogradska vrata (between south part of Kornati islands and the island of Žirje) and south between the island of Žirje and the mainland.

Three passages lead to Šibenik channel:

a. through Logorunska vrata towards the north part of the island of Prvić;
b. through Šibenska vrata between the islands of Prvić and Zlarin, and
c. between the island of Zlarin and the islet of Dvainka(source: basic information of port: http://www.portauthority-sibenik.hr/en/port_of_sibenik/index.asp)

Usually, ships sail through the passage between the islands of Prvić and Zlarin. When approaching Šibenik channel from the south in case of southern winds, it is recommended to sail through the passage between the island of Zlarin and the islet of Dvainka.

Some data regarding the Port are reported in the Table S1 (Supporting Information) in Annex 2.

As can be deemed, the port is very big and one of the best-protected ports in Croatian Adriatic. Statistic data on the port are available in different database of the Croatian ports as well as in repository database at international level. The methodology plan presented in the next paragraphs for Detailed Contingency Plan can be fully applicable for the Port of Sibenic.

Nevertheless, due to the environmental and natural value of the area, the construction of Sensitivity Maps (Annex 1) is considered a useful tool for Risk Assessment.

Split Port – Croatia

Split port - Port of Split is situated at central Adriatic and it is the largest port in Dalmatia. The access to the port is guaranteed by coastal or internal access waterways through Drvenik, Šolta and Brač channel and "Splitska vrata". The longest access waterway from the open sea is the Hvar and Braç channel having a length of 55 M. (Features of the two Ports are given in the Table S2 and Table S3 Source (Annex 2):

***Figure 5**- a) Split Port alongside Dalmatian Coast. b) Zoom of the port location*

The Port of Split is situated at exceptional geographic position in the Mediterranean, with extraordinary maritime characteristics for reception of vessels, has earned the rank of one of the most important centres for local and international maritime traffic.

Due to its distinctive historical heritage and 1700 years of tradition, the port and City of Split have developed in unavoidable destinations for the cruise vessels sailing in the Mediterranean.

For the abovementioned features, the port of Split can be considered as the Pilot Area for which the Methodology reported in the next paragraphs can be fully adopted.

Nevertheless, as in the case of Sibenik port, due to the importance of the area by the environmental and natural point of view, construction of Sensitivity Maps is considered vital for developing the Detailed Contingency Plan for this site.

Some general recommendation for Croatian Coastal Pilot Sites.

For all sites selected in Croatia, it seems that risk analyses cannot have significant effects at cross border level in the short term, but the pollution risk seems to be more emphasized at local and regional level.

Because of Croatia's long coastline, it is obvious that protection of the entire coast is not easy and feasible with a common CP. Therefore, long-term national adaptation strategies and plans of actions should be prepared that identify areas and places of importance and include relevant adaptation/mitigation activities for each site.

Delta del Po – Veneto Regional Park

The Po Delta Veneto Park is part of the Emilia Romagna Park, located at the eastern border of the Po Valley, where the big Po river widens its Delta into the Adriatic Sea. The pilot areas (Delta Po of Veneto Regional Park) leaning into the sea like a triangle with the axis on the central branch of the Po of Venice, exactly on the 45th parallel and with the northern sides along the Adige and in the south along the Po di Goro. The Po Delta constitute the portion of territory youngest in Italy.

At the extremities of this area, there is a concentration of beauty, art, culture and nature, represented by the enchanting cities of Venice, Ferrara and Ravenna.

Figure 6 *- a) Po Delta River in the Adriatic Sea. B) zoom of the Delta Po Veneto Regional Park.*

In the Delta there are various environments, each with peculiar characteristics:

- the countryside with paleo-river beds,
- fossil dunes,
- embankments,
- flood plains,
- fishing valleys,
- lagoons or pockets and benches.

These elements of the landscape meet up coming from the east, descending along the current of the Po. These peculiarities make the area a very important site, and it was recognized as a Biosphere Reserve of UNESCO on June 9, 2015 in Paris.

As to the pollution consequences on the pilot area, those can be referred to the coastal surfaces and groundwater, wetlands and biodiversity loss, marine biological communities and commercial species.

Indeed, the whole area is subjected to different anthropic pressures such as petrochemical industry, seaport/port activities and ship traffic. In addition, the Northern Adriatic Sea coast near the Delta Po comprises a very precarious coastal environment subject to continuous morphological changes that can be appreciable even over short geological time scales (Gambolati and Teatini, 2002). Erosion is still active in many areas, both on the coastal sea floor and on the beach, since the beginning of the 20th century and especially after 1960 (Bondesan et al., 1995). Many areas around the Po River Delta are also located below the mean sea level and affected by natural or man-induced subsidence (Pirazzoli, 2005; Carbognin et al., 2009).

General recommendation for Italian Pilot Sites

For the above-mentioned features the Detailed Contingency Plan for the Delta Po should take into account specific environment (as above reported) and a multidisciplinary approach that takes into account a wide range of biogeochemical and socio-economic (land use) factors should be considered.

For analysing the vulnerability of multiple natural and human coastal receptors to oil sea pollution probably Multicriteria Decision Analysis (MCDA) that includes a wide variety of techniques for the evaluation and ranking of different alternatives, could be useful.

The methodology can include, besides the step of Hazard Identification and Characterization the following additional Steps in the Vulnerability Analyses ((i.e. the characteristics of a system that increase its susceptibility to the impact of pollution-induced hazards).

The methodology should be focused on:

1. Definition of the regional vulnerability matrix (identifies multiple coastal receptors that could be affected by multiple pollution impacts. Receptors could represent both natural or anthropogenic systems of interest within the considered area, due to ecological, economic or social reasons, and that can be not equally affected by the identified hazard)
2. Definition of vulnerability classes and classification of vulnerability values (The definition of vulnerability classes represent some thresholds (hazard degree level) to which each receptor may be affected by the pollution)

Construction of vulnerability maps (GIS-based vulnerability maps that represent the spatial variability of the vulnerability index (procedure presented in the Annex I

ANNEX1 - Risk map generation

Risk maps plays an essential role in supporting the entire risk assessment procedure since they are suitable to show information about hazards, vulnerabilities, elements at risk and risks over a specified territory. Therefore, they allow:

- to set priorities for risk reduction strategies;
- to share information among the several actors involved in the procedure;
- to share risk assessment outcomes among the stakeholders;
- to support the overall risk management strategy.

Due to the complexity of the investigated issue, the final risk maps are generated through the integration of information extracted in various steps. Following, the maps to be prepared are described:

1. Hazard maps, showing the expected spatial distribution of hazard;
2. Exposure maps, showing the spatial distribution of all relevant elements that need to be protected, such as infrastructures, naturally protected areas, economic resources etc. Each element at risk should be individually reported in a specific map;
3. Vulnerability maps, showing the spatial distribution of sensitivity to damage for each detected element at risk. The sensitivity of the elements at risk should be separately reported in different maps.
4. Final risk maps, showing the combination of likelihood and impact of a certain hazardous event as well as for aggregated hazard maps.

1. Generation of Hazard (H) maps

The hazard map can be generated integrating the information useful to characterize it, as explained in section 4.1. Therefore, meteorological and oceanographic data should be implemented together with information related to oil spill events in order to simulate the potential hazardous scenarios, which should be described in terms of trajectory, probability of dispersion and amount of oil along the path. Depicting those characteristics allows generating the final hazard map (Fig.1.1).

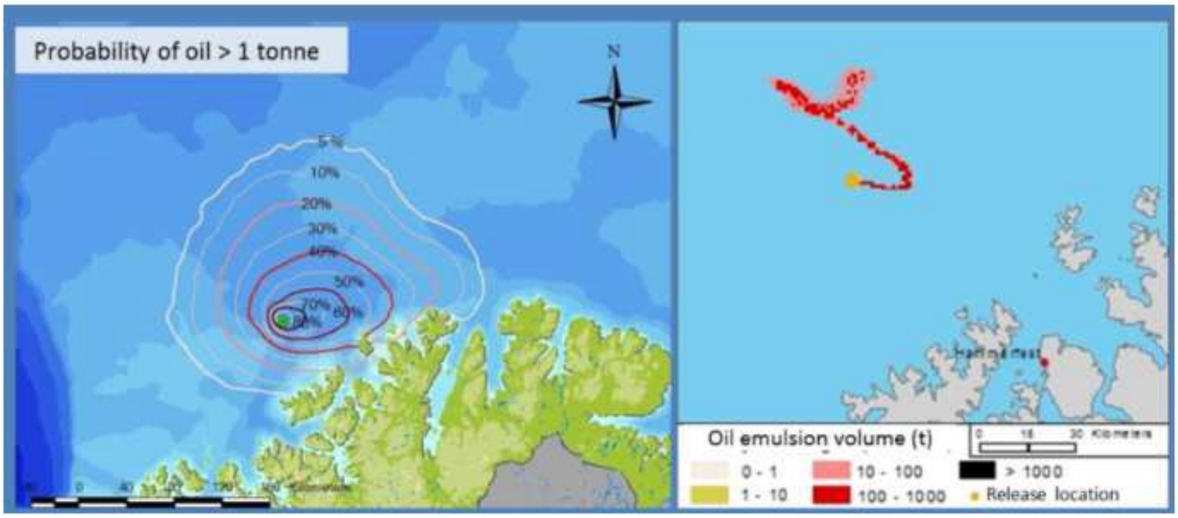

Figure 1.1 *- Example of oil spill fate and trajectory*

2. Generation of Exposure (E) maps

Basically, the exposure phase is composed by three steps:

1. identification of elements potentially at risk;
2. identification of features of each element at risk, identified in the previous step, in order to examine their response to the considered hazard;
3. mapping of the spatial distribution of each element at risk and their features.

As described in the previous section, the detected elements at risk to be considered in case of oil spill event are:

- coastline
- marine eco-environment
- economic resources

Each element at risk is subjected to a specific level of damage according to intrinsic features, able to influence their response to oil spill. Following, the characteristics to be considered are summarized for each element at risk:

- Coastline
    - shoreline type (grain size, slope) since it determines the capacity of oil penetration and/or burial on the shore, and movement
    - exposure to wave (and tidal energy) which determines the natural persistence time of oil on the shoreline
    - general biological productivity and sensitivity
- marine eco-environment
    - protected areas and important areas of biodiversity
    - types of coastal habitats/ecosystems
    - endangered sensitive species
- economic resources
    - non-living resources that may be directly damaged by oiling
    - managed areas that may suffer economically, e.g. through interruption of use if oiled
    - areas that may be valuable in the event of a spill for access or staging activities

Information regarding the spatial distribution of protected areas and the presence of species can be extracted from the UNEP-WCMC World Database of protected Areas (WDPA), while information related to the biodiversity can be obtained through the IBAT tool. Even the endangered species (unaccounted for by the ESI) must be identified and localized, as well as the coastal areas of interest for the marine flora and fauna. Moreover, endangered sensitive species may include:

- birds (seabird, shorebird, wading bird, migratory species, etc.);
- marine mammals (whale, dolphin, sea lion, seal, walrus, manatee, etc.);
- terrestrial mammals (which may be affected by contact with beached oil or by feeding on contaminated water species, e.g. beaver, mink, bears, wolves);
- fish (nursery areas, coastal species, commercial pelagic species, etc.);
- invertebrates (crustaceans, lobster, shrimp, endangered insects, etc.);
- reptile/amphibians associated to water (turtle, alligators, frogs, etc.).

Regarding the third element at risk, not all the possible socio-economics resources should be detected but just that ones that could potentially suffer because of a hypothetical oil-spill. Information related to them can be obtained by fieldwork activities, EUROSTAT data, etc.

Those activities could be grouped in different categories:

- subsistence, artisanal and commercial fishing, and fishing villages;
- aquaculture;
- water intakes (salt marsh plant, desalinization plant, aquaculture and salt production, industrial use);
- tourism and recreation areas (hotels, restaurants, marinas, beaches, recreational fishing, diving, etc.);

- port (including the activities and infrastructures);
- industrial activities (relying on maritime transport);
- infrastructures related to oil exploration, production and transport activities;
- cultural sites (archaeological, historical, religious, etc.).

Once the elements at risk have been identified, the exposure map for each of them should be generated assigning a binary code (0, 1) to each cell, according to their absence or presence. The cells with a value equal to 1 have to be investigated more in depth and for each of them all the features have to be mapped. The final outcome is composed by all the maps representing the spatial distribution of the features of each element at risk.

3. Generation of vulnerability maps

As underlined in section 4, vulnerability is the third essential element in order to assess the risk. Therefore, vulnerability maps are an indispensable tool to face oil spills since it allows detecting environmentally sensitive areas. According to the information that they provide, three typologies of vulnerability maps can be distinguished:

- Tactical vulnerability maps: able to assign a vulnerability values according to environmental, socio-economic, logistical and operational information needed to plan and implement response and protection operations;
- Strategic vulnerability maps: suitable for providing information related to the locating and prioritizing the most vulnerable sites at detailed geographic scale;
- Operational vulnerability maps: able to provide information on the general logistical and operational resources in order to generate detailed information for onsite oil spill responders.

Those three maps are strictly interconnected and are based on the elements at risks and their respective response features.

3.1 Tactical vulnerability maps

The tactical maps consist in assigning a vulnerability value to each element at risk according to their features in the study area. Vulnerability value assigned in this phase describes the intrinsic vulnerability due to the "physic" characteristics of the zone under investigation.

The procedure to be applied related to each element at risk is explained more in depth in the following sub-sections.

Coastline vulnerability map

The tactical map related to shoreline is obtained using the Environmental Sensitivity Index (ESI), which shows a value between 1 (low sensitivity) and 10 (very high sensitivity). That index is color-coded (from cold to warm colours), as shown in Fig.1.2, that means each colour identifies a specific shoreline.

***Figure 1.2** - Color code of Environmental Sensitivity Index (International Petroleum Industry Environmental Conservation Association, 2012)*

Therefore, the final map, an example is shown in Fig.1.3, is generated assigning the colour – code defined by the ESI index to each features of coastline.

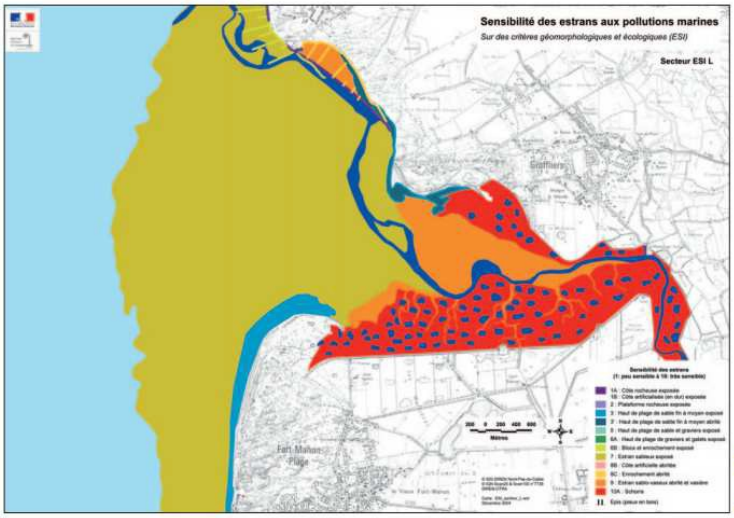

Figure 1.3 *- Example of shoreline typology map(International Petroleum Industry Environmental Conservation Association, 2012).*

Marine eco-environmental vulnerability map

The exposure map related to marine eco-environment is subsequently elaborated in order to tactical vulnerability map. This one can be obtained mapping the most sensitive species to oil, which are listed in IUCN Red List, through the application of a standardized set of biological symbols (Fig.1.4). Like ESI index, also in this case the symbols are color-coded, in order to specify the species vulnerability according to the month; on the contrary, the vulnerability depending on the season is expressed by the point position in the symbol (Fig.1.5).

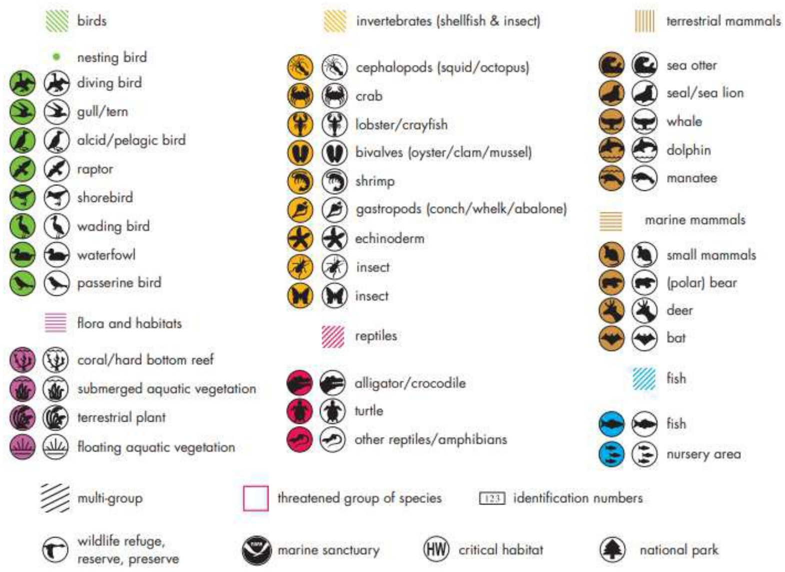

Figure 1.4 *- Symbols for the mapping of sensitive biological resources(International Petroleum Industry Environmental Conservation Association, 2012)*

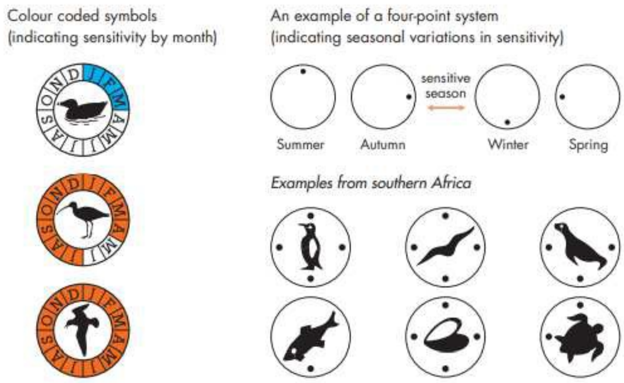

Figure 1.5 *- Symbols indicating monthly (left) and seasonal (right) periods of greatest sensitivity(International Petroleum Industry Environmental Conservation Association, 2012)*

The same procedure has to be applied also for the sub-tidal habitats (coral reefs, sea grass beds and kelp beds).

Socio-economic resources vulnerability map

Not all the possible socio-economics resources are interesting in this phase, indeed just which ones that could potentially suffer because of a hypothetical oil-spill should be mapped. The importance of those activities should be set according with the opinion of local and regional policy makers. Moreover, their relevance should also take into account seasons information (i.e. fishing season, aquaculture season, etc.). Therefore, like in the previous step, the symbols shown in Fig.1.6, have to be coded using a colour suitable for implementing their different vulnerability according to season and policy makers' opinions.

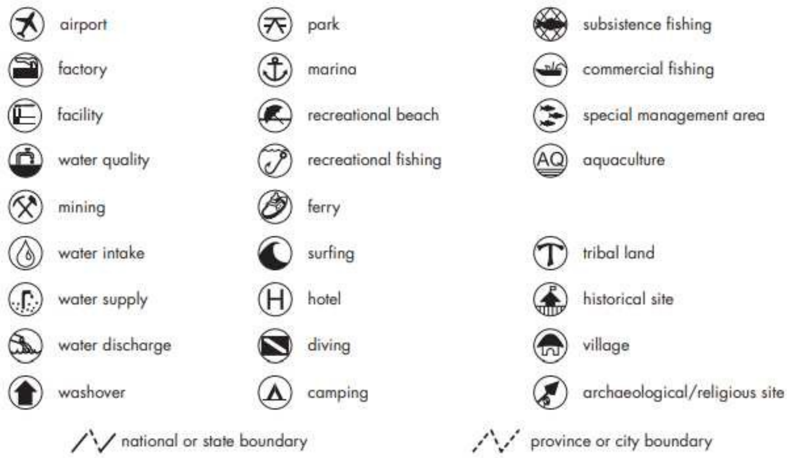

Figure 1.6 *- Symbols for mapping the socio-economic resources(International Petroleum Industry Environmental Conservation Association, 2012)*

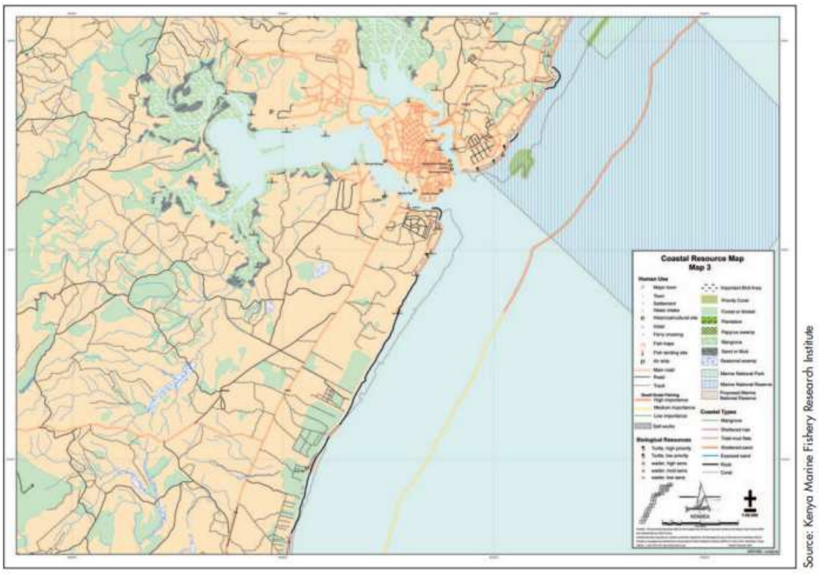

Figure 1.7 *-Example of socio-economic resources map(International Petroleum Industry Environmental Conservation Association, 2012)*

3.2 Strategic vulnerability maps

The strategic vulnerability map is aimed to define the priority of vulnerable sites and resources, identified in the tactical vulnerability map.

The suggested map-based approach to simplify and rank the vulnerability information involves three steps:

1. Ranking of the vulnerability of the shoreline
2. Ranking of the vulnerability ecosystems and natural resources
3. Ranking of the vulnerability of socio-economic features.

The first step consists in simplifying the ESI classification of shoreline from 10 to 5 categories, as shown in Fig.1.8.

ESI (from 1 to 10)		Simplified ESI	Mapping of simplified ESI
Index 1 and 2	→	1 (very low)	Not represented
Indexes 3, 4, 5 and 6	→	2 (low)	Not represented
Index 7	→	3 (medium)	Not represented
Index 8	→	4 (high)	**4 (high)**
Index 9 and 10	→	5 (very high)	5 (very high)

Figure 1.8 *- Shoreline type ranking(International Petroleum Industry Environmental Conservation Association, 2012)*

The second step, instead, consists in categorizing vulnerable natural resources through the application of the various existing lists, such IUCN red list (conservation status and distribution information on endangered species), lists of rare, endangered and threatened species and habitats, etc. Recovery time after a spill should be the criterion to be applied in order to classify all the sensitive natural resources. Moreover, the likelihood of impact must also be considered. When different vulnerable species are present in the same area, the highest vulnerability should be set. The vulnerability can be generated using a simple matrix, like that one shown in Fig.1.9.

sensitivity of species or protected area (highest) \ diversity of sensitive species (on the same area)	very low	low	medium	high	very high
very high	very high	very high	very high	very high	very high
high	high	high	high	high	very high
medium	medium	medium	medium	high	high
low	low	low	medium	medium	medium
very low	very low	low	low	low	medium

Figure 1.9 *- Sensitivity species ranking(International Petroleum Industry Environmental Conservation Association, 2012)*

Those values of that matrix should be subsequently reported on a map.

The third phase is related to rank the socio-economic features. A matrix similar to that ones used to assign the ranking to species vulnerability should be generated also for this features, although the parameters to be considered are: the importance of the activity, the number of personnel employed, the revenue and the duration of interruption for various degrees of pollution (developed by CEDRE).

3.3 Operational vulnerability maps

Operational maps are optional and have to be performed only for the most vulnerable and the highest risk sites, identified in the strategic vulnerability map, such as ports and oil and ling facilities. They have to include all operational and logistical information available, at scale of 1:10000 or 1:25000, as well as instructions for protection and response operations. Those maps will be used by the operators on site and, consequently, they should be printed, on two sides, in a proper format that can be brought on the field.

Following all the information that should be reported on the map are listed:

- detailed information to assist the operators on site (access points to the coast, launching and anchoring points for the booms, staging areas close to the shore, temporary waste storage locations, dangerous areas/areas to avoid, tidal range, currents, waves, winds, specific dangers on site, etc.)
- geo-referenced and explicit information for the operators, including GPS coordinates of the features displayed on the map, and operational instructions for the deployment of the equipment; and
- baseline information to locate the resources easily without prior knowledge of the area, e.g. high-resolution satellite images, aerial photos, topographic maps.

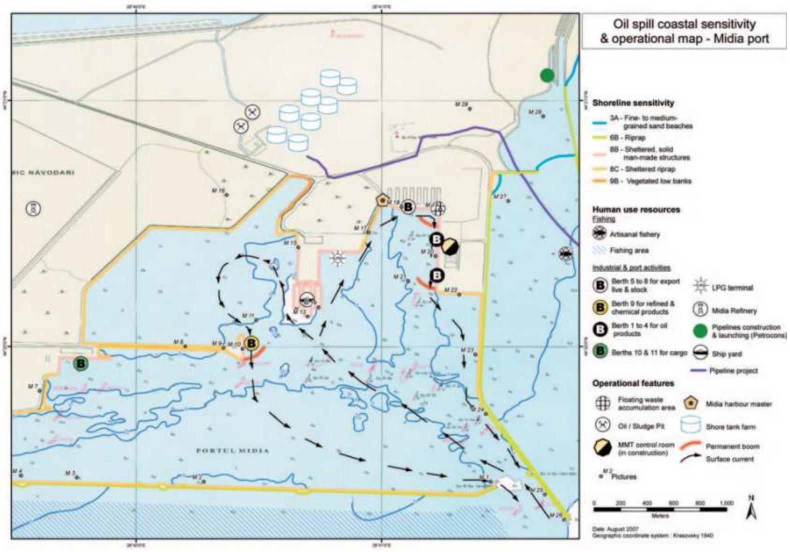

Figure 1.10 *- Example of an operational map related to the port of Midia, Romania(International Petroleum Industry Environmental Conservation Association, 2012)*

4. Risk map

Since vulnerability maps do not consider the information provided by the hazard characterization phase, the risk maps are necessary to take into account also the probabilities and the amount of the spilled oil to reach coastal environment. Indeed, risk maps are able to integrate the information provided by hazard characterization and "Strategic" vulnerability step. Therefore, a matrix crossing vulnerability index with the probabilities of oil reaching the coastal environments should be performed, assigning positive and negative values to both categories. In particular, the following code should be assigned to the strategic vulnerability map:

- (-) to low vulnerability
- (+/-) to medium vulnerability
- (+) high vulnerability
- (++) very high vulnerability

A code should be attributed to the probabilities, as well:

- (-) to low
- (+/-) to medium
- (+) to high
- (++) to very high.

For example, Table 1.1 reports the codes assigned to ESI and probability.

Table 1.1 *- ESI and probabilities code attribution.(Romero et al., 2013)*

ESI	Probability (%)	Code	Description
1	1–10	–	Low sensitivity or low probability
2	11–20		
3	21–30	+/–	Medium sensitivity or medium probability
4	31–40	+	High sensitivity or high probability
5	41–50		
6	51–60		
7	61–70	++	Very high sensitivity or very high probability
8	71–80		
9	81–90		
10	91–100		

That integration allows to compute the Environmental Vulnerability to Oil (IEVO) (Table 1.2).

Table 1.2 *- Index of Environmental Vulnerability Index to Oil (IEVO) (Romero et al., 2013)*

Crossing	Vulnerability	IEVO
(–) (–)	Low	2
(–) (+/–)		
(–) (+)	Medium	3
(+/–) (+/–)		
(+/–) (+)	High	4
(+) (+)		
(+/–) (++)		
(–) (++)		
(++) (++)	Very high	5
(+) (++)		

Once this step is completed, the environment can be classified according to the environmental vulnerability index to oil, generating a map, characterized by 5 grades of risk (Fig.1.11). That map is the final risk map.

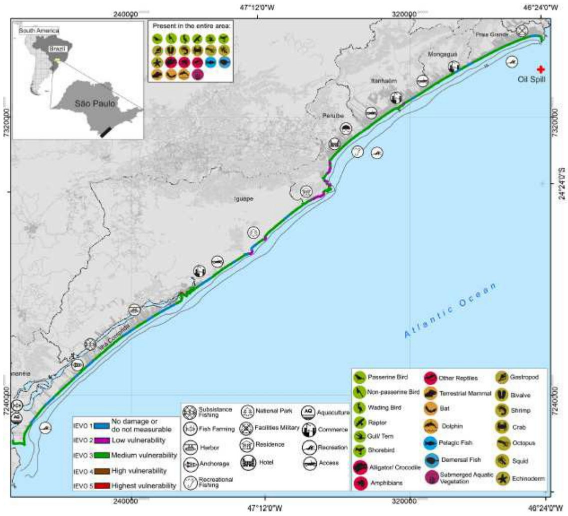

Figure 1.11 *- Example of risk map(Romero et al., 2013)*

ANNEX 2- Additional information

Table S1 *- Supporting Information – Port of Sibenik*

Services in the port of Šibenik		
	Indices	**Values**
Port Operations	Annual non-operating time (hours)	24/7/365
Anchoring services	Anchoring available	YES
	Pilot mandatory	YES
	Tugboat assistance - requirements	YES
Security services	Access monitoring system – brief description	NO, security guard on entry
	Other security systems – brief description	24 h surveillance, operation officer: 7.00 – 20.00
Goods handling support services	Customs services – operation hours	24/7/365
	Electronic documents management systems – brief description	NO
Railway services	Port shunting company	Croatian Railways
Technical specifications of port of Šibenik		
Features of Terminal	Linear length of quay (m)	1.564 m (+ 600m under construction)
	Berths and relative lengths (m)	1.564 m (+ 600m under construction)
	Draught (m)	5,20 – 10,0 m
	Maximum ship length (m)	260 m
	Capacity of yard (n° lorries)	8
	Size of yard (km^2)	0,050
Terminal equipment	Number of dedicated entrance gate	2
	Size of parking areas (km^2)	0,010
	Lighting for night-time operations	YES
	Customs warehouse (m^2)	5.000
	Quay and storage area (m^2)	32.000
	Car capacity	200
	Trailer capacity	N/A
	Trailer handling services	N/A
	Passenger terminal – brief description	Under construction: Berth No. 1: 191 m Berth No. 2: 133 m Berth No. 3: 50 m Berth No. 4: 114 m
	Offices, phones, faxes, internet	YES
Connections of port of Šibenik		
Port infrastructure connections	Number of access to motorways	1 (limited)
	Direct access to railway line	YES
	Number of road tracks	2

Table S2 *- Supporting Information – Port of Split (Gradska Luka)*

Services in the port of Split		
	Indices	**Values**
Port Operations	Annual non-operating time (hours)	24/7/365
Anchoring services	Anchoring available	YES
	Pilot mandatory	YES
	Tugboat assistance - requirements	YES
Security services	Access monitoring system – brief description	Video cameras (21) used by port authority and maritime police. On border crossing there are 2 entrances with cameras, controlled by the maritime police
	Other security systems – brief description	Metal–detectors and x ray for luggage, used by police and custom
Goods handling support services	Customs services – operation hours	24/7/365
	Electronic documents management systems – brief description	NO
Railway services	Port shunting company	NO
Technical specifications of port of Split – Gradska luka		
Features of Terminal	Linear length of quay (m)	-
	Berths and relative lengths (m)	28 (63 m-173 m)
	Draught (m)	7,9
	Maximum ship length (m)	250 or more
	Capacity of yard (n° lorries)	175 total for all queys
	Size of yard (km^2)	0,084654
Terminal equipment	Number of dedicated entrance gate	-
	Size of parking areas (km^2)	-
	Lighting for night-time operations	YES
	Customs warehouse (m^2)	-
	Quay and storage area (m^2)	2,807 (length of the quay)
	Car capacity	-
	Trailer capacity	-
	Trailer handling services	NO
	Passenger terminal – brief description	Agencies, shop, coffee shop, forwarding, custom, maritime police,
	Offices, phones, faxes, internet	YES
Connections of port of Split		
Port infrastructure connections	Number of access to motorways	1 (limited)
	Direct access to railway line	NO
	Number of road tracks	2

Table S3 *- Port o Split (Sjeverna Luka).*

Services in the port of Split		
	Indices	**Values**
Port Operations	Annual non-operating time (hours)	24/7/365
Anchoring services	Anchoring available	YES
	Pilot mandatory	1
	Tugboat assistance - requirements	1 (2)
Security services	Access monitoring system – brief description	Entrance control, video cameras used by port authority and maritime police
	Other security systems – brief description	-
Goods handling support services	Customs services – operation hours	24/7/365
	Electronic documents management systems – brief description	PML file for container ship stowage planning
Railway services	Port shunting company	1
Technical specifications of port of Split – Gradska luka		
Features of Terminal	Linear length of quay (m)	871
	Berths and relative lengths (m)	6 (171m)
	Draught (m)	10,2
	Maximum ship length (m)	200
	Capacity of yard (n° lorries)	150
	Size of yard (km^2)	160.000
Terminal equipment	Number of dedicated entrance gate	2
	Size of parking areas (km^2)	10.000
	Lighting for night-time operations	YES
	Customs warehouse (m^2)	38.000
	Quay and storage area (m^2)	123.000
	Car capacity	-
	Trailer capacity	4
	Trailer handling services	3
	Passenger terminal – brief description	-
	Offices, phones, faxes, internet	YES
Connections of port of Split		
Port infrastructure connections	Number of access to motorways	1 (limited)
	Direct access to railway line	YES
	Number of road tracks	2

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