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The Algarve Region Coast case study

Author Rui Jorge Baptista Conceição Graça

Advisor Emília Maria Delgado Domingos Antunes Malcata Rebelo (PhD)

Co-advisor Flávio Augusto Bastos da Cruz Martins (PhD)

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VULNERABILITY IDENTITY (V.ID) FOR COASTAL TERRITORIES SUBJECT TO OIL SPILL ACCIDENTS

The Algarve Region Coast case study

RUI BAPTISTA GRAÇA

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Advisor: Professor Doutor Emília Maria Delgado Domingos Antunes Malcata Rebelo

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Co-advisor:: Professor Doutor Flávio Augusto Bastos da Cruz Martins

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MASTER IN SPATIAL PLANNING AND URBAN PROJECT 2015/2016

CIVIL ENGINEERING DEPARTMENT

Tel. +351-22-508 1901

Fax +351-22-508 1446

✉ mppu@fe.up.pt

Edited by

FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Rua Dr. Roberto Frias

4200-465 PORTO

Portugal

Tel. +351-22-508 1400

Fax +351-22-508 1440

✉ feup@fe.up.pt

http://www.fe.up.pt

To my partner, Ana Laura, who has been a constant source of support and encouragement during these challenging times;

To my parents, who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve.

We already have the statistics for the future: the growth percentages of pollution, overpopulation, desertification. The future is already in place.

Gunter Grass

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RESUMO

Portugal tem um 942 km de costa e cerca de 1,72 milhões de km^2 de águas territoriais (cerca de 18 vezes a área do país), incluindo o mar territorial e Zona Económica Exclusiva (ZEE), representando a 11ª maior área no mundo. Dentro da UE, Portugal é o país com a maior área de águas territoriais, com exceção dos territórios ultramarinos da França e do Reino Unido.

A ZEE Portuguesa é atravessada diariamente por cerca de 200 navios superiores a 500 toneladas, dos quais 40 são petroleiros, para além dos cerca de 61000 que anualmente atravessam o Estreito de Gibraltar. Este tráfego é perigoso, representando um alto risco económico, ambiental e social para a região.

Nesta tese é proposta a criação de um índice multi-indicador para a vulnerabilidade face a poluição por hidrocarbonetos, o ID.V (Identidade de Vulnerabilidade). Ao contrário de índices tradicionais com um único indicador, o ID.V considera diferentes vetores de vulnerabilidade face a um derrame de hidrocarbonetos para criar um "cartão de identidade" de cada Unidade no domínio de estudo, associando uma imagem gráfica a ele e proporcionando uma leitura fácil e imediata.

Os vetores considerados incluem vários indicadores estatísticos socioeconómicos, ambientais e de património associados a cada um dos municípios. Estes vetores integram informações sobre o comprimento e tipo da costa de cada município, áreas naturais e zonas de Rede Natura 2000, a população, o valor económico gerado pelas pescas, hotelaria e portos e marinas na economia de cada município. A visualização explícita dos diferentes vetores permitirá a análise *per si* dos diferentes tipos de vulnerabilidades, os quais podem ser facilmente mascarados quando agregados num único índice de valor único. Considera-se este um passo fundamental para expandir os resultados de estudos anteriores relativos ao risco de derrames de petróleo na costa do Algarve. Este modelo é facilmente escalável, podendo ser usado para comparar as vulnerabilidades de municípios face a uma região, regiões face a um país ou países face a um continente.

Pretende-se que este ID.V seja utilizado por entidades e técnicos ligados ao planeamento regional e urbano aquando da elaboração de Instrumentos de Gestão Territorial a serem aplicados em faixas costeiras, entidades e técnicos ligados à produção de Cartografia de Risco bem como Instituições com responsabilidades na resposta a ocorrências de derrame de hidrocarbonetos de modo a planear a sua resposta de emergência.

A metodologia proposta é totalmente genérica e escalável, permitindo sua aplicação em outras regiões do mundo.

PALAVRAS-CHAVE: derrame de petróleo, avaliação de riscos, Identidade de Vulnerabilidade, Algarve, planeamento urbano.

ABSTRACT

Portugal has a 942 km long coastline and approximately 1.72 million km2 of territorial waters (about 18 times the area of the country), including territorial sea and Exclusive Economic Zone (EEZ), representing the 11th largest area in the world. Within the EU, Portugal is the country with the largest area of territorial waters, excluding the overseas territories of France and the United Kingdom.

The Portuguese EEZ is crossed daily by approximately 200 vessels larger than 500 tons, of which 40 are tankers, in addition to about 61000 ships of all types that cross annually the Straits of Gibraltar. This traffic is hazardous, representing a high economic, environmental and social risk to the region.

In this thesis, a multi-indicator index for costal oil spill vulnerability, the V.ID (Vulnerability Identity) is proposed. Unlike traditional single indicator indexes, V.ID considers different vectors of oil spill vulnerability to create an "Identity Card" of each Unit in the Study Domain, associating a graphical image to it, providing easy and immediate reading.

The vectors considered include various socio-economic and environmental statistical indicators associated with each of the municipalities. These vectors integrate information regarding the length and type of coast of each municipality, natural areas and Natura 2000 areas, population, importance of hotel business and fishing on the economy of each municipality. The explicit visualization of the different vectors will allow the analysis of each independent aspect of vulnerability, easily masked when aggregated in a single index. It is a key step to expand the results of previous studies concerning the risk of oil spills on the Algarve coast. This model is easily scalable and can be used to compare the vulnerabilities of municipalities face to a region, regions with a country or countries face a continent.

It is intended that V.ID can be used by entities related to urban and regional planning in the preparation of Land Management Plans to be applied in coastal areas, authorities related to the Risk Cartography production and institutions with responsibilities in the response to oil spills in order to plan their emergency response.

The methodology proposed is fully generic and scalable, allowing its application in other regions of the world.

KEYWORDS: oil spill, risk assessment, Vulnerability Identity, Algarve, Urban Planning

SUMMARY

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ABBREVIATIONS AND SYMBOLS

BII	-	Beach Importance Index
CIP	-	Public Interest Set
E	-	Economy Vector
EN	-	Environment and Nature Vector
ESI	-	Environmental Sensitivity Index
H	-	Heritage Vector
ICNF	-	Portuguese Forests and Nature Conservation Institute
IGT	-	Instruments of Territorial Management
IIP	-	Public Interest Building
IM	-	Municipal Rating Heritage
IMO	-	International Maritime Organization
INAG	-	Portuguese National Institute of Water
IPTM	-	Portuguese Institute for Ports and Maritime Transport
MIP	-	Public Interest Monument
MN	-	National Monument
OSRA	-	Oil Spill Risk Assessment
OSRA-IT	-	Oil Spill Risk Assessment – Information Technology
PDM	-	Municipal Land Use Plan
PEOT	-	Special Plan of Territorial Management
PM	-	World Heritage – UNESCO
PMOT	-	Territorial Management Municipal Plan
PNPOT	-	National Spatial Planning Policy Program
POAP	-	Protected Areas Management Plan
POC	-	Coastline Program
POOC	-	Coastal Zone Management Plan
PROT	-	Regional Plan for Territorial Management

PS - Sectoral plans

RCM - Council of Ministers Resolution

S - Social Vector

SIP - Public Interest Site

V.ID - Vulnerability Identity

VA1 - Beaches with aptitude to water sports

VA2 - Beaches with existence of concession

VA3 - Beaches with Blue Flag

VC - Heritage in the process of classification

VCC - Load capacity allows us to estimate the number of users according to the size of the beach and to the criteria of POOC

VCP - Classification in the Coastal Zone Management Plan (POOC), which identifies the main use of the beach

VRSA - Vila Real de Santo António

1

INTRODUCTION

1.1 SCOPE OF WORK

Oil has become a cornerstone in the development of civilization (due to its extensive use in transportation, in heating, as raw material in manufacturing and in many other applications). Obtaining, transporting and transforming it safely and effectively has thus become a major issue, affecting both public safety and economic activities.

This concern is divided into several sectors: part of the society cares about its extraction, the other part with its price, another part is still concerned to combat its exploitation. And there is a part of society which is concerned with the effects of oil spills on the environment around us.

The report of the International Tanker Owners Pollution Federation Limited (ITOPF) states that 19 of the 20 largest spills recorded occurred before the year 2000 (Figure 1). A number of these incidents, despite their large size, caused little or no environmental damage as the oil was spill some distance offshore and did not impact coastlines [1]. Nevertheless, the risks of a spill at open sea can be quite harmful if not detected early. The oil can take time to get eroded and stay on the surface long enough to affect seabirds, also interfering with the trophic balance of the ecosystem.

According to ITOPF, the number of incidents has been substantially reduced, as in the 70s, 24.5 spills per year on average were observed, a number which was reduced to an average of 1.8 oil spills a year by 2014 (Figure 1).

Estimates published by the U.S. National Academy of Sciences [2] revealed that, every year, over 600,000 tonnes of oil are spilled in the marine environment due to human activities. Notwithstanding the decreasing number of large spills over the last 40 years, what is certain is that currently the volume transported (either in terms of capacity of tankers and the number of tankers in circulation) is much higher than in the 70s. Ship-borne transportation and the size of tankers have been increasing and this trend is likely to persist [3]. The volume of oil transported per tanker is rapidly increasing due to changes in transportation strategies, including the widening of the Panama Canal and the increase in efficiency of larger vessels. This also increases the risk of an oil spill accident.

Operational discharges associated to the maritime traffic (e.g. tank washing or leakage of lubricants) contribute with over 270,000 thousands of tonnes/year, ranking as the main anthropic input of oil to the marine environment. Vessel-related accidental spills (e.g. collisions, explosions, etc) contribute with about 100,000 tonnes/year. In spite of the international efforts in reducing the oil pollution, spills still occur and it is not possible to predict when, where or how they will happen.

Oil Spill Risk Assessments (OSRAs) have been carried out in several parts of the globe to deal with such uncertainty, supporting decisions for the protection of the marine and coastal environments [4].

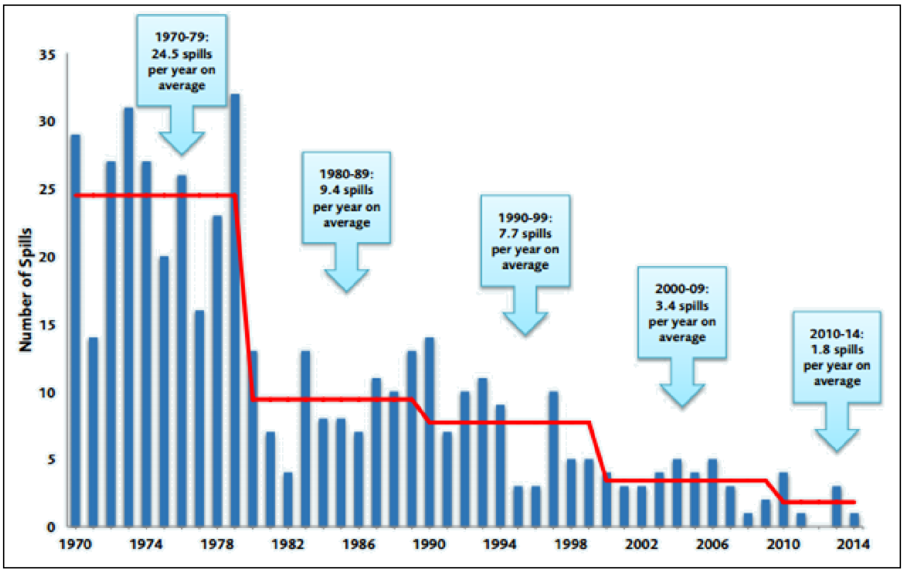

Figure 1 - Number of large spills (>700 tonnes) from 1970 to 2014 (ITOPF 2015)

According to Neves [4], the risk of an oil spill accident in each coastal sector n follows the equation (1):

$$R_n = (P_{cc})_n * I_n \tag{1}$$

where $(P_{cc})n$ is the probability of oil beaching for the segment n and I_n are the impacts of the spill once it reaches land.

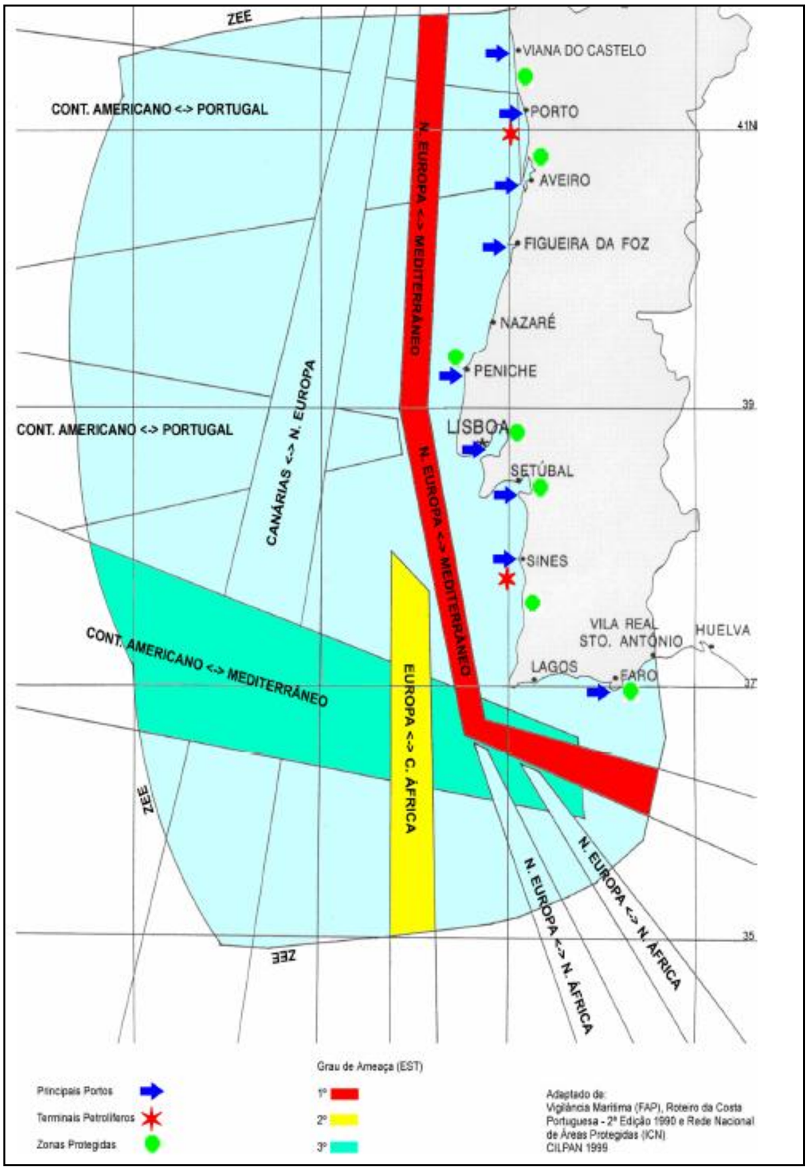

Figure 2 - Map of navigation corridors

Portugal is located in the southwest of Europe, one of the main routes for entrance in Europe. As can be seen in Figure 2, the corridors to the American continent, to North Africa and mainly the corridor that links North Europe to the Mediterranean Sea crosses the Exclusive Economic Area of Portugal.

In Portugal, maritime transport of goods is an important component of the international transport system - almost 60 million tons moved (1998). In this context, the main ports are Lisbon, Leixões and Sines. Although smaller, the Port of Viana do Castelo, Setúbal, Faro and Portimão[5] are also important as regional ports or for specialized cargo. Over the national maritime traffic corridors sail, every day, about 200 ships carrying over 500 tons of various goods, 40 of which are oil tankers[6].

Spills may occur around the world anywhere that oil is produced, transported, stored, or consumed. The vast majority of spills are relatively small. 72% of spills are 0.003 to 0.03 ton or less. The total amount of these small spills comes to 0.4% of the total spillage. The largest spills (over 30 tons) make up 0.1% of incidents but involve nearly 60% of the total amount spilled. Naturally, the relatively rare large spill incidents get the most public attention owing to their greater impact and visibility, though spill size itself is not a direct measure of damage. Location and oil type are extremely important in determining the degree of environmental and socioeconomic damage. Oil spills and discharges can occur at any point in the “life cycle” of petroleum during oil exploration and production; transport by vessel, pipe- line, railroad, or tanker truck; refining; storage, consumption or usage as fuel or as raw material for manufacturing; or waste disposal. The regional and national patterns of spillage depend on the oil-related activities in those locations, the amount of oil handled, and the degree to which oil prevention measures have been implemented and enforced.[7]

The impact of the spill on land depends on the vulnerability of the stretch of coast affected by the oil spill. The main objective of this thesis is to develop a Vulnerability Index, the V.ID, associated to a graphic image through which the oil spill vulnerability of an area can be readily assessed.

V.ID is intended to create an image that agglutinates four key vectors in the analysis of a territory: Social, Economy, Heritage and Environment and Nature.

1.2 OBJECTIVES

The objectives of this thesis are:

- To develop a graphical identity to compare the coastal vulnerability facing an oil spill;
- To do so resorting to the calculated vulnerability and to propose a method to achieve sectorial risks of a coastal territory.

Being able to demonstrate the vulnerability of a certain region through a graphical representation makes its reading more immediate, thus facilitating the analysis of this region to environmental managers for decision makers, for companies in the sector (producers and transporters), to NGOs, but mainly it’s intended to be a valuable index for urban planners to characterize the vulnerability of a region or territory during the elaboration of land use plans, strategic plans or special plans.

1.3 THESIS STRUCTURE

The thesis is organized as follows. Section 2 goes over other methodologies used to approach the topic. Section 3 describes how to calculate and normalise each of the vectors of vulnerability. In Section 4 the case study (five municipalities of Algarve) is described and analysed, and in Section 5 the discussion and conclusions are presented.

2

STATE OF THE ART

2.1 OTHER METHODOLOGIES

One of the first forays into the establishment of methodologies for estimating the vulnerability of coastal areas facing the oil spills was made by Gundlach, E.R., Hayes [8], where this vulnerability was only estimated taking into account the physical and geological characteristics of the coast. From 1978 to the present day, several approaches have been developed trying to include the threat an oil spill poses to natural environments as well as to the socio-economic activities in a given geographical area.

Castanedo et al. [9] developed an integrated oil spill Vulnerability index (Vi) for coastal environment and implemented it to the Cantabrian Coast. This index takes into account the main physical, biological and socio-economical characteristics by means of three intermediate indexes. Although this approach is the one that is more close to what is intended in this thesis, it is considered that the vector "Heritage" should not be disregarded. On the other hand, this Vi is presented with a unique value resulting from the compilation of values referred to and the final value results in a mask of the different vulnerabilities of the coast.

C. Frazão Santos et al [10] developed a methodology to assess the spatially differential degree of vulnerability to oil spills that consisted on the creation of a composite indicator, formed by a series of individual, relevant and multidimensional indicators compiled into a unique index.

According to Lee and Jung, [11], the oil spill risk assessment is carried out by using two factors:

1. The impact probability of the oil spill, and;
2. The first impact time of the oil that has been spilt.

The risk assessment is conducted for environmentally sensitive areas, such as the coastline and aquaculture farms in the Garorim Bay area. The prediction of the oil spill spread is based on real-time sea conditions and this risk assessment is conducted for environmentally sensitive areas. Thus, the conclusions and the study of the probabilities of spilt oil on the coastline and aquaculture farms can be used to understand what kind of damages to the environment could result from the spill. It acknowledges that there is a high probability of errors when using real-time sea and wind conditions, because the hydrodynamic conditions and wind conditions are rapidly changing. The same authors highlight that Oil Spill Risk Assessment (OSRA) methodologies do not fulfil some requirements necessary to support decision making:

1. Uncertainties in the risk estimates may be underestimated;
2. Operational oil spills (i.e. intentional small, but frequent, spills associated to vessel operations such as tank washing) have not been addressed and;
3. The risk analysis outputs are not appropriate for communication with stakeholders [4].

Neves [4] developed a new OSRA approach based on a critical analysis of the ISO 31000:2009 on risk management principles and guidelines, addressing the limitations observed in previous OSRA and including Information Technology tool, the so called IT OSRA.

Part of the work held by the author was related with the calculation of beaching probability of an oil spill, taking into account not only the location of the release point and spillages but also wind direction, oceanic currents and intensity of maritime traffic. After about 70,000 simulations made he was able to empirically confirm the validity of Formula 1) presented.

2.2 COMPOSITE INDEXES VS MULTI-INDICATOR INDEXES

Multi-indicator indexes have clear advantages over single (composite) indicators, but also some disadvantages, as namely.

When an assessment is made using a composite indicator, the individual values of each variable composing the indicator are hidden in the final value, i.e. the indicator can have the same value with different combinations of individual variables, so the real characteristics of the vulnerability remain camouflaged in this reduction. In opposition to this a multi-indicator index reveals the true nature of vulnerability, making it possible to distinguish between different types of vulnerability.

The multi-indicator index proposed in this article (the V.ID) results in an identifying image of each municipality in the form of web graphic as regards to oil spill vulnerability, working as an “ID card” of each sub-region allowing an easy visual identification of its vulnerability value as well as its nature. The methodology can be easily applied in other regions, and scaled to other dimensions to analyse countries or even regions. The graphical nature of the index helps the communication with the decision makers and is a valuable tool for aiding oil spill response in their three aspects (strategical, mapping and operational) as systematized in IPIECA [12].

Once V.ID is a graphic identity, the strengths and weaknesses of a unit of study can easily be checked without having to rely on tabulated values.

A disadvantage of this kind of indexes is that it produces a set of numbers which must be converted into a single objective function when developing optimization algorithms or computing absolute risk.

Despite the advantages associated with the concept here presented, the fact of some indicators not being included (such as intangible heritage and biological data of biodiversity) can be seen as a negative point. However, taking into account that V.ID will be helpful in urban and territorial planning; these points can be considered in later work.

2.3 FRAMEWORK OF TERRITORIAL MANAGEMENT INSTRUMENTS

2.3.1 NATIONAL SCOPE

Once an oil spill occurs along a certain costal stretch, it will become (even in a low dimension) a national issue. The impacts can be felt in several areas of activity and influence on a short or long period the economy and environment, and the natural recovery of coastlines may last several years (depending on the species).

The National Spatial Planning Policy Program sets out the main relevant options to the organization of the national territory. It constitutes the reference framework for considering and balancing options in the development of other land management instruments and is an instrument of cooperation with the other member states for the organization of the European Union. There are two main planning instruments with greater influence in the establishment of strategies with direct impact over the development of the Portuguese Coast: the Coastal Zone Management Plans (POOC) and the Protected Areas Management Plans (POAP).

2.3.1.1 Coastal Zone Management Plans (POOC)

The Coastal Zone Management Plans (POOC) emerges as a framework instrument for the improvement, upgrading and management of the resources present on the coast. These plans are concerned, especially with the protection and integrity of biophysical space, with the use of existing resources and the conservation of environmental and landscape values.

POOC have as objectives the definition of safeguard regimes, protection and management by establishing preferred, conditioned and prohibited uses in the intervention area and the articulation and harmonization, in its area of intervention schemes and the measures other territorial management tools and instruments planning of water.

In the Algarve region three POOC were produced to regulate the uses of the coastal area:

- POOC Sines – Burgau;
- POOC Burgau – Vilamoura;
- POOC Vilamoura – Vila Real de Santo António.

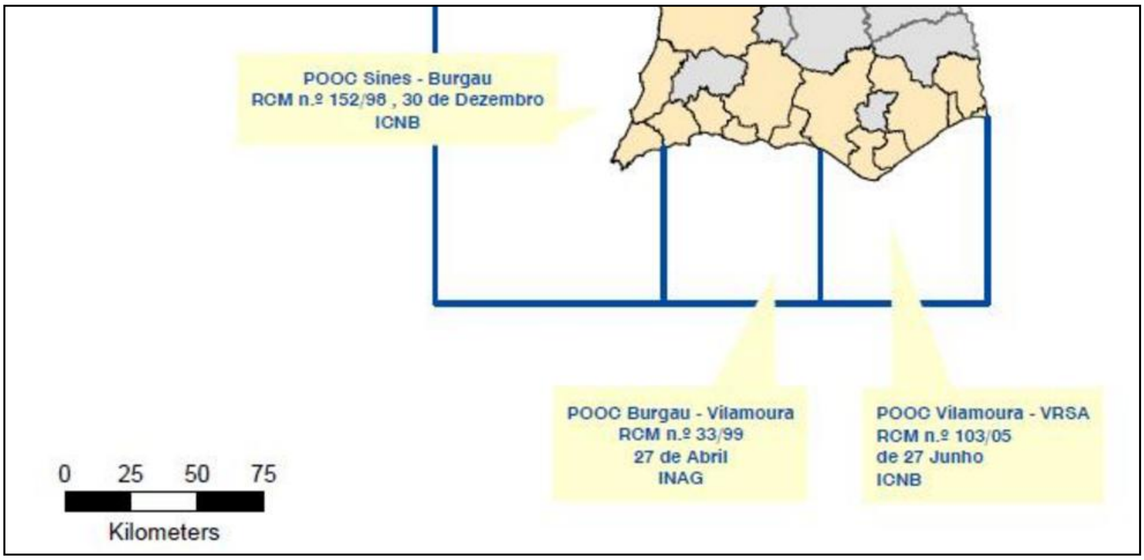

Figure 3 – Localization of the three POOC in the Algarve Coast

After consulting the different laws that regulate the three POOC it was possible to verify that none of them refer the possibility of an oil spill in the area affect to each of the protected areas and its effects.

Nevertheless, after the publication of the General Law of Public Land Uses Policy, Spatial Planning and Urbanism (LBPSOTU) - Law No. 31/2014 of 30 May - the territorial management system has changed and the POOC assumed a new designation: Coastal Zone Program (POC).

The Odeceixe - Vilamoura section is covered by two POOC, the Sines - Burgau (RCM nª152/98) and Burgau - Vilamoura (RCM nª 33/99). The new Program of the Coastal Zone Odeceixe-Vilamoura (POC OV) covers the coast belonging to the municipalities of Aljezur, Vila do Bispo, Lagos, Portimão, Lagoa, Silves and Albufeira, corresponding to a sea front of 210 Km, and is nowadays in preparation.

While the Technical Report [13] of the Public discussion period refer as a threat (in a SWOT analyses) the "*Degradation of sea water quality caused by oil spills and dangerous products in coastal areas*", no vulnerability assessment is done for each municipality or even a vulnerability comparison is proposed according to the risk of the different coastal areas.

2.3.1.2 Protected Areas Management Plans (POAP)

The POAP establish the protection and conservation policy that is to be set in each of the protected areas of the National Network of Protected Areas (RNAP), subject to the planning process, through the establishment of resource protection schemes and natural values and the regime management compatible with sustainable use of the territory, which results in different protection schemes and its zoning (Uses and activities to interdict, to condition and to promote, for protection system) as well as a set of Specific Areas of Intervention . The POAP in force are binding on the Public Entities and also for private parties.

The 25 Protected Areas (PA) with approved POAP are:

- 1 National Park;
- 13 Natural Parks;
- 9 Nature Reserves;
- Protected Landscapes.

The set of 25 AP with POAP nationwide covers a total area corresponding to 7.6% of the territory of mainland Portugal, and since 2008 all AP were provided with POAP. In the coastal area of the Algarve Region, three POAP are in effect:

- POAP 12 - Southwest Alentejo and Costa Vicentina Natural Park;
- POAP 14 – Ria Formosa Natural Park;
- POAP 23 - Castro Marim and Vila Real de Santo António Marsh Natural Reserve.

After consulting the different laws that regulate the three PAOT it was possible to verify that none of them refer the possibility of an oil spill within the protected areas and its effects.

2.3.2 REGIONAL SCOPE

Following the orientations given by the National Spatial Planning Policy Program (PNPOT), in 2007 the Portuguese Government published the Algarve Regional Plan for Territorial Management – PROT (RCM n.º 102/2007 of 3 August).

This Plan is divided in three volumes:

- Volume I - Plan Report - is the fundamental document that contains the options strategic territorial basis, the territorial model and guidelines. The document is divided into 6 chapters, with the following contents:
    - Chapter I - Introduction: contains the framework the preparation of PROT, territorial scope and content and documentary material;
    - Chapter II - Vision for the Algarve: presents the national strategic framework, a synthesis of diagnosis of the region and the vision, ambition and objectives defined strategy for the development of Region long-term;
    - Chapter III - Territorial Strategy: consisting of the strategic options for territorial base and the model territorial organization advocated for the Region;
    - Chapter IV - Policy Coordination: focuses on the integration of complementary policy strategy territorial defined;
    - Chapter V - Guiding Standards: Describes the rules that should guide the actions of public bodies in pursuit of PROT strategy, distinguishing general standards, territorial nature and character sector;
    - Chapter VI - Evaluation and Monitoring: Provides guidelines for monitoring and evaluation actions the implementation of PROT Algarve.
- Volume II - Characterization and diagnostics - are presented the Biophysical studies of characterization, analysis of population dynamics and settlement and prospects economic, social and cultural development Algarve.
- Volume III - Additional elements – in this volume are presented the regional sectoral strategies that complement the strategic options for territorial basis, contains the Programme Implementation and includes a set of Attachments with reference elements for the implementation of the guidelines and still cartography at 1: 200 000 accompanying the plan.

In the referred RCM n.º 102/2007, it can be read that the sustainability index "oil spill" can affect two kind of Strategic Policies, such as:

- Strategic Policy 2 - Diversification and tourism qualification;
- Strategic Policy 13 - Recovery of role of 'exporter' of agriculture, fisheries, aquaculture and processing industries

Consulting the Map of Risks of this Plan, it can be seen that the risk of *beaching* (when an oil spill hits the coast) was not considered, neither the vulnerability assessment was done for each municipality or even a vulnerability comparison is proposed according to the risk of the different coastal areas.

2.3.3 Local Scope

The Municipal Land Use Plan (PDM) is a Territorial Management Municipal Plan (PMOT) that establishes the territorial development strategy, the municipal policy planning and urbanism and other urban policies, integrates and articulates the guidelines established by the Instruments of Territorial Management (IGT) nationwide (PNPOT, PS and PEOT) and regional (PROT) and establishes the spatial organization model of the municipal territory.[14]

After consulting the different PDM of the Algarve Region, despite all the chapters, characterizations, risk studies and harmfulness maps, it was not possible to find single reference to the possibility of an oil spill, what can be damaged or destroyed due the contact of hydrocarbons with the fauna and flora of the municipalities coastal areas, or even what can happen to the municipal economy if an oil spill occurs.

3

METHODOLOGY

3.1 VECTORS FOR IMPLEMENTING THE V.ID

After an oil spill, several resources and activities may be affected in the region. In this study, four different vectors are identified characterizing an area or region. For the purposes of nomenclature simplification "Unit" is hereafter referred as the area intended to be characterized as a subsystem of a larger territory and "Study Domain" the region in which that subsystem is included. The methodology to attribute numerical values to each of the four different vectors is described below.

3.1.1 SOCIAL VECTOR

When an oil spill happen in a certain area the direct and indirect impacts will affect the area for a long period. One of the possible aftermaths of an oil spill can be the unemployment of the affected territorial area, mainly in the economic areas related to tourism and fisheries.

Following the BP Deepwater Horizon oil spill, Cope and Slack [15] developed a social vulnerability index to examine how emplaced characteristics engender unique susceptibility to the disaster, with specific attention on the influence of natural resource employment and community sentiment. Results show negative mental health impacts to be more pronounced at baseline compared to later time points and that shifts in negative mental health were not uniform for localities with divergent levels of social vulnerability, where places identified with high levels of social vulnerability the effectiveness of attributes associated with resilience were muted, while the effect of vulnerability attributes was amplified.

On another point of view, after an Oil Spill the affected communities usual receive compensations. A compensation regime for oil pollution damage caused by spills of persistent spills of oil from tankers, the International Oil Pollution Compensation Funds (IOPC Funds), was established in 1971 with support from International Maritime Organization (IMO) [16]. Nervertheless, the authors found that only 11% of the 2007 *Hebei Spirit* Oil Spill in Korea claims were approved for compensation. The size of admitted claims is minimal compared to the economic value of the damage suggested by the contingent valuation literature on tidal flats in Korea.

Field observations are few and mostly qualitative and anecdotal. Nonetheless there are several reports of human response to acute exposure during spills. Symptoms characteristic of acute toxicity to petroleum vapours were reported following the Amoco Cadiz oil spill along the coast of France. An estimated 40,000 metric tons of light hydrocarbons may have been released into the atmosphere of the coastal area during the spill, creating a potential health hazard to the inhabitants, as well as the personnel in spill cleanup activities. Exposure to the workers was increased by mists and aerosols resulting from the high-pressure projection of water and steam during various phases of the cleanup operation. Such activities contributed to increased dermal contact and even ingestion of small amounts of petroleum by the cleanup personnel. There are recognized human biochemical and physiological responses associated with acute exposure to natural crudes or their refined products. In general these responses appear to be transient and short lived unless the exposure levels are unusually high. Prolonged subacute exposures, however, can result in tissue damage. In situations where the potential for human contact exists, efforts should be made to limit exposure through the use of respiratory and protective equipment [2].

Observing this, three subvectors are considered, characterizing the Study Unit relatively to the Study Domain regarding:

i. Resident population in the Unit;
ii. Employed population in Hospitality in the Unit and;
iii. Employed population in Fisheries in the Unit.

For the calculations of this study, it is considered only the employed population in Hospitality. However, this subvector can be extended and also include all maritime-tourist activities with expression on the coast.

3.1.2 ECONOMY VECTOR

The economic vector analyses the vulnerability of an area in terms of income losses resulting from interrupting activities related to the coastal uses.

The number of the variables to consider in the economy vector after a possible oil spill can be very high as stated in the work of Shang *et al* [17]. For the sake of simplicity, this work considers only the more relevant three:

i. Economic value generated by Ports and Marines in the Unit;
ii. Economic value generated by the Tourism sector in the Unit and;
iii. Economic value generated by the Fisheries sector in the Unit;

3.1.2.1 PORTS AND MARINAS

Since the beginning of times, populations from coastal areas felt the need of construction of Ports and/ or a Marinas to berth their boats. In these places was where the boats were protected from the waves and where the fisheries and exotic products were landed.

Nowadays, the characteristics and function are almost the same, but depending on places it can have another function: recreation.

In a way to fulfil the needs of this study, it is necessary to evaluate the Economic value generated by Ports and Marines in the Unit, i.e., the total income that all kinds of functions associated to a port or to a marina.

If an oil spill occurs in a port or marina area, this infrastructure may have to be close to navigation due the operations of cleaning.

In the Algarve Coast it's possible to find 3 main marinas (Portimão, Albufeira and Vilamoura), 2 Docapesca and several smaller ports.

The 3 Marinas can be found in the municipalities of Lagos, Albufeira and Loulé (Vilamoura Marina). With full protection of the sea and surrounded conditions of an extraordinary beauty of the environment and history, these Marinas have hotels, apartments, shops and leisure areas.

The Docapesca is a public company under the Ministry of Agriculture and Marine that came to succeed in February 2014 the Port Institute and Maritime Transport (IPTM) the functions of the port authority in fishing ports and marinas and marinas, so far under jurisdiction of that institute [18]. In the Algarve Coast there can be found two, one in Olhão and one in Portimão.

Figure 4 - Marinas in Algarve: a) Lagos Marina, b) Albufeira Marina, c) Vilamoura Marina

3.1.2.2 TOURISM

In what concerns to Tourism, Algarve is one of the Europe's best destinations. As can be seen in the Table 1, from 2010 to 2013 there was an increase of 11.2% of overnight stays in hotels in Portugal. A similar increase was observed in the Algarve Region (11.3%) in the same period of time. On the other hand, it can be observed that tourism in Algarve is responsible for 35% of overnight stays in Portugal. Tourism is one of the top economic drivers of the Algarve Region.

Table 1 - Total overnight stays in Hotels

Total overnight stays in hotels		
	2010	2013
Portugal	37 391 291	41 569 716
Algarve	13 247 450	14 741 969
Lagos	616 645	788 062
Olhão	14 920	83 643
Portimão	1 708 149	1 789 486
Tavira	610 313	559 778
Vila Real de Santo António	990 137	972 734

Data Sources: INE - Survey on Bed Capacity and Persons Employed (up to 2004)| Survey Guests stays in Hospitality and Guest Accommodation (from 2005)
Source: PORDATA
Last updated: 28/07/2015

Using the same period of time, the report prepared for the U.S. Travel Association [19] states that, depending on a low or high impact scenario, the Tourism revenue in the Gulf Region can suffer losses until 3 years after the occurrence (Figure 5). The potential economic impacts of the crisis could be cut by one-third ($7.5 billion) with the establishment of a $500 million emergency marketing fund to counter misperceptions and encourage travel to the affected regions.

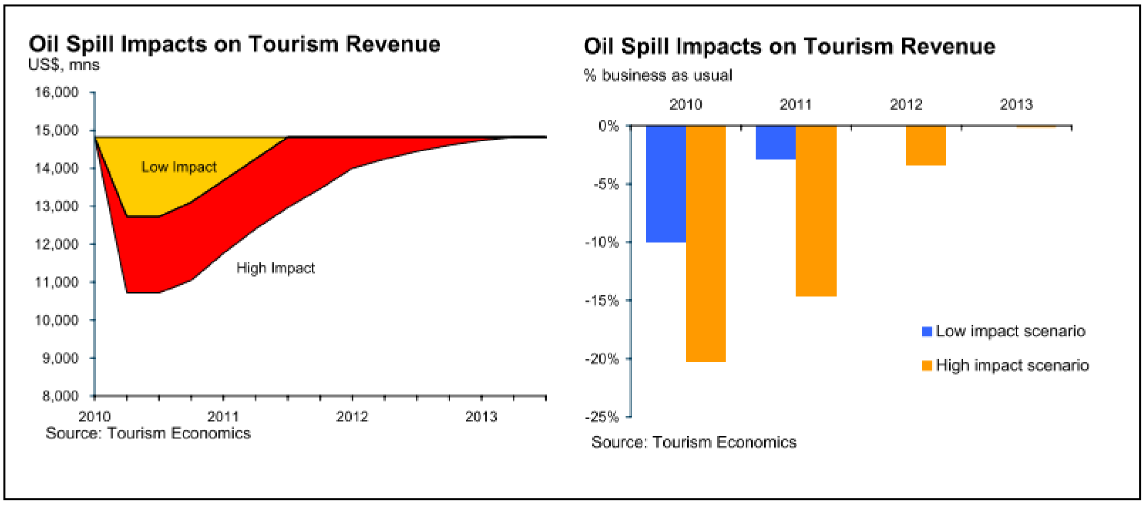

Figure 5 - Oil Spill impacts on tourism revenue

According to the same report, the average range of the duration of oil spill impacts is between 12 and 28 months (Figure 6). Given the amount of population who works in the hospitality in Algarve (Table 5), it can represent an huge impact on the economy of the region.

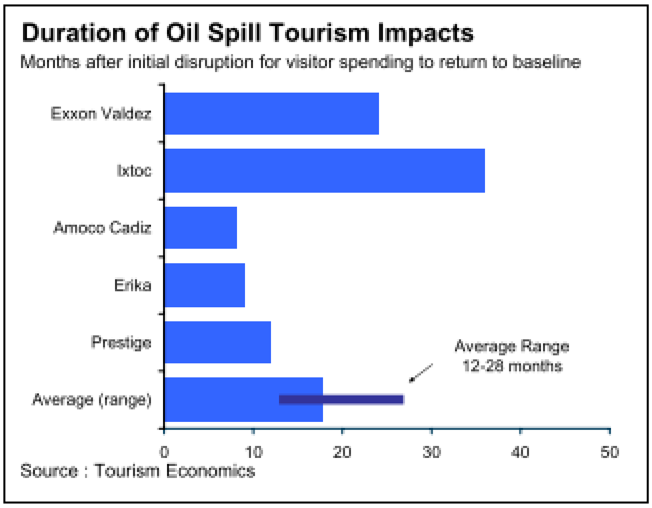

Figure 6 - Duration of Oil Spill Tourism Impacts [19]

According to Tourism of Portugal [20], between 2007 and 2014, the Region had increased its accommodation capacity by about 18%. The qualification of the offer of hotel accommodation in the region is reflected in the high percentage of 4 * and 5 * hotels, which represent about 78.5% of the total supply of hotels. The region is based on assets related to the product of Sun and Sea which has been present in a multithreaded way. The highlight for the planning and development of natural resources will be crucial for the development of tourism in the region.

For the calculations of this study, it is considered the data provided by Statistics Portugal about the Economic value generated by the Tourism sector in the Unit. However, this subvector can be extended and also include economic data from the maritime-tourist activities increasingly popular in the Algarve region: diving, whale watching, birdwatching, nature walks, surfing, etc.

3.1.2.3 FISHERIES

The fishing industry is of particular importance to Portugal. With its EEZ of some 1 700 000 km², the largest in any of the European Union Member States, a mainland coastline 942 km long and two large island regions, Portugal has always relied on fishing as a major means of subsistence, in particular for some coastal communities that depend almost exclusively on fisheries and related activities.

In Portugal, fishing is a way of life for thousands of people with few or no opportunities for alternative employment. Its purpose is to feed the population. Fisheries are typically not industrial but highly labour- intensive [21].

Currently fisheries in the Algarve, as elsewhere in the country, are in crisis. Actually as can be seen in Figure 4, two years after the adhesion of Portugal to the European Economic Union in 1986, the number of registered fishermen in Algarve region was reduced from more than 10000 to around 6000. In 2013 the number of fishing licences in Algarve was 5347 and in 2014 decreased to 5271 [22].

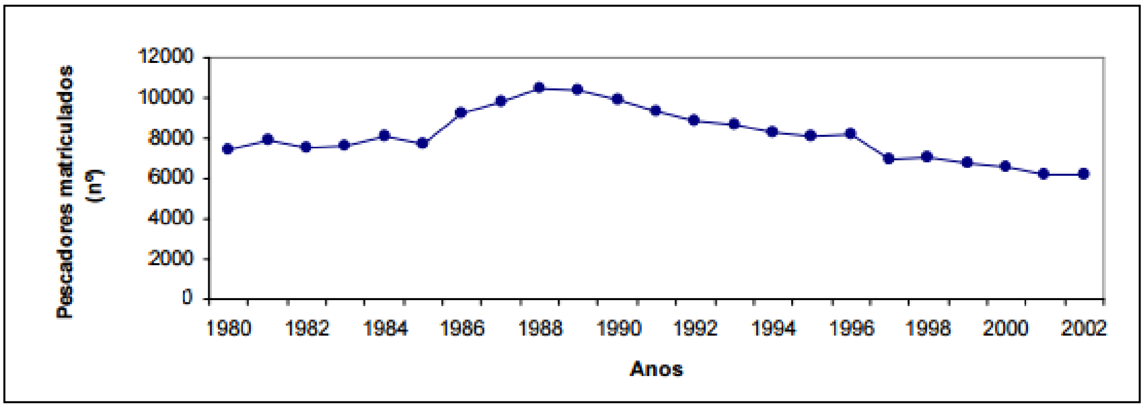

Figure 7 - Registered fishermen in Algarve region 1980 – 2002 (Font: Fishing Statistics INE/DGPA)

Nevertheless, with a coastline of about 160km, historically, Algarve has in fisheries one of the main economic resources and certainly one of the most typical activities in the region. Portimão, Olhão and Vila Real de Santo António are typical cases of Algarvian cities where there is a significant impact of fishing activities on the social and economy sectors.

The fisheries sector in the Algarve region (integrating the capture, production, processing and marketing of fish), is an activity whose significance transcends the purely economic side and that takes social contours of undeniable importance and cultural significance.

The aquaculture and salt production are two other important activities in this field of study. Regarding to aquaculture, the Algarve produced in 2011, 35% of volume and 50% of aquaculture production in Portugal. These impressive results are linked to existence of two great areas of lagoon (Ria Formosa and the Ria de Alvor) and activity units licensed there. The salt production is another important activity in the Algarve. In 2012, the region accounted for more than 96% of the national salt production. That same year, the production of sea salt in Continental Portugal was 89 000 tonnes, an increase of about 85% compared to 2011, while in the Algarve grew 89%. The average annual production in Portugal is about 2,500 tonnes per salt pond while Algarve recorded the highest productivity 3,500t[23]. However, although considering the importance of these activities, the values presented refer only to fisheries.

3.1.3 HERITAGE VECTOR

In every domain, the built heritage is present all along the coast. Given its historical, cultural or aesthetic value, these factors should be considered in the decision making process in the event of an incident involving the oil spill.

Most of the built heritage is not built in contact with the waters, thus it's hard to say that these buildings will be directly affected by the oil spills. However response operations to an incident of this type may interfere with this heritage.

According to the classification given by the Portuguese General Directorate of Cultural Heritage in SIPA - Information System for the Architectural Heritage [24], a classification (weight δ) from 1 to 8 is considered, depending if it is an heritage of Municipal Interest or World Heritage Monument.

Table 2 - Heritage Classification

Classification	δ
1. CM - Municipal Rating	1
2. VC – Heritage in the process of classification	2
3. SIP - Public Interest Site	3
4. CIP - Public Interest Set	4
5. IIP - Public Interest Building	5
6. MIP - Public Interest Monument	6
7. MN - National Monument	7
8. PM - World Heritage – UNESCO	8

3.1.4 ENVIRONMENT AND NATURE VECTOR

Hydrocarbons affect directly and indirectly living beings, as individuals or as members of communities of organisms inhabiting a particular environment and interacting with the environment and each other [25].

As informed by the National Oceanic and Atmosphere Organization (NOAA) [26] in general, oil spills can affect animals and plants in two ways: from the oil itself and from the response or cleanup operations. Understanding both types of impacts can help spill responders minimize overall impacts to ecological communities and help them to recover much more quickly.

Spilled oil can harm living things because its chemical constituents are poisonous. This can affect organisms both from internal exposure to oil through ingestion or inhalation and from external exposure through skin and eye irritation. Oil can also smother some small species of fish or invertebrates and coat feathers and fur, reducing birds' and mammals' ability to maintain their body temperatures.

The same Organization explains as well that, most often, shellfish and finfish either are unaffected by oil or are affected only briefly because most oils float and routes of exposure to organisms living in the water column or on the ocean floor are typically very limited. However, these animals can be substantially affected in some circumstances, especially when oil spills into shallow or confined waters.

Many shellfish species are relatively immobile and often are indiscriminant filter-feeders, which means they may not be able to avoid exposures to oil. In addition, they don’t possess the same suite of enzymes to breakdown contaminants as finfish and other vertebrates. Juvenile and adult finfish, on the other hand, usually are much more mobile, can be more selective in the foods they ingest, and have a variety of enzymes that allow them to detoxify many oil compounds. As a result, they are often better suited to limit oil exposures and related impacts.

Even so, spills of light oils and petroleum products (such as diesel fuel, gasoline, and jet fuel) into shallow water have been observed to trigger mass fish kills. We also have found that fish eggs in shallow water, such as salmon eggs in a streambed, can be wiped out by an oil spill. Other habitats of concern for fish kills are in contained areas, such as lakes, lagoons, and some shallow-water nearshore areas, where spilled oil naturally concentrates. For example, in 1994, territorial reef fishes in nearshore areas off Puerto Rico were greatly affected by No. 6 fuel oil spilled from the Barge *Morris J. Berman*[1].

Even if the finer biological aspects of an oil spill won't be studied in this thesis, there is still a necessary exercise in the analyses of how the oil spills interfere with the Protected Areas, the Natura 2000 areas and the coast itself, i.e. analyzing the type of coast by stretches and the type of beaches found in the coast of the Study Units.

3.1.4.1 Protected areas

According to ICNF [27], the Portuguese Network of Protected Areas is divided in 3 classes, performing a total of 52 protected areas:

- National Scope (38 areas);
- Regional/Local Scope (13 areas) and;
- Private Scope (1 area).

These areas are classified for being those where biodiversity or other natural occurrences present, for their rarity, scientific, ecological, social or scenic value, achieve a special importance that require specific measures for the conservation and management in order to promote rational management of natural resources and the enhancement of natural and cultural heritage.

3.1.4.2 Natura 2000 areas

According to ICNF [27], Natura 2000 is an ecological network for the European Union Community space resulting from the application of Directive 79/409 / EEC Network of April 2, 1979 (Directive Birds) - repealed by Directive 2009/147 / EC - and Directive 92/43 / EEC (Habitats Directive), which aims to ensure the long-term conservation of species and most threatened habitats in Europe, helping to stop the loss of biodiversity. It is the main instrument for the conservation of nature in the European Union.

The Natura 2000 network, which also applies to the marine environment, consists of:

- Special Protection Areas (SPA) - established under Directive Birds, which are intended primarily to ensure the conservation of birds and their habitats, listed in Annex I and migratory bird species not listed in Annex I and regularly occurring;

[1] Morris J. Berman oil spill occurred on January 7, 1994, when the *Morris J. Berman*, a single-hull 92 meters-long barge, with the capacity to carry more than 3 million gallons of oil, collided with a coral reef near San Juan, Puerto Rico, causing the release of 750,000 gallons of heavy grade oil.

- Special Areas of Conservation (SAC) - set up under the Habitats Directive, with the express purpose of "contribute to ensuring biodiversity through the conservation of natural habitats (Annex I) and species of flora habitats and of wild fauna (Annex II), considered threatened in the European Union space."

Since these areas correspond to such important conservation sites, they are to be represented and studied carefully.

3.1.4.3 Coast type classification

As presented by IPIECA [12], for the various types of shoreline (and riverine or lacustrine ecosystems), the widely accepted Environmental Sensitivity Index (ESI) can be adapted for each country. The ESI, ranging from 1 (low sensitivity) to 10 (very high sensitivity), integrates the:

- shoreline type (grain size, slope) which 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; and
- general biological productivity and sensitivity.

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- shoreline type (grain size, slope) which 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; and
- general biological productivity and sensitivity.

The 10 levels referred above are the following:

- 1A Exposed rocky shore;
- 1B Exposed, solid man-made structures;
- 1C Exposed rocky cliffs with boulder talus base;
- 2A Exposed wave-cut platforms in bedrock, mud or clay;
- 2B Exposed scarps and steep slopes in clay;
- 3A Fine- to medium-grained sand beaches;
- 3B Scarps and steep slopes in sand;
- Coarse-grained sand beaches;
- Mixed sand and gravel beaches;
- 6A Gravel beaches (granules and pebbles);
- 6B Riprap structures and gravel beaches (cobbles and boulders);
- Exposed tidal flats;
- 8A Sheltered scarps in bedrock, mud or clay and sheltered rocky shore;

- 8B Sheltered, solid man-made structures;
- 8C Sheltered riprap;
- 8D Sheltered rocky rubble shores;
- 8E Peat shorelines;
- 9A Sheltered tidal flats;
- 9B Vegetated low banks;
- 9C Hypersaline tidal flats;
- 10A Salt and brackish water marshes;
- 10B Freshwater marshes;
- 10C Swamps;
- 10D Mangroves.

The 10 levels referred above are divided in 23 sublevels. To implement this methodology the levels and sublevels were simplified as shown in the Table 3.

Table 3 - Simplification of ESI sensitivity rankings ESI (Adapted from **[12]**)

ESI (from 1 to 10)	Simplified ESI
Index 1 and 2	1 (very low)
Indexes 3, 4, 5 and 6	2 (low)
Index 7	3 (medium)
Index 8	4 (high)
Index 9 and 10	5 (very high)

3.1.4.4 Beach Importance Index (BII)

The formulation defined by Leal [28] is followed in this study. Accordingly, BII is the result of the formula (2):

$$BII = (VCP + VCC) + VA1 + VA2 + VA3 \quad (2)$$

Where:

VCP - Classification in the Coastal Zone Management Plan (POOC), which identifies the main use of the beach.

VCC - Load capacity allows us to estimate the number of users according to the size of the beach and to the criteria of POOC

VA1 - Aptitude to water sports. Identifies the propensity of beaches to practice water sports: surfing, kite surfing and diving.

VA2 - Existence of concession. It identifies the existence of concession areas on the beaches

VA3 – Beaches with Blue Flag

In order to systematize all the information regarding the BII, the Table 4 (adapted from Leal [28]) presents the variables identified in BII:

Table 4 - Variables and Values of IIB

Variable	Classes		Value
VCP	Beaches Type IV, V and suspended or prohibited use	beach not equipped with conditioning use; beaches with restricted use	4
	Beaches Type III	beach with conditioning use	6
	Beaches Type II	not urban beach with intensive use	8
	Beaches Type I	urban beach with intensive use	10
VCC	VCC < 3200 users or no information		2
	3200 ≤ VCC <6400 users		4
	6400 ≤ VCC <9600 users		6
	9600 ≤ VCP <12800 users		8
	VCC ≥ 12800 users		10
VA1	No		0
	Yes		2
VA2	No		0
	Yes		2
VA3	No		0
	Yes		2

3.2 METHODOLOGY APPLICATION

In this section, the application of the proposed methodology is explained.

3.2.1 WEIGHING

One of the great advantages of this proposed methodology is the possibility to calibrate the model by simply changing their weights.

Despite there are four vectors in this methodology, three of them can be calibrated according to the territory, region or country. In the Social, Economy and Environment and Nature Vectors, when using the final formulas to calculate the value of each vulnerabilities of the Study Unit (formulas (7), (11) and (17)) it’s possible to choose the values of "α", "β" and "ρ", being the only condition that the sum of the weights equals 1. The weight δ in the Heritage Vector is fixed once it depends on the type of classification of the Heritage.

3.2.2 SOCIAL VECTOR (S)

To develop the Social Vector, there is the need of observing the population of the area as well the population of the Study Domain in which the referred area is included.

Once the S Vector will have three components (S1, S2 and S3), the calculation can be done as the showed in Equations (3), (4) and (5):

$$S1 = \frac{\text{Resident population in the Unit}}{\text{Population of the Study Domain}} \tag{3}$$

$$S2 = \frac{\text{Employed population in Hospitality in the Unit}}{\text{Population of the Study Domain}} \tag{4}$$

$$S3 = \frac{\text{Employed population in Fisheries in the Unit}}{\text{Population of the Study Domain}} \tag{5}$$

After obtaining the values of S1, S2 and S3, using a convex linear combination, in which the sum of the parts is equal to 1.

$$\alpha 1 + \alpha 2 + \alpha 3 = 1 \tag{6}$$

The normalization of the Social Vector (S) can be done as showed in (7):

$$S = \alpha 1 * S1 + \alpha 2 * S2 + \alpha 3 * S3 \tag{7}$$

3.2.3 ECONOMY VECTOR (E)

The Economy Vector is a combination of three subvectors which are calculated using Equations (8), (9) and (10):

$$E1 = \frac{\text{Economic value generated by Ports and Marines in the Unit(€)}}{\text{Economic value generated by Ports and Marines in the Study Domain}} \tag{8}$$

$$E2 = \frac{\text{Economic value generated by the Tourism sector in the Unit(€)}}{\text{Economic value generated by the Tourism in the Study Domain}} \tag{9}$$

$$E3 = \frac{\text{Economic value generated by the Fisheries sector in the Unit(€)}}{\text{Economic value generated by the Fisheries a in the Study Domain}}$$

(10)

The normalization of the Economic Vector (E) can be done as showed in Equation (11), respecting the convex linear combination and assigning the different weights to the value β:

$$E = \beta1*E1 + \beta2*E2 + \beta3*E3 \quad (11)$$

3.2.4 HERITAGE VECTOR (H)

According to point 3.1.3 and shown in Table 2, eight classifications were given to the different types of heritage. The eight classifications are equivalent to the eight weights given the lowest to the municipal interest and the higher to world heritage.

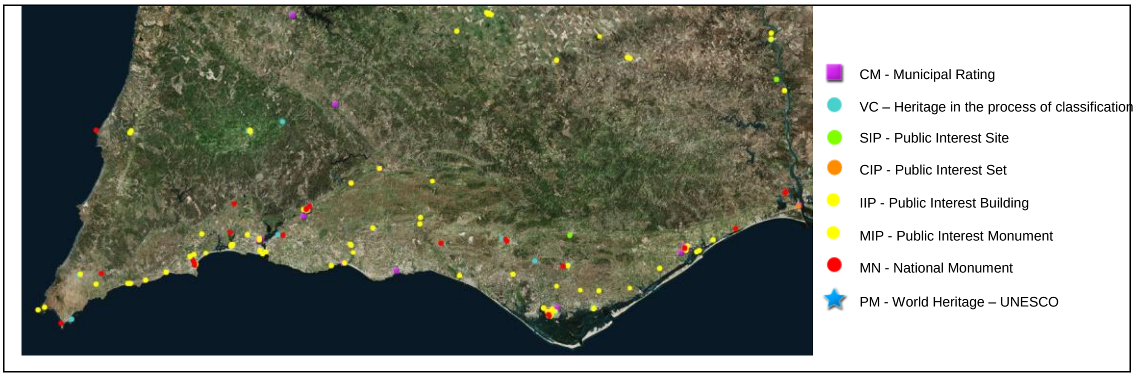

Figure 8 - Localization of Heritage in the Algarve Region

Since this work concerns on oil spills, not all the classified Heritage were considered. A buffer of 1 km from the coastal line was drawn so as to isolate “coastal” sites. As such, only 47 of the 208 classified Heritage sites in the Study Domain (Figure 8) were taken in consideration. In the municipalities of Faro and Olhão, the south boundaries drawn surround the barrier islands and the Natural Park of Ria Formosa. The buffer line shown on the map (Figure 9) was drawn taking into account the main land and not the marshes between it and the barrier islands. It’s understood that not only the oil spill can directly affect the Heritage but also that cleanup operations and affected fauna can spread the oil in the surroundings.

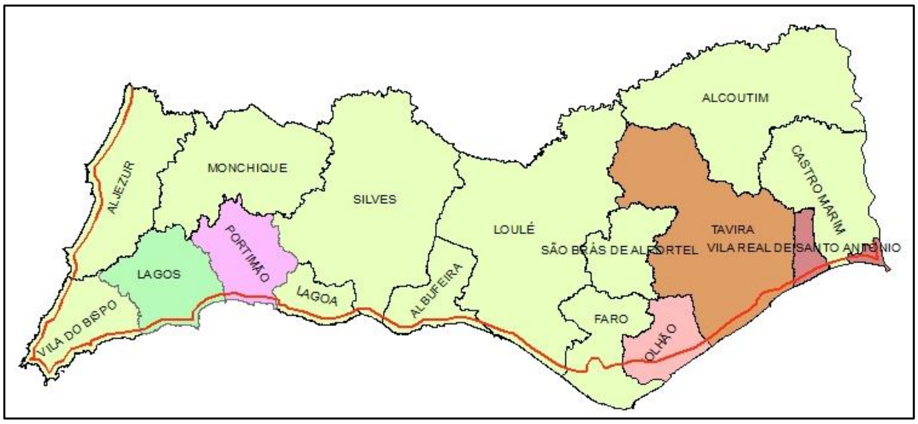

Figure 9 – Buffer of 1 km from the coastal line

To calculate the value H the Equation (12) is proposed, where the weights δ are presented in Table 2, *n* is the number of heritage classified and affected by the oil spill in the Unit (in the strip of 1 km) and *m* is the total of heritage in the Study Domain:

$$H=\frac{\sum_1^n \delta}{\sum_1^m \delta} \tag{12}$$

3.2.5 ENVIRONMENT AND NATURE VECTOR (EN)

To calculate subvector EN1, it is necessary to evaluate the total amount of protected areas in the Study Unit which are affected by the oil spill and related them to the total of Protected Areas in the Study Domain, using the Equation (13):

$$EN1 = \frac{\text{Area of Protected Areas on the coast of the Unit(ha)}}{\sum \text{Protected Areas in the Study Domain}} \tag{13}$$

To calculate subvector EN2 it is necessary to evaluate the total amount of Natura 2000 areas in the Study Unit that are affected by the oil spill and related them to the total of Natura 2000 Areas in the Study Domain, using the following Equation:

$$EN2 = \frac{\text{Area of Natura 2000 Areas on the coast of the Unit (ha)}}{\sum \text{Natura 2000 Areas in the Study Domain}} \tag{14}$$

Oil behaves differently in the different coastal environments, depending on factors such as the porosity of the sediments and the wave-erosion activity acting on them. In high energy environments, mainly rocky shores, the stranded oil coats the rocks and gradually hardens by weathering into a tough, tarry "skin." The oil is gradually removed by wave erosion, although the rate of removal declines as weathering progresses. As much as 50% is lost within a year and a half to two years, although pools of oil are likely to collect in hollows among the rocks, protected by a skin of weathered oil, and may remain essentially unchanged for a long time. On cobble and sandy beaches the oil can sink more deeply into the sediments and can remain longer than on bare rocks. Wave erosion becomes less effective, and microbial degradation assumes a more important role. However, as the oil is mobile in these porous systems, some of it is gradually returned to the overlying water, where it is more subject to dissipation but may also have toxic effects on the organisms. A general hypothesis has emerged which appears to be applicable to the low energy systems: sandy beaches, marshes and tidal rivers. Tidal pumping is the active factor causing penetration into the sediments. Sediment grain size controls the rate of penetration. In muddy sediments, penetration is minimal, and only the upper few centimetres are affected. However, because these are low energy environments with little physical weathering, stranded oil can persist here for up to decades, frequently becoming bound up in the soft organic sediments [2].

To calculate the sub vector EN3, the levels above were simplified in five classes, with a correspondent weight μ, as shown in Table 3.

Thus, the sum of multiplication of a given Coastal Segment (CS) of a Study Unit corresponding to each class by its weight (μ), divided by the sum of multiplication of a given Coastal Segment (CS) of all the Study Domain corresponding to each class by its weight (μ) (*n* for the Unit and *m* for the Study Domain) corresponds to the value calculated by the Equation (15):

$$EN3 = \frac{\sum_1^n CS*\mu}{\sum_1^m CS*\mu} \qquad (15)$$

As seen above, the Beach Importance Index (BII) is the result of a sum of different factors, characterizes each beach, and gives a value of importance. In this work, the objective is to characterize a Unit and a region so the value must reflect all beaches of the area.

Considering the best situation, a beach with the most valuable characteristics (which is a beach Type I, with more than 12800 users, with aptitude to water sports, with concession and with blue flag) the total value obtained is 26. This value giving thus normalizes EN4:

$$EN4 = \frac{\sum_1^n BII}{m*26} \qquad (16)$$

where *n* stands for the number of beaches in the Unit and *m* for all the beaches in the Study Domain.

Finally, the values from the different subvectores of the Environment and Nature Vector are agglutinated in the Equation (17), where $\rho1+ \rho 2+ \rho 3+ \rho 4 =1$:

$$EN = \rho1*EN1 + \rho2*EN2 + \rho3*EN3 + \rho4*EN4 \qquad (17)$$

As referred above, the Vulnerability Identity (V.ID) is a multi-index indicator shown in a graphic way to facilitate the interpretation of a certain region or area and to facilitate the work of decision makers, planners or operational staff. The 4 subvectores (S, E, H and EN) values must thus be represented in a “radar type” graphic. This graphical description simplifies the comparison of vulnerabilities between territories facing an oil spill, enabling it to be done visually with the “radar” graphic.

4

CASE STUDY: FIVE MUNICIPALITIES OF ALGARVE REGION

4.1 BRIEF CHARACTERIZATION OF THE STUDY DOMAIN

The Study Domain is the main area in which all the Study Units are included. For aspects related to this thesis, the Study Domain is the territorial area of the municipalities of Algarve Region which have a coastal area.

With an area of 4,996Km2 and a resident population of 450 993 inhabitants, spread throughout 16 municipalities, the Algarve is located at Europe's westernmost tip, in the south of Portugal. It has an average population density of roughly 90.3 inhabitants per Km2 and an entirely Atlantic coastline that measures roughly 150Km in length.

It is subdivided into three main areas, each of which contains some extraordinarily beautiful landscapes:

- **The coastal area** is where most of the region's economic activity is concentrated. In terms of landscape, the Algarve coast is very diversified, varying between abrupt and jagged coastlines, extensive sandy beaches, inlets formed by lagoons, marshland areas and various formations of sand dunes. The predominant rocks are essentially of the sedimentary type (as is the case with the arenites and conglomerates). Morphologically, the coastal area has a low altitude and mainly consists of plains, divided into fields and meadows;
- **The "Barrocal" area** marks the transition between the coast and the mountains, consisting of limestone and schist. This area is also known as the "beira-serra" (literally the mountain edge) and is where most of the agricultural produce of the Algarve originates from;
- **The hills** occupy 50% of the territory and are essentially formed from schist and some granitic rocks (in this latter case, in Monchique, where there is an outcrop of nepheline syenite). The main ranges of hills are the Serra de Espinhaço de Cão, Serra de Monchique (where Foia, the highest point in the Algarve is to be found, at an altitude of 900 metres) and the Serra do Caldeirão or the Serra do Mú.

The Algarve's geographical position gives it some special bioclimatic features. Although situated by the Atlantic Ocean, it has a temperate climate with Mediterranean characteristics, more than 3,000 hours of sunlight per year and a low annual average rainfall.

The most important sector of activity is the tertiary sector (retail and services), resulting from the region's main economic activity - tourism. This subsector of activity is so important in the Algarve that it accounts, both directly and indirectly, for roughly 60% of total employment and 66% of the regional GDP. It should be stressed that the Algarve receives roughly 5 million tourists per year.[29]

4.2 IMPLEMENTATION OF THE METHODOLOGY IN THE 5 MUNICIPALITIES

To implement presented methodology, five municipalities of the Algarve Region were studied: Lagos, Portimão (West Algarve), Olhão (Central Algarve), Tavira and Vila Real de Santo António (East Algarve).

Figure 10 – Map of Algarve with localization of the 5 municipalities chosen

Applying the proposed Equations in this work is possible to achieve the Vulnerability Identity (V.ID) of each municipality.

4.2.1 SOCIAL VECTOR

Using the values presented by the Statistics Portugal [30] (Table 5) and applying them to Equation 7) is possible to calculate the Social Vector (Table 6).

Table 5 – Population of the Study Units

	Resident population	Employed population in Fisheries	Employed population in Hospitality
	S1	S2	S3
Lagos	30776	114	2240
Olhão	45216	658	1505
Portimão	55209	123	4018
Tavira	25753	165	1439
VRSA	19067	125	1462
Algarve	425358	2037	30315

Table 6 – Social Vector (S)

	Lagos		Portimão		Olhão		Tavira		VRSA	
	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight
S1	0,07	0,3	0,13	0,3	0,11	0,3	0,06	0,3	0,04	0,3
S2	0,07	0,5	0,13	0,5	0,05	0,5	0,05	0,5	0,05	0,5
S3	0,06	0,2	0,06	0,2	0,32	0,2	0,08	0,2	0,06	0,2
S	0,07		0,12		0.12		0,06		0,05	

Analyzing the Tables 6 and 7 is possible to verify the social differences between the five municipalities.

The weights to be used in the Equations (6) and (7) are random values which the only condition is their sum is equal to 1. Thus, this methodology can be used in different territories with different characteristics, where whom is managing the methodology can adjust the vectors to put them the more closely to reality as possible.

According to the weights chosen, the municipalities with more social vulnerability facing an oil spill are Portimão and Olhão. VRSA and Tavira are the less vulnerable.

4.2.2 ECONOMY VECTOR

To calculate the Economy Vector, a similar procedure was applied using the Equation described in (8), (9) and (10).

It was not possible to retrieve all the necessary data to calculate the values for the Economic value generated by Ports and Marines in the Unit, so an informed estimate for some of the values is presented.

To calculate the vector E2 - Economic value generated by the Tourism sector in the Unit (Table 8) were used the values of Statistics Portugal.

Table 7 - Economic value generated by the Tourism sector

Economic value generated by the Tourism sector		
	2013 (€)	E2
Algarve	437 972 000 €	---
Lagos	25 844 000 €	0,06
Olhão	2 892 000 €	0,01
Portimão	47 866 000 €	0,11
Tavira	11 725 000 €	0,03
Vila Real de Santo António	26 330 000 €	0,06

Font: http://www.ine.pt

From the five municipalities studied, Portimão displays the largest Tourism sector value, which means that facing a situation of an Oil Spill this municipality would be the one likely to suffer greater economic losses related to the tourism sector. On the opposite corner, Olhão is the one with less impact, since the tourism here is not so developed as in the other four municipalities.

As can be observed in Tables 9 and 10, the amounts of Estimated Landing of Fisheries are quite diverse, not only in the price/kg but as well in the quantity that was fished.

The values of 2015 published by DATAPESCAS (Tables 9 and 10) were used to calculate E3 (Table 10).

Table 8 – Values used to calculate E3

	Estimated Landing (€/Kg)			Estimated Landing (ton)		
	2013	2014	2015	2013	2014	2015
Lagos	3,44	3,87	4,03	2706,7	2574,7	2983,3
Portimão	2,08	2,29	2,44	5464,3	5392,3	4443,8
Olhão	1,89	1,51	1,13	11677,5	12410,4	15967,9
Tavira	3,29	5,24	5,34	1411,8	721,2	627,9
VRSA	7,39	7,54	10,35	1457,3	1170,3	897,4

Font: DATAPESCAS - Janeiro a Dezembro 2015, nº 107

Table 9 – Values used to calculate E3

	Estimated Landing (€)	
	2015	E3
Lagos	12 022 699 €	0,22
Portimão	10 842 872 €	0,20
Olhão	18 043 727 €	0,34
Tavira	3 352 986 €	0,06
VRSA	9 288 090 €	0,17
Total	53 552 389 €	

Since Olhão is one of the main fishing ports in the Study Domain, is not surprising that the highest vulnerability in the subvector E3 occurs here. While Tavira and VRSA were, in the beginning of the 20th century, two of the main places were Tuna was fished, nowadays the fisheries in this municipalities are much reduced, as can be observed in the tables above.

Table 10 – Economy Vector (E)

	Lagos		Portimão		Olhão		Tavira		VRSA	
	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight
E1	0,19	0,3	0,15	0,3	0,13	0,3	0,09	0,3	0,11	0,3
E2	0,35	0,5	0,11	0,5	0,01	0,5	0,03	0,5	0,06	0,5
E3	0,22	0,2	0,20	0,2	0,34	0,2	0,06	0,2	0,17	0,2
E	0,28		0,29		0,11		0,05		0,10	

After analysing the subvectors for each Study Unit and multiplying them for each weight, is possible to say that the municipalities from West Algarve are much more vulnerable (Lagos and Portimão) than the Central and East Algarve, in what relates to the Economy Vector.

4.2.3 HERITAGE VECTOR

The third vector is related with the Heritage in the Study Units compared with the Classified Heritage in the Domain Unit.

After consulting the Portuguese General Directorate of Cultural Heritage in SIPA - Information System for the Architectural Heritage, it was possible to calculate the sum of the different weights of each classified heritage located in a strip with 1 km wide in the Study Units coasts and compare with the classified heritage in the whole the Region (inside the same strip).

Table 11 – Heritage Classification

Study Unit	Name	Localization	Classification	δ	∑
Lagos	Forte da Ponta da Bandeira	Lagos	IIP	5	26
	Castelo da Senhora da Luz	Luz	IIP	5	
	Estação Arqueológica Romana da Praia da Luz	Luz	IIP	5	
	Igreja de Nossa Senhora da Luz	Luz	IIP	5	
	Forte da Meia Praia	Lagos	MIP	6	
Portimão	Forte de Santa Catarina	Praia da Rocha	IIP	5	5
Olhão	Mercado Municipal de Olhão	Olhão	MIP	6	12
	Igreja Paroquial de Olhão	Olhão	MIP	6	
Tavira	Antigo Arraial Ferreira Neto	Tavira	IIP	5	38
	Forte do Rato	Tavira	IIP	5	
	Ponte Antiga sobre o Rio Gilão	Tavira	IIP	5	
	Edifício Compromisso Marítimo de Tavira e Igreja de Nossa Senhora das Ondas	Tavira	MIP	6	
	Igreja de Santa Ana	Tavira	IM	1	
	Santa Casa da Misericórdia de Tavira	Tavira	IIP	5	
	Palácio da Galeria	Tavira	MIP	6	
	Forte da Conceição	Tavira	IIP	5	
VRSA	Monumentos da Quinta da Nora	Vila Nova de Cacela	MN	7	17
	Núcleo urbano de Cacela Velha	Vila Nova de Cacela	IIP	5	
	Hotel Guadiana	VRSA	IM	1	
	Núcleo Pombalino de Vila Real de Santo António	VRSA	CIP	4	
Algarve					208

After using the database of the Portuguese General Directorate of Cultural Heritage in SIPA - Information System for the Architectural Heritage, and search for the classified Heritage located inside the 1 km strip wide, it was possible to find different kinds of Heritage. After applying the weight for each classification and then the Equation (12), the vulnerability for the Heritage vector can be calculated.

Table 12 – Heritage Vector (H)

	Lagos		Portimão		Olhão		Tavira		VRSA	
	Study Unit	Study Domain	Study Unit	Study Domain	Study Unit	Study Domain	Study Unit	Study Domain	Study Unit	Study Domain
∑	26	208	5	208	12	208	38	208	17	208
H	0,13		0,02		0,06		0,18		0,08	

Tavira appears as the Study Unit with higher vulnerability (Table 12), mostly because of a great number of churches and classified buildings as compared to the other Study Units.

4.2.4 ENVIRONMENT AND NATURE VECTOR

The last Vector to be studied is the Environment and Nature Vector. According to Portuguese Forests and Nature Conservation Institute (ICNF), in Table 13 are listed the areas of each county which are classified as Protected Areas and Natura 2000 Areas.

Table 13 – Protected and Natura 2000 Areas in the Coast

	Municipality	Protected Area (ha)	Natura 2000 Area	
			Area (ha)	Area in the Coast (ha)
Study Unit	Albufeira	---	2282	---
	Aljezur	18239,21	23615	18239,21
	Castro Marim	1148,79	3879	1148,78
	Faro	8009,16	8009.16	6380
	Lagoa	---	279	279
	Lagos	0	3406	3406
	Loulé	3405,29	40178	3405,29
	Olhão	4839,15	4839.15	3838
	Portimão	---	1377	1377
	Silves	---	22068	---
	Tavira	4517,18	6513	4517,18
	Vila do Bispo	14383,81	16393	14383,81
	Vila Real de	1301,27	1500	130,27

	Santo António			
Study Domain	Algarve		121490	57104,54
	TOTAL	55843,86		

Observing the Equations (13) and (14) the subvectors EN1 and EN2 are the follow:

Table 14 - Calculation of EN1 and EN2

	Lagos		Portimão		Olhão		Tavira		VRSA	
	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight
EN1	0	0,1	0	0,1	0,09	0,10	0,08	0,1	0,02	0,1
EN2	0,06	0,4	0,02	0,4	0,07	0,40	0,08	0,4	0,00	0,4

To calculate EN3 it is necessary to observe all the stretches of the coast and compared them to the proposed table to apply the different weights to each Coastal Segment (Table 15).

Using orthophotomaps of the Algarve Region worked in a GIS environment all the Coastal Stretches (CS) of Algarve Coast were measured (Annex A) and multiplied by the weight given on Table 5.

Table 15 - Coastal Units

	Municipality	CS (m)	EN3
Study Unit	Aljezur	54672	0,12
	Vila do Bispo	73030	0,16
	Lagos	36583	0,08
	Portimão	21868	0,05
	Lagoa	28129	0,06
	Silves	7768	0,02
	Albufeira	45625	0,10
	Loulé	31564	0,07
	Faro	46456	0,10
	Olhão	19122	0,04
	Tavira	37218	0,08
	Castro Marim	6898	0,02

	VRSA	34948	0,08
Study Domain		443881	

At first glance the values may seem somewhat exaggerated. Nonetheless, due to the coastal characteristics and given the irregularities of the coastline, especially along rocky stretches and embayments, these correspond to the actual exposed length of coastline, rather than what a simplified straight-line measurement would lead one to assume.

To calculate EN4 – Beach Importance Index (BII) it was necessary to compile information from different sources, as the Coastal Zone Management Plan (POOC) from Sines – Burgau, Burgau – Vilamoura and Vilamoura-Vila Real de Santo António, the data presented by the European Blue Flag Association [31] and the work developed by Leal [28]. It was considered 115 beaches in the Algarve coast.

Table 16 – Parameters and values of Beach Importance Index

Study Unit	Beach	VCP	VCC	VA1	VA2	VA3	BII
Lagos	Batata	8	2	2	2	2	16
	Balança	4	2	0	0	0	6
	Canavial	4	2	0	0	0	6
	Camilo	6	2	0	0	2	10
	D. Ana	8	2	2	2	2	16
	Luz	10	4	0	2	2	18
	Pinhão	4	2	2	2	0	10
	Estudantes	4	2	0	0	0	6
	Meia Praia	8	8	0	2	2	20
	Porto de Mós	8	2	0	2	2	14
Olhão	Armona-Mar	6	2	0	0	2	10
	Cavacos	6	2	0	0	0	8
	Fuseta-Mar	6	2	0	0	2	10
	Fuseta-Ria	6	2	0	2	2	12
Portimão	Alvor Nascente - Três Irmãos	10	2	0	2	2	16
	Amado	6	2	0	2	0	10
	Barranco das	4	2	0	2	0	8

	Canas						
	Prainha	4	2	0	2	0	8
	Careanos	6	2	0	2	0	10
	Alvor Poente	8	2	0	2	2	14
	Rocha	10	4	0	2	2	18
	Três Castelos	6	2	2	2	2	14
	Vau	10	2	0	2	2	16
Tavira	Barril	8	2	2	2	2	16
	Cabanas-Mar	6	2	0	2	2	12
	Ilha de Tavira-Mar	8	2	2	2	2	16
	Homem Nú	4	2	2	2	2	12
	Terra Estreita	6	2	2	2	2	14
VRSA	Lota	6	2	0	2	2	12
	Cacela Velha	4	2	0	0	0	6
	Manta Rota	8	2	0	2	2	14
	Monte Gordo	10	4	0	2	2	18
	Santo António	6	4	0	0	2	12

Fonts: POOC Vilamoura - VRSA
POOC Burgau - Vilamoura
POOC Sines Burgau
Bandeira Azul 2015 (http://bandeiraazul.abae.pt/our_news/praias-bandeira-azul-2015/ em 13/04/2016)
Leal, T, 2011

After calculating the four subvectores of the Environment and Natura Vector, and applying to each one the considered weights, are obtained the values of the Vulnerability in what concerns to the environmental factors (Table 17).

Table 17 – Environment and Nature Vector (EN)

	Lagos		Portimão		Olhão		Tavira		VRSA	
	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight
EN1	0	0,1	0	0,1	0,09	0,10	0,08	0,1	0,02	0,1
EN2	0,06	0,4	0,02	0,4	0,07	0,40	0,08	0,4	0,00	0,4
EN3	0,08	0,1	0,05	0,1	0,04	0,10	0,08	0,1	0,08	0,1
EN4	0,04	0,4	0,04	0,4	0,01	0,40	0,02	0,4	0,02	0,4

EN	0,03	0,01	0,04	0,05	0,01

4.2.5 FINAL RESULTS

The methodology developed, after the sectorial analysis can be presented as follows.

Vulnerability Identity (V.ID) of Lagos	
S - Social	0,07
E - Economy	0,10
H - Heritage	0,13
EN - Env & Nature	0,03

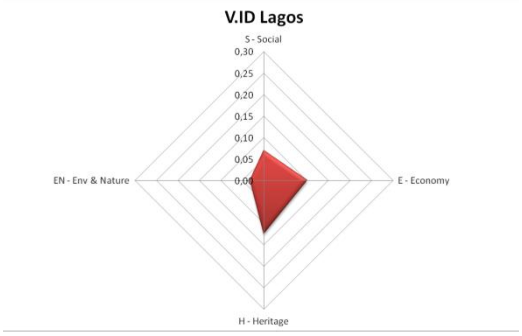

Figure 11 - Values and graph of V.ID for the municipality of Lagos

Vulnerability Identity (V.ID) of Portimão	
S - Social	0,12
E - Economy	0,14
H - Heritage	0,02
EN - Env & Nature	0,01

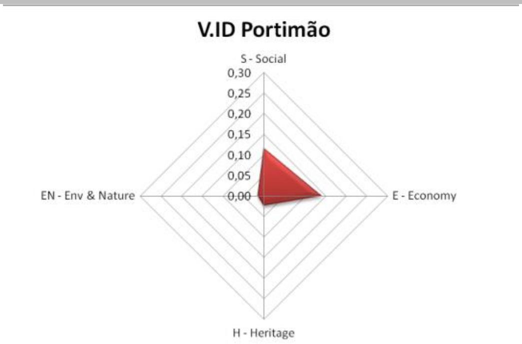

Figure 12 - Values and graph of V.ID for the municipality of Portimão

Vulnerability Identity (V.ID) of Olhão	
S - Social	0,12
E - Economy	0,11
H - Heritage	0,06
EN - Env & Nature	0,04

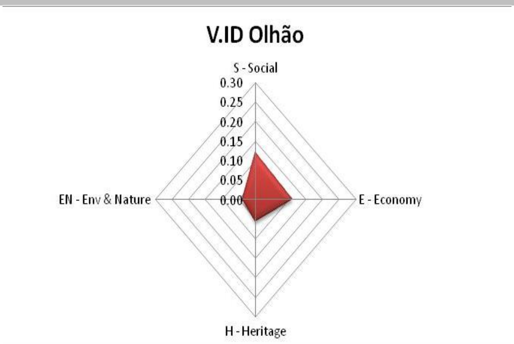

Figure 13 - Values and graph of V.ID for the municipality of Olhão

Vulnerability Identity (V.ID) of Tavira	
S - Social	0,06
E - Economy	0,05
H - Heritage	0,18
EN - Env & Nature	0,05

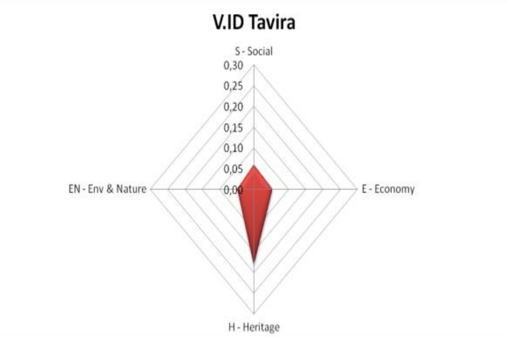

Figure 14 - Values and graph of V.ID for the municipality of Tavira

Vulnerability Identity (V.ID) of VRSA	
S - Social	0,05
E - Economy	0,10
H - Heritage	0,08
EN - Env & Nature	0,01

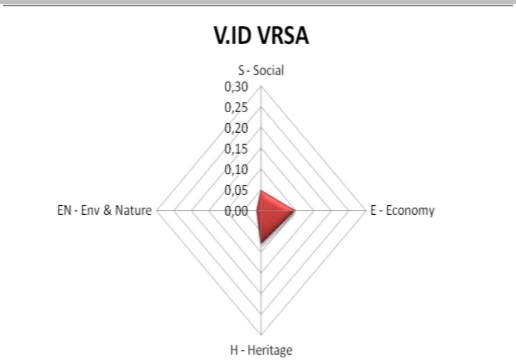

Figure 15 - Values and graph of V.ID for the municipality of VRSA

In demography, the concept of Population Pyramids (also called Age Pyramids) is well spread. Population pyramid is a graphical illustration of the various age groups of a population from a country or region, and are often seen as a useful tool for understanding the structure and composition of populations because they graphically portray many aspects of a population, such as sex ratios and age structure. Immediately, with a quick glance, you can verify whether that country or region has an aging or young population.

What is intended with V.ID is something similar, as can be seen in the Figures 11 to 15. With a quick glance it is possible to verify which are the vulnerabilities of each territory and what weight each of the four vectors have in the Study Unit.

Thus, analyzing Figure 11 is possible to say that in Lagos the main vulnerabilities facing an oil spill are in vectors Economy and Heritage and the same happen in VRSA (Figure 15) but on a smaller scale. Portimão and Olhão (Figure 12 and 13) presents their greatest vulnerabilities in the vectors Social and Economy. The Study Unit Tavira (Figure 14) is the only municipality of five studied that has a peak highlighted, in this case the vector Heritage.

4.3 RISK MAPPING

According to the work of Neves A. [4] developed in his PhD thesis, the Oil Spill Beaching probability depends not only in the release point but also on the weather conditions, wind direction and as well the meteo-oceanographic conditions correspondent to the seasons of the year.

In Figure 16, Neves presented a grid with potential release points. The color inside the circles represents the computed level of hazard for the release point. The diameter of the circle represents the traffic density. The main shipping corridor is represented by the biggest circles.

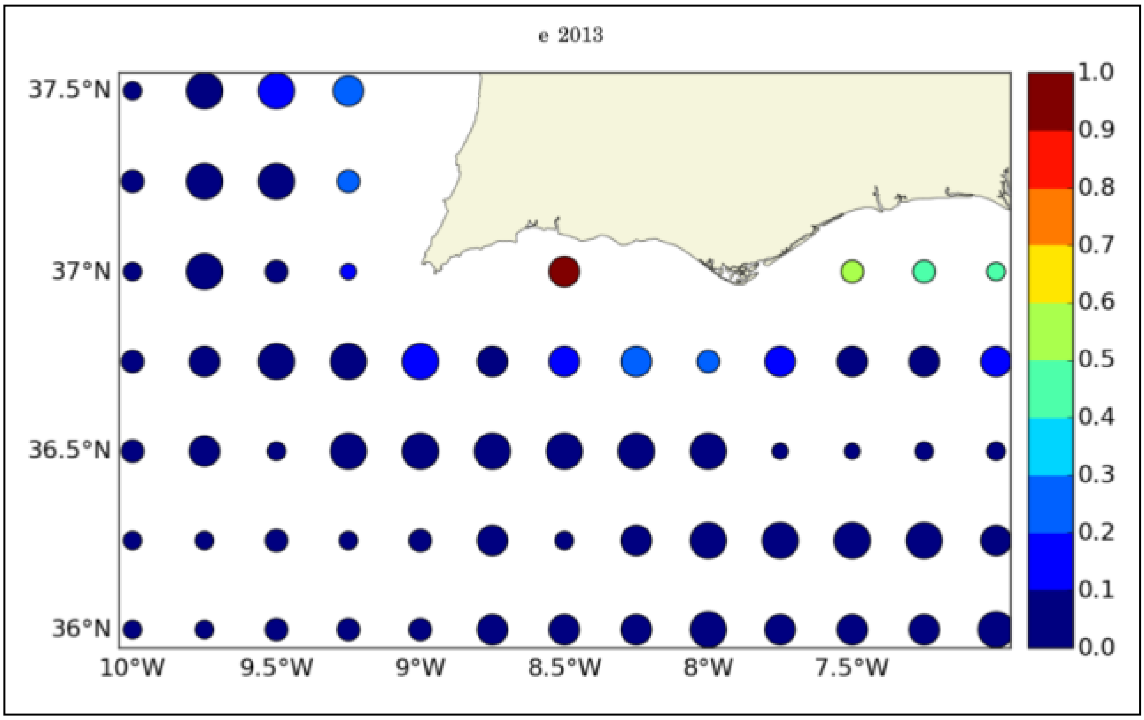

Figure 16 - Sources of risk for the seasons of the year of 2013. [4].

According to the definition of Risk and according to Equation (1), once the vulnerability is known and the beaching probability (Pb) is known as well (Figure 17 [4]) it's possible to obtain the results of the Sectorial Risks.

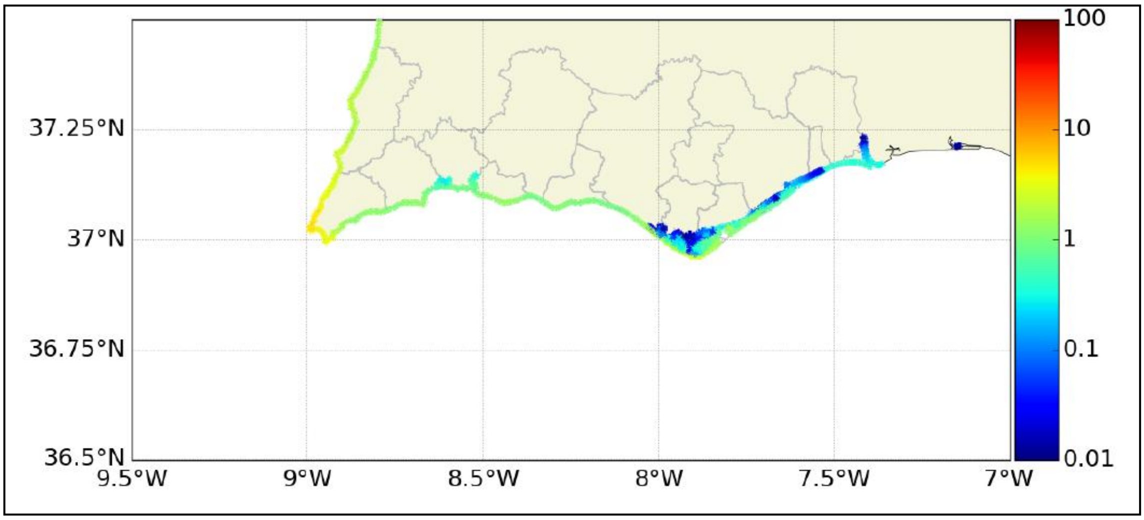

Figure 17 - Probability of a coastal segment to be hit by oil (Pb) for the accidental experiment

To do so, by analysing the Figure 17 and the data developed by Neves, is possible to verify the value of the Probability of a certain coastal segment be hit by oil (Pb) on an accidental spill (Table 18). For reasons of simplification, were used the most significant value in each Study Unit.

Table 18 - Sectorial Vulnerability

Vectors	Study Units				
	Lagos	Portimão	Olhão	Tavira	VRSA
S	0,07	0,12	0,12	0,06	0,05
Pb (%)	4	4	3	0,8	0,5
E	0,10	0,14	0,11	0,05	0,10
Pb (%)	4	4	3	0,8	0,5
H	0,13	0,02	0,06	0,18	0,08
Pb (%)	4	4	3	0,8	0,5
EN	0,03	0,01	0,04	0,05	0,01
Pb (%)	4	4	3	0,8	0,5

Using a simple multiplication process, where the Pb is multiplied by each value of S, E, H and EN, the Sectorial Risks are calculated for each Study Unit, as presented on the Table 19.

Table 19 - Sectorial Risks

Sectorial Risks	Lagos	Portimão	Olhão	Tavira	VRSA
S.r	0,28	0,48	0,36	0,05	0,03
E.r	0,40	0,56	0,33	0,04	0,05
H.r	0,52	0,08	0,18	0,14	0,04
EN.r	0,12	0,04	0,12	0,04	0,01

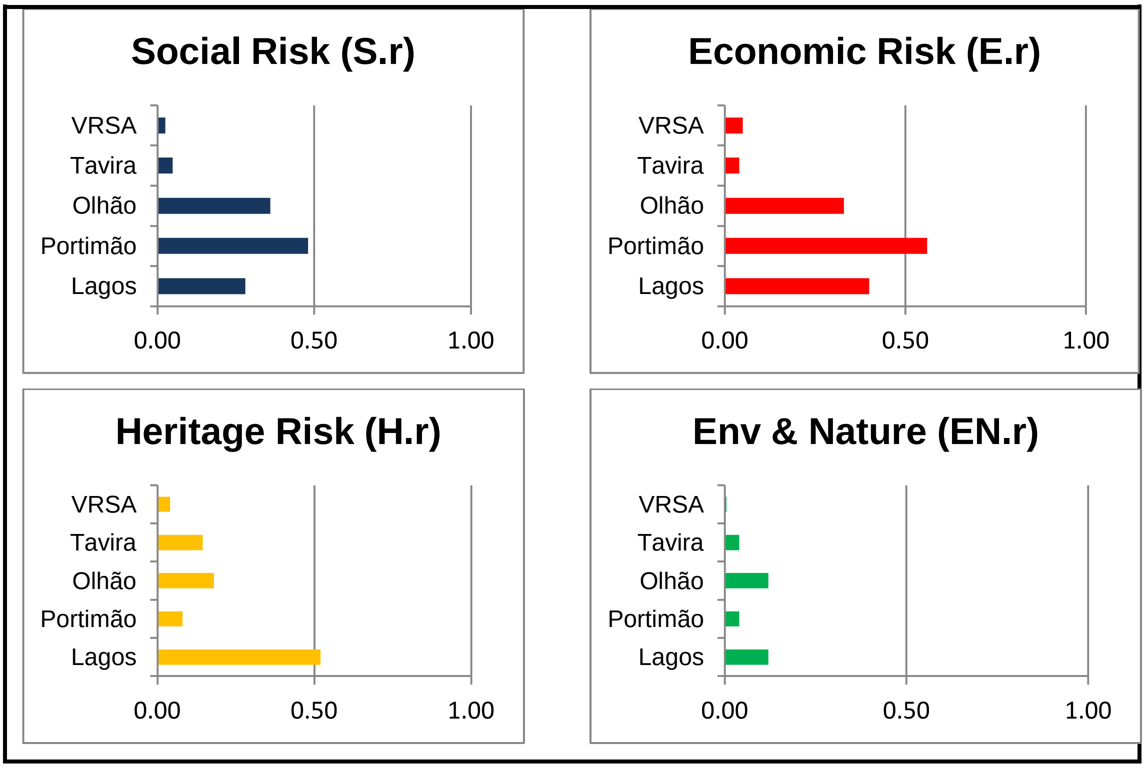

Figure 18 – Sectorial risks

Analyzing the Table 19 and the Figure 18, it is shown how easy it is to draw conclusions immediately in regard to Sectorial Risks of each of the Study Units and what is their absolute importance.

The Study Unit that shows bigger Social Risks is Portimão, followed by Olhão and Lagos. Regarding to Economic Risks after an oil spill, Portimão owns the first place as well, but this time followed by Lagos and then Olhão. Due to the high value of percentage of Pb and five heritages with high weights, Lagos is the Study Unit with higher Heritage Risk. Even Olhão and Lagos are quite distant from each other, they present the same Environmental Risk followed by Tavira and Portimão *ex aequo*, due to the different values of Beaching Probability.

The possibility of comparing the risks in a immediate way, can help urban planners and stakeholders in the decision making process relatively to the coast planning process.

5

DISCUSSION AND CONCLUSIONS

The territory is the land, sea and air on which government bodies can exercise their power ([32]). Given this, all the territory consists on natural areas, forest areas, agricultural and urban areas, being some of them located on or nearby the coast. Due to ships crossing, oil tanks washing, drilling or others, those areas are under a permanent risk.

Damage from oil can be extensive and catastrophic, affecting several hundred kilometres of shoreline as in the case of the supertanker Amoco Cadiz breakup (in France) or the Prestige breakup in Galiza, Spain. Entire communities have been impacted or even eliminated. In addition to these oil spill that are accidental, the communities settled along the coasts are also subject to operational oil spills resulting of the discharge of bilge water from machinery spaces, fuel oil sludge, and oily ballast water from fuel tanks. Also other commercial vessels than tankers contribute operational discharges of oil tankers from machinery spaces to the sea. Cargo-related operational discharges from tankers include the discharge of tank-washing residues and oily ballast water[33].

However, with time such communities do recover. The recovery time varies, depending on the degree of oiling, the physical conditions of the ecosystem, and the nature of the community. Recovery to something approaching prespill conditions begins within a matter of months, and general prespill appearances will return within a year or two [2].

As stated on “Spatial Development Glossary” by European Conference of Ministers responsible for Spatial/Regional Planning (CEMAT) [34], an integrated, participative territorial approach is required to ensure that the management of Europe’s coastal zones is environmentally and economically sustainable, as well as socially equitable and cohesive. It aims at resolving the conflicting demands of society for products and services, taking into account both current and future interests. Major objectives are to:

- strengthen sectorial management by improving training, legislation and staffing;
- preserve the biological diversity of coastal ecosystems by preventing habitat destruction, pollution and over-exploitation; and
- promote the rational development and sustainable use of coastal resources.

Coastal zones are of strategic importance. They are home to a large percentage of European citizens, a major source of food and raw materials, a vital link for transport and trade, the location of some of the most valuable habitats, and the favoured destination for leisure time.

Yet coastal zones are facing serious problems of habitat destruction, water contamination, coastal erosion and resource depletion. This depletion of the limited resources of the coastal zone (including the limited physical space) is leading to increasingly frequent conflict between uses, such as between aquaculture and tourism. Coastal zones also suffer from serious socio-economic and cultural problems, such as weakening of the social fabric, marginalization, unemployment and destruction of property by erosion.

As stated in "A new vision for planning" [35], "*Sustainable planning integrates the objectives of economic development, social justice and inclusion, environmental integrity and integrated transport*". To achieve all those objectives is fundamental to be aware first of the risks of a certain territory. A territory without people, without economic development and with its environmental integrity destroyed won't be sustainable.

While definitions of what constitutes spatial planning are diverse and not always illuminating (echoing the multiple interpretations of similar notions of sustainable development and sustainable communities) there is a broad agreement that it involves a focus upon the qualities and management of space and place. With their clear focus on localities, planners arguably have a key role to play in bringing a clearer spatial dimension to the integration of a wide variety of policy sectors, such as economic development, health and education, and transport, and the way they interact and play out differently in different places [36].

As stated by Allmendinger and Haughton, what shall be seeked is planning being used to develop conjointly with other sectoral actors a form of `spatial strategy', through which the government is forcing through an integrated policy-making process. The result is that, at all levels, an increasingly wide range of bodies and institutions are being drawn into the planning apparatus to varying degrees: substantially in the case of economic development, transport, and environmental regulators, increasingly so in the case of energy and water providers, and very unevenly in the case of social infrastructure, such as education and health sectors.

The development of the Vulnerability Identity (V.ID) is intended to help support the decision of politicians, decision makers and those who have duties on public management on one hand and on the other all the operational forces, in their mission to fight and control oil spills and decide where there is a bigger need to fight it first, and to mobilize the appropriate means to protect points and sensitive areas where the risk is bigger.

Another possible application of V.ID is the application on Global Information Systems (GIS). Oil spills in industrialized cities pose a significant threat to their urban water environment. Given the enormous amount of remaining oil entering into the fragile urban ecosystem (mainly in areas with big ports and refineries) it is important to develop effective pollution prevention and control plan for the city. J. Li [37] developed a GIS planning model to characterize oil spills and determine preventive and control measures available in the city. This author attributed to each record such as spill volume, oil type, location, road type, sector, source, cleanup percentage, and environmental impacts were created. GIS layers of woodlots, wetlands, watercourses, Environmental Sensitive Areas, and Areas of Natural and Scientific Interest were obtained from the local Conservation Authority.

On another point of view, the risk mapping is reflected in a set of thematic maps that spacialize the various risks (natural, technological or mixed) by applying specific methodologies and field work. Risk mapping is produced with the aim of integrating a plan (like Civil Protection Emergency Municipal Plans (PMEPC), Forest Protection Against Fires Municipal Plans (PMDFCI), Municipal Master Plans (PDM), etc.).

Within the PMEPC, risk mapping is very diverse and considers various types of risk: natural (e.g. mass movements), mixed (e.g. forest fires) and technological (e.g. accidents in the transport of dangerous goods). This mapping allows the analysis of the risks present in the territory and to cooperate in the implementation of preventive actions.

Cascais City Hall developed “Sensitivity and Potential Map of Cascais Coastal Zone” which is a planning and management tool that provides a centralized source of information on natural values and heritage to protect and the activities developed in the area, particularly those in some way, influence and are influenced by the marine environment. The condensed information on this mapping aims to contribute to support the management processes in the Municipality of Cascais in particular on the implementation of socio-economic and tourism activities, environmental protection, identification of areas subject to greater pressure and implementation of response actions in case of marine pollution. In this kind of urban planning tools, V.ID can be very helpful, once it can be scalable so it can be adopted to compare the vulnerability of the parishes of a municipality.

This new tool presented in this thesis serves as a support tool in the elaboration of Spatial Plans, in the Planning and Management of Protected or Classified Areas or in Environmental Assessments. As it is known, the POOC and POAT do not include any chapter where the coastal vulnerability questions are discussed. Some POOC are even suffering some alterations given place to POC – Coastline Program. This alteration can be an interesting opportunity to implement the vulnerability assessment of the coast, in case of an oil spill.

Since V.ID is a graphical tool with 4 important vectors, fully visible and easy to interpret, rather than hidden behind an abstract value, it can be used by anyone who intends to protect, plan the territory or even the safety forces that need to organize their strengths in a way to be able to identify risky areas. Besides a cumulative vulnerability index, the visual representation of each sectorial vector allows for a quick inference of the relative importance of each sub-type of vulnerability, allowing for a more targeted, and possibly more efficient, programming of disaster management and response.

The selected subsectors are those that were considered the most important for the development of V.ID. However others may be studied depending on the needs of the teams who use it or depending on the territorial realities that are installed.

As can be read in the work of Chang S. et al [17] several other indicators can be used and the V.ID can be improved by adding other variables such as:

- Social Vector:
  - Human capital– capacity of mobilization of volunteers;
- Environment & Nature Vector:
  - Number and type of species;
  - Generation time.
- Economy Vector:
  - Agriculture - Marine-based agriculture (e.g., seaweed farms) can be affected;
  - Other marine-based industries - Industries that pump water for cooling and other processes are vulnerable to oil spills or Transportation industries such as ferries and float planes may also be affected;
  - Real estate - "Pure stigma" losses that devalue coastal or regional properties due to adjacency to the spill;

- Heritage Vector:
  - Intangible heritage – in this methodology only built heritage was taken in consideration, but it is considerate that the Intangible Heritage shall be studied.

From an governance point of view, another impact with a considerable weight when an oil spill happen is the Municipal/regional government impacts, are the direct and indirect costs form the Public Administration. Thus, the direct administrative costs, increased demand for public services, and loss of tax revenues can strain government budgets. Opportunity costs, loss of staff to cleanup efforts, municipal/ regional brand damage, and political fallout are also factors impacting governments.

Another innovation introduced in the proposed methodology is that the equations include the input of different weights. This allows it to be easily recalibrated to reflect different needs/requirements which can be adjusted to reflect the real needs of each region. Theoretically, it could be customized so as to be suited to characterize small territorial units, or compare different countries of a particular continent.

After characterizing the vulnerability of a territory using the methodology proposed in this thesis and as was shown on point 4.3, its possible to analyze as well the sectorial risks. Thus, V.ID can be used on risk mapping helping the spatial planners to understand which can be the real problems of a territory if an oil spill occurs.

New solutions to optimize the implementation of risk analysis (like V.ID) to spatial planning will improve the planning process efficiency, especially for regions or municipalities that do not have all the human and material resources to develop their own methodology in identification and mapping of natural and technological risks.

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ANNEX A - measurement of Algarve coast sections

Study Unit	Coastal Streches (m)	Type ESI		Total Study Unit (m)
Aljezur	2840	1	2840	54672
	250	1	250	
	296	2	592	
	1297	1	1297	
	1316	1	1316	
	292	2	584	
	656	1	656	
	967	2	1934	
	2173	1	2173	
	2203	2	4406	
	375	1	375	
	228	4	912	
	265	1	265	
	669	2	1338	
	1913	1	1913	
	830	2	1660	
	3511	1	3511	
	321	2	642	
	1431	1	1431	
	658	2	1316	
	2561	1	2561	
	1035	2	2070	
	975	1	975	
	1819	2	3638	
	2410	1	2410	
	3100	2	6200	
	4651	1	4651	
	1018	2	2036	
	720	1	720	
Vila do Bispo	280	2	560	73030
	789	1	789	
	104	2	208	
	1331	1	1331	
	112	2	224	
	673	1	673	
	721	2	1442	
	3653	2	7306	
	3911	1	3911	
	558	2	1116	

	3332	1	3332	
	393	2	786	
	2073	1	2073	
	4489	1	4489	
	106	2	212	
	355	1	355	
	84	2	168	
	1751	1	1751	
	524	2	1048	
	3190	1	3190	
	518	2	1036	
	2995	1	2995	
	1066	2	2132	
	1602	1	1602	
	1158	4	4632	
	1364	2	2728	
	165	1	165	
	281	2	562	
	4298	1	4298	
	227	2	454	
	2007	1	2007	
	130	2	260	
	1046	1	1046	
	602	2	1204	
	2226	1	2226	
	107	2	214	
	1700	1	1700	
	972	1	972	
	1096	2	2192	
	479	1	479	
	202	2	404	
	954	1	954	
	476	2	952	
	2034	1	2034	
	409	2	818	
Lagos	4808	1	4808	36583
	728	2	1456	
	2284	1	2284	
	930	2	1860	
	432	1	432	
	172	2	344	

	600	1	600	
	55	2	110	
	995	1	995	
	186	2	372	
	1289	2	2578	
	88	1	88	
	278	2	556	
	1135	4	4540	
	4964	2	9928	
	1408	4	5632	
	4020	2	8040	
	1414	1	1414	
Portimão	3373	2	6746	21868
	1417	4	5668	
	1276	4	5104	
	268	2	536	
	625	1	625	
	294	2	588	
	260	1	260	
	477	2	954	
	2758	1	2758	
	117	2	234	
	823	1	823	
	92	2	184	
	254	1	254	
	202	2	404	
	1287	1	1287	
Lagoa	441	1	441	28129
	235	2	470	
	2733	1	2733	
	45	2	90	
	628	1	628	
	124	2	248	
	264	1	264	
	98	2	196	
	894	1	894	
	392	2	784	
	203	1	203	
	257	2	514	
	702	1	702	
	97	2	194	

	537	1	537	
	45	2	90	
	230	1	230	
	235	2	470	
	57	1	57	
	555	1	555	
	25	2	50	
	470	2	940	
	198	1	198	
	432	1	432	
	220	2	440	
	246	1	246	
	756	2	1512	
Silves	3884	2	7768	7768
Albufeira	1842	2	3684	45625
	54	1	54	
	34	2	68	
	45	1	45	
	126	2	252	
	51	1	51	
	230	2	460	
	299	2	598	
	160	1	160	
	155	1	155	
	675	2	1350	
	433	1	433	
	328	2	656	
	193	1	193	
	207	2	414	
	204	1	204	
	136	2	272	
	334	1	334	
	176	2	352	
	280	1	280	
	825	2	1650	
	1278	2	2556	
	656	4	2624	
	358	1	358	
	1939	2	3878	
	12272	2	24544	

Loulé	785	4	3140	31564
	976	2	1952	
	811	4	3244	
	11614	2	23228	
Faro	5916	2	11832	46456
	7032	2	14064	
	2116	4	8464	
	6048	2	12096	
Olhão	9561	2	19122	19122
Tavira	11470	2	22940	37218
	934	4	3736	
	5271	2	10542	
VRSA	6145	2	12290	34948
	5921	2	11842	
	2704	4	10816	
Castro Marim	3449	2	6898	6898

Title VULNERABILITY IDENTITY (V.ID) FOR COASTAL TERRITORIES SUBJECTED TO OIL SPILL ACCIDENTS The Algarve Region Coast case study

Author Rui Jorge Baptista Conceição Graça

ADMINISTRATIVE OFFICE FACULDADE DE ARQUITETURA

FACULDADE DE ENGENHARIA

U. PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO