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SDI as Holistic Framework for Integrated Coastal and Marine Management (SDI-ICMM)

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"A robust national information management system dedicated to coastal and marine scientific data and information products is required to meet the diverse data and application requirements of CMSP, and the varying technical capabilities of users."

The White House Council on Environmental Quality, July 19, 2010

Abstract

Abdelghaffar KHORCHANI

SDI as Holistic Framework for Integrated Coastal and Marine Management (SDI-ICMM)

Humanity has always had a close relationship with marine and coastal environments. The coastal zone is one of the most complex areas of management in the world consisting of both the marine and terrestrial environments. Marine and coastal ecosystems are economically and culturally important for many countries, especially for people living near coastlines (40% of the world's population living within 100 km of the sea). It is also a home for an increasing number of activities, rights and interests. Population along the coastline is continuously increasing, bringing about anthropogenic pressures on the fragile ecosystem of the coastal zone.

The need to manage the dynamic environment, the inability to integrate marine and land based spatial information is an increasing problem in many regions. Sustainable development of the coastal zone is impossible without spatial data. The absence of a holistic approach prevents the sustainable development of land – marine interface where so much pressure and the development is taking place. Currently, the most SDI initiatives stopping at the land-ward or marine-ward boundary of the coastline, institutionally and/or spatially. SDI design is focused mainly on access to and use of land related datasets or marine related datasets thus leading to data duplication. Consequently, there is a lack of harmonised and universal access to datasets from marine, coastal and land-based. This leads to the creation of inconsistencies in spatial information policies, data creation, data access, and data integration.

A Spatial Data Infrastructure for Integrated Costal and Marine Management (SDI-ICMM) covering the land and marine environments on a holistic platform would facilitate greater access to more interoperable spatial data and information across the land-marine interface enabling a more integrated to the management of the coastal zone. SDI-ICMM leads to the promotion of data sharing and communication between organisations thus facilitating better decision-making involving marine and coastal spatial information.

The development of an SDI-ICMM model and implementation guidelines has built on the investigation of theory and practice in regards to SDI developments throughout the world. A case study (Gulf of Gabes in Tunisia) has been used to test model and to assist in validating the results. The case study demonstrated the difficulties of integrating terrestrial, coastal and marine data and the need for an SDI-ICMM.
The results are an SDI-ICMM model and implementation guidelines that covers both land and marine environments and can be used by stakeholders in the coastal zone to create an enabling platform for the use and delivery of services and spatial information and therefore to facilitate decision-making.

Keywords: Integrated Coastal and Marine Management, Spatial Data Infrastructure, SDI model, Decision-making, Land – marine interface.

Sommario

La SDI come quadro olistico per la Gestione Integrata della Zona Costiera e Marina

L'uomo ha sempre avuto uno stretto rapporto con gli ambienti marini e costieri. La zona costiera è una delle aree più complesse da gestire, costituita sia da ambienti marini che terrestri. Gli ecosistemi marini e costieri sono economicamente e culturalmente importanti per molti paesi, soprattutto per le persone che vivono nei pressi della costa (il 40% della popolazione mondiale vive nel raggio di 100 km dal mare). È anche luogo favorevole ad un crescente numero di attività, diritti e interessi. La popolazione lungo la costa è in costante aumento, determinando pressioni antropiche sul fragile ecosistema della zona costiera. La necessità di una gestione dell'ambiente dinamico e l'incapacità di integrare le informazioni spaziali marittime e terrestri sono un problema crescente in molte regioni. Lo sviluppo sostenibile delle zone costiere è impossibile senza dati spaziali. L'assenza di un approccio olistico impedisce lo sviluppo sostenibile dell'interfaccia tra l'ambiente marino e terrestre dove tanta pressione e sviluppo sono in corso. Attualmente, la maggior parte delle iniziative per la creazione di una SDI (Infrastruttura di Dati Spaziali) si fermano alla frontiera marina o terrestre del litorale, istituzionalmente e/o spazialmente. Il design della SDI è focalizzato principalmente sull' accesso e sull'uso di dati relativi al territorio o al mare portando così alla loro duplicazione. Di conseguenza, c'è una mancanza di accesso armonizzato e universale ai dati marittimi, costieri e terrestri. Ciò da origine ad incoerenze nelle politiche di informazione territoriale, nella produzione, nell'accesso e nell'integrazione dei dati. La creazione di una Infrastruttura di Dati Spaziali (SDI – Spatial Data Infrastructure) per la gestione integrata della zona costiera che copra gli ambienti terrestri e marittimi su base olistica dovrebbe facilitare un più ampio accesso ai dati spaziali e informazioni maggiormente interoperabili attraverso l'interfaccia terra-mare consentendo un approccio più integrato alla gestione delle zone costiere. Una SDI per la Gestione Integrata della Zone Costiera e Marina conduce alla promozione della condivisione dei dati e alla comunicazione tra le organizzazioni facilitando e migliorando il processo decisionale che coinvolge informazioni spaziali marine e costiere. Lo sviluppo di un modello SDI per la Gestione Integrata della Zona Costiera e Marina e l'implementazione di linee guida si basa sulla ricerca di una teoria e di una pratica relativa agli sviluppi della SDI in tutto il mondo. Un caso di studio (Golfo di Gabes in Tunisia) è stato utilizzato per testare il modello e aiutare nella convalida dei risultati. Lo studio ha dimostrato la difficoltà di integrare dati terrestri, costieri e marittimi e la necessità di una SDI per la Gestione Integrata della Zona Costiera. I risultati sono un modello SDI e linee guida di implementazione che coprono ambienti sia terrestri che marini e che possono essere utilizzati dagli stakeholders nella zona costiera per creare una piattaforma volta all'utilizzo e alla fornitura di servizi e informazioni spaziali e facilitando così il processo decisionale.

Parole chiave: Gestione Integrata della Zona Costiera e Marina, Infrastruttura di Dati Spaziali, modello SDI, Processo decisionale, Interfaccia terra-mare.

Acknowledgements

I would like to thank my supervisor, Pr. Cesare Corseli for entrusting me this project.

I had a feeling that Coastal and Marine Spatial Data Infrastructures will be a rather wide subject to study, but I could not imagine how far-reaching, indeed. I am quite grateful for the encouragement and advices of Pr Corseli at all stages of my work.

I would also like to extend my appreciation to the University Milani-Bicocca members of staff at RITMARE project.

Last, but not the least, I thank my family for their limitless support and trust in my efforts. . . .

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List of Abbreviations

3R Rights, Restrictions, and Responsibilities

4D 4 Dimension

AFI Industrial Real Estate Agencies

AMCP Marine and Coastal Protected Areas

AMVPPC Agency for the Development of Heritage and Cultural Promotion

ANPE National Agency for the Protection of the Environment

APAL Agency for the Protection and Development of the Littoral

AR4 Fourth Assessment Report

CATU Land Use Planning Code

CITET Tunis International Center for Environmental Technologies

CMSP Coastal and Marine Spatial Planning

CSDGM Content Standard for Digital Geospatial Metadata

CZM Coastal Zone Managemen

DEM Digital Elevation Model

DGAT Directorate General for Regional Development

DGF General Direction for Forestry

DGPA Directorate-General for Fisheries and Aquaculture

DGSAM General direction of Air and Maritime Services

DWG DraWinG

EBM Ecosystem-based management

EBSM Ecosystem-Based Management System

ECW Enhanced Compression Wavelet

EEZ Exclusive Economic Zone

EFZ Exclusive Fishing Zone

EM Ecosystem Management

EPZ Ecological Protection Zone

EU European Union

EUROGI European Umbrella Organisation for Geographic Information

EV Extreme Vulnerability

FAO United Nations Food and Agriculture Organization

FGDC Federal Geographic Data Committee

FIG International Federation of Surveyors

GEF Global Environment Facility

GEONAT National Geomatisation Program

GES Good Environmental Status

GESAMP Group of Experts on the Scientific Aspects of Marine Pollution

GG Gulf of Gabes

GGP Global Gross Product

GIS Geographic Information System

GIZ Deutsche Gesellschaft für Internationale Zusammenarbeit

GML Geography Markup Language

GOOS Global Oceans Observing System

GSDI Global Spatial Data Infrastructure

HSR Hierarchical Spatial Reasoning

HV High Vulnerability

ICA International Cartographic Association

ICZM Integrated Coastal Zone Managemen

IHB International Hydrographic Bureau

IHO International Hydrographic Organization

INM National Institute of Meteorology

INSPIRE Infrastructure for Spatial Information in Europe

INSTM National Institute of Marine Science and Technology

IPCC Intergovernmental Panel on Climate Change

ISO International Organization for Standardization

ISO TC International Standards Organization Technical Committee

IT Information Technology

JORT Official Journal of the Republic of Tunisia

JPEG Joint Photographic Experts Group

LPC Local Public Authorities

MAERH Ministry of Agriculture, Environment and Water Resources

MC Municipality Council

MEAT Ministry of Infrastructure, Habitat and Spatial Planning

MEDD Ministry of Environment and Sustainable Development

MedPAN Network of Marine Protected Areas managers in the Mediterranean

MLC Maritime Labor Convention

MPA Marine Protected Area

MSDI Marine Spatial Data Infrastructure

MSDI Marine Spatial Data Infrastructures

MSFD Marine Strategy Framework Directive

MSP Marine Spatial Planning

netCDF Network Common Data Form

NGII National Geographic Information Infrastructure

NGO Non-Governmental Organization

NSDI National Spatial Data Infrastructure

NTT New Tunisian Triangulation

OFT Tourism Agencies

OGC Open Geospatial Consortium

OMB Office of Management and Budget

OMG Object Management Group

OMMP Office of the Merchant Marine and Ports

ONTT Tunisian National Tourist Office

OOM Object Oriented Modelling

OTEDD Tunisian Observatory on Environment and Sustainable Development

PAD Detail Planning Plan

PAT Tourist Planning Plan

PAU Urban Planning Plan

PC-IDEA Permanent Committee for Geospatial Data Infrastructure of the Americas

PMD Public Maritime Domain

POI Point of Interest

POP Persistent Organic Pollutants

POP Plans of Occupation of the Beaches

RM-ODP Reference Model for Open Distributed Computing

SDA Master Planning Plan

SDATN National Master Plan for the Planning of the Territory

SDAZS Master Plan for the Planning of Sensitive Zones

SDI Spatial Data Infrastructures

SDI-ICMM Spatial Data Infrastructure for Integrated Coastal and Marine Management

SHP Shapefile

SOA Service Oriented Architecture

SRS Spatial Reference Systems

STT Tunisian Triangulation System

TIFF Tagged Image File Format

TIN Triangular Irregular Networks

TPS Thyna Petroleum Services

UDDI Universal Description Discovery and Integration

UML Unified Modelling Language

UN United Nations

UNCED United Nations Conference on Environmental Development

UNCLOS United Nations Convention on the Law of the Sea

UNFCCC United Nations Framework Convention on Climate Change

UTM Universal Transverse Mercator

VGI Volunteered Geographic Information

VM Moderate Vulnerability

WCS Web Coverage Service

WFD Water Framework Directive

WFS Web Feature Service

WGS84 World Geodetic System 1984

WMS Web Map Service

WOG Whole-Of-Government

WSDL Web Services Description Language

WWF World Wildlife Fund

WWW World Wide Web

XML eXtensible Markup Language

Dedicated to my parents . . .
. . . Reader and for all.

1 Introduction

1.1 Research Background

The world's oceans cover around two-thirds of the earth's surface. Humans have used the ocean for alimental, obtaining material and providing transportation throughout history.

Humanity has always had a close relationship with marine and coastal environments. The coastal zone is one of the most complex areas of management in the world consisting of both the marine and terrestrial environments. Population along the coastline is continuously increasing, 40% of the world's population living within 100 km of the sea (Schwartz et al., 2005), and brought new pressures on the fragile eco-system of the coastal zone. The more people that crowd into coastal areas, the more pressure they impose both on land and sea. This zone is also a home for an increasing number of activities, rights and interests. The coastal seas, the marine parts of coastal areas, are increasingly concentrated (Katsanevakis et al., 2011) as aquaculture, maritime transport, extraction of materials, exploitation of renewable marine energies, leisure activities, etc. (Cicin-Sain et al., 1998). These activities, which consume spaces and resources, interact with ecosystems, the structure and operation of which can modify individually or cumulatively (Halpern et al., 2008; Lotze, 2006). Their concentration and diversity also generate interactions between them, which can be conflicting (Johnson and Pollnac, 1989). Despite its overwhelming importance to society, the coastal and the marine zone are a difficult geographical area to manage due to jurisdictional and organizational overlaps with many competing and overlapping rights, restrictions and responsibilities (Longhorn, 2004). This has brought with it an increased need to more effectively and efficiently manage this area to meet the economic, environmental and social outcomes of sustainable development. Describing, analyzing and understanding the complex interactions between activities and the environment are the major objectives of the scientific community and civil society.

Many different local, national and regional government agencies are typically responsible for the different aspects of the same physical areas and different uses. The level at which environmental issues dominate national and global forums today is an indication that the earth is environmentally under vicious threats. Several difficulties are created in the coastal and marine areas because the onshore and offshore environments are combined and interdependent. There is always a lack of understanding of coastal and marine environments. The coastal environment includes in general all the natural and artificial elements of environment and define its various ecosystems. However, the marine environment is also fluid and the natural resources and features are more likely to move with time. There is a complex relationship and interaction between overlapping, and sometimes competing rights, restrictions and responsibilities of various stakeholders, both in the marine environment and at the land – marine interface. There are increasingly serious signs that the economic uses of our coastal resources are undermining their long term sustainability. This has brought with it an increased need to more effectively and efficiently manage marine and coastal environments to meet the economic, environmental, and social goals of sustainable development. This fact necessitates devising integrated approach to handling the environment (Comert et al., 2008).

This idea is reflected in the number of global and regional initiatives that aim to improve marine and coastal management such as Integrated Coastal Zone Management (ICZM). In this respect, Coastal Zone Management (CZM) initiatives are turning to more integrated strategies worldwide, attempting to harmonise economic, environmental, and social objectives, similar to the better-developed land use management frameworks of many urban areas. In coastal areas however, the diversity of interests, some terrestrial and some marine, compounds the issue. ICZM recognises that the coastal resources management situation is unique; that is, it differs greatly from management of either land or marine resources, being a combination of both (Bartlett et al., 2004).

In order to minimize conflicts or environmental concerns while resolving or mitigating those that do arise, managers, planners and policy makers require comprehensive knowledge of resources, uses and stakeholders. It is now being recognized that the information required to balance competing interests over the coastal zone have an inherent spatial dimension (Williamson et al., 2004a; Rajabifard et al., 2005a).

So as to reconcile these objectives, accurate and reliable information must reach decision makers in an appropriate and easy way so as to use them formats, so that they can make informed decisions on behalf of stakeholders. Effective governance and administration is underpinned by the need for access to spatial information (Ting and Williamson, 1999; Barry and Fourie, 2002). Spatial information aids decision making by providing a spatial/geographic context to planning, management and resource allocation and is increasingly recognized as essential to emergency response.

With the advancement of technology in spatial data creation, spatial data is created and owned by many different agencies that utilise spatial data to satisfy their own needs. The fragmentation of spatial data owners causes diversity in policies related to spatial data, and standards and tools to manage and coordinate spatial data. The diversity of approaches in data coordination leads to inconsistency and heterogeneity among multi-source spatial datasets.

The term Spatial Data Infrastructures (SDI) is often used to denote the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data. The SDI provides a basis for spatial data discovery, evaluation, and application for users and providers within all levels of government, the commercial sector, the non-profit sector, academia and by citizens in general. SDI is now playing a much broader role in a modern society. The concept involves a complex digital environment including a wide range of spatial databases and is concerned with standards, institutional structures and technologies including the World Wide Web (WWW). SDI is now moving to underpin an information society and enable a society to be spatially enabled (Rajabifard et al., 2006).

A similar facility is needed for marine management. The concepts of Marine SDI (MSDI), marine cadastre and Marine Spatial Planning (MSP) have all emerged recently in response to a global realisation of the need to improve management and administration of the marine environment (Strain et al., 2006a). Tools such as marine cadastre can provide a means for delineating, managing and administering legally definable off-shore boundaries. Nevertheless, the marine environment requires an overarching spatial information platform that facilitates coordinated use and administration of these tools.

Currently, the most SDI initiatives stopping at the land-ward or marine-ward boundary of the coastline, institutionally and/or spatially. The complex physical and institutional relationships existing within the coastal zone make it impossible for development of a marine SDI to occur in isolation from land based initiatives (Longhorn, 2004; Gillespie et al., 2000). SDI design is focused mainly on access to and use of land related datasets or marine related datasets thus leading to data duplication. Consequently, there is a lack of harmonized and universal access to datasets from marine, coastal and land-based. This leads to the creation of inconsistencies in spatial information policies, data creation, data access, and data integration.

To achieve the required sharing and integration of coastal databases across regions and disciplines, and with marine and land based spatial data, there is a growing and urgent need for the extension of existing SDIs to fully encompass the information needs of all coastal zone stakeholders. This SDI should deliver a holistic model that creates a spatially enabled land – marine interface and bridges the gap between the marine and terrestrial environments to more effectively meet sustainable development goals.

To improve management of the coastal zone, there needs to be access and interoperability of both marine and land based spatial data (Longhorn, 2004; Bartlett et al., 2004). However, the differences in the marine and terrestrial environments in terms of fundamental datasets; data collection and technology used in these environments will make interoperability and integration between marine and land based spatial data a challenge. The current situation needs to focus on combining these initiatives.***A Spatial Data Infrastructure for Integrated Coastal and Marine Management (SDI-ICMM)*** covering the land and marine environments on a holistic platform can facilitate greater access to more interoperable spatial data and information across the land-marine interface and enabling a more integrated to the management of the coastal zone. SDI-ICMM can lead to the promotion of data sharing and communication between organisations thus facilitating better decision-making.

1.2 Research Problem

Marine and coastal environment issues are dynamic and diverse. With climate change, rising sea levels and the need to manage our resources more carefully in this dynamic environment, the inability to integrate marine and land based spatial information is a problem in many countries. These issues and their potential impacts are forcing the governments around the world to find solutions. Interactions between human beings and their environment must be analyzed particularly in the context of interactions between its various components, such as land, coast and sea. It is very difficult, if not impossible, to achieve sustainable development of coastal zone without spatial data.

Most SDI initiatives stop at the land-ward or marine-ward boundary of the coastline and most of them focuses on access to and use of the land datasets or marine datasets. Consequently, there is a gap between the terrestrial and marine environments due to lack of a holistic framework of spatial information. This leads to the need to develop Spatial Data Infrastructure for Integrated Coastal and Marine Management (SDI-ICMM) that enables the access and sharing of spatial information of land, coast, and marine zone.

1.3 Hypothesis

The development of a holistic platform as Spatial Data Infrastructure for Integrated Coastal and Marine Management (SDI-ICMM) covering the land and marine environments would facilitate greater access and share to more interoperable spatial data.

1.4 Research Aim

The aim of this research is to design, develop and test an SDI-ICMM model that integrates marine, coastal and land-based spatial information in a unique platform.

1.5 Research Objective

As a result of the identified research problem and the aim of the research, the research objectives are:

1. Justify the need for SDI-ICMM covering the land and marine environments;
2. Understand the concepts of current land and marine SDI initiatives;
3. Investigate the characteristics and components for the design of a SDI-ICMM model;
4. Develop and propose an SDI-ICMM model and associated guidelines;
5. Test the SDI-ICMM through case study (Gulf of Gabes, Tunisia).

1.6 Research Design

The proposed research design and stages for the study are incorporated into four major steps: This research can be broadly grouped into four major areas of: literature review; SDI-ICMM design; SDI-ICMM model development and implementation guidelines; and test and analyse SDI-ICMM by using case study.

To establish the theoretical background of the research, an extensive literature review has been undertaken. The literature review provides the basis for the development of the research strategy and highlights the significant issues that must be taken into consideration through case studies. The developments of the required tools and associated guidelines will be effected based on the outcomes of the case study analysis.

The **literature reviews** highlight marine and coastal issues together with current inefficiencies in the ability to create and access spatial data relating to the marine and coastal environments.

An investigation into the concepts and components of marine and coastal SDIs has also been undertaken, within the context of identifying barriers/challenges to create and **design of a SDI-ICMM**. This led to the identification of opportunities and barriers for combining land and marine components of SDIs.

The **development of a SDI-ICMM model and implementation guidelines** have been proposed based on the Hierarchical Spatial Reasoning and Object Oriented Modelling method. It uses the Unified Modelling Language (UML) approach to address the objectives of the research and responds to the problems discussed earlier.

To **test and analyse SDI-ICMM** a case study of Gulf of Gabes in Tunisia was designed. The ability to access and share spatial information has been examined. The common limitations and problems in the development of SDI have been tested.

1.7 Thesis Outline

The thesis is presented in three sections. **Introduction** comprising Chapter 1. It is the introduction and includes the statement of the research problem, the aim and objectives.

The first part, comprising chapters 2 to 4, presents a review of the literature related to the need for a holistic approach including the land – marine interface. Chapter 2 describes marine and coastal issues. Chapter 3 contains a review of Coastal and marine jurisdiction. It examines the management and administration of rights, restrictions and responsibilities in Tunisia's coastal and marine environments. Chapter 4 reveals the need for spatial information to support marine and coastal administration through the presentation of coastal and marine management initiatives.

The second part of the thesis comprising chapter 5 and chapter 6. It led to the identification of opportunities and barriers for combining land and marine components of SDIs. Chapter 5 describes concept, nature, and components of SDI. It identifies the barriers and challenges to create SDI and describes the characteristics and components of the design of a SDI-ICMM. Chapter 6 develops an SDI-ICMM conceptual model and implementation guidelines using UML and object oriented modelling.

The third part, comprising chapter 7. The research strategy uses a case study approach to assist in refining and validating the results. This chapter presents the answer the research objectives. It also focuses on the case study area of Gulf of Gabes in Tunisia, and examines the applicability of a SDI-ICMM within this environment.

Conclusion comprising Chapter 8. It discusses and summarises the overall research findings and development of the final model based on the analysis of case study.

The research was presented using the thesis structure in nine chapters (Figure 1.1).

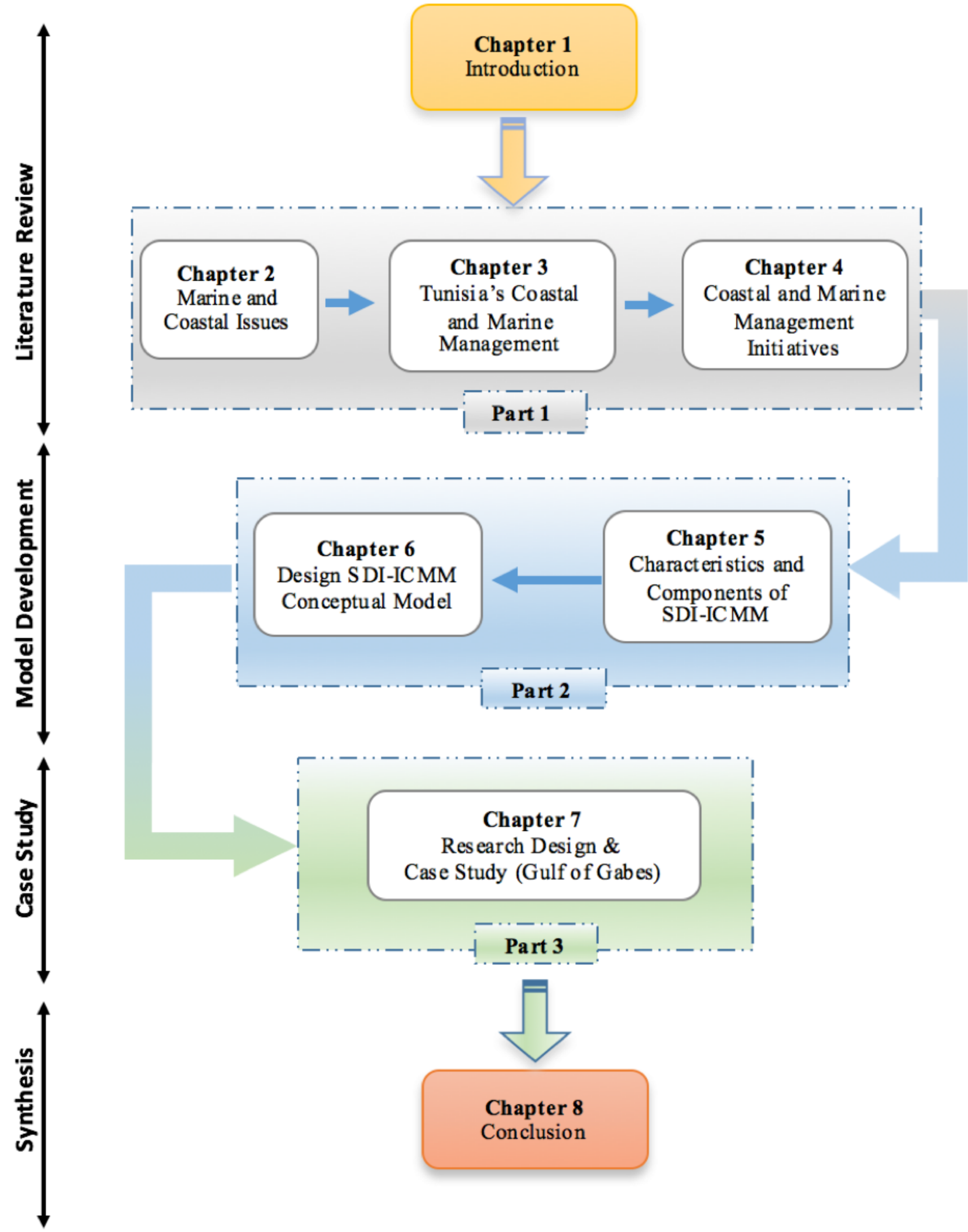

FIGURE 1.1: Thesis structure

2 Marine and Coastal Issues

2.1 Introduction

During the interactions between human beings and their environment, the marine and coastal environment must be analyzed particularly in the context of interactions between its various components, such as land, sea, fauna and flora. This has led to the need to create a holistic spatial data infrastructure, including the land area, maritime area and land-sea interface.

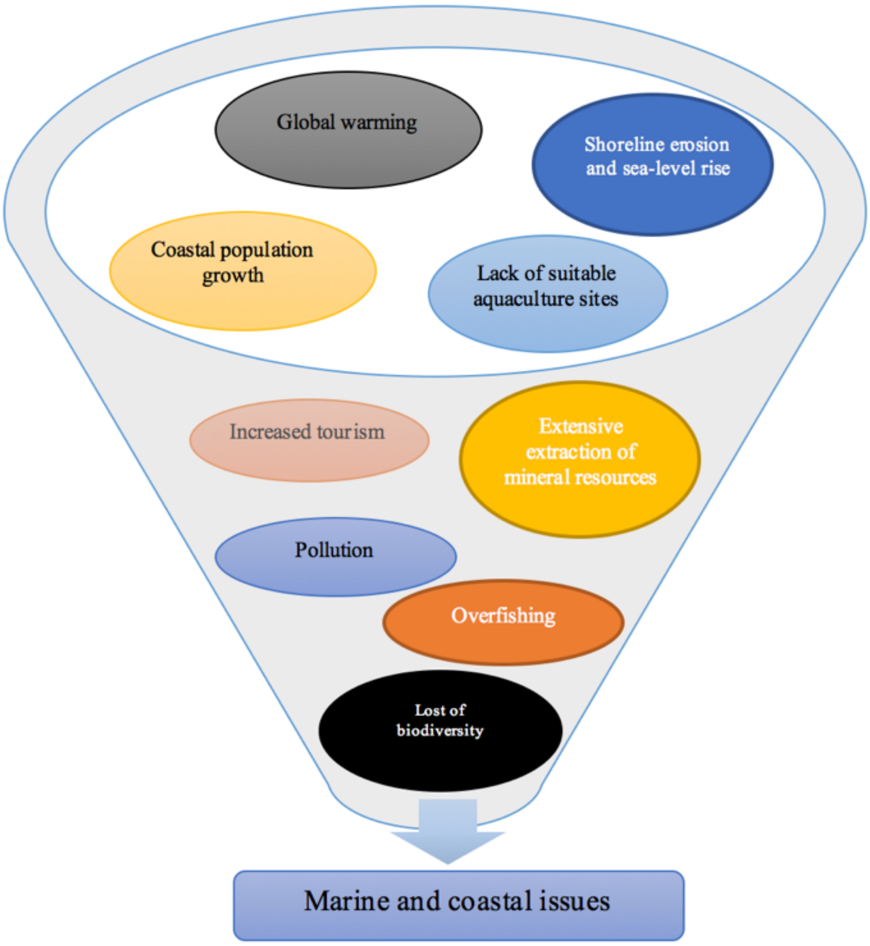

FIGURE 2.1: Marine and coastal management issues

These issues and their potential impacts (Figure 2.1) are forcing coastal states and localities to find solutions. The major concern in these issues is global warming and the resulting sea-level rise and shoreline movement. The subsections issues focus on national marine and coastal management regimes.

2.2 Major Marine and Coastal Issues

2.2.1 Global warming

Global warming is the term used to describe a gradual increase in the average temperature of the Earth's atmosphere and its oceans. A change that is believed to be permanently influencing the Earth's climate. It has been identified as one of the greatest threats facing the living systems of the planet. The increase in the average temperature of the Earth and oceans raises the level of greenhouse gases in the atmosphere. Since the industrial revolution the human activity, have contributed to a warming of the atmosphere and the oceans.

Global average air temperature at the Earth's surface has increased by $0.8°$C since 1900 (Stocker et al., 2013). Global mean air temperature is expected to increase by $1.0°$C – $3.7°$C by the end of this century, with concurrent changes in global and regional precipitation regimes (Stocker et al., 2013). Latest climate change scenario projections for Europe suggest that by 2100 temperatures will increase between about $2°$C – $5°$C and by $1.4°$C – $5.8°$C globally, depending on the quantity of future greenhouse gas emissions (Peters et al., 2013).

On 12 December 2015, the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) adopted the "Paris Agreement". Paris thus finally concluded the long process of crafting a new international climate regime that began with the adoption of the Bali Roadmap in 2007, failed spectacularly in Copenhagen 2009, and resumed with a new approach in Durban 2011. The conference in Paris concluded this process, as demanded in the Durban Platform, with the adoption of a treaty under international law that represents the first really collective effort by the world community to tackle climate change.

The states discussed the necessity of limiting global warming to below $2\,°\mathrm{C}$ and to pursue efforts to limit the temperature increase to $1.5\,°\mathrm{C}$ above pre-industrial levels. Consequently, climate change and global warming would be a serious crisis which would require greater attention to coastal protection and change management. Political and public debate continues regarding climate change, and what actions to take in response. The available options are mitigation to reduce further emissions; adaptation to reduce the damage caused by warming; and, more speculatively, geoengineering to reverse global warming.

Changes resulting from global warming may include rising sea levels due to the melting of the polar ice caps, as well as an increase in occurrence and severity of storms and other severe weather events. Additional anticipated effects include species extinctions, reductions in the ozone layer, changes in agriculture yields and ocean oxygen depletion (Intergovernmental Panel on Climate Change, 2001). Social and economic effects of global warming may be exacerbated by growing population densities in affected areas (coastal zone). Some effects on both the natural environment and human life are, at least in part, already being attributed to global warming. Climate change will drive changes in many of the processes associated with inundation or erosion of the coastline and will increase the frequency of individual high water level events. With increasing frequency, the likelihood of events occurring simultaneously increases and what were once seen as rare and independent events will increasingly become more common.

The atmosphere, land and oceans are greatly interconnected and interrelated. Our climate is actually very complex and intimately connected to life on Earth. Considering the atmosphere interaction with the underlying surface-land and oceans on many different scales in both space and time, it causes a large natural variability in climate; and human influences such as greenhouse gas emissions add further complexity.

Figure 2.2 shows the complexity of interactions in the coastal zone and suggests that the impacts of climate change could manifest in many ways. Anthropogenic climatic forcing is mediated primarily by greenhouse gas (predominantly CO_2) emissions. Together, elevated CO_2 and the resultant increases in global mean temperature will result in a cascade of physical and chemical changes in marine systems.

The climate change and socioeconomic drivers combine to lead to the specific impacts caused by climate change. The temperature changes of 2-4 degrees

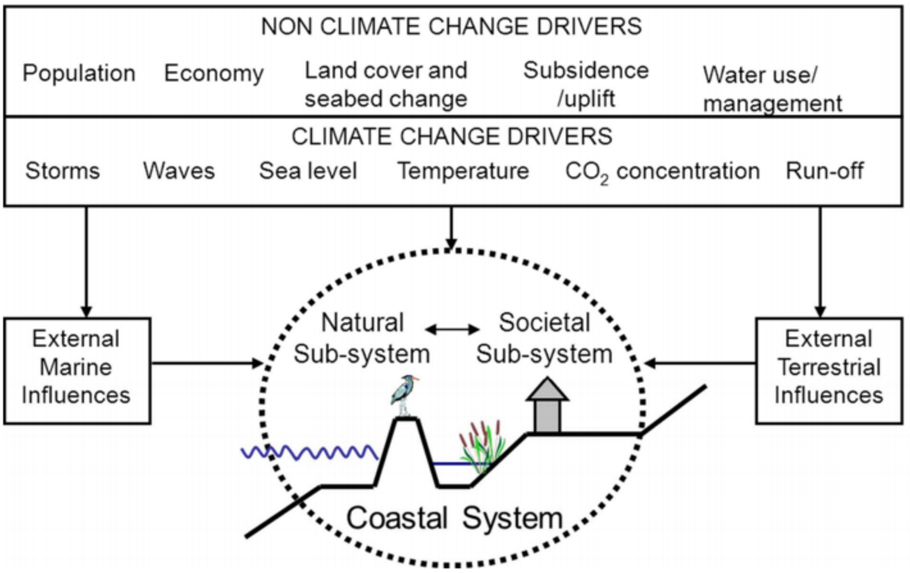

FIGURE 2.2: Climate change drivers and impacts on the coast (Nicholls et al., 2014)

Celsius and the sea level rises which could displace millions along the coasts. But this also happens within a context of already existing economies, population growth, urbanization, and water management along these coasts. We can no longer think about climate change alone.

Tunisia signed the UNFCCC in 1992 and ratification took place in July of the following year. This commitment has only affirmed the country's will to face the impact of climate change by acting both on mitigation and adaptation.

The first climate projections for Tunisia were carried out in the framework of the study of the national strategy for adaptation of the agricultural sector and ecosystems to climate change carried out between 2006 and 2007 by the Ministry of Agriculture, Hydraulic Resources and Fisheries with the support of GIZ.

The National Institute of Meteorology (INM), published in 2015 the results of modelling of downscaling of climate projections for Tunisia. The parameters considered for the reduction of scale are temperature and precipitation. The INM is planning to carry out the work also for moisture soon. Projections were made in 2050 and 2100.

The results provided by the projections for 2050 (Figure 2.3) are as follows:

- A decrease of between 2% and 16% in precipitation over the whole;

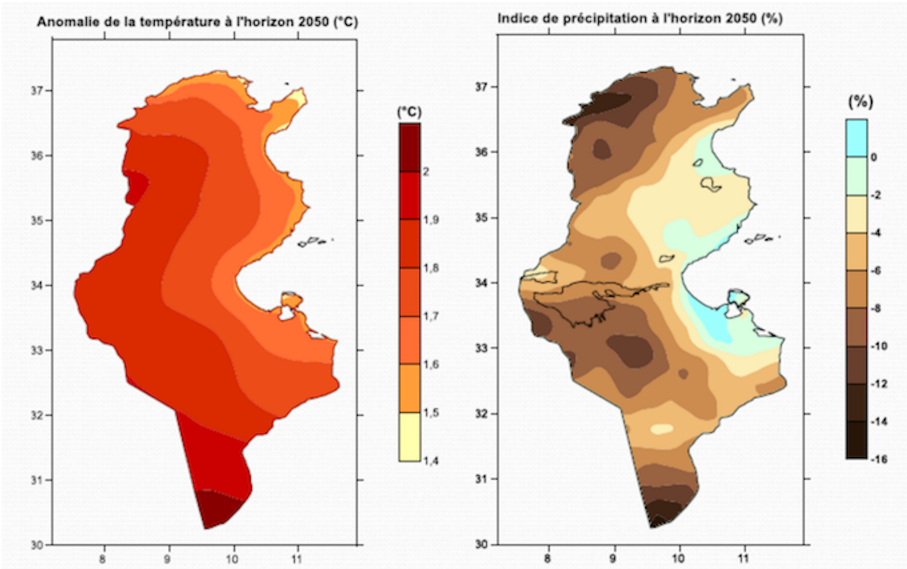

FIGURE 2.3: Temperature anomaly (left) and Precipitation index (right) by 2050. (INM, 2015)

- The period 1961-1990. The central and southern coasts remain less vulnerable to changes compared to other regions of the country;
- Temperature averages will increase between $1.4\,°C$ and $2.1\,°C$, over the whole of the country in relation to the average calculated over the period 1961-1990. This increase is greater in the extreme south of Tunisia.

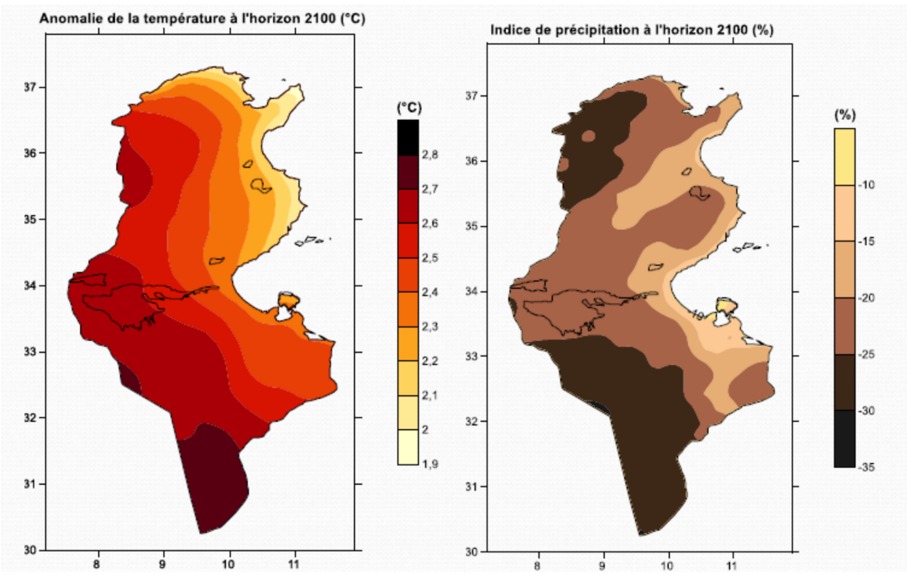

FIGURE 2.4: Temperature anomaly (left) and Precipitation index (right) by 2100. (INM, 2015)

The trends are the same at 2100 (Figure 2.4) with:

- A more significant decrease in precipitation averages ranging from 10% to 35%
- A significant increase in the mean temperature between $1.9\,^{\circ}\mathrm{C}$ and $2.9\,^{\circ}\mathrm{C}$.

Climate and Sea have always been the major forces shaping the Tunisian coast, and over time the position of shoreline has changed. Now climate change is driving the evolution of a new coastline for Tunisia, but the location of that coastline is not yet clear. With much of Tunisia's infrastructure concentrated in the coastal zone around centers of population, climate change will bring a number of risks to build environment assets which could have consequences for the national economy. In Tunisia, floods are not something new. The human memory will always preserve the most important ones (1969, 1973, 1979, 1982, 2003, 2007, 2009, 2012 and most recently in 2013). These events resulted in the loss of life and several millions of dinars of material damage.

By 2030, according to the climate change hypothesis adopted, the frequency of exceptional rainfall is expected to increase: the return rainfall 20 years in the present situation would become decadal, the 100-year rain in the present situation would return period of 50 years. The rate of soil waterproofing, due to urbanization, would rise from 31% in 2010 to 47% in 2030.

The impacts of climate change are extremely diverse. Their effects intersect and amplify each other, amplifying the effects of coastal activities and developments. These changes due to climate change (temperature, precipitation, winds, increase in carbon dioxide levels, rise in sea level, etc.), are combined with those due to man (pollution, coastal development, overexploitation of natural resources, of non-indigenous species) impact and will increasingly affect both socio-economic and natural systems.

The example of rising sea levels is a major issue; this phenomenon, which is already perceptible but is expected to accelerate, will affect coastal ecosystems and mainly wetlands, tidal islands and low islands and islets which are the unique or privileged habitat of many animal and plant species and will be affected by accelerated erosion. This will also affect human activities and development. The thermal effect and moderation of the precipitation regime will be felt both on land and in the sea, it will affect ecosystems, habitats and biodiversity as well as economic activities.

More generally, global spatial information platform can serve as a basis for climate change adaptation and mitigation. The management of natural disasters resulting from climate change can also be enhanced through integration of land and marine environments. This would enable control of access to land and marine environments as well as control of the use of these environments. The integrated administration system can include the perspective of possible future climate change and any consequent natural disasters. The engagement of all stakeholders (governments, individuals, and the private sector) is essential to develop and implement a comprehensive. All parties will have a role to play. The fact of climate change is not a geographical local problem but can be solved by local or regional efforts alone. To address climate change, international efforts must integrate with local, national, and regional abilities (Chiu, 2009).

2.2.2 Shore line erosion and sea-level rise

Sea-level rise is a major effect of climate change. It has drawn international attention, because higher sea levels in the future would cause serious impacts in various parts of the world.

Sea level variations are not uniform, either on a global scale or on a Mediterranean-wide scale. They are due to several phenomena of variable spatio-temporal scales which lead to the elevation, stagnation or lowering of the sea level on a regional or even local scale. The forces acting are the displacement of atmospheric action centers and the variation of atmospheric pressures, tectonic movements, water supply in basins, melting ice and steric effects.

Regional variations in sea level are due to the displacements of atmospheric action centers (anticyclones and depressions), which allow the variation of atmospheric pressure and influence the pressure gradients between these action centers. Therefore, it plays on the strength and speed of the wind. At the global level, several sets have been highlighted Sea-level rise affects the natural shoreline in several ways. Higher water levels erode beaches, dunes, and cliffs; inundate wetlands and other low-lying areas; and increase the salinity of estuarine systems, displacing existing coastal plant and animal communities. These coastal environments provide a protective buffer to areas further inland, as wetlands can reduce flooding and cliffs, beaches, and dunes protect coastal property from storm waves. Global mean sea-level has risen about 20 centimeters since pre-industrial times, at an average rate of 1.7 millimeters per year during the 20th century (Church and White, 2006).

The IPCC AR4 projections estimated global sea-level rise of up to 79 centimeters by 2100, noting the risk that the contribution of ice sheets to sea-level this century could be higher. However, there is growing consensus in the science community that sea-level rise at the upper end of the IPCC estimates is plausible by the end of this century, and that a rise of more than 1.0 meter and as high as 1.5 meters cannot be ruled out (Steffen and Government, 2009). Sea-level rise projections ranged from 0.75 to 1.9 meters by 2100 relative to 1990, with 1.1 – 1.2 meters the mid-range of the projection (Rahman and Hua, 2011).

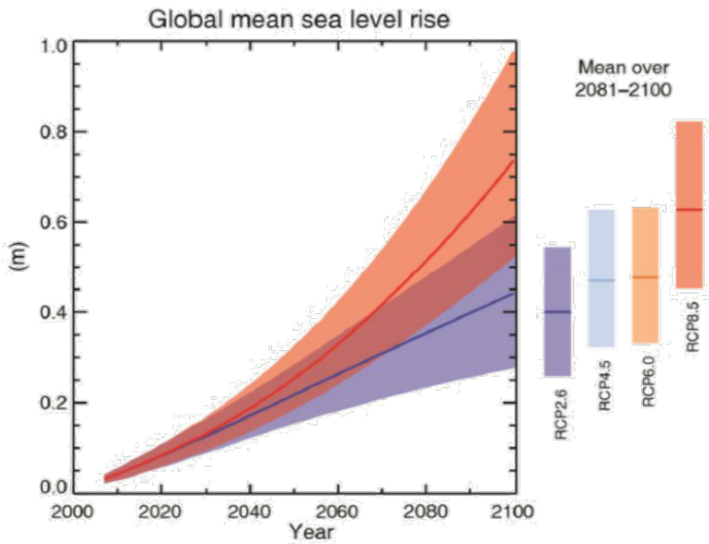

FIGURE 2.5: Projections of the change in the average sea level during the 21st century compared to the period 1986-2005. (GIEC et al., 2013)

Many coastal areas are facing long term shoreline erosion and accretion problems. Coastal erosion is and will continue to be one of the most severe impacts of sea-level rise. The beaches are critical components of the coastal zone; not only are they significant habitats in their own right (Defeo and McLachlan, 2013), but also provide protection from marine flooding to other transitional ecosystems and the coastal assets, infrastructure and activities they front (Neumann et al., 2015). At the same time, tourism has been increasingly associated with beach recreational activities according to the dominant 'Sun, Sea and Sand-3S' tourism model (Phillips and Jones, 2006). Consequently, beaches have become very important economic resources (Ghermandi and Nunes, 2013), forming one of the pillars of tourism, an economic sector that contributes an estimated 5% of Global Gross Product (GGP), and about 6 – 7% of global employment (directly and indirectly) (Hall et al., 2013).

Determining the socio-economic impacts of sea-level rise on coastal areas comprises one of this century's greatest challenges (Nicholls and Leatherman, 1996). This challenge, in turn, depends on accurate determinations of the effect of accelerated sea-level rise on the natural (physical and ecological) environment (Fitzgerald et al, 2008).

Shoreline erosion is not restricted to marine-based influences like waves and surge, but can also be effected by the adjacent land use. Property owners on high bluff shorelines can contribute to their shoreline erosion problem. A variety of other human alterations can affect shoreline erosion and accretion patterns as well. At the level of the Mediterranean Sea, sea-level rise in the coastal zones of the different countries is not the same. Especially the eastern part of the Mediterranean has been confronted with a rise in sea level.

In Tunisia, rising sea levels are beginning to be clearly visible on the coasts. Some archaeological show an elevation ranging from 20 to 40 cm since the historical times. Similarly, recordings of tide gauges indicate a sea-going rise at some sites bearing at the shoreline and the morphology of the coast. The study of Tunisian coastline vulnerability map to climate change mentioned that the majority of this rise in sea level was recorded between 1992 and 2002 linking this increase to a change in kinetic energy at the scale of the Mediterranean.

In its initial national communication, Tunisia estimated the average sea-level rise on the Tunisian coasts between 0.37m and 0.66m by 2100. This rise in sea level would have more coupled with the effects of climate variability. For example, storms will result in shoreline changes that can further aggravate erosion in addition to sand movement.

An initial assessment of sea-level rise for Tunisia was carried out in 2008 in the context of the study of the environmental and socio-economic vulnerability of the Tunisian coastline in the face of an accelerated rise in sea levels due to climate change. The scenario that was selected from three scenarios advanced in the study is that of a sea level rise of 55 cm by 2100 for a global warming of $0.25\,^{\circ}\mathrm{C}$ per decade.

The study of the map of vulnerability of the Tunisian coastline to climate change realized by the APAL and the UNDP in 2012 updated this first evaluation and proposed the following scenarios to the horizon 2100:

- An assumption of an effective coastal management and climate change adaptation policy leading to the moderate vulnerability scenario (MV), which corresponds to a sea level rise of 38 cm;
- An extension of the current policy on occupancy, management and protection of the littoral zone leading to the scenario of high vulnerability (HV), which corresponds to a sea-level rise of 50 cm;
- An assumption of a lack of protection and adaptation to sea level rise leading to the extreme vulnerability (EV) scenario with sea level rise of 100 cm.

The optimistic scenario was retained in this study with a rise of 38 cm by 2100.

In Tunisia, an increase in sea levels is corroborated by the indications of the archaeological remains. Observations made at different points on the Tunisian coast agree to indicate a slight transgression since antiquity. Its amplitude is variable (from 1.5 to 0.2 m) because, depending on the location, local tectonic behavior has accentuated or reduced it (Paskoff, 1979; Slim et al., 2004).

Tangible signs of sea level rise and erosion are already perceptible (Oueslati, 1993; Oueslati, 2004). They are reflected in the decline of beaches, the submergence of coastal areas by maritime arrivals and the exhibition of strategic urban infrastructure, in particular port infrastructure (Figure 2.6). It is likely that the coast has receded during historical times. In Carthage-Salammbo, for example, Roman ruins can clearly be seen extending into the water a few hundred meters in front of the shore. According to archaeological findings, the rise observed in historical times reaches 20 to 40 cm (Oueslati, 1993).

These archaeological remains, visible on the coasts, are among the best indicators of the modification of the shorelines. Moreover, the first treatments carried out on the tidal recordings of the ports of Sfax and La Goulette confirm the above remarks. They show a sea lift, at a significant rate since the beginning of the 20th century. It is also estimated on the basis of tide gauge records that the mean level of the Mediterranean Sea rose by 1.5 cm per decade for the period 1891-1950 (Paskoff, 1979).

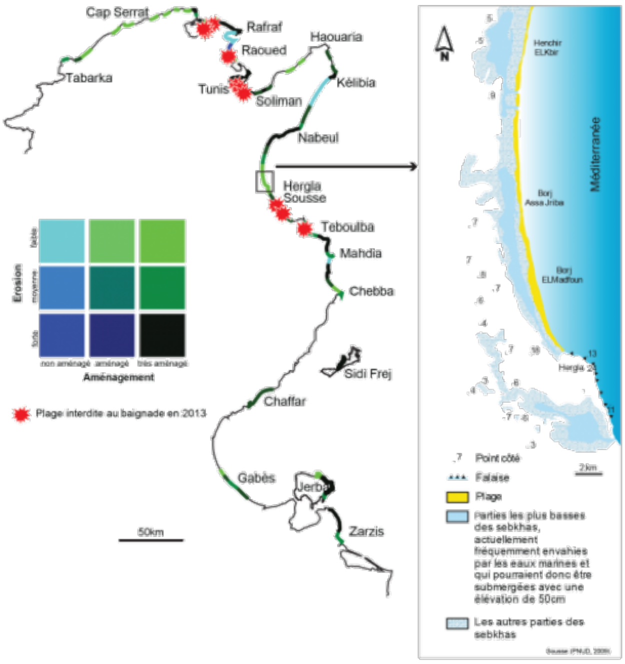

FIGURE 2.6: Vulnerability to sea level rise. (Chouari and Belarem, 2017)

The Tunisian coastline is particularly vulnerable to sea-level rise. The risks associated with this rise are manifested in the acceleration and aggravation of the erosion phenomenon, which is already a serious threat to a large number of segments coastal. The phenomena of shoreline retreat and salinization of coastal soils are likely to increase with a risk of submersion. As a result, rising sea levels threaten both the economic sectors that depend on the sea and the coast and the environmental balance of the environment.

The relative rise in sea level (environmental disturbance) has led to major physical disturbances that have themselves influenced the life of the population and increased the vulnerability of the island as well as the islanders. The inhabitants were forced to change occupations from agriculture to fishing and tried to stop the retreat of the coast by various adjustments. But the salinization of the land and its disappearance by marine erosion did not allow the land to retain any agricultural potential.

Salinization affects Tunisia's shallow coastal aquifers, particularly the Cap Bon aquifer in the northeast (García et al., 2010). It is caused by the intrusion of seawater into the aquifer and the flow of agricultural drainage water with concentrated salts. In 2003, overuse of the Cap Bon aquifer led to the salinization of over 2,800 freshwater wells (Gaaloul and Cheng, 2003). This not only affects the amount of potable water available for human use, but also the health of species that rely on a clean water supply. If water use is not regulated, the entire coastal aquifer may become saline due to seawater intrusion, as it is the case for neighboring Libya.

Many coastal environments such as beaches, estuaries, coral reefs, wetlands and low-lying islands are closely linked to sea-level. There is a lack of knowledge in many cases as far as concerning the environment respond to sea-level rise, but the risk of beach loss, salinization of wetlands and inundation of low-lying areas and reefs beyond their capacity to keep pace must be considered in regional decision-making. Long term shoreline erosion and sea-level rise represent major future challenges for coastal states and localities to deal with.

The development of holistic spatial data bases across land – marine interface covering coastal landforms, digital elevation models and tidal/storm surge will serve to mitigate sea-level rise risk and, ultimately, to making informed, cost-effective decisions to adapt to climate change. The management of natural disasters resulting from sea-level rise can also be enhanced through integration of land and marine spatial data.

2.2.3 Rapid coastal population growth

Few of the world's coastlines are now beyond the influence of human pressures, although not all coasts are inhabited (Buddemeier et al., 2002). Utilization of the coast increased dramatically during the 20th century, a trend that seems certain to continue through the 21st century. Coastal population growth in many of the world's deltas, barrier islands and estuaries has led to widespread conversion of natural coastal landscapes to agriculture, aquaculture as well as industrial and residential uses (Leslie, 2008). It has been estimated that 23% of the world's population lives both within 100 km distance of the coast and <100 m above sea level, and population densities in coastal regions are about three times higher than the global average (Small and Nicholls, 2003). The average population density in coastal areas is about 80 persons/km^2, twice the global average (Brown, C., Corcoran, E., Herkenrath, P., & Thonell, 2006; Tedsen et al., 2014). Of the world's 17 largest cities, 14 are located along coasts - and 11 of these are in Asia. In addition, two-fifths of cities with populations of one million to 10 million people are located near coastlines (Figure 2.7) (Creel, 2003).

An estimate said than more of one billion people in the low-elevation coastal zone globally by 2060 with an average population density of 405 people/km^2 (Neumann et al., 2015).

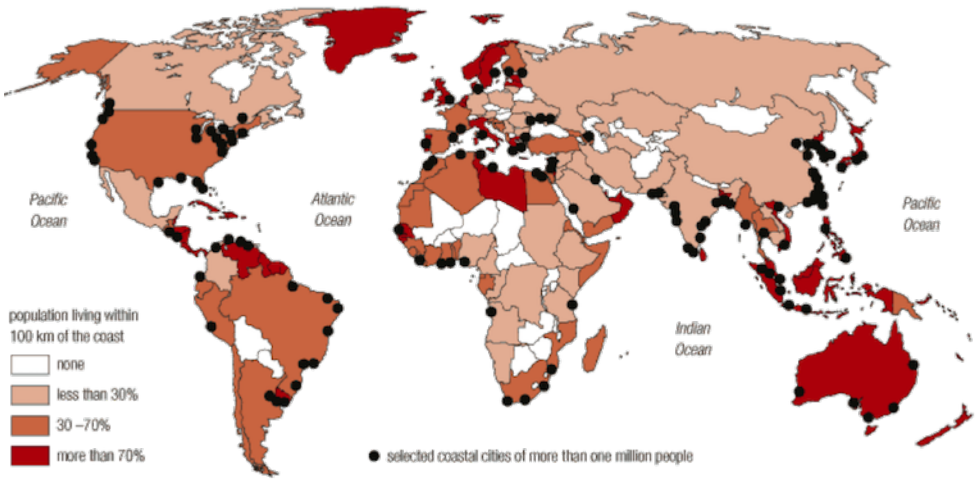

FIGURE 2.7: The most cities of more than one million people. (UNEP, 2006)

Most coastal developments in the Mediterranean do not take into account the long-term impact. More than 50% of the population of the Mediterranean countries is concentrated on the coast. In Tunisia the population is almost 12 million in 2016. Around, 64% of Tunisian's live on the coast. The greatest growth occurred in Tunis (density 3 053 people/km^2), followed by Sfax, then Nabeul.

The coastal regions are the most attractive places to live in, both in terms of economics and aesthetics. Due to the transport, recreation, food, and ecological benefits, the most cities have been located on coastlines for a long time. Largely for transportation reasons, major industrial and commercial centers developed around port cities. The resources of the coastal zone provide numerous job opportunities, and many people come to the coast for recreation. This has set a precedence for populations to naturally migrate towards coastal areas.

Demographic trends suggest that coastal areas around the world are undergoing serious population growth pressures. The more people crowd in the coastal areas, the more pressure they impose both on land and sea. Natural landscapes and habitats are altered, overwhelmed and destroyed to accommodate them.

Population growth is the driver behind many, if not most, coastal problems. The population and development pressures that coastal areas experience generate a number of critical problems and policy issues and raise serious and difficult challenges for coastal planners.

2.2.3.1 Accelerating rate of urbanization

The attractiveness of the coast has resulted in disproportionately rapid expansion of economic activity, settlements, urban centers and tourist resorts. People migration to coastal regions is common in both developed and developing nations. 60% of the world's 39 metropolises with a population of over 5 million are located within 100 km of the coast, including 12 of the world's 16 cities with populations greater than 10 million. Nearly 30% of the land area in the world's coastal ecosystems had already been extensively altered or destroyed by growing demand for housing, industry, and recreation. 19% of all lands within 100 km of the coast (excluding Antarctica and water bodies) are classified as altered, which means that they are in agricultural or urban uses; 10% are semi-altered, involving a mosaic of natural and altered vegetation; and 71% fall within the least modified category. Rapid urbanization has many consequences: for example, enlargement of natural coastal inlets and dredging of waterways for navigation, port facilities, and pipelines exacerbate saltwater intrusion into surface and ground waters.

More of the narrow strip of land along the world's coasts and its habitats has been ruined by poorly planned and badly regulated activities, from the explosive growth of coastal cities and towns to the increase in tourism and from industrialization to the expansion of fish farming. The pressures are particularly exacerbated along the coasts of many developing countries, where rapid population growth combines with persistent poverty, and there is little capacity to manage the situation. But developed countries' coastlines are often overdeveloped too, as people and businesses demand foreshores properties (Moltke, 2001).

The resident population of the riparian states of the Mediterranean was 246 million in 1960, 380 million in 1990 and 450 million in 1999. 'Blue Plan' estimates that depending on the development scenarios applied, this figure will rise to 520-570 million in the year 2030, is expected to reach approximately 600 million in the year 2050 and possibly as much as 700 million at the end of the 21st century (EEA, 1999).

In Tunisia, an imbalance between coastal and inland areas, marked by a concentration of the population on the coast (Figure 2.8), which now comprises 2/3 of the population, 73% of the country's dwellings on less than 1/3 of the national territory (Chouari and Belarem, 2017).

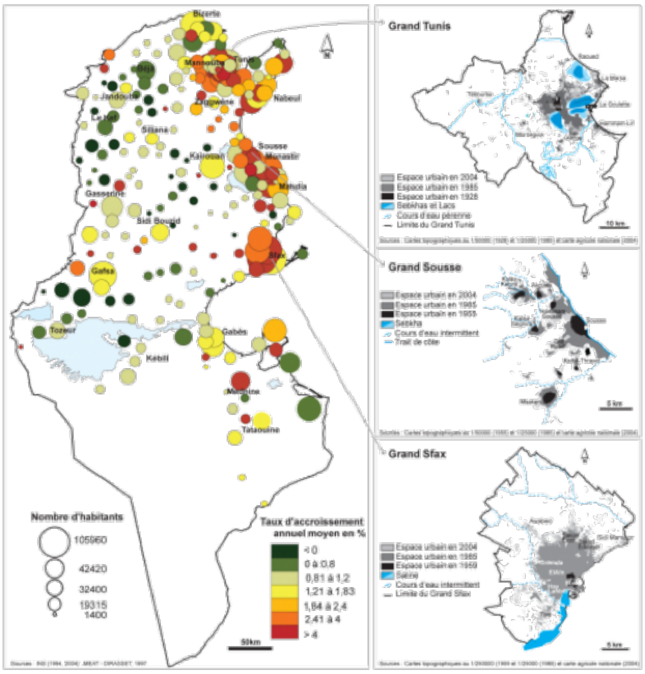

FIGURE 2.8: Population growth in Tunisia (Chouari and Belarem, 2017)

The agglomeration of Grand Tunis alone accounts for about 1/4 of the population and 34% of the country's urban population. If one considers the "metropolitan" arc which extends from Bizerte to Hammamet, this share will rise to 1/3 of the country's population (Ben-Nasr et al., 2012).

2.2.3.2 Conflict and competing demands

The direct impacts of human activities on the coastal zone have been more significant over the past century than impacts that can be directly attributed to observed climate change (Scavia et al., 2002; Lotze, 2006). The major direct impacts include drainage of coastal wetlands, deforestation and reclamation, and discharge of sewage, fertilizers and contaminants into coastal waters. Extractive activities include sand mining and hydrocarbon production, harvests of fisheries and other living resources, introductions of invasive species and construction of seawalls and other structures. Ecosystem services on the coast are often disrupted by human activities.

The conflict of uses can be defined as "competition between incompatible uses of space" (Torre et al., 2005). Both in the marine environment and at the land – marine interface, the rights, restrictions, and responsibilities (RRRs) interact among overlapping and sometimes competing across various activities.

In the marine environment, Johnson and Pollnac (1989) identify four types of conflicts of use according to their origins. They may arise from sectoral management, divergence of perception, competition for space and time, or competition for the resource. Suman (2001), based on the analysis of different case studies in Europe and the United States, also proposes a characterization of the conflicts of use in the coastal sea by their origins, anchored in one or more of the following categories:

- Competition for space and/or resources;
- Differences in values and perceptions of the environment;
- Divergence of economic interests;
- Use and interpretation of facts.

The evaluation of the more or less conflicting interactions between maritime activities linked to superimpositions between spaces generated by uses has given rise to various formalizations such as the matrix proposed by Couper (1983) (Figure 2.9). It identifies interactions between two-to-one activities that may be conflicting, or potentially risky, for either or both activities, or for both, or for one or both.

There are also a large number of stakeholders with rights, interests, or responsibilities for management. The complex and dynamic nature of these rights which regularly overlap creates the need for interaction between a wide range of stakeholders and activities. There are many issues in the coast and marine management but one of the highlighted issue is overlapping coastal interests (shipping, fishing, aquaculture, conservation, recreation, tourism, etc.). In the case of the gulf of Gabes, the coastal zone has spatially overlapping rights, restrictions, and responsibilities for many stakeholders. In coastal areas, the diversity of interests, some terrestrial and some marine, compounds the issue. The task of efficiently and effectively managing all

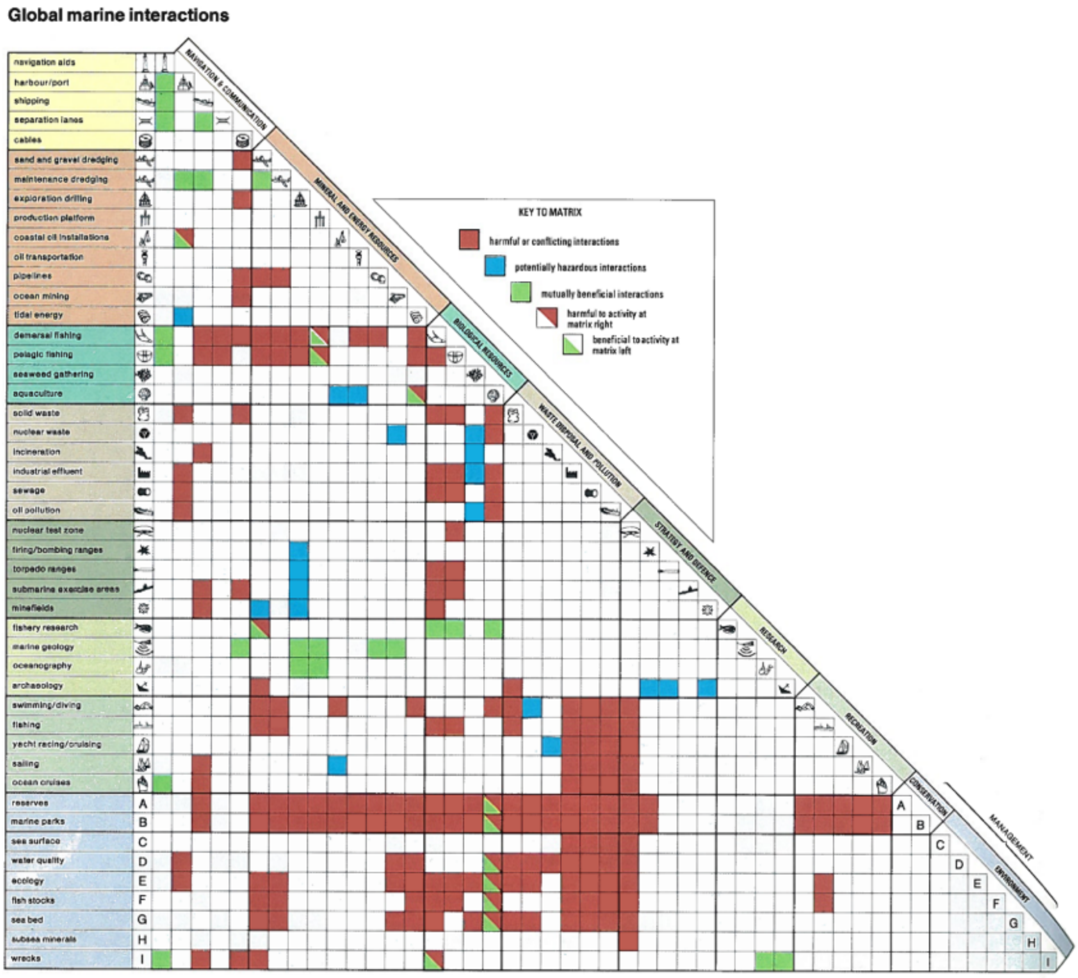

FIGURE 2.9: Interactions between offshore activities. (Couper, 1983)

stakeholders is complicated by the fact that their rights can often overlap which gives rise to the need for cooperation between agencies.

The coastal resources management situation is unique; that is, it differs greatly from management of either land or water resources, being a combination of both. This is made more complicated by a deficiency in the availability of reliable and accurate spatial data for the marine and coastal environments and a lack of coordination in management of their resources (Binns et al., 2004; Strain, 2006). Common platform is necessary for giving access to global spatial information including land and marine information to different stakeholders involved in the administration of overlapping.

2.2.4 Pollution of Coastal and Marine Environment

Since coastal and inland populations continue to grow, their impacts in terms of pollutant loads into the marine environment can be expected to grow much deeper. The coastal development activities involving manmade alterations of the coastal environment have also accelerated the impacts of pollution leading to the deterioration of coastal environmental quality, depletion of coastal resources, public health risks and loss of biodiversity. Marine pollution as defined by the Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP), which is part of the basic framework of the UNCLOS 1982 (Article 1.4) is:

"The introduction of man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water, and reduction of amenities."

The pollution problems have arisen as a result of the indiscriminate discharge of effluent from industrial and agriculture sources and disposal of untreated liquid and solid wastes generated from domestic sources into the coastal environment. Under the framework of international law, sources of marine pollution are the following:

- Land-based sources and activities;
- Shipping and other sea-based activities such as fishing and aquaculture;
- Dumping;
- Seabed activities, both near and off-shore; and
- Atmospheric sources.

Land-based activities constitute the largest sources of pollution as around 80% of contamination in the marine environment (Ducrotoy, 2013). The United Nations Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP), estimated that land-based sources account for up to 80 percent of the world's marine pollution, 60 to 95 percent of the waste being plastics debris.

Contaminates come from a number of sources including sediment runoff, sewage, solid waste, pipes and drains, high nutrient loads, synthetic organic chemicals, rivers and urban catchments, oil, and the atmosphere. This results in the eutrophication, and deterioration of water quality, which have adverse effects on coastal ecosystems and its living resources. Therefore, pollutants from as far away as thousands of kilometers in land can impose a pollutant load into marine environment.

The protection of our coasts and marine waters faces complex and multi-facetted problems. Our marine and coastal environment is under severe pressures from both land-based and ocean-based pollution sources.

To address the potential for degradation of the marine environment from a wide range of activities, Agenda 21 calls for the adoption of a precautionary and anticipatory approach to development planning. It encourages the integration of marine environmental protection into relevant general environmental, social and economic development policies and the adoption of economic incentives to apply clean technologies. Agenda 21 also stresses the need to improve the living standards of the coastal population.

A number of cooperative and collaborative mechanisms to address, manage and mitigate pollution and degradation of the environment at the global and regional levels have been developed in partnership with governments, industries, scientific institutions, international organizations, NGOs and the public at large.

The Tunisian experience in the field of disposal of waste management is not mature. Until now, throughout Tunisia, the alternative is simple, the disposal of waste manager usually has no other choice than to put them in landfills, to keep them away or to burn them without recovery.

In most cases waste is disposed of without much concern consequences, which could eventually occur and cause harm to the natural environment (atmosphere, water, soil etc.) and human. Extensive urbanization, with its accelerated rate in recent years, has exacerbated the situation. Indeed, the production of solid waste is growing in proportion to changes in the modes and standard of living of the population (Chouari and Belarem, 2017). The number of uncontrolled and uncontrolled landfills is multiplying and there is insufficient control and rehabilitation of these landfills (Figure 2.10).

The pollution is further aggravated by the situation of Tunisia within the framework of the Mediterranean Sea, a semi-closed and shallow sea, where the renewal of waters is long. 55% of the wastewater from 120 coastal cities is discharged into the sea without prior treatment (Brûlé, 1991).

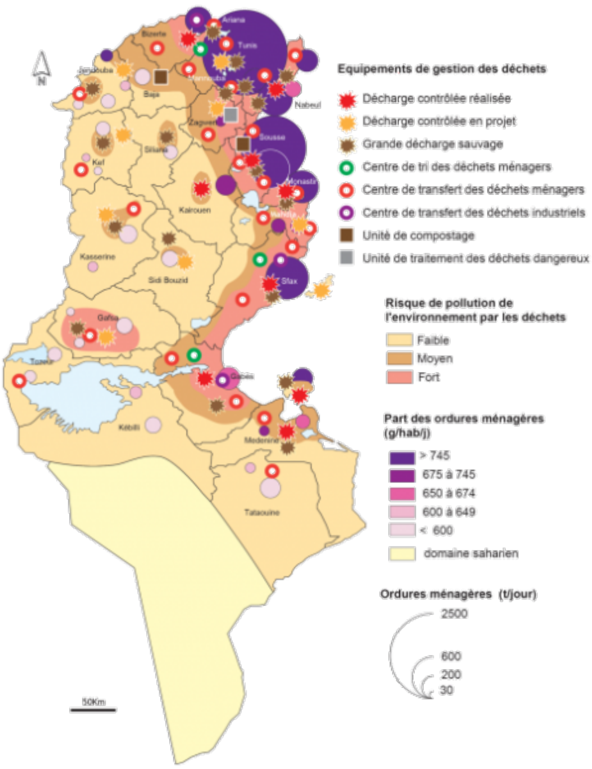

FIGURE 2.10: Disposal of waste in Tunisia. (Chouari and Belarem, 2017)

The most striking example of the effects of pollution in Tunisia is that of the Gulf of Gabes, which, following intensive pollution, has seen the degradation of these prairies of posidonia and the drop in its fishing production. The increase in the fish content of toxic substances, presents a serious risk to health (Hayder, 1986; Hamza-Chaffai, 1993). The same can be said for the coasts of other cities: The Lake of Bizerte, the Gulf of Tunis, the coast of Mahdia.

The presence of several highly polluting industrial companies near the coast, as in Mahdia, Sfax and Gabes, which discharge their polluting and highly toxic waste on the shore and in the sea, contributes fully to the deterioration of the marine environment. The environment in general is very detrimental to the health of the inhabitants. Therefore, there is an urgent and essential need to combat these forms of pollution.

Maritime transport represents an equally polluting activity in the coastal marine environment and a threatening danger in the same time. Tunisian beaches welcome each year millions of holidaymakers with excessive use that hurts their environment.

The origins of pollution of seawater and shorelines are multiple, requiring the intervention of various stakeholders to combat this phenomenon and limit its effects. The Mediterranean includes the levels of global maritime traffic. That's more than 220,000 boats cross this sea each year. The transport of dangerous cargoes constituting potentials of pollution.

However, this generous source of revenue contributes to the degradation of the marine and coastal environment. In order to satisfy the needs of tourists, the rapid development and construction of infrastructures have caused serious problems of erosion and pollution Mediterranean Sea in Tunisia. Millions of tons of macro-debris are found at the bottom of the sea or in suspension. Toxic waste that is released by industry into the sea directly by threatening the Mediterranean environment.

Population growth pressure exerted on the coastal region also involves the disposal of waste. Dumping at sea has been a common practice as it was perceived to minimize the impacts of land-based waste disposal on population centers in a time when there was not much awareness of potential environmental impacts. Humans have been using the oceans and the coastal zone as dumping grounds for years, hoping the capacity of the ecosystem will take care of the problem (Beatley et al., 1994).

Ocean waste disposal is considered to derive from two main sources: land-based sources and dumping at sea. Garbage is often dumped on important habitats, like wetlands and mangroves; they are destroyed, and contaminants leach from the rubbish into coastal waters. It can cause eutrophication and endanger public health. The most important types of materials dumped in waters are the chemical and industrial waste, and the treated water.

In the case of Tunisia, population increases along Tunisia's shorelines and the corresponding industrial development has resulted in a rapid increase in sewage outflow into rivers, estuaries and oceans. Land use and storm water systems influence the nutrient load of rivers as well as the turbidity and sedimentation in coastal environments.

Adding heavy metals, persistent organic pollutants (POP), sediments, solid wastes and domestic wastewater creates irreversible risks to health and marine life. The most dangerous of all these pollutants contain high levels of mercury, cadmium, zinc and lead that can travel for millions of kilometers, beyond national borders and far from their point of origin.

Unlike the past, however, current sea disposal is highly regulated, especially with respect to potential environmental impacts. The ability to successfully manage waste and dump sites needs careful spatial planning in order to avoid unnecessary disturbance or disruption of waste within the marine environment. Such management also needs spatial location of other activities such as shipping routes and the location of marine parks, enabling permits to be granted for the most appropriate areas. This will minimize disturbance to other marine stakeholders as well as the marine ecosystem as a whole. There is still a need for seamless spatial information to facilitate the management of the whole environment.

Spatial-based management and marine spatial planning can provide a far more promising approach to implementing marine pollution management. However, current regulatory methods for the management of the coastal zone separate it into land and sea, with the use of spatial information for this area also remain separated. This separation hinders the development of solutions to issues which straddle the land – marine interface, such as the pollution of the marine environment from land based sources. For this reason , the integration of management techniques and spatial data within the coastal zone needs to occur.

2.2.5 Overfishing

Overfishing Coastal fisheries have historically been an open access resources although this has started to change in recent years. Fish and other sea foods fulfil a significant portion of the dietary needs for millions of people around the world, while the industries of fisheries and aquaculture are commercially essential for thousands of coastal communities.

Tidal zone shoreline sea life that can be collected on foot is particularly vulnerable, but all coastal and open sea fisheries are badly over-harvested. The foreign industrial fishing fleet uses sophisticated technology for efficiently "scouring" the seas. Indeed, many owners of the fishing fleet invested heavily in equipment that became available at bargain prices. There are increasingly serious signs that these economic uses of our coast are undermining their long term sustainability.

Overfishing through unsustainable fishing techniques (small mesh, hand trawls, submerged nets, blocking of whole width of rivers during migration with nets and traps) and during the closed season when the species is spawning, is affecting freshwater fish populations. The United Nations Food and Agriculture Organization (FAO), which monitors the state of world fisheries, has estimated that since 1990 approximately one-quarter of fish stocks have been overexploited, depleted, or are recovering from depletion (17%, 7%, and 1%, respectively) (Peter Manning, 2005), with the north–east and north–west Atlantic, the Mediterranean, and the Black Sea being the areas with the largest number of depleted stocks (Garcia and Grainger, 2005).

With 89% of its stocks in overfishing, the Mediterranean is one of the most threatened areas of the planet in terms of loss of fishery resources. Tunisia, whose marine heritage presents a particularly important economic, social and cultural stake, is also concerned in the forefront by the need to preserve its fish and fishers.

Since the sea is a very important vector for economic and social development in Tunisia, it has always been one of the main concerns of the country's environmental policy. Several laws have been promulgated to minimize pollution and degradation of the quality of seawater and marine habitats. However, this policy has suffered from the lack of enforcement and weak involvement of civil society and users of the sea. This has led to alterations in the marine environment in some areas in the Gulf of Gabes, which represents today hot spots of pollution and environmental degradation.

In 2010, the fisheries contribution to Tunisian agricultural production was 11.3% and the fisheries sector accounted for 17% of the value of agri-food exports, making it the second largest agricultural sector in terms of exports after the 'olive oil. Thus, the fisheries sector is a strategic stake for Tunisia in terms of food security.

Artisanal fisheries, present themselves as a subsistence inshore fishery using traditional techniques that respect the natural environment and often have their raw material products of nature. Although it contributes on average only 27% of the national production of peach, it has a particular social importance, since it employs two thirds of seafarers in Tunisia and represents 90% of the fleet. It generally targets species of high market value: its contribution to the total value of national fisheries production is on average 40%.

Marine and freshwater ecosystems are poorly studied and poorly understood. The state lacks the means to effectively enforce regulations on the activities of coastal fishermen. Demographic growth and poverty are the major causes driving the overexploitation of coastal marine resources. The state has not been effective in preventing the over-harvesting of the industrial open sea fisheries. The historical movement of the fishing fleet as fish stocks are depleted in the north is evidence of this.

At the institutional level, the country has many structures in charge of planning and managing the environment and natural resources. Most of these structures are not specifically marine, but they have prerogatives and means to intervene at the level of terrestrial and marine environments such as the Coastal Protection and Protection Agency and the National Agency for Environmental Protection.

The identification of legal and institutional aspects of the fishing occurring within Tunisia's marine environment along with the key institutions and agencies responsible for implementing such legislation, demonstrates the complex inter- jurisdictional relationship between users and stakeholders of the marine environment. The complex regime of geographically overlapping fishing catchments, which was managed under separate management arrangements results in redundant effort, inefficiency, ineffectiveness and a lack of coordination amongst state agencies. The seamless management framework across states and different stakeholders would be required. This means that rights should clearly defined which in return means that the holding of rights, their precise limits and how these rights are enforced should be explicit.

The fisheries sector is particularly susceptible to the impact of other land-based and sea- based activities on the marine environment, its quality and productivity. If fisheries are to make an optimal contribution to economic and social welfare, these interactions must be taken into account, by integrating fisheries management into broader-based coastal area management framework. The problem regarding the overfishing can be solved spatially, as the location and the map of overfished areas is available and accessible. Holistic spatial data platform enables a holistic, integrated and coordinated approach to spatial information for decision-making.

2.2.6 Increased tourism

In more recent decades uses of the coastline have shifted to include more recreational and conservation uses. Population growth along the coast has fostered local and regional booms in the construction of tourist facilities and housing. Tourism especially, marine and coastal tourism is one the fastest growing areas within the world's largest industry. Yet despite increased awareness of the economic and environmental significance of tourism, it is only in recent years, scientific researches have emerged (Hall, 2001).

Negative impacts from tourism occur when the level of visitor use is greater than the environment's ability to cope with this use within acceptable limits of change. Uncontrolled conventional tourism poses potential threats to many natural areas around the world. It can put enormous pressure on an area and lead to many impacts such as soil erosion, increased pollution, discharges into the sea, natural habitat loss, increased pressure on endangered species and heightened vulnerability to forest fires. It often puts a strain on water resources, and it can force local populations to compete for the use of critical resources.

The Mediterranean is the world's leading tourist destination, accounting for 30% of international tourism and one third of international tourism. Coastal tourism is strongly seasonal and increases annually. Pressures on the coastal zone are likely to continue to increase in the future, with an estimated doubling of tourism fluxes over the next twenty years from 135 million arrivals in 1990 to 235-350 million in 2025 (EEA, 1999).

The interactions between tourism and the environment in the Mediterranean region are seen in the following issues: land use; consumption of water resources; pollution and waste and physical and socio-cultural pressures. Coastal tourism causes reduction of natural sites and open spaces, substantial alteration of coastal landscapes and conflicts on the use of land, water and other resources. Pressures on the coastal zone are likely to increase in the future, with an estimation of a doubling of tourism related development in the Mediterranean in the next twenty years. However, in recent years, tourism itself has produced a strong incentive for the protection of the landscape and the improvement of the quality of the environment (e.g. bathing waters, beaches, etc.).

Tunisia concentrates on tourism which constitutes an important source of income. In Tunisia, tourism and construction, which are related economic

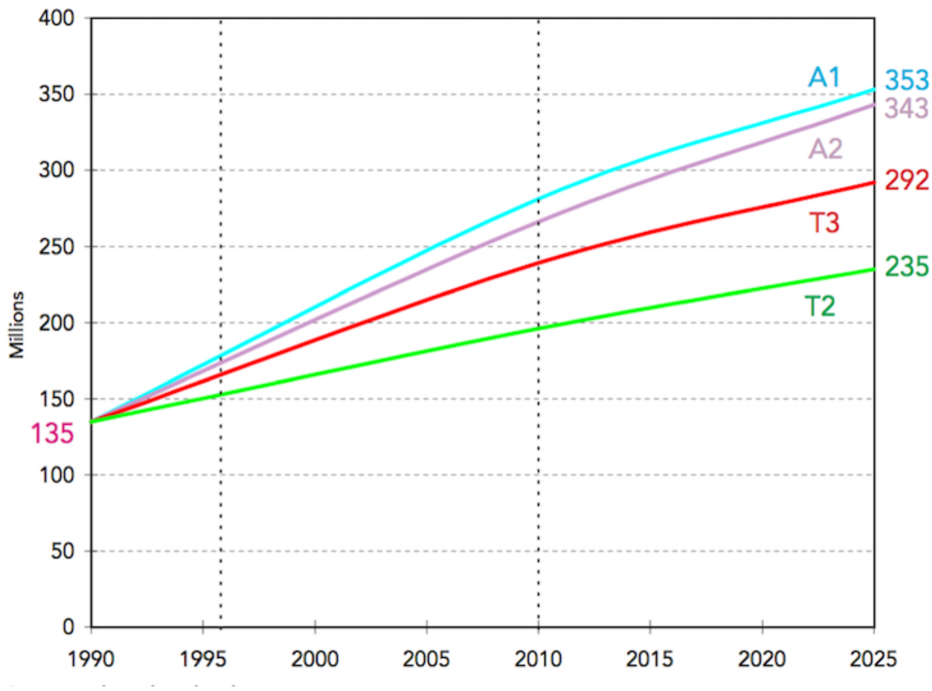

FIGURE 2.11: Alternative estimates of the distribution of the tourist frequency during the peak period (May-September) in the Mediterranean region (EEA, 1999)

activities, are major contributors to coastal centers. In 2000, the coastline concentrated 93% of the country's tourist activities (Chouari and Belarem, 2017).

Tourism in Tunisia is mainly located on the coast (95% of tourist activities) on the east coast between Nabeul and Sfax. However, tourism is often concentrated in the natural areas near the beach as constituents of the serious threats to the Mediterranean species. According to the MedWetCoast program, 35% of the species (all taxa combined) would be threatened on the coast of Tunisia.

The rapid increase of tourism leads to impacts such as soil erosion, increased pollution, waste discharges into the sea, and loss in biodiversity. it makes a host of environmental and land use conflicts and issues. In order to address the potential threats and pressures caused by tourism and recreational activities, access to holistic spatial data and information across the land-marine interface enables a more integrated and holistic approach to management of the coastal zone. Tourism can play a role in the sustainable development of coastal areas and be a positive force for conservation and environmental protection, if it is well planned

2.2.7 Extensive extraction of mineral resources

Oil and gas extraction create most of the energy and resources needed to run our society. They also result in a range of present and future environmental and social costs, both direct and indirect, which need to be balanced against the benefits they bring. The world is highly dependent on oil – it powers transport, heats and cools buildings, creates industrial and domestic chemicals and provides the feedstock for many materials and clothing.

The oil and gas industry impacts on people and the environment in three ways; through climate change, operations on land and at sea and through positive or negative impacts on National economies. Unregulated actions by the oil industry destroy habitats and damage biodiversity. Oil spills at sea have damaged mangrove forests, coral reefs and fisheries, both through major accidents and regular leakage from tankers, loading buoys and drilling rigs and platforms. Transport of oil is also implicated in ecological damage: for example, there were an estimated 16,000 spills during the construction of the Trans-Alaskan pipeline (Dudley and Stolton, 2002). Oil tanker accidents are another well-known example of ecological disasters that can have long-term effects. The extractive industries have often failed to make a contribution to sustainable development and to protect the environment adequately.

Offshore oil development usually starts with seismic surveys and is followed by exploratory drilling. The development of offshore oil is furthermore associated with increased support vessel and oil tanker traffic. The general impacts of exploration and exploitation include noise and vibration, solid and liquid production wastes, increased water column turbidity from dredging, disturbance of the sea bed areas, avoidance of the area by marine wildlife such as fish and marine mammals due to construction noise, vibration and the presence of erected facilities, and possible invasions of non-indigenous species carried in ballast water of support vessels and oil tankers (Wills, 2000; Matthiessen, 1999). The environmental stress caused by offshore oil development may cause different biological responses including complex transformations at all levels of the biological hierarchy. The leakage at the point of extraction of gas and oil causes some immediate issues of pollution.

Environmental concerns have a considerable impact on the future course and scale of off-shore oil, gas and mining activity. However, there are other socio-economic factors to consider, particularly the projected rise in world population and the overall rise in living standards.

Until the early 1980s, Tunisian natural gas resources were modest. But in 1983, royalties levied on the passage of gas to Italy enabled Tunisia to access its interesting gas resources. The years 94 and 95 marked Tunisia's entry into the gas era with the doubling of the capacity of the trans-Mediterranean gas pipeline in 1994 and the start-up of the production of Miskar in 1995, 2 billion m^3 per year. As a result, national natural gas resources have increased by an average of 9% per year since 1980, reaching 3.2 Mtoe (Million Tonnes of Oil Equivalent) in 2004 compared to 0.4 Mtoe in 1980.

In 2004, total natural gas supplies increased by 7% compared to 2003 due to increased intercontinental gas purchases (7% increase in Algerian gas purchases) and an 11% increase in gas Algerian gas tax (royalty) accruing to the Tunisian State, given the total quantity transported to Italy via Tunisia increased from 20.6 Mtoe in 2003 to 22.8 Mtoe in 2004, an increase of 11%. One of the new components of the economy of the Gulf of Gabes is the offshore gas extraction. The main natural gas field currently in operation is Miskar, which covers a total area of 352 km^2 and has a capacity of 22.7 billion m^3. British Gas "BGplc", and has operated 1.8 million tonnes per year since 1996. The Miskar Field is located at 125 km. This concession covers an area of 352 km^2 at a depth of 62 m. New concessions have been granted in recent years closer to the Kerkennian coasts and companies operated by the Tunisian company TPS (Thyna Petroleum Services) and the English company PETROFAC.

The economic uses of our coast are losing their long term sustainability. The question of whether or not an off-shore petroleum or minerals deposit can be commercially exploited is subject to a range of issues including location (distance from shore/port, depth, etc.), grade, price, environmental impact, extraction technology and government policy.

The oil and gas industry currently has its own spatial management system to administer permits and lease areas. In the petrol domain, the rights, restrictions and responsibilities of those with exploration licenses are well documented (permit holders and permit numbers attached to each parcel). Within the lease and exploration areas of the oil and gas sector however, there are also other rights that occur which are also of concern (Binns, 2004).

FIGURE 2.12: Main fields of oil exploitation in the Gulf of Gabes

The ability to spatially define oil, gas and minerals fields on the map would be an essential component for a more efficient and effective management regime, balancing the rights and responsibilities and ensuring the other activities to take place.

2.2.8 Loss of biodiversity

Humans may live in almost every corner of the globe, but our favorite place is the sea. As coastlines around the world are steadily turned into new housing, holiday homes, and tourist developments, this intense human presence is taking a huge toll on marine ecosystems and species. The coastal areas are some of the most productive and biologically diverse on the planet is place. It provides a unique habitat for thousands of plant and animal species. Of the 13,200 known species of marine fish, almost 80% are in coastal (UN, 2016).

The biodiversity of marine and coastal ecosystems is rich and extremely diverse due to the wide assortment of environments along the coast. The continental shelf covers an extensive area and favors the establishment of sea grasses. The shores at the country's center are used by turtles for spawning.

Loss of biodiversity in coastal ecosystems has both direct and indirect causes. The direct mechanisms involved include habitat loss and fragmentation, physical alteration, over-exploitation, pollution, introduction of alien species and global estoclimate change. The root causes that drive these proximate threats lie in the high; and rate of human population growth, the unsustainable use of natural resources, economic policies that fail to value the environment and its resources, insufficient scientific knowledge, and weak legal and institutional systems.

The Mediterranean Sea is a marine biodiversity hot spot highly affected by several sources of disturbances interacting synergistically: global warming, habitat loss and overfishing threaten marine biodiversity and disrupt the ecosystem balance. To ensure a sustainable management of coastal marine ecosystems according to the Ecosystem Approach to Fisheries, it is necessary to study the ecosystem responses to these disturbances. However, despite the variety of global change studies in Mediterranean areas, ecosystems responses to these changes remain poorly understood and particularly at the southern part of the Mediterranean Sea.

The Tunisian study on biological diversity was updated in 2009 and identified 7,212 terrestrial and marine animal and plant species. This noteworthy inventory indicates the presence of 165 endemic species/varieties of flora in Tunisia and surrounding areas, 24 species that are quite rare and 239 that are rare. More than 200 animal and plant species are listed in the IUCN Red List of rare and endangered species for Tunisia. Tunisian flora comprises 2,162 species, of which 2103 species are distributed among 115 families and 742 genera.

In Tunisia at the sea level, the most serious forms of degradation are marine erosion and the extension of the Sebkhas. Progressive eutrophication threatens the marine ecosystem, which manifests itself in the development of microscopic algae (red water) and green macro-algae (green tides) that follow seasonal cycles.

Wastewater and other nutrient inputs from drainage of agriculture and other lands pose environmental problems that threaten human health and the coastal and marine ecosystem. These liquid discharges are visible to any observer by its smell and by the presence of green algae on the littoral (eutrophication).

The coastal ecosystem is disrupted by numerous forms of urban development, by removing sand, by establishing port infrastructures that are obstacles to natural activities. Marine erosion is more active on the northern coast of the archipelago, giving a totally uneven and rugged coastline with cliffs and steep slopes, although the altitude is low. The erosion and / or fattening of beaches are two natural processes, but are reinforced by the establishment of infrastructures and structures on the coast (ports, jetties, roads etc.). The degradation of the underwater vegetation cover is due to the increasing use of certain fishing gear that are destructive to seagrass beds, such as kys (small trawl) on beaches and shallow trawling (<20 m), which Are forbidden: the use of the kys is prohibited, as well as trawling to less than 50 m of bottom. Overfishing is attested by all fishermen. It is confirmed by numerous stock assessment studies. The fishing effort is above the optimum. Moreover, there is a strong pressure on the juveniles, which induces a low regeneration of the stocks. This pressure is exerted by benthic trawling and by artisanal craft. The current fishing effort exceeds resource possibilities with the presence of more motorized coastal boats, some of which use the "kys" on the beaches, which is another destructive herbarium and wildlife craft.

The anthropogenic alterations of the marine environment are apparent, their decline during the last thirty years has increased at an alarming rate. Thus several factors can react synergistically to unbalance biodiversity habitat:

- Modifications of sedimentary inputs (coastal development) may lead to the burial of vegetative points or, on the contrary, to the depletion of the rhizomes and to the collapse of the herbarium;
- The development of the coastal front and the retention of sediments behind the dams cause the sediment deficit;
- Turbidity contributes to the rise of the lower limit (reduction of the photic depth);
- Eutrophication by increasing the importance of phytoplankton blooms decreases the transparency of the water (rise of the lower limit);
- The discharge at sea of untreated domestic or industrial effluents is considered to be responsible for the regression of the herbaria in the vicinity of the major industrial and port centres;
- Vessels casting anchor in an herbarium open breaches in the mat;

- Trawling in seagrass beds is the most important threat to herbarium degradation.

Tunisia has ratified several international conventions and is committed to the protection of marine biodiversity, ecological integrity and the sustainable use of marine and coastal resources.

Marine Protected Areas (MPAs) for just such a purpose. These areas are dedicated to the protection and maintenance of biodiversity and cultural resources, and are managed through legal means. While the oceans comprise 70% of the earth's surface, less than 1% of the marine environment is within protected areas, compared with 9% of the land surface.

In Tunisia 25 sensitive areas have been identified. For each of these areas a management plan has been set up. Six of these areas are MPAs: La Galite Archipelago, Cap Negro – Cap Serrat, Zembra and Zembretta Archipelago, Kuriat islands, Kerkenah islands and Kneis. The Network of Managers of Marine Protected Areas in the Mediterranean (MedPAN) identified two SPAMIs along Tunisia's seashore. In 1998, the Tunisian government developed a national program for the creation of protected maritime and coastal areas. The program aimed to establish a network of Marine Protected Areas and coastal areas along the Tunisian coast by:

- Improving the legal framework for MPAs and coastal areas;
- Developing a national strategy for the creation and management of MPAs and coastal areas;
- Carrying out engineering studies to develop MPAs and coastal areas;
- Implementing management plans for each area (MPA or coastal area).

All of these have relevance to the marine environment with the public needing spatial information of areas such as world heritage sites, RAMSAR and marine protected areas in order for the legislation governing these areas to work effectively. Users cannot adhere to spatially defined rights in legislation if the area concerned is not clearly delineated and publicized. The ability to join up marine and land based spatial information aids decision-making by providing a spatial/geographic context to planning, management and protection of habitats and protected areas across land – marine interface. This leads to the effective and efficient management of marine resources and the accomplishment of the economic, environmental, and social goals of sustainable development.

2.2.9 Lack of suitable sites for aquaculture

Aquaculture is currently facing a significant challenge: how to alleviate the pressure exerted on fish stocks by commercial fishing and yet meet the increasing demand for sea products in local and international markets in a sustainable way. As a consequence, aquaculture is expected to develop considerably in the near future around the world.

The availability of suitable areas for aquaculture is becoming a major problem for the development and expansion of the activity. There is a need to have sites with appropriate environmental characteristics and good water quality. In addition to these natural limiting factors, the social aspects of interactions with other human activities or conflicts over the use and appropriation of resources in the much-exploited coastal zone are constraints to be considered when aquaculture facilities are set up. Site selection and site management are among the most important issues for the success of aquaculture and need to be carried out in accordance with sustainability and best practice.

The development of such zones is giving rise to the need for accurately defined maritime boundaries. There are some aquaculture leases that straddle the land – marine boundary and unless there is a link between the marine and terrestrial environments, these areas would be hard to spatially define and manage effectively. Currently the management of the coastal zone is separated into land and sea, with the use of spatial information for this area also remaining separated. This separation hinders the development of solutions to issues which straddle the land – marine interface, such as the aquaculture leases across coastal zone. The confliction of marine and coastal management, environmental management, land use policy, land tenure and quarantine and translocation together they impede both business activities and regulatory arrangements. Diverse policies and implementation in aquaculture and fisheries legislation create an uncertain legal and regulatory environment. The industry needs dual access to land and water: the hybrid nature of mussel and oyster production where land access is required. This is an excellent example of the need for consistent management of both land and marine environments. Eventually, the integration of management techniques and spatial data within the coastal zone needs to occur.

2.3 Spatial Dimension of Coast and Sea

Environmental protection and conservation measures are priorities for most coastal nations due to the increasing demand for resources, and the growing potential for user conflicts within a dynamic and three-dimensional space. Managers, planners and policy makers require comprehensive knowledge of resources, uses and stakeholders, in order to minimize conflicts or environmental concerns while resolving or mitigating those that do arise. At the same time, these decision makers may also be required to facilitate and support the expansion of economic activities linked to the sea. In order to reconcile these objectives, accurate and reliable information must reach decision makers in an appropriate and easy way in order to use them formats, so that they can make informed decisions on behalf of stakeholders. Historically, where such information has existed at all, it has often been difficult to access or use due to a variety of institutional, political and technical reasons.

In many cases, important data and information required for sound decision making have been acquired and held by individuals working in federal, provincial/state, government departments and research institutes, rather than being treated as an enterprise-wide corporate resource. While considerable efforts have been made in recent years to rectify this situation, through collaborative projects (Ricketts, 1992), and moves towards greater sharing of information through the use of spatial data infrastructures and geoportals, management of marine and coastal data holdings remains a significant challenge.

These and others are useful for understanding the spatial and temporal dynamics of marine ecosystems in relation to environmental variation (Katsanevakis et al., 2011).

The issues in marine and coastal management are in need for accurate and up-to-date spatial information to support a holistic and integrated approach to management and decision-making. Furthermore, marine and land spatial data cannot be treated separately because the link between the terrestrial and marine environments is indispensable. The need to address environmental, economic and social issues of sustainable development resulted the necessity to administer the spatial dimension of the marine and coastal environments. The importance of the spatial dimension in administering marine environments was recognized by the International

Federation of Surveyors Commissions 4 and 7 as well (Sutherland and Nichols, 2006). Spatial information aids decision-making by providing a spatial/geographic context to planning, management and resource allocation and is increasingly recognized as essential to emergency response. It enables a better understanding of an area and thus better management (Binns et al., 2005). Many coastal management issues could be overcome if a spatial data platform that enables a holistic, integrated and coordinated approach to spatial information for decision-making existed (Vaez et al., 2009). To improve management of the coastal zone there needs to be access and interoperability of both marine and terrestrial spatial data (Strain et al., 2004a).

The different activities require spatial data and information such as tide charts, bathymetry, climate, sea surface temperatures and currents, living and non-living resources, property rights in the area, legislation and international conventions in order to be managed successfully. However, problems with accessing, sharing and using spatial data related to these areas is often reported. Therefore, there is increasing need for the development of platform to underpin decision making, and better manage and share spatial datasets. Administering the spatial dimension of the both land and marine environment is very important as decision-makers need to access marine related datasets.

2.4 Drivers for Integrating Land and Marine Environments

Minimizing the impacts of land-based threats to marine ecosystems is an important objective of coastal and marine management, but it has to be balanced with economic and social objectives and environmental objectives.

The separation between land-ward and marine-ward complicates the solutions to identify marine and coastal management issues which straddle the land – marine interface. For this reason, the integration of land and marine spatial data within the coastal zone needs to occur.

Integrated marine and coastal area management is a participatory process for decision making to prevent, control, or mitigate adverse impacts from human activities in the marine and coastal environment, and to contribute to the restoration of degraded coastal areas.

Integration problem of land, coastal and marine information in the same framework is a common issue for many people. Indeed, many development plans have failed due to the lack of necessary integration of information (Vaez et al., 2009). This especially applies to archipelagos where seawater is the "bridge" connecting islands. While most of the countries are aware the problem of disconnected land and marine information, few have committed to resolving the problem (Murray, 2007).

However, the primary drivers for land and marine integration can be categorized into societal drivers, commercial drivers; and technological drivers.

Primary drivers are defined as motivators for integration of land and marine environments (Figure 2.13)

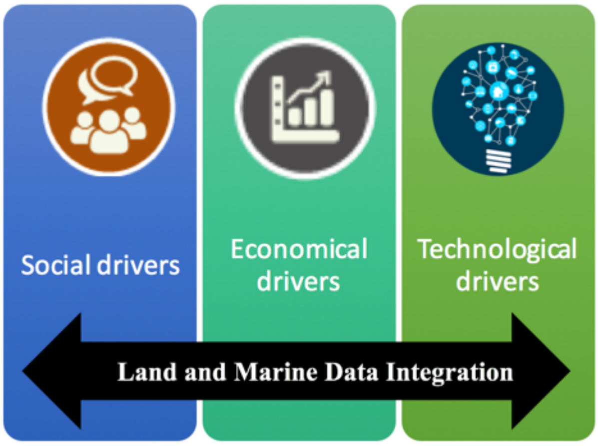

FIGURE 2.13: Drivers for integrating land and marine environments

2.4.1 Social drivers

The interface between land and sea, the coastal ecosystem, is of vital relevance to the terrestrial and marine life forms-including humankind, and an important geologic, ecological, and biological domain.

The importance and value of the coastal zone cannot be overstated. Since antiquity, the coastline has been used in many ways. It is one of the most productive areas accessible to people. Fish and other seafood meet a significant portion of the dietary needs for millions of people around the world, and the fishery and aquaculture industries are commercial mainstays for thousands of coastal communities.

The coast also is an important safety feature for people living near the ocean. Many type of coasts provide a barrier from natural hazards emanating from the turbulent seas. Beaches, dunes, cliffs, and barrier islands all act as buffers against the high winds and waves associated with coastal storms (Beatley et al., 2002).

Presently about 40% of the world's population lives within 100 kilometers of the coast (UN, 2008). Pressures on coastal ecosystems increase due to growth of human activities on the coastal zone. Population growth is the driver behind many, if not most, coastal problems (Beatley et al., 2002). This puts more pressure on the land – marine. There is a need to change the traditional approach by a collaborative integrated approach and particularly among coastal zone.

The use of resources and producing wastes by the society is unsustainable. Consequently, the pollution, climate change and global warming are a serious threat to coastal areas.

2.4.2 Economical drivers

Coastal zones are among the most productive areas in the world, offering a wide variety of valuable habitats and ecosystems services that have always attracted humans and human activities. The beauty and richness of coastal zones have made them popular settlement areas and tourist destinations, important business zones and transit points The coastal zone facilitates the trade and economic growth of the region through the shipping networks involving all types of vessels from the smallest to the largest, from domestic ferry operations and fishing activities to those involved in international trade. There are a number of archipelagic states for which domestic shipping services are of paramount importance.

However, serious signs show that coast sustainability is in danger due to the intensive economic uses. The consequence of economic development shows in overfishing and the pollution.

Today there is need to achieve the sustainable development in the coast and marine area by focus more on economic development, social development and environmental protection for future generations.

2.4.3 Technological drivers

The rapid advances in geospatial information and technologies, and their easy accessibility, have made such information as invaluable tool in research, policy and business planning and implementation. Across all sectors of society, it is increasingly recognized that the effective use of geospatial information helps address many of the current social, environmental and economic challenges facing the world. There is a need to make the land and marine data infrastructures so that planning, management of these zones can be done with holistic approach.

2.5 Chapter Summary

Marine and coastal environment issues are dynamic and diverse. This chapter examined the most issues in the coast and the sea with the focus of Tunisia's coastal and marine jurisdictions. Investigation and examination of these issues led to the need for integrating coastal and marine management system in order to increase the efficiency and effectiveness of management across the land – marine interface. Therefore, the first objective of this thesis which is the investigation and justification of seamless information by including real examples of marine and coastal issues that need holistic and seamless spatial information.

3 Legal and institutional issues in Tunisia

3.1 Introduction

In order to fully understand the challenges faced in developing a holistic SDI framework, it is important to examine Tunisia's historical involvement in the management of its marine environment. This includes not only the dynamic nature of both national and international tools of ocean governance, but also problems that need to be addressed through the development of a marine cadastre. Such issues are highlighted within chapter 2. The world's oceans cover almost 75% of the earth's surface, regulating weather patterns and providing life to thousands of varieties of aquatic plants and animals, yet the oceans are the least regulated part of the earth. Human's relationship to land, along with the various rights and obligations which go along with it, have been well documented, but the same cannot be said for our relationship to the sea. According to Ting and Williamson (1999) the rights, restrictions and responsibilities that society creates in relation to land reflect the diverse meaning and significance that land has held for humankind. This can also be said for the marine environment, for which the management systems currently in place have evolved over the past 100 years, governed by a complex web of legislative arrangements.

The Tunisian coast is the backbone of the country because of the richness of its natural resources, terrestrial and marine. Exercising a very strong attraction on successive civilizations, it has always been the seat of intensive and multiple human activities. The coastline offers a wide variety of natural environments and landscapes, as well as an archaeological heritage of great value, covering about 2290 km (sea front 1730 km and façades sheltered 560 km). At the same time, it concentrates more than 76% of the population and almost all tourist activities and 87% of industrial activities. Often under control, economic development and urbanization are disrupting the coastal and marine environment, disrupting landscapes and land use patterns, and aggravating erosion. Industrial effluents affect natural ecosystems and reduce fish stocks. Taking into account the organization of the coastline and the sea by Tunisian law is not only due to the emergence of the first texts relating to the preservation of the maritime public domain and the coastline but also to other written sources.

3.2 International Law

Although domestic law has played an important role in regulating the management of the marine environment, international law has been the primary basis for the implementation of Tunisia's maritime policies and boundaries over the past century. According to Mitchell et al. (2001), although maritime law dates back to Roman times it has "traditionally been ill-defined and poorly documented". Historically, the world's oceans operated under the principle of freedom of the seas, which provides unrestricted access for activities such as navigation and fishing. The only restrictions to such freedom was a strip of ocean adjacent to a nation's coastline, under which sovereign jurisdiction was granted (defined today as the "territorial sea"). The width of the strip was undefined, but generally held to be the range of a shore-based cannon shot (Mitchell et al., 2001). Since then, the rapid improvement in technology and increasing interest in exploring the marine environment has caused the need for more modern laws governing the world's oceans.

UNCLOS establishes the jurisdictional regimes under which a coastal State can claim, manage and utilize its marine territories. As the law of the sea has evolved, so has a sovereign State's right to jurisdiction over marine areas. The four Geneva Conventions on the Law of the Sea, beginning in 1958, were the first successful attempts to codify relevant international maritime law. They recognized a coastal State's right to a territorial sea and contiguous zone, although the outer limits of these were not defined. The conventions also recognized coastal States' rights over a continental shelf, with its outer limits determined by the depth of the water column and exploitability (Rothwell and Haward, 1996). However only a minority of States were bound by the Conventions as a whole, with 56 parties to the High Seas Convention, 45 to the Convention on the Territorial Sea and Contiguous

Zone, 53 to the Convention on the Continental Shelf and 35 to the Convention of the Conservation of Fisheries (Tanaka, 2012).

Issues and disputes over fishing rights and environmental degradation however became more common place and were attempted to be resolved through unilateral acts and regional agreements, rather than through an international forum. There was also a feeling that more developed nations would be able to exploit deep sea bed resources more easily then less developed ones. A proposal to consider the seabed beyond a nations jurisdiction as “the common heritage of mankind” (Friedheim, 1993) was put forward, however the developed countries were reluctant to agree to such a proposal (Mitchell et al., 2001). This forced the United Nations (UN) to play a greater role in maritime jurisdictional issues, with the implementation of the 3rd United Nations Convention on the Law of the Sea. This convention became “the largest, most complex and most difficult global negotiations ever hosted by the United Nations” (Miles, 1998).

The 3rd United Nations Convention on the Law of the Sea (UNCLOS), held from 1974-1982, negotiated the 320 articles which make up the convention, legally recognizing a number of maritime zones for the first time. As the convention was initiated by questions of access to mineral resources in the deep sea bed, it also brought to the fore the subject of the limits of the continental shelf and territorial sea. The convention was divided into three committees, “*the first concerned with deep sea mining, the second with the subject of jurisdiction, and the third with a miscellany, including pollution and scientific research*" (UNCLOS, 1982). In 1982, the convention was put to a vote, with 130 countries voting in favor, four against and 17 abstaining. The convention was then open for signatures for a period of two years, in which time 158 signatures were officially recorded. These signatures then had to be ratified, and 12 months after the deposit of the sixtieth instrument of ratification on the 16th of November 1993, the Convention entered into force. Australia ratified the Convention on the 5th of October 1994 (Mitchell et al., 2001).

One of the major achievements of the convention was the recognition of a number of maritime zones. The territorial sea (12nm limit), contiguous zone (24nm limit), Exclusive Economic Zone (EEZ) (12nm – 200nm limit) and continental shelf form the basis of a coastal State’s maritime boundaries. UNCLOS also recognized the deep seabed, archipelagic waters and high seas, which are classified as international waters.

3.3 Tunisian's Maritime Boundaries

From a legal point of view, maritime space falls under different jurisdictions, according to the law of the United Nations Convention on the Law of the Sea (UNCLOS). The Convention adopted on 10 December 1982 in Montego Bay, Jamaica, lays down the framework for the establishment and delimitation of maritime areas and lays down a comprehensive framework for the regulation of areas (Figure 3.1).

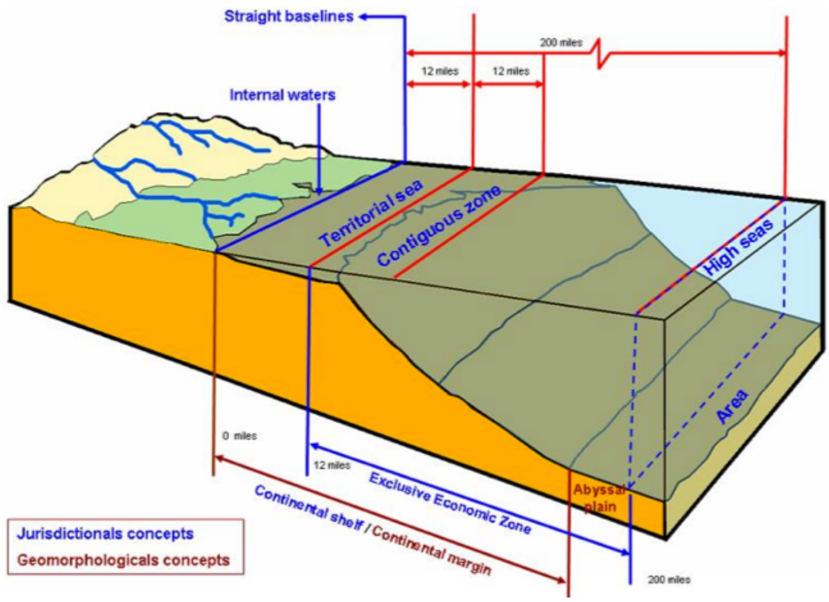

FIGURE 3.1: Maritime boundaries (Vivero et al., 2009)

Historically, the first general texts that governed fishing and coastal areas are the Beylical Decree of 1882 on the protection of the fishing industry in Tunisian Waters, the Beylical Decree of 24 September 1885 on the public domain, The Beylical Decree of 28 August 1887 on the Maritime Fisheries Police and the Beylical Decree of 26 September 1887 relating to the delimitation of the public maritime domain. But these different sectoral texts certainly did not offer the necessary institutional tools to develop protection and conservation mechanisms. This situation prevailed until the promulgation of the first texts relating to maritime public domain. Tunisian Law No. 94 -13 of 31 January 1994[1] on the fishing year defines the term Tunisian waters as *"Waters subject to Tunisian sovereignty or jurisdiction and*

[1]JORT No. 11 of 8 February 1994, p 227: The text of Law No. 94-13 of 31 January 1994 was amended by Act No. 97-34 of 26 May 1997 (JORT No. 44 of 3 June 1997 , P 1008), by Law No. 99-74 of 26 July 1999 (JORT No. 61 of 30 July 1999, p. 1253); By Act No. 2009-17 of 16 March 2009 on the biological rest system in the fisheries sector and its financing (JORT No. 22 of 17 March 2009, p. 785); By Act No. 2009-59 of 20 July 2009 on the simplification of administrative procedures in the field of agriculture and fisheries, which also amended

including inland waters, territorial waters, continental shelf, exclusive fishing zone, contiguous zone and exclusive economic zone"

UNCLOS[2] in art.7 have defined the Straight baselines as *"In localities where the coastline is deeply indented and cut into, or if there is a fringe of islands along the coast in its immediate vicinity, the method of straight baselines joining appropriate points may be employed in drawing the baseline from which the breadth of the territorial sea is measured"*(UNCLOS, 1982).

The decree No. 73-527 of 3 November 1973[3] Concerning baselines fixed the baselines as follows *"The baselines from which the breadth of the Tunisian territorial sea is measured shall run from the frontier between Tunisia and Algeria to the frontier between Tunisia and Libya and around the islands, the low-tide elevations of Chebba and the Kerkennah Islands, enclosing the permanent fishing grounds, and the low-tide elevations of El Bibane, and shall follow the low-water mark, the straight baselines drawn towards the low-tide elevations and the straight closing lines of the gulfs of Tunis and Gabes".*

The baselines shall consist of:

- **Low-water mark:**
  - The low-water mark from the frontier between Tunisia and Algeria to Cap Sidi Ali El Mekki;
  - The low-water mark of the reefs of the Sorelles, Galiton of the Galite, Estern Galitons, and the Fratelli, Cani and Pilau islands;
  - The low-water mark from Cap-Bon to Ras Kapudia;
  - The low-water mark of the Kuriates islands;
  - The low-water mark from Ras Turgueness to the point of Sidi Garus;
  - The low-water mark from Ras Marmor to the frontier between Tunisia and Libya;
  - The low-water mark from the low-tide elevations of El Bibane.
- **Straight baselines enclosing:**

certain provisions of the Forestry Code (JORT No 59 of 24 July 2009, P 1996) ; As well as by law n ° 2010-21 of 26 April 2010 (JORT n ° 35 of 30 April 2010, p 1230).

[2] The United Nations Convention on the Law of the Sea, adopted at Montego Bay on 10 December 1982, ratified by Law No. 85-6 of 22 February 1985.

[3] Act No. 73-49 of 2 August 1973: delimitation of Tunisian territorial waters.

It is a method which consists in drawing an artificial demarcation line linking fixed points to set a baseline other than the low-water line. This method has been adopted by Tunisian law for the following regions:

- The closing line of the Gulf of Tunis made up of the baselines joining Cap Sidi Ali Mekki, Plane island, the northern point of Zembia island and Cap-Bon;
- The straight baselines enclosing the permanent fishing grounds of Chebba and the Kerkennah islands and marked out by Tas Kapudia;
- The straight closing line of the Gulf of Gabes joining the Samoum buoy defined above and Ras Turgueness;
- The straight baseline joining the point of Sidi Garus to Ras Marmor.

3.3.1 Internal Waters

UNCLOS in art.8 have defined the internal water as « Internal Waters are the waters on the landward side of the baseline of a nation's territorial waters, except in archipelagic states. It includes waterways such as rivers and canals, and sometimes the water within small bays » (UNCLOS, 1982).

The law of Decree 73-527 of 3 November 1973 on the baselines delimits inland waters as waters on the land side of the baselines from which the territorial sea is defined. The internal waters are delimited as follows:

- **Gulf of Tunis:** the waters behind the closing line of the Gulf of Tunis joining Cape Sidi Ali El Mekki, Plane Island, the northern tip of Zembra Island and Cape Bon;
- **Gulf of Gabes:** the waters behind the closing line of the Gulf of Gabes enveloping the fixed fisheries of Chebba and the islands of Kerkennah and passing through the beacon Ras Samoum and Ras Turgueness., Sidi Garus and Ras Marmour defined previously.

3.3.2 Territorial Sea

Territorial waters, or a territorial sea, as defined by the 1982 United Nations Convention on the Law of the Sea, is a belt of coastal waters extending at most 12 nautical miles from the baseline (usually the mean low-water mark) of a coastal state (UNCLOS, arts. 2-3).

The Law No. 73-49 of 2 August 1973, fixed the Tunisian territorial sea shall extend, from the Tunisian-Algerian frontier to the Tunisian-Libyan frontier and around the islands, the elevations of Chebba and the Kerkennah Islands where permanent fisheries are installed and the low-tide elevations of El Bibane and shall comprise a belt of sea of an established limit of 12 nautical miles from the baselines.

3.3.3 Contiguous Zone

According to the UNCLOS (Article 33), the contiguous zone may not extend beyond 24 nautical miles from the baselines from which the breadth of the territorial sea is measured.

Tunisia has created a contiguous 12-nautical-mile archaeological zone adjacent to their territorial sea for the protection of the underwater cultural heritage. It was not until June 2008 that a law was adopted defining the contiguous zone and the powers that the State could exercise in this area in accordance with the provisions of UNCLOS.

3.3.4 Continental shelf

According to the UNCLOS (Article 76), The legal continental shelf extends out to a distance of 200 nautical miles from its coast, or further if the shelf naturally extends beyond that limit.

Tunisia has undertaken to harmonize its legislation with the provisions of the Montego Bay Convention 1985. Several laws have been adopted, including the Fisheries Act of 1994. It concerns the preservation of marine species living on the bottom of the continental shelf. Several provisions for the delimitation of the Tunisian continental shelf have been initiated with:

- **Italy**: Agreement between the Government of the Republic of Tunisia and the Government of the Italian Republic concerning the

Delimitation of the Continental Shelf between the two countries, 20 August 1971[4];

- **Algeria**: Agreement on Provisional Arrangements for the Delimitation of the Maritime Boundaries between the Republic of Tunisia and the People's Democratic Republic of Algeria, 11 February 2002[5];
- **Libya**:
  - Special agreement between Tunisia and Libya for the submission to the International Court of Justice of the question of the continental shelf between the two countries, 10 June 1977[6];
  - Case concerning the continental shelf (Tunisia and Libya), Application for permission to intervene, International Court of Justice,14 April 1981;
  - Case concerning the continental shelf (Tunisia and Libya), International Court of Justice, 24 February 1982;
  - Application for Revision and Interpretation of the Judgment of 24 February 1982 in the case concerning the Continental Shelf (Tunisia and Libya)10 December 1985;
  - Agreement between the Libyan Arab Socialist People's Jamahiriya and the Republic of Tunisia to Implement the Judgment of the International Court of Justice in the Tunisia/Libya Continental Shelf Case, 8 August 1988.

3.3.5 Exclusive Economic Zone

In Art. 55 of UNCLOS, exclusive economic zone EEZ is a zone under national jurisdiction (up to 200 nautical miles wide) declared in line with the provisions of UNCLOS, within which the coastal State has the right to explore and exploit, and the responsibility to conserve and manage, the living and non-living resources (UNCLOS, 1982).

The possibility of adopting an EEZ in Tunisia was declared for the first time in Article 2 of Law No. 94-13 of 31 January 1994. In 2005, Law 2005-50 of

[4]Entry into force: 6 December 1978; registration: 17601; registration date: 9 March 1979
[5]With annex of 7 August 2002
[6]Entry into force: 27 February 1978; registration: 17408; registration date: 15 December 1978

27 June 2005 establishes an EEZ off the Tunisian coasts without specifying its external limits and specifying that they will be settled by agreement with the neighboring States concerned. The question of its breadth, however, has not yet been resolved; at most it can extend over 200 miles. Tunisia reserves the right, within this EEZ, to create more restricted areas of competence by regulation. Article 4 of this law allows the creation of other maritime areas such as the fishing protection zone and the ecological protection zone (EPZ).

3.3.6 Exclusive Fishing Zone

Tunisia in Decree of 26 July 1951 as modified by Law No 63-49 of 30 December 1963, claimed an exclusive fishing zone that is bordered for about half of its length by the 50 m isobaths. This area includes:

- From the Algerian-Tunisian frontier to Ras Kapoudia and around the adjacent islands that part of the sea between the low-water line and a parallel line drawn 3 miles offshore except for the Gulf of Tunis which has an interior of the Cap Farina line, flat island, Zembra Island, Cape Bon is fully included in said area;
- From the Ras Kapoudia to the Tripolitan frontier, the part of the sea bounded by a line which runs from the end point of the 3-mile line described above, joins on the parallel of the Ras Kapoudia the 50-meter isobath and follows this isobath to its meeting point with a line from Ras Aghdir in a northeast direction ZV = $45°$.

Tunisia claimed an exclusive fishing zone (EFZ) that is delimited for about half of its length by the 50-m isobath. Use of this criterion to delimit a maritime zone is unique in international practice. Because of the shallow waters in the region, the external limit of this fishing zone is a line the points of which are located, in certain cases, as far away as 75 nautical miles from the Tunisian coast and only 15 nautical miles from the Italian island of Lampedusa. The Tunisian fishing zone encompasses the rich bank called Il Mammellone (*"the Big Breast"*), which has traditionally been exploited by Italian fishermen and is considered as an area of the high seas by Italy.

3.3.7 Ecologic Protected Zone

There is no official definition of the ecological protection zone, but it can be defined as an area worthy of conservation for its biodiversity and fishery resources and protected for environmental reasons.

The Decree of the Minister of Agriculture of 9 November 1973 created a zone of biological protection around the island of Zembra with a width of 1.5 thousand where the practice of fishing is prohibited. Thus the Order of the Minister of Agriculture of 28 September 1995 also prohibited fishing within a 1.5-mile perimeter around the Zembra and Zembretta islands and the Galite and Galite islands.

3.3.8 High Seas

According to UNCLOS (Article 87), the high seas are open to all States, whether coastal or land locked. Freedom of the high seas is exercised under the conditions laid down by this convention and by other rules of international law. Tunisia signed on 30 October 1958 the Geneva Convention on the High Seas of 29 April 1958.

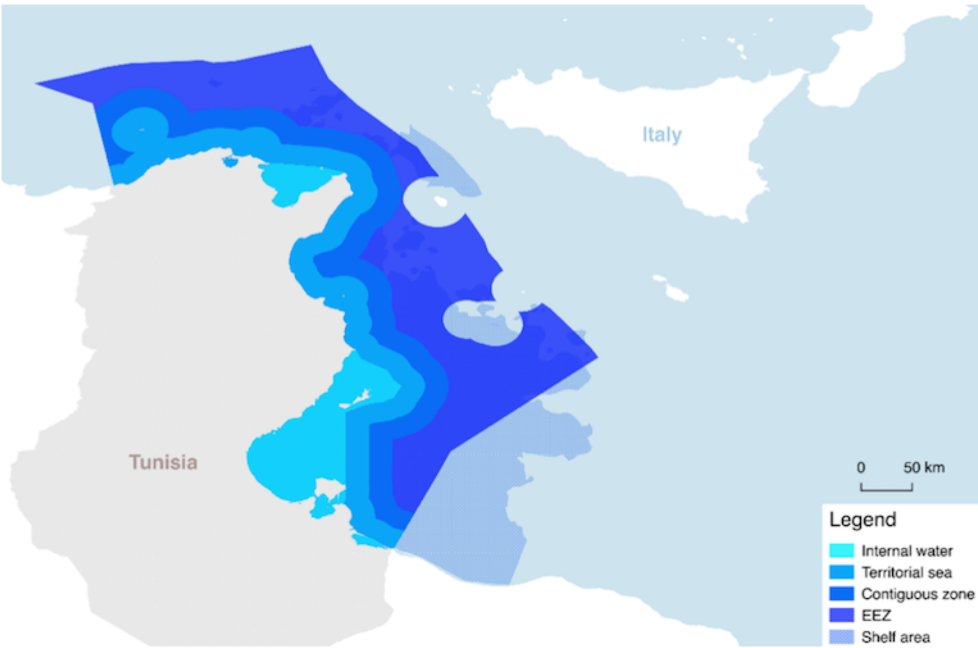

FIGURE 3.2: Tunisian's maritime boundaries

Figure 3.2 gives a clearer idea of the marine boundaries in Tunisia where it presents a map containing internal water, territorial sea, contiguous zone, economic exclusive zone, and shelf area.

TABLE 3.1: Tunisian maritime boundaries legislation

Zone	**Law**	**Description**	**Area (km^2)**
Baselines	73-527 of 3 November 1973	- The low-water mark from the frontier between Tunisia and Algeria to Cap Sidi Ali El Mekki; - The low-water mark of the reefs of the Sorelles, Galiton of the Galite, Estern Galitons, and the Fratelli, Cani and Pilau islands; - The low-water mark from Cap-Bon to Ras Kapudia; - The low-water mark of the Kuriates islands; - The low-water mark from Ras Turgueness to the point of Sidi Garus; - The low-water mark from Ras Marmor to the frontier between Tunisia and Libya; - The low-water mark from the low-tide elevations of El Bibane.	Length: 2290 km
Internal Waters	73-527 of 3 November 1973	- The closing line of the Gulf of Tunis; - The straight baseline covering the fixed fisheries of Chebba and the kerkennah islands; - The straight line of closure of the Gulf of Gabes; - The straight baseline joining the point of Sidi Garus to Ras Marmor.	16588
Territorial Seas	73-49 of 2 August 1973	12 nautical miles measured from the baselines	26493
Contiguous Zones	18 June 2008	24 nautical miles measured from the baselines	24176

Table 3.1 – *Continued on next page*

Table 3.1 – *Continued from previous page*

Continental shelf	Montego Bay Convention on 24 April 1985	It can extend up to 200 nm	/
Exclusive Economic Zone	2005-50 of 27 June 2005	200 nautical miles	99763
Exclusive Fishing Zone	Article 3 (b) Decree of 26 July 1951 amended by Act No. 63-49 of 30 December 1963	Up to 50-m isobath off the Gulf of Gabes	76123
Ecologic Protected Zone	Order of the Minister of Agriculture of 9 November 1973 as amended by order of 28 September 1995	1.5 nautical miles around the Zembra and Zembretta islands and the Galite and Galite islands	/
High Seas	30 October 1958	/	/

3.4 Legal Coastline Framework

3.4.1 Coastal activities

3.4.1.1 Energy

Since the 1990s, Tunisia has been interested in the development of wind energy through the realization of pilot projects with small wind turbines to serve dispersed rural households, then there has been the exploitation of high-power wind turbines through the first wind power plant in 2000. In 2009, Tunisia gave itself the means to implement a national program of energy and development of renewable energies through several texts and framework laws such as law n ° 2009-7 of 9 February 2009 and its implementing decree no. 2009-2773 of 28 September 2009, which open the way for private operators to various investment and development scenarios.

Since 2009 an onshore wind farm is operating near the coat in Sidi Daoud. The use of energy is a priority in the field of energy in Tunisia.

3.4.1.2 Tourism and ecotourism

In Tunisia, the legislator has not put in place a specific legal text to govern the ecotourism activity. It is a cross-cutting notion that is integrated into several legal texts, rarely in a direct way, but more often in an implicit way.

Ecotourism is part of the scope of a set of legal texts, such as the Act of 2 August 1988 on the National Agency for Environmental Protection (ANPE). The same applies to the Forest Code as promulgated by the Act of 13 April 1988 governing activities in and around national parks, nature reserves and recreational forests. Similarly, the 2009 Act regulates marine and coastal protected areas, but also ecotourism, which represents a way of managing and developing these areas.

3.4.1.3 Industry

The coastal industries, for logical reasons of transport and trade facilities, constitute a very important source of pollution of the coasts. Illegal discharges into sewage systems lead to coastal pollution and degradation of the coastal environment. Among the texts that organize the discharges the Water Code can be located promulgated by Law No. 75-16 of 31 March 1975[7] and amended by Law No. 87-35 of 6 July 1987, Law No. 88-94 Of 2 August 1988, Law No 96-29 of 3 April 1996, Law No 2001-116 of 26 November 2001[8] and Law No 2004-24 of 15 March 2004[9]. The Water Code contains a chapter devoted entirely to the identification of the harmful effects of water, one of the section relate to the "control of water pollution".

3.4.1.4 Urbanization

The rules to be followed for the optimal organization and use of space, planning, creation and development of urban agglomerations are laid down

[7]JORT of 1-4 April 1975, p 672 to 646
[8]JORT n. 95 of 27.11.2001, p 3395-3996
[9]JORT n. 22 of 16 March 2004, p 621

by Act No. 94-122 of 28 November 1994 promulgating the " Land use planning and town planning.

The general regulations relating to the protection of the coastline such as Article 23 which prohibits construction at a fixed distance according to the particularities of each zone and not less than 15 meters from the boundaries of the maritime public domain.

Article 24 authorizes concessions in the maritime public domain to be developed in an area delimited by a fictitious line parallel to the line that delimits the DPM and located at a maximum distance of 500m.

For areas not covered by an urban development plan, Article 25[10] prohibited the construction of a zone within 100 meters from the boundaries of the public maritime domain and from the boundaries of some components of the public water Such as lakes, Sebkhas that are not in natural communication and on the surface with the sea, canals, watercourses and reservoirs established on rivers. This distance may be extended in areas threatened by sea erosion and whenever coastal protection requires it.

Easement distances do not apply to public facilities and economic enterprises whose activity requires close proximity to the seashore or proximity to the components of the public hydraulic domain.

Similarly, Decree No. 98-2092 of 28 October 1998, which lists major agglomerations and sensitive areas, constitutes an integral part of this coastal area.

3.4.2 Littoral Area

Tunisia does not have a framework law on the coast but a specialized agency, An Agency for the Protection and Development of the Littoral (APAL), which since 1995 aims to institute an integrated development.

The Tunisian coastline has been defined in art. 1 of the Law of 24 July 1995 establishing an APAL. It is "*the contact area that concretizes the natural and biological ecological relationship between land and sea and their direct and indirect interaction*". These are essentially:

[10] Modifié par la loi n° 2003-78 du 29 décembre 2003

- The sea shore, beaches, Sabkhas, sand dunes, islands, cliffs and various components of the maritime public domain except fortresses and other defensive structures.
- Inland areas within varying boundaries depending on the degree of natural and human interaction between them and the sea, such as coastal forests, estuaries, sea-heads and coastal wetlands;

3.4.2.1 Urban and Land Use Planning

Territorial planning and town planning is organized by Law No. 94-122 of 28 November 1994, as amended by Act No. 2003-78 of 29 December 2003, but it does not have laws specifically and coastal town planning. It can be said that there is no special code on the littoral compiling the relevant texts. The laws applicable to coastal zones are: Act of 24 July 1995 on maritime public domain, Act of 24 July 1995 (creation of the APAL), Act of 02 August 1988 (creation of ANPE), Law of 28 November 1994 on The Land Use Planning Code (CATU). And other sectoral laws that complement the laws as a water code of 13 March1975, law of 09 May 1986 on historic monuments, law No. 88-20 of 13 April 1988 on the forestry code, law No. 95-70 of 17 July 1995 on the conservation of water and soil and Decree 2005-1991 of 11 July 2005 on the environmental impact assessment.

Some specific regulations that can be applied to the coastline include the 100 meter rule or the inconstructibility rule. This rule can be cancelled, for example, by applying the principle of intangibility of public works, or by harmonizing the urban fabric on the coast.

3.4.2.2 Public Maritime Domain

The Public Maritime Domain (PMD) is governed by Act No. 95-73 of 24 July 1995, revising the 1985 and 1987 texts. Six main chapters define its consistency, the modalities of its delimitation, the servitudes it supports, its use and occupancy regime, its policy and various special provisions. The PMD consists of both the public natural maritime domain (shore, lakes and lagoons in natural communication with the sea, the exclusive fishing zone, the exclusive economic zone) and artificial maritime public domain (harbors, harbors, islands Artificial, etc.). It should be noted that the 1995 law extended its terrestrial component, thus creating an environmental awareness. This extension is important insofar as it allow both the conservation of the most vulnerable sectors and the prevention of the risks of erosion and submersion of the littoral.

3.4.2.3 Coastal sensitive zones

Since 1995, Tunisia has initiated the implementation of Master Plan for the Planning of Sensitive Zones (SDAZS) at the level of the Directorate General for Regional Development (DGAT). The SDAZS, amongst others, arrest, in each region, on the basis of a detailed diagnosis, the sensitive natural areas which must be protected. They are subject to regional and local consultation. To this end, Decree No. 98-2092 of 28 October 1998, established a list of sensitive areas requiring the drawing up of master plans for development. These areas, which are generally large scale, rarely encounter the sensitivity they bear, and more closely resemble the guiding patterns of economic regions, far from the concerns of sustainable development and the issues of integrated management.

The Forestry Code entrusts to the General Directorate of Forests the management and application of the forestry regime, which represents the set of special rules applicable to forests, alfalfa, rangeland, forest land, national parks and reserves Natural resources, with the aim of ensuring their protection, conservation and rational exploitation and also guaranteeing the legal exercise of their rights.

Coastal sensitive areas are set by Decree No. 98-2092 of 28 January 1998 (of which 15 are littoral and 6 are MPAs). The identification of these zones makes it possible to protect them against the pressure of land. Management of coastal sensitive areas is entrusted to the APAL, which manages them either directly or through concessions and temporary occupation. Protection is thus entrusted to the APAL, first of all, which coordinates with the various administrations, central, regional and local, associations, NGOs and citizens. The development of these areas is carried out by Master Planning Plans (SDAs), Urban Planning Plans (PAU), Detail Planning Plans (PADs), Tourist Planning Plans (PATs) and Plans of Occupation of the Beaches (POP).

3.5 Legal Marine Framework

3.5.1 Marine activities

3.5.1.1 Fisheries and aquaculture

Fishing is an important economic activity in Tunisia. The mariculture has experienced growth and is expected to increase further since plans are being made to increase the production capacity. However, on the other hand worries exist about the environmental impact of mariculture. The most productive fishing areas are located in the Gulf of Gabes; more than 70% of fish is caught in the Gulf (Figure 3.3).

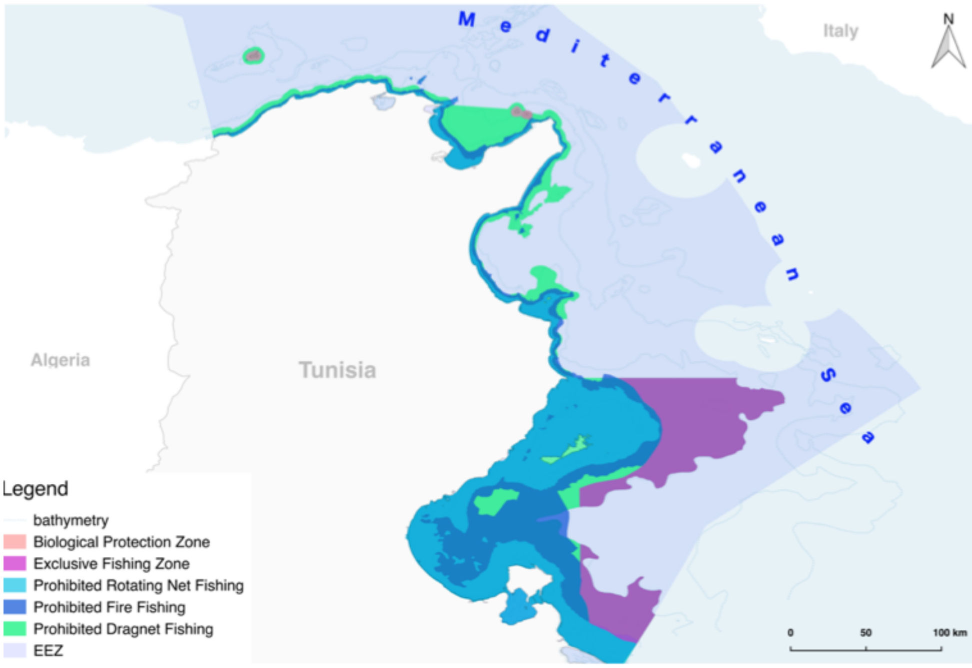

FIGURE 3.3: Map of the fishing boundaries in Tunisia

Because of this importance of fisheries and aquaculture sector, Tunisia has given importance to the legislation on this sector. In examining the texts collected on the fishing exercise, it can be seen that their promulgation went through four important periods:

- **From 1883 to 1905**
  The first general text governing fishing in Tunisia is the Beylical Decree of 19 April 1892 on the protection of the fishing industry in Tunisian waters. Previously there were regulatory texts for specific types of fishing or interested in particular species of fishery resources such as

the decree of 18 August 1883 regulation torpedo fishing in the gulf of Gabes.

- **From 1906 to 1950**
  The first modern text which attempted to govern the whole sector was the instruction of 31 December 1904, which for the first time instituted the drafting of an integrated legal basis for the identification and delimitation of fishing grounds and legal regime for fishing activity in Tunisia. Shortly afterwards, a specific text was enacted, namely the Beylical Decree of 15 April 1906 regulating maritime and coastal fishing. In 5 April 1931 a Beylical decree was promulgated regulating the exploitation of the chrafis of the islands of Kerkennah.

- **From 1951 to 1993**
  A revision of the fisheries legislation was carried out by the Beylical Decree of 26 July 1951. Another law, Law No 73-49 of 2 August 1973, was promulgated by fixing the reserved fishing zone.

- **Since 1994**
  Law No. 94-13 of 31 January 1994 became the basic text on fishing after the abrogation of all previous provisions contrary to this Law. The Act was amended twice in 1997 and 1999. Other texts regulated the fishing sector, setting out the Law No 2008-44 of 21 July 2008 on the organization of maritime professions and the Law No 2009-48 of 8 July 2009 on the Code of seaports.

3.5.1.2 Oil and Gas Sector Offshore hydrocarbon

Offshore hydrocarbon activities take place in the Pelagian Province, a marine area surrounding Tunisia. These activities encompass both territorial and cross-border petroleum systems (Figure 3.4). In this respect, Tunisia is involved in national as well as cross-border exploitations:

- Oil exploitation, e.g. the Pantelleria Permit (Italian waters): Sambuca prospect, extends into the Kerkouane permit across the Italian-Tunisian maritime border;

- Gas exploitation, e.g. the Kerkouane Permit (Tunisian waters) - Dougga gas/condensate field;

- Oil wells at the Libyan-Tunisian border are exploited by a Libyan-Tunisian joint venture called the Joint Oil Company.

Tunisia organized this sector by Act No. 99-93 of 17 August 1999, promulgating the hydrocarbons code, supplemented by Law No. 2002-23 of 14 February 2002, Law No. 2004-61 of 27 July 2004, Law No. 2007-70 of 27 December 2007 and Law No. 2008-15 of 18 February 2008. The hydrocarbons code contains certain provisions relating to the obligations of licensees of exploration, exploitation and drilling licenses, covering both the protection of the environment, the control of accident events and the need for the state of the environment in the event of degradation, as well as the obligation to carry out a preliminary impact assessment.

FIGURE 3.4: Offshore hydrocarbon activities

3.5.1.3 Maritime traffic

Tunisia has five codes related to maritime transport which take up the main requirements of maritime activities in general, in most cases they do not refer to the rules included in the international conventions

- **Maritime Commerce Code**
  Enacted by Law No. 62-13 of 24 April 1962, as amended by Laws No. 72-4 of 15 February 1972, No. 98-22 of 16 March 1998 and No. 2004-3 of 20 January 2004. It relates essentially to the legal aspects, Economic and commercial aspects of maritime transport.

- **Maritime Navigation Administration Police Code**
  Promulgated by Law No. 76-59 of 11 June 1976 and amended by Laws No. 99-55 of 28 June 1999, No. 2004-4 of 20 January 2004 and No. 2005-8 of 19 January 2005. It constitutes the legal basis for The maritime administration in the field of safety and security of ships under national flag. It contains the provisions on these subjects but without any reference to the international SOLAS Convention and the resulting codes.

- **Maritime disciplinary and penal code**
  This code, similar to those in other countries, is national legislation not regulated by international conventions. It is a code that contains the disciplinary and penal regime of seafarers, faults, crimes, offenses and penalties.

- **Maritime Labor Code**
  It contains the administrative regime for seafarers, professional booklet, enrollment, remuneration, etc. This code may be linked to the Maritime Labor Convention 2006 (MLC) (MLC 2006) but this is not mentioned.

- **Marine Ports Code**
  Promulgated by Act No. 2009-48 of 8 July 2009, the Sea Ports Code lays down the conditions governing the establishment and management of seaports. With the exception of the Police Code of the Maritime Administration, the other codes mentioned above do not contain references to marine safety, security and pollution.

Marine traffic is most intense to the north of Tunisia, more particular in the Strait of Sicily.

3.5.2 Marine Area

The practice of fishing was subordinated until 1994 to the Beylical Decree of 26 July 1951 revising the legislation on the fisheries police. This text has been replaced by Act No. 94-13 of 31 January 1994 on the exercise of fishing as supplemented by subsequent texts, which repealed most of the earlier texts. The updating of the legislation governing the fisheries sector is Law 9413 of 31 January 1994, the decrees of the Ministry of Agriculture, the institution of incentives for the improvement of fishing techniques and abandonment and The development of aquaculture for the sake of establishing measures

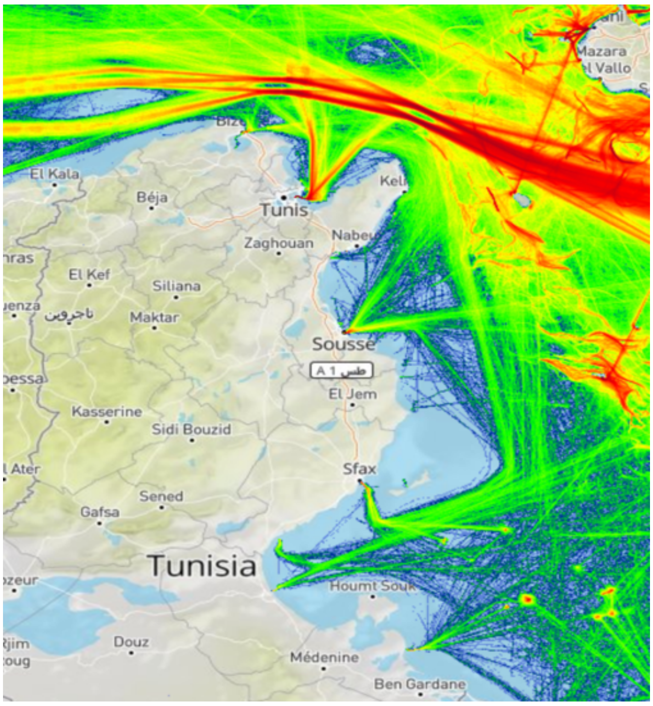

FIGURE 3.5: Shipping routes (www.marinetraffic.com)

to protect endangered species, the increased monitoring of the various indicators of the health of the sea and the control of pollutants in marine organisms.

Law No. 89-21 of 22 February 1989 on shipwrecks applies mainly to abandoned vessels and / or aircraft, to all floating objects without control and to objects which may have been extracted from the seabed and which have historical or archaeological values.

Law No. 96-29 of 3 April 1996, establishing a national emergency response plan to combat marine pollution. On the internal level, the fight against accidental pollution of the marine environment justifies the mobilization of adequate means for the management of the emergency in this matter. To this end, Act No. 96-29 of 3 April 1996 establishing the PNIU sets out the framework and mechanisms for rapid, effective and coordinated action to enable public authorities to protect themselves and to combat accidental marine pollution. These main elements are:

- Delineating the responsibilities of all stakeholders in the struggle, its support, preparation and follow-up;
- Setting the responsibilities and tasks of the authorities and structures responsible for the preparation for the control, the conduct of the control operations and the coordination;

- Establishing procedures to enable all stakeholders to contribute in a coordinated manner and to mobilize resources quickly and efficiently.

Two structures have been set up, namely the National Commission for Prevention and Control of Marine Accidental Pollution, the composition of which is laid down by Decree No. 96-1250 of 15 July 1996 and by the operational response structure set up when necessary. Another law concerning pollution is Law 9641 of 10 June 1996 on waste and control of their management and disposal.

Decree No. 97-1836 of 15 September 1997 concerning the carrying out of scientific research, exploitation, survey and drilling by vessels in the waters and the continental shelf of Tunisia. The exercise of scientific surveying and drilling activities in territorial waters and on the Tunisian Continental Shelf is subject to the issuance of an express authorization by the competent authority in accordance with Article 2 of the Decree.

In examining the instruments of Tunisian law, we can see that it did not offer until 2009 a sustainable solution for the protection of marine ecosystems. Prior to that date, Tunisian law did not have specific legislation on marine protected areas and devoted sectoral protection to the marine environment, revealing an institutional dispersal. Law No. 2009-49 of 20 July 2009 on marine and coastal protected areas came to fill this gap. In order to comply with its international commitments on the protection of nature and to mitigate the limits of national legislation on protected areas, Tunisia has put in place a specific legal framework for marine and coastal protected areas. The establishment of a national network of marine protected areas.

Act No. 2005-33 of 4 April 2005 amended the natural elements of the list previously established by Act No. 95-73 of 24 July 1995. According to this law, the natural elements of the maritime public domain include:

- The shores of the sea (mainly coastal and sand dunes) constituted by the coastline alternately covered and discovered by the highest and lowest waters of the sea, and by the lands formed by the lays and the relays[11]; As well as by the sand dunes located in the immediate vicinity of these lands subject to the provisions of the Forest Code;

[11]Reminder of the definition: lays and relays of the sea are the deposits left by it and which are definitely and naturally located outside the water (exudates). More precisely, lais are lands formed by the deposits formed by the sea along or outside the shore; While the relays are lands whose sea has receded and are no longer covered by the highest tide (e.g., beaches are often made of lays or relays of the sea).

- Lakes, ponds and Sebkhas in natural and surface communication with the sea;
- Inland maritime waters and the territorial sea *"whose limits and organization have been provided for in the special texts"* and without prejudice to the *"right of innocent passage of other States"*.

On the other hand, the other natural elements which figured until 2005 in this list, namely:

- The soil and subsoil of the continental shelf *"for the purpose of exploring and exploiting their natural resources"*;
- Exclusive fishing zone;
- The exclusive economic zone.

They were removed from the list by the amendment to Act No. 95-73 of 24 July 1995 on the DPM by Act No. 2005-33 of 4 April 2005, thus bringing Tunisian legislation into line with legal logic The most elementary.

For more rigor, the legislator benefited from the revision of the law on the DPM in 2005, when it also delimited the EEZ to specify that the Continental Shelf, the Ecological Protected Area and the Economic Zone Exclusive were not part of the DMP because, in any case (including in the Montego Bay Convention of 10 December 1982), these areas are not subject to the exercise of State sovereignty, as it expressly Law No. 2005-50 of 27 June 2005 on the EEZ. This text provided for the adoption of implementing decrees which could eventually create "reserved fishing zones", "fishing protection zones" or "ecological protection zones" (Article 4 of Law No. 2005 -50 of 27 June 2005).

In addition, these laws have remained in force the provisions relating to the reserved fishing zone provided for by Article 5 of Act No. 73-49 of 2 August 1973 on the delimitation of territorial waters and the custodial sentences provided for by chapter 3 of Title IV of Law No 94-13 of 31 January 1994 on fishing in respect of offenses under the same Act committed in the EEZ (Article 6).

Act No. 2009-49 of 20 July 2009 on marine and coastal protected areas has given the possibility to manage certain sensitive areas as areas.

With the promulgation of 2009, Tunisia finally has a legal framework specific to these spaces. This law has defined these areas and clarified their legal regime which is a more rigorous regime than that of the coastal or maritime public domain (DPM). According to art.2 of the Act, GCAPs are "areas designated by law for the purpose of protecting natural environments, flora, fauna, marine and coastal ecosystems of particular interest from a Natural, scientific, educational, recreational or educational point of view which constitute remarkable natural landscapes that have to be preserved ". The 2009 Act requires the development of an AMCP management plan (art. 24), as well as the content of these plans (art.26). Art.27 has no fewer than 26 activities subject to restriction (between prohibition and authorization). These restrictions cover different activities and behaviors.

In Tunisia 25 sensitive areas have been identified. For each of these areas a management plan has been set up. Six of these areas are MPAs: La Galite Archipelago, Cap Negro – Cap Serrat, Zembra and Zembretta Archipelago, Kuriat islands, Kerkenah islands and Kneis6. The Network of Managers of Marine Protected Areas in the Mediterranean (MedPAN) identified two SPAMIs along Tunisia's seashore. Figure 3.6 shows their location and some general information.

In 1998, the Tunisian government developed a national program for the creation of protected maritime and coastal areas. The program aimed to establish a network of Marine Protected Areas and coastal areas along the Tunisian coast by:

- Improving the legal framework for MPAs and coastal areas;
- Developing a national strategy for the creation and management of MPAs and coastal areas;
- Carrying out engineering studies to develop MPAs and coastal areas;
- Implementing management plans for each area (MPA or coastal area).

3.6 International conventions ratified by Tunisia

The number of universal treaties ratified by Tunisia, which apply to the protection of the sea, coastal zones and biodiversity in general, are numerous and concern themselves with various aspects of the valorization of these spaces. Particular mention should be made of:

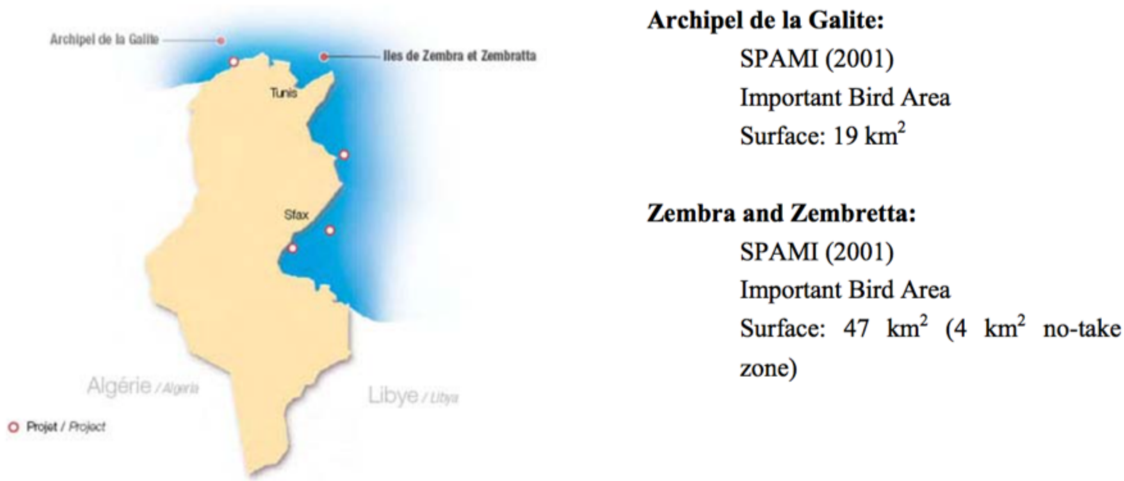

FIGURE 3.6: Marine Protected Areas (www.medpan.org)

- The RAMSAR Convention on Wetlands of International Importance (RAMSAR, 1971 as amended by the Paris Protocol of 3/12/82), ratified in 1981;
- The Convention concerning the Protection of the World Cultural and Natural Heritage (Paris, 1972), ratified in 1975;
- The Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean against Pollution adopted in Barcelona on 16 February 1976 (ratified by Act No. 77-29 of 25 May 1977 and amended by Act No. 98-15 of 23 February 1998);
- Protocol concerning Specially Protected Areas of the Mediterranean (ratified by Law No. 83-44 of 22 April 1983)[12];
- United Nations Convention on the Law of the Sea (ratified by Act No. 85-6 of 22 February 1985)[13];
- The United Nations Convention on Biological Diversity (Earth Summit, Rio 1992, ratified by Act No. 93-45 of 3 May 1993) ;
- The United Nations Convention on Climate Change (ratified by Act No. 93-46 of 3 May 1993);
- The Agreement on the Conservation of Cetaceans of the Black Sea, the Mediterranean and the Adjoining Atlantic Zone ACCOBAMS (ratified by Act No. 2001-68 of 11 July 2001);

[12]JORT No. 32 of 26 April 1983, p.1127
[13]JORT No. 17 of 1st March 1985, p.310

- The Kyoto Protocol, annexed to the United Nations Framework Convention on Climate Change (ratified by Decree 2002-2674 of 14 October 2002).

3.7 Institutional framework

Responsibility for the management and protection of coastal areas is owed to the Ministry of Planning and Environment Equipment, Ministry of Industry, Ministry of Agriculture, Ministry of Local Development, Ministry of Transport, Ministry of Tourism and Handicrafts and specialized agencies such as the Agency for the Protection and Development of the Coastal Region (APAL) National Agency for Environmental Protection (ANPE) Tourism Agencies (OFT), Industrial Real Estate Agencies (AFI).

The main actor involved in the management of the Maritime Public Domain is the Coastal Protection and Management Agency (Agence de Protection et d'Aménagement du Littoral – APAL). The agency is subordinated to the Tunisian Ministry of Environment and Sustainable Development and was created by law in 1995 to implement national policy with regard to coastal protection in general and the public maritime domain in particular. The responsibilities of the agency are:

- Coastal area management and the monitoring of management operations to ensure compliance with rules and standards as set by laws and regulations;
- The regularization and control of land-use which is not in accordance with laws and regulations;
- Carrying out studies on coastal protection;
- Analyzing the evolution of coastal ecosystems.

As regards to the protection of the marine environment, the Tunisian key player is the National Agency for the Protection of the Environment (Agence Nationale de Protection de l'Environnement – ANPE), which is also subordinated to the Tunisian Ministry of Environment and Sustainable Development.

INSTM (Institut National des Sciences et Technologies de la Mer) is the focal point touching fishing and aquaculture. The institute studies the

Tunisian sea in order to provide the DGPA (Direction Générale de la Pêche et de l'Aquaculture) with recommendations about the actions that are needed to preserve ecosystems. INSTM and DGPA are part of the Ministry of Agriculture, Fisheries and Water Resources. The distribution of the responsibilities of each institution on the spaces is as follows:

- Coastal zones are assigned to several national authorities;
- The coastal zone is dealt with in the general national environmental or spatial planning committees;
- As a result, organized coordination is weak despite the existence of an Inter-Ministerial Committee for Regional Planning and the Coastal Protection and Management Agency. It covers specific sectors such as water, agriculture, tourism and industry;
- Local co-operation is rarely possible or foreseen in the coastal zone, as local authorities are generally jealous of their prerogatives especially in land planning.

In the field of ecotourism, there is a multiplicity of public actors intervening as this notion is transversal by touching several areas at the same time. The main actors are the Ministry of Tourism, the Ministry of the Environment and the Ministry of Agriculture) with specialized institutions such as the Tunisian National Tourist Office (ONTT), the Protection Agency (APAL), the International Center for Environmental Technologies in Tunis (CITET), the forest management board, the agency for the promotion of heritage and cultural promotion, and finally civil society and local populations.

3.8 Analyse of legal and institutional framework

Tunisia has an important regulatory and legislative arsenal that governs the management of coastal and marine areas and covers various aspects of environmental protection, including those related to the phenomenon of climate change. However, there are some gaps in the regulatory framework that require updating and strengthening tools for enforcement.

3.8.1 Legal framework

Tunisia's legal texts have recently made a major step forward in the field of the environment, which is the declaration of Tunisian citizens' right to a healthy and balanced environment and participation in climate security in Article 45 of the new Tunisian Constitution adopted on January 26, 2014, which stipulates that « *The State guarantees the right to a healthy and balanced environment and participation in the security of the climate. The State must provide the means necessary for the elimination of environmental pollution* ».

These legal texts have an important regulatory arsenal, but there is no harmony and a unifying logic of these elements. It is a complex set of laws, scattered over a large number of texts and legal provisions that are conceived and elaborated in isolation from one another. Tunisian law makes no reference to transboundary terrestrial, coastal or marine natural areas. However, the Law on Marine and Coastal Areas is characterized by its innovative aspect of planning and zoning.

The area's most often cited as not sufficiently covered by the existing law are coastal town planning (illegal constructions, both in the public domain and the private coastal fringe), coastal industrial estates, Sand, coastal erosion and salinization of land, waste and sanitation, marinas, control and access to beaches in the event of strong tourism pressure. Decree No. 98-2092 of 28 October 1998, laying down the list of major urban areas and sensitive areas requiring the drawing up of development master plans. The latter is not the ideal framework for coastal planning. It is in fact a document applied to the ground and not to the littoral with its two components land and sea.

It can be said that the current Tunisian law devotes a certain diversification of actors and types of governance in the management of protected areas / natural spaces. This diversity reflects the different objectives assigned to each type of area. On the other hand, the soil and subsoil of the Continental Shelf, the Ecological Protection Zone and the Exclusive Economic Zone were removed from the list, thus bringing Tunisian legislation into line with legal logic. However, the provisions relating to the reserved fishing zone provided for in Article 5 of Act No. 73-49 of 2 August 1973 concerning the delimitation of territorial waters and the custodial sentences provided for in chapter 3 of the Convention were repealed. Title IV of Law No 94-13 of 31 January 1994 on fishing in respect of offenses under the same Act committed in the EEZ (Article 6).

In Decree No. 97-1836 of 15 September 1997 on the exercise of scientific research, exploitation, survey and drilling by vessels in the waters and the continental shelf of Tunisia is not specified precisely Competent authority to issue the authorization.

Law No. 2008-23 of 1 April 2008 on concessions is a single text of the general system of concessions, whether public service concessions, public concessions or a mixture of both. It is a law that does not openly integrate environmental concerns.

Law No. 2009-49 of 20 July 2009 on Marine and Coastal Protected Areas (AMCP) is an opportunity for the establishment of a sustainable management of marine ecosystems but the definition of AMCP in art.2 is too broad. It is a definition with no provisions on the financial aspect and no implementing decrees. Efforts to promote ecotourism in Tunisia are not negligible because of the absence of a legal text specific to ecotourism.

For Integrated Coastal Zone Management, there is a lack of long-term vision at different levels: national, regional and local. This absence is also noted in the National Master Plan for the Planning of the Territory (SDATN). The development options proposed in coastal areas are often incompatible with the imperatives of integrated management. So it can be said that there is a lack of texts relating to the Integrated Management of Coastal Zones as well as texts relating to the Strategic Environmental Assessments of the major projects modifying in a very sensitive way the coastal zones.

3.8.2 Institutional framework

The diagnosis of the Tunisian institutional framework relating to the coastal and marine zone reveals the presence of several constraints which constitute obstacles to the implementation of an integrated management of these zones, Management of coastal zones, which are dealt with by several structures distributed between several ministries at the local level (defense, interior, agriculture, environment, equipment, transport, tourism, etc.). For example, the lack of integration of sectorial development plans at the local level and the lack of mechanisms for horizontal integration of planning decisions at national, regional and local levels and the limited contribution of local communities and other stakeholders in the design of Planning Plans. It was noted that community structures (development groups, fishermen's trade unions) are too compartmentalized and do not lead to consensus for effective management of coastal and marine resources.

The institutional framework is characterized by a strong centralization of the active administration, a sectorial consultative administration noting that there is a decentralization that is beginning to regain interest (Local Public Authorities (LPCs), public institutions, (ANPE and APAL), participation of economic actors and public participation (non-profit) and the participation of the local population and civil society, which is still limited.

The diversity and multiplicity of institutions can lead to coordination problems, where institutional fragmentation also reflects a lack of rationality, the risk of functional duplication, because several actors are assigned the same competencies on the same space, and Risk of confusion of responsibilities.

The primacy of the central administration can increase the management and protection of natural areas (problems related to bureaucracy). Coordination between the various administrative bodies should be strengthened and staff awareness and training campaigns should be strengthened. It is also possible to rethink administrative structures, the size of their staff and their material resources must depend on the area in which they are located. Independent specialized bodies (public institutions) may need to be strengthened because the autonomy of action guarantee its efficiency. Moreover, this type of administrative structure gives rise to two modes of control: self-control and supervision of the supervisory authority.

Issues relating to the management of coastal zones are dealt with by several structures split between several ministries (MEHAT, MEDD, APAL, MARH, etc.) at national and regional level, which leads to several philosophies of intervention in this area, varying from one partner to another. This overlap between the structures becomes a slowness in the issuance of decrees fixing coastal sensitive areas, delaying the application on the ground of the planning plans for these sites, which once established will not fail to give a real Added value in the Integrated Coastal Management Approach. This is due to the lack of integration of sectoral development plans at the regional level (Agriculture, Equipment, Transport, Tourism, etc.) and the absence of a policy that ensures the horizontal integration of planning decisions.

3.9 Chapter Summary

This chapter examined the coast and marine administration systems in Tunisia. The literary review of the laws assert that Tunisia has an important regulatory and legislative arsenal that governs the management of coastal and marine areas and covers various aspects of environmental protection, including those related to the phenomenon of climate change. However, there are some gaps in the regulatory framework that require updating and strengthening tools for enforcement. These gaps can be resolved with effective economic, social, and environmental management by integrating the marine and coastal management in a holistic spatial data infrastructure.

4 Coastal and Marine Management Initiatives

4.1 Introduction

Multiple approaches to the management of human activities, resources and integrity of ecosystems in the marine environment and developed by the world (Coleman et al., 2011). There is no consensus on the links between these approaches. For example, for some authors, ICZM is a variation, for coastal zones, of ecosystem management (EM). For others, Maritime Spatial Planning (MSP) has supplanted marine Ecosystem-Based Management System (EBSM) in terms of political terminology (Ogden 2010), or Maritime Spatial Planning (MSP) represents an ecosystem management tool in the marine environment (EBSM) (Katsanevakis et al., 2011).

Ardron (2010), in an article entitled "Marine planning: the tragedy of acronyms", deplores the fashion effects in the terminology used, and takes as an example a recent variant of the MSP, Coastal and Marine Spatial Planning (CMSP) whose definition "tends to make the concepts of EBM, ICZM and MSP very similar". The Centre for Ocean Solutions in 2011 makes the same observation and highlights the points of convergence: *"terms such as ecosystem-based management in the marine environment, marine spatial planning, maritime spatial planning, integrated coastal zone management, integrated ocean management, Systematic conservation, planning of uses in the marine environment, often cover similar approaches. They aim to help decision-making and mobilize scientific and spatial information to tackle conflicts of use, organize human activities at sea, wishing to maintain the functions of ecosystems and the services they provide"*.

4.2 Coastal Management System

4.2.1 Integrated Coastal Zone Management (ICZM)

The different coastal uses causes conflicts of interest between the users, including direct and indirect users of particular coastal and marine areas involve competition of uses for coastal and marine areas, adverse effects of one activity to another, and effects of activities to coastal and marine ecosystems.

Cicin-Sain (1993) argues that conflicts among government agencies at various levels occur due to various reasons, including different legal mandates and missions, different interest in the management of land-side of the coastal areas, different capacity on human resources, divergent in funding sources, and lack of information and communication. To reduce this pressure and conflicts, an integrated coastal zone management (ICZM), is advocated by Chapter 17, Agenda 21 of United Nations Conference on Environmental Development (UNCED) held in Rio de Janeiro in June 1992.

Multiple reports internationally have highlighted the need for better coordination and integration between and within levels of government to improve coastal zone management (Hudson and Smith, 2002; Middle, 2002). In this respect, worldwide Coastal Zone Management (CZM) initiatives, attempted to harmonize economic, social and environmental objective. However, in coastal areas the diversity of terrestrial interests and marine compounds the issue.

The aim of integrated coastal zone management (ICZM) is to achieve sustainable use and development of coastal resources by balancing environmental, economic, social, cultural and recreational objectives (Khakzad et al., 2015). The implementation of ICZM requires an understanding and knowledge of the physical, social and biological environment, as well as the relationships between these agents (Rodríguez et al., 2009). It has become the standard approach to coastal planning and management (Wescott 2004) with nearly 700 ICZM initiatives occurring at international, national and sub-national levels (Chuenpagdee, 2004). ICZM has been slowly accepted over the last decade as a unifying approach for coastal planning and management through the world (Wescott, 2004). ICZM has been described as a process for decision-making: it should be continuous, iterative, and should recognize the contributions of stakeholders and the natural dynamism, both physical and ecological, of the coastal environment. A primary goal of ICZM is to overcome the compartmentalized approach to managing coastal resources by harmonizing the decisions of diverse jurisdiction. ICZM, therefore, is also about building institutions that facilitate this integration. It is founded on principles of sustainable development, recognizing that the coastline is the fount of resources of great value to human communities and that these resources should be managed in ways that conserve their value for future generations (Cicin-Sain et al., 1998).

ICZM recognizes that the coastal resources management situation is unique, that is, it differs greatly from management of either land or marine resources, being a combination of both. Therefore, management needs to consider the multiple activities and interests in the area and provide an integrated approach, horizontally across different jurisdictions and vertically between different organizations and levels of government.

According to the very definition of ICZM, the field of action must be freed from traditional administrative units, *"convenient but unsuitable for geographical realities"* (Péron, 1998), to take into account *"an area of littoral and adjacent ecosystems characterised by common natural elements (climatic, physical, biological) and / or by the presence of particular antropic activities"* (Moltke, 2001). Similarly, Post and Lundin (1996) note that *"the managed area should cover all resources"*. ICZM recognizes that the coastal resources management situation is unique, that is, it differs greatly from management of either land or marine resources, being a combination of both. Therefore, management needs to consider the multiple activities and interests in the area and provide an integrated approach, horizontally across different jurisdictions and vertically between different organizations and levels of government.

Coastal areas of interest and all activities capable of affecting the resources and waters of the coastal zone ". This necessarily calls for a definition of the scale of intervention taking into account land-sea integration. As Hall (2002) put it, *"integrated coastal management projects and programs are meant to cover both the ocean space affected by terrestrial territory and land space affected by the ocean - although the perimeter of coastal programs varies significantly depending on the issues to be addressed and the capacities of the implementing agency"*.

The definition of the perimeter of the ICZM plan should be considered with particular attention. Therefore, the geographical coverage of ICZM programs has widened from a strict focus on the coastal fringe, defined according to administrative (land-ward) and jurisdictional (marine-ward) criteria, to a wider area defined according to administrative and ecological criteria. In this respect, the literature often invokes the need to go beyond administrative boundaries to take into account a coherent perimeter from an ecological point of view. However, this recommendation should be qualified for practical reasons. If the competences of public authorities are totally eliminated, there is a great risk of losing time and energy in coordinating the various public authorities concerned.

ICZM is a process includes several steps. It is usually represented by the ICZM policy cycle (Figure 4.1) which slightly varies between authors but always has the basic idea of the initiation–planning–implementation–evaluation steps. Each cycle could be considered as an ICZM program in itself and is limited by the geographic area covered and by the number of stakeholders and economic sectors involved. Once one ICZM program is successfully accomplished, it can become wider in scope (González-Riancho et al., 2009).

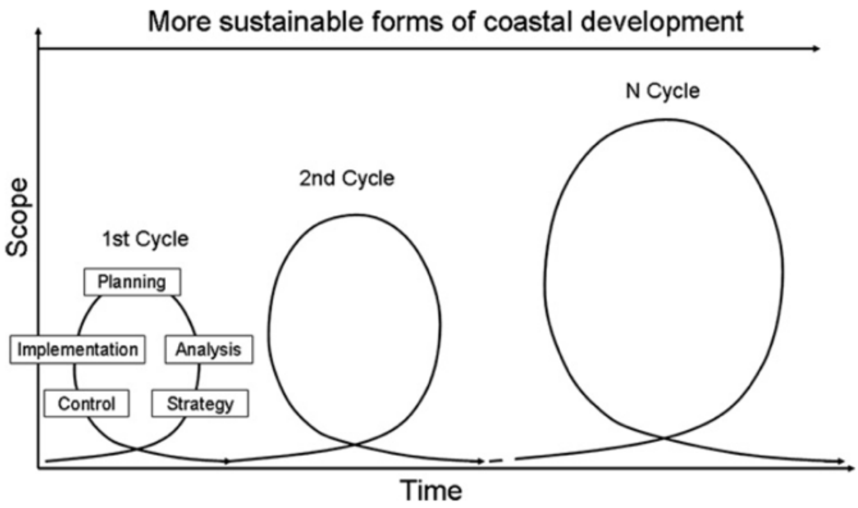

FIGURE 4.1: ICZM policy cycle (González-Riancho et al., 2009)

Data is seen as an important element in the ICZM process as shown by Bartlett et al. (2004) *"if goals such as sustainable development of coastal zones are to be reached, then coastal researchers from different disciplinary backgrounds require access to a wide variety of marine and coastal databases"*. ICZM recognizes the need to integrate planning and management over the land – marine interface and so there is a need for data and information that covers both these areas. The Protocol on Integrated Coastal Zone Management in the Mediterranean, within the framework of the Barcelona Convention, was developed in 2008 to provide a common framework for the Contracting Parties to promote and implement integrated coastal zone management. The main perceived coastal problems in the Mediterranean region for the attendees are sewage discharges and coastal erosion followed by a fish stock diminishing, water chemical contamination and coastal urbanization (González-Riancho et al., 2009).

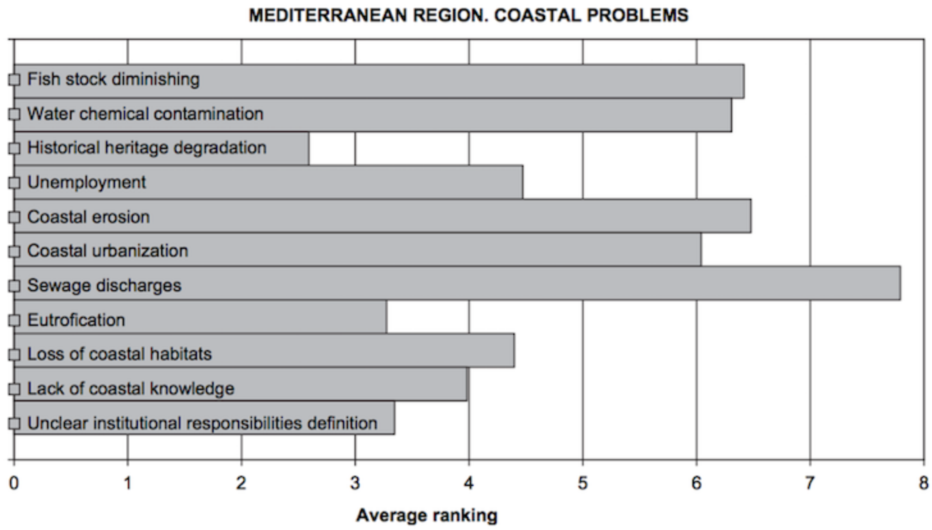

FIGURE 4.2: Coastal problems in the Mediterranean region (González-Riancho et al., 2009)

The Tunisian coast, coveted and subject to multiple pressures, constitute a fundamental element of the planning of the territory. The multiple uses of this area, which account for two thirds of the national population, the vast majority of the country's tourist areas and more than 80% of the industrial areas, have caused environmental damage that is detrimental to the assembly of users. The coastal areas are vital for the economy and tourism development. This zone includes urban areas, intensive industry (phosphate-gypsum plants, oil extraction), tourism development sites and sensitive ecosystems such as dunes, lagoons and sea grass beds. Reports indicate that:

- Urban sprawl and tourism development are putting pressure on coastal land;
- Several areas are subject to serious coastal erosion;
- Pollution of coastal waters is being addressed by municipal wastewater treatment plants (65% of wastewaters is treated);
- Eutrophication is reported in coastal lagoons;

- Protection of marine and coastal biodiversity is being strengthened by the establishment of new protected coastal areas.

The government gives high priority to integrated coastal zone management (ICZM) and has established the Coastal Protection and Management Agency (APAL) to manage the maritime public domain. Other agencies involved in coastal management include the Ministry of Agriculture, Environment and Water Resources (MAERH) and the National Agency for the Protection of the Environment (ANPE). But in Tunisia the ICZM have some issues in the urban sprawl and tourism development, in the pollution of coastal waters by urban, industrial and ship-generated waste, in the biodiversity protection and creation of coastal protected areas and in the lack of public awareness and participation.

4.2.2 Water Framework Directive (WFD)

The Water Framework Directive (WFD, directive 2000/60/EG) aims at achieving a "good status" for rivers, lakes, groundwater bodies and coastal waters in Europe with an implementation deadline of 15 years which means that it aims at achieving said "good status" by 2015. The WFD provides a common framework for European water policy by linking physical planning with water resource planning and defining that water quality goes hand in hand with emission controls and groundwater protection. Apart from focusing on water quality the WFD centers on improving biodiversity (Kaika, 2003). The WFD is described by Kaika (2003) as a:
"[...] legally binding policy that provides a common framework for water management and protection in Europe and that promises to transform the European water sector".

4.2.3 Coastal Spatial Data Infrastructure (CSDI)

Same countries use the coastal SDI in the management of the coastal zone. But they are encountering several problems because of the users needs for spatial data in the marine environment to manage the coastal zone.

4.2.3.1 People

SDI people are data providers, consumers of values and data (Strain et al., 2004b). In the marine environment, people will come from private industries such as fishing, defense, aquaculture and transportation, as well as government at the local and national levels. When developing an SDI where these people are the users, it is important that their needs are taken into account, so that the SDI is oriented by users who are not just the users of the coastal zone, towards the marine area such as fishermen and offshore oil companies.

Data management should be integrated with national and international standards and policies and should share data between the institutions involved in maritime administration.

4.2.3.2 Standards

Standards, as defined by the International Organization for Standardization, are *"documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics, to ensure that materials, products, procedures, and services are fit for their purpose"*. Standards facilitate data sharing and increase interoperability and integrity of the different datasets. In the terrestrial environment, there are many different standards, often established at the international and national levels. The International Standards Organization Technical Committee 211 (ISO TC/211) has developed a set of 40 standards related to geographic information, most of which focus on terrestrial space data. In the marine environment the International Hydrographic Organization (IHO) in conjunction with the International Hydrographic Bureau have developed a transfer standard for digital hydrographic data (S-57 and S-100) and are examining other standards for marine data. These standards, however, are not at the same level of completeness as the ISO TC/211 standards.

Standardization at the international level is necessary for interoperability at national, regional and global levels. Standardization provides a common format for storing data, and thus allows data exchanged easily between vendors, value adders and users.

4.2.3.3 Policies

The policies cover access, data store, conformity, privacy, quality, content, and metadata. Policies are influenced by international best practice in spatial data management and exchange. It is likely that there will be differences in terms of data quality, data access and privacy among others (Strain et al., 2004a). In the marine environment there may be a need for the capability of data transfer for offshore or offshore data. Therefore, the complexity of the coastal environment may be more difficult to achieve the same level as terrestrial data and marine data.

4.2.3.4 Access Networks

To facilitate access to spatial data around the world, the access networks usually comprise data warehouses, data portals, one-stop shops, on-line atlases or similar. Use the coastal data without the ability of share of someone offshore is the big issues for the coastal SDI. For example, the rights and restrictions attached to a particular location in an accident of pollution in the sea.

4.2.3.5 Data

The coast environment is dynamic, multi-dimensional and composed by land and marine zone, which give a more difficult area for data collection and updating. the data is usually collected on a project-based approach and is rarely shared between different organizations. Some of land data can be extended to include the marine environment for this we need holistic SDI which includes coastal data and marine data in the same platform. The differences in the marine and terrestrial environments and in data collection and technology used will make a big challenge in the interoperability of data.

4.2.3.6 Partnerships

Multiple reports internationally have highlighted the need for better coordination and integration between and within levels of government to improve coastal zone management (Hudson and Smith, 2002; Middle, 2002).

Most countries around the world have agreed on the idea of a seamless administration system that includes the marine and terrestrial environments. Currently most countries have a land administration system and some kind of marine administration system, but these operate as separate entities causing a lack of management at the coastal zone.

The development of a holistic SDI platform would aid in combining these systems, through providing interoperable data from both environments and allowing integrated spatial management. This will recognize the interrelatedness of the marine and terrestrial environments and also improve management of activities or resources that occur across these boundaries.

4.3 Marine System Management

4.3.1 Marine Spatial Planning (MSP) and Ecosystem-Based Management(EBM)

Marine spatial planning (MSP) is widely recognized as an effective method for implementing ecosystem-based management (Katsanevakis et al., 2011; Pomeroy and Douvere, 2008). This requires the integration of best available science and data into decision making through the development of measurable indicators and planning guidelines (Ehler and Douvere, 2009). By definition, MSP results in geospatially explicit plans, and as such requires spatial data and information as key inputs. A variety of resource management and policy initiatives, including MSP, are increasingly making use of information provided by citizen science endeavors, and can make important contributions to environmental monitoring and mapping biodiversity (Hyder et al., 2015; Wood et al., 2015).

MSP is an approach that can make of the key components of applying the ecosystem approach to marine areas a reality. It does so by analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that typically have been specified through a political process.

Ecosystem-based management (EBM) is an integrated approach to managing natural resources and biodiversity by maintaining ecosystem processes, functions and services (Crowder and Norse, 2008; Cavanagh et al., 2016;

Nishida et al., 2016). The goal of EBM is to maintain healthy ecosystems capable of providing a range of benefits (McLeod et al., 2005; Lester et al., 2010). These benefits include food, energy, recreational opportunities and shoreline protection, many of which are declining or are seriously compromised in coastal and ocean ecosystems around the world (UNEP, 2006; Foley et al., 2010; Lester et al., 2010).

In Europe, the Marine Strategy Framework Directive (MSFD) and MSP are combined to facilitate management actions for sustainable use of coastal and marine resources. Environmental policies such as the MSFD focus on preventing and reducing adverse and undesirable changes to natural systems as the result of human activities (Harrald and Davies, 2010), and if required, mitigation of undesirable changes (Borja et al., 2010). Marine management as part of the political agenda has moved towards integrated and ecosystem-based management systems; quantitative cumulative impact assessments and analytical map- ping; and integrated monitoring.

4.3.2 Marine Strategy Framework Directive (MSFD)

Article 1.1 of directive 2008/56/EC (Marine Strategy Framework Directive) summarizes the directive very well:
"This Directive establishes a framework within which Member States shall take the necessary measures to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest".

To achieve the aim of a marine GES (Good Environmental Status) the directives proposes strategies which *"[...] protect and preserve the marine environment, prevent its deterioration or, where practicable, restore marine ecosystems in areas where they have been adversely affected" and "[...] prevent and reduce inputs in the marine environment [...] to ensure that there are no significant impacts on or risks to marine biodiversity, marine ecosystems, human health or legitimate uses of the sea."*

The initial assessment in conjunction with the definition what a GES is and the foundation of environmental targets and associated indicators was completed on 2012. On 2014 a monitoring program for on-going assessment and regular updating of said targets has to be implemented. The program of measures which aims at achieving or maintaining a GES developed in 2015 and operated in 2016.

The assessment of the reports which have to be prepared for the two program (monitoring and measures) are based on eleven descriptors – which are further subdivided into criteria and indicators:

(1) Biodiversity
(2) Invasive species
(3) Commercially exploited species
(4) Food webs
(5) Eutrophication
(6) Sea-floor integrity
(7) Hydrographical conditions
(8) Contaminants and pollution effects
(9) Contaminants in fish and other seafood
(10) Marine litter
(11) Underwater noise/energy

4.3.3 Marine Cadastre

The concept of a "Marine Cadastre" and the need to build a marine regulatory system and a cadastre that underpins offshore rights and responsibilities and sensibly matches its onshore counterpart (Robertson et al., 1999) became apparent in in late nineties' when awareness of the importance of marine natural resources and the recognition of the actual and potential value of a marine environment as an economic resource, led to increased competition for its' management. Important drivers are considered the enforcement of the United Nations Convention on the Law of the Sea (UNCLOS) in 1994, the rise of the environmental movement after the Rio Summit in 1992 and the continuous development of Spatial Data Infrastructures (Balla, 2015).

Following the rise of several research initiatives and pilot projects on the topic of Marine Cadastre, several definitions have been given in the attempt to conceptualize its notion and its content (Andersson et al., 2017). In this regard, and according to one of several definitions that have been given to the topic. The Marine Cadastre is *"a system to enable the boundaries of maritime rights and interests to be recorded, spatially managed and physically defined in relationship to the boundaries of other neighboring or underlying rights and interests."* (Grant, 1999).

Marine Cadastre is a marine information system, encompassing both the nature and spatial extent of the interests and property rights, with respect to ownership, various rights and responsibilities in the marine jurisdiction.

As with Land Cadastre, a second important term, along with the notion of the Marine Cadastre, is the idea of the marine or sea cadastre parcel which is defined as (De Latte, 2016):

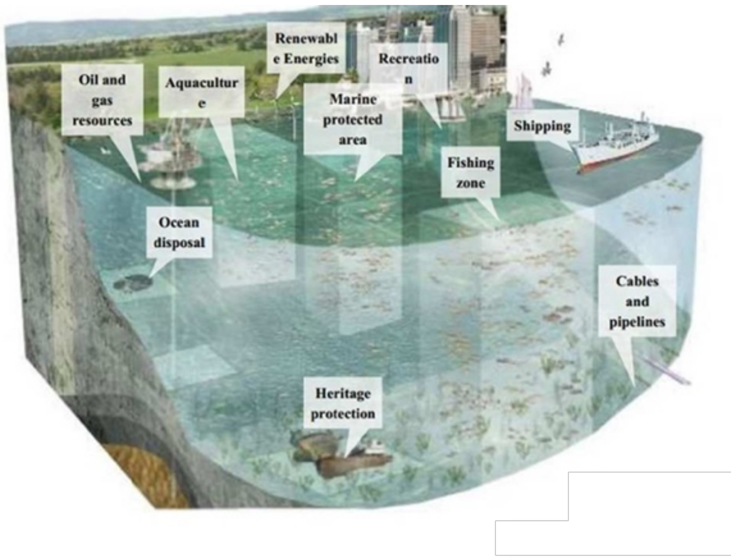

FIGURE 4.3: Concept of the Marine Cadastre (Andersson et al., 2017)

- The volumetric reality of every distinct marine zone (sea surface, water column, seabed or soil and subsoil) with:
  - The rights and charges under the UNCLOS;
  - The patrimonial rights which include rights in rem.
- Fourth dimension, meaning the temporary nature of many particular rights (fixed terms licenses, concessions and leases for mining, production of energy, aquaculture, fishing, etc.).
- A considerable portion of the conducted international research on Marine Cadastre considered the similarities and differences between the Marine Cadastre and its counterpart on land. Most of them converge on the fact that the marine environment has unique features that does not apply in the case of the terrestrial environment and therefore to the Land Registry and Cadastre (Binns et al., 2004; Collier et al., 2001; Widodo, 2003) though many of the cadastral components such as adjudication, survey, owner rights have a parallel condition in the ocean (Neely et al., 1998).
- Specifically, as regards the similarities, related research (Tamtomo, 2004), argues that as in the land cadastre, the marine cadastre has also been built based on three pillars or benchmarks, as follows:
  - The legal pillar (3R: rights, restrictions, and responsibilities); As a part of the legal system (legal cadastre), the marine cadastre

provides legal certainty to sea-space development planning, sea parcel rights and leases, and public access to and from the seas.

- The technical pillar (surveying, mapping, and spatial infrastructure). As far as concerning the technical pillar, a marine cadastre is designed as a tool and mechanism for providing data and information as a resource for planning and the decision making process, and as legal evidence of a certain sea and marine rights and lease.
- The institutional pillar (formal and informal institutions and human resources). The marine cadastre, as part of a public administration system, acts as a public service provider and sea-conflicts resolution.

Marine cadastre is a layer of MSDI: Marine Spatial Data Infrastructure including: seabed topography, geology, marine infrastructure, resources utilization, administrative and legal boundaries, areas of conservation, marine habitats and oceanography (IHO, 2011).

4.3.4 Marine Spatial Data Infrastructure (MSDI)

The Agenda 21 resolution of the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 already addressed the need to stop and reverse environmental deterioration.

The need for a specific or integrated Marine Spatial Data Infrastructure comes back to the United Nations Convention on the Law of the Sea (UNCLOS, 1982) under which marine boundaries are required to be managed and made available by each country. Also Maritime Spatial Planning (MSP), allocating rights for marine resources, defense, fisheries, monitoring marine areas, intercepting illegal activities, quick maritime surveillance, legislation covering oceans and ecosystem health, require detailed knowledge of maritime boundaries and other marine information.

The concept of the Marine Cadastre, is closely related to the concept of the Marine Spatial Data Infrastructure (MSDI). According to IHO (2011), *"Marine Spatial Data Infrastructure (MSDI) is the component of an SDI that encompasses marine geographic and business information in its widest sense. This would typically include seabed topography, geology, marine infrastructure, resources utilization, administrative and legal boundaries, areas of conservation, marine habitats and*

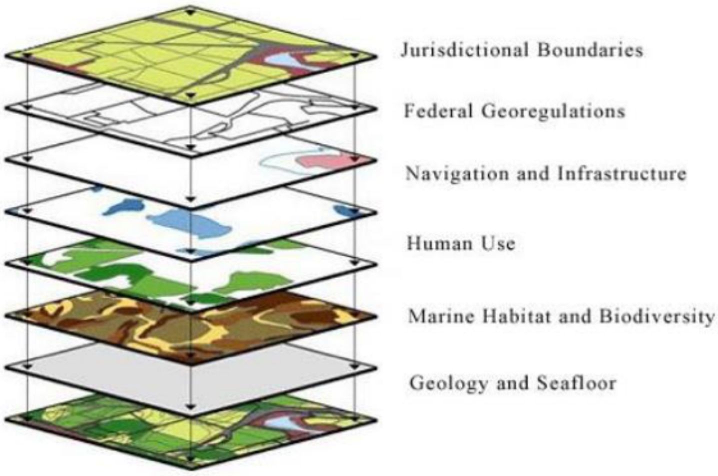

FIGURE 4.4: Marine Spatial Data Infrastructure themes (Fowler et al., 2010)

oceanography". MSDI places emphasis on the unlocking of hydrographic and all the other marine geospatial information.

In fact, the Marine Cadastre is considered as a base layer of a MSDI with fundamental information relating to maritime boundaries and associated rights and responsibilities, regularly updated and maintained (Sutherland and Nichols, 2006). In Malaysia in 2004, the role of the Marine Cadastre as a data layer in a marine SDI has been addressed in the international workshop on Administering the Marine Environment. The workshop recommended, in an analogy to a *"Land Administration System"*, to adopt the term *"Marine Administration System"* for the "administration of rights, restrictions and responsibilities in the marine environment with the spatial dimension facilitated by the Marine SDI. The workshop further recommended that *"a Marine Cadastre is defined as a management tool which spatially describes, visualizes and realizes formally and informally defined boundaries and associated rights, restrictions and responsibilities in the marine environment as a data layer in a marine SDI, allowing them to be more effectively identified, administered and accessed"*(PCGIAP, 2000). In order to avoid management gaps in the coastal zone, the workshop promoted the idea of a SDI-ICMM that includes data from land, coast and marine environments to enable the access and sharing of data between those environments to be improved.

According to Strain (2006), MSDIs are about the exchange and sharing of spatial data like SDIs with the significant difference that SDIs are primarily focused on land-related data, while MSDIs are aiming at improved access to marine themed data to advance marine and coastal zone administration

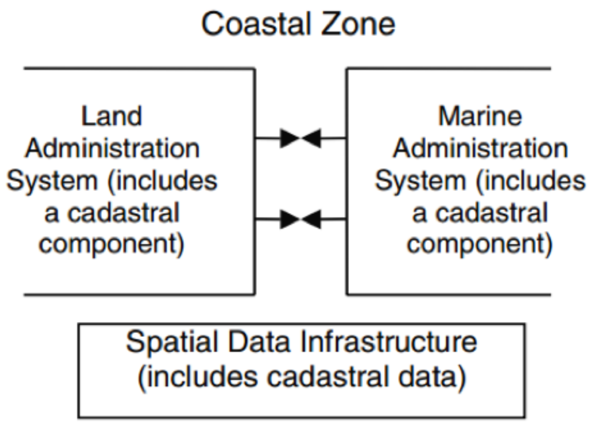

FIGURE 4.5: The spatial dimension in the marine environment (FIG, 2006)

and management. Figure 4.6 shows some of the activities marine and coastal zone administration involves and which an MSDI has to cover.

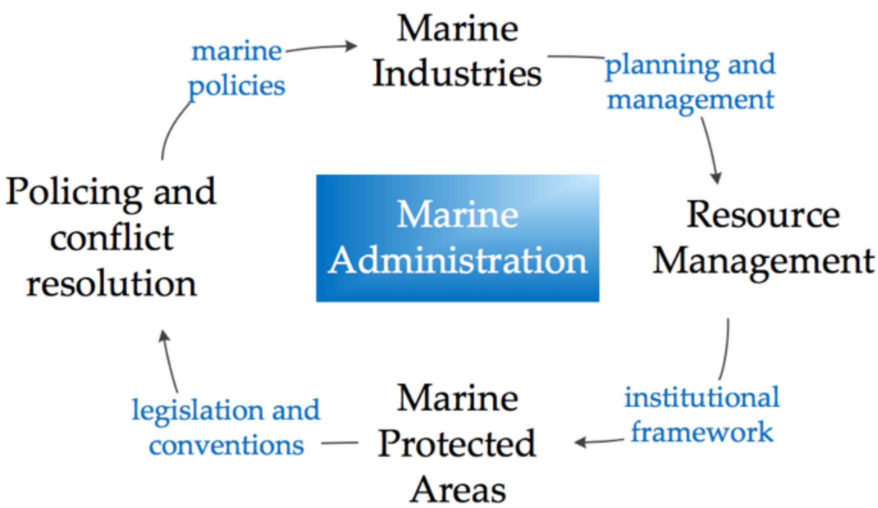

FIGURE 4.6: Marine administration (modified after (Strain, 2006))

As with Spatial Data Infrastructures, the field of the MSDI is very wide with a lot of related technological developments and applications. However, compared to SDIs, the Marine SDI has not yet taken a stance nor the terrestrial SDI, because the subject of MSDI is still new (Tares, 2013). Nevertheless, it has been argued further that even though the number of MSDI themes is currently relatively small in number, it's likely to increase as understanding and new activities evolve in the marine environment (Tares, 2013). It has to be indicated that an MSDI is not in all cases a component of a National SDI because is also stating examples for MSDIs on a regional and global level (Strain, 2006). While not mentioning a coherent example for a regional MSDI she lists two global MSDI initiatives: Global Oceans Observing System (GOOS) and Oceans 21. An example for a regional MSDI (although not calling itself SDI or MSDI) is the Oregon Coastal Atlas for instance.

Conflicts are starting to emerge in those six functional areas listed above, calling for Maritime Spatial Planning (MSP) or Coastal and Marine Spatial Planning (CMSP) in many locations. *"There is no doubt that GIS will be the technological basis on which marine spatial management will best function"* (Meaden and Aguilar-Manjarrez, 2013). To be sustainable, marine planning requires not only political, jurisdictional, socio-economical, technical etc. information on paper, but people responsible for planning and exploitation must get to know and understand the ocean, in particular (Tares, 2013).

The real challenges confronted by maritime planners include (Seys et al., 2004):

- Increase in the volumes of remotely sensed and other data;
- Diversity in data types: physicochemical, geological, meteorological and biological;
- Discrepancy between the scales at which data are gathered and at which needed;
- Global warming, sea-level rise, depletion of fish stocks, pollution etc.;
- Integration of local datasets to support global decision-making.

On the other hand, data and information can be exchanged in the internet quickly and at very low cost, and improving computers and database systems make it possible to analyze huge datasets and better manage the marine environment. Also international collaboration and standardization are aiming at interoperable terrestrial and marine data infrastructures.

Korduan (2013) analyses the coverage of marine data within the INSPIRE directive. He states that there are 19 themes important for the marine domain of which the most important ones are:

- Oceanographic Geographical Features (OF): e.g. sea surface temperature, currents, wave heights or salinity;
- Land Use (LU): use and functions of a territory, e.g. Aquaculture and Fishing;

- Energy Resources (ER): e.g. offshore wind parks, energy derived from tidal movement, wave motion or ocean current;
- Mineral Resources (MR): e.g. mineral resources in or on the sea floor;
- Natural risk zones (NZ): e.g. marine related hazard types like floods;
- Environmental monitoring Facilities (EF): Oceanographic Geographical Features are derived from Environmental Monitoring Facilities;
- Habitats and biotopes (HB): e.g. includes fresh water and marine areas;
- Bio-geographical regions (BR): Areas of relatively homogeneous ecological conditions with common characteristics, e.g. Baltic sea;
- Sea Regions (SR): is a defined area of common characteristics, e.g. coastline;
- Area management/restriction/regulation zones and reporting units (AM): areas managed, regulated or used for reporting;
- Agricultural and Aquaculture Facilities (AF): e.g. marine and freshwater aquaculture;

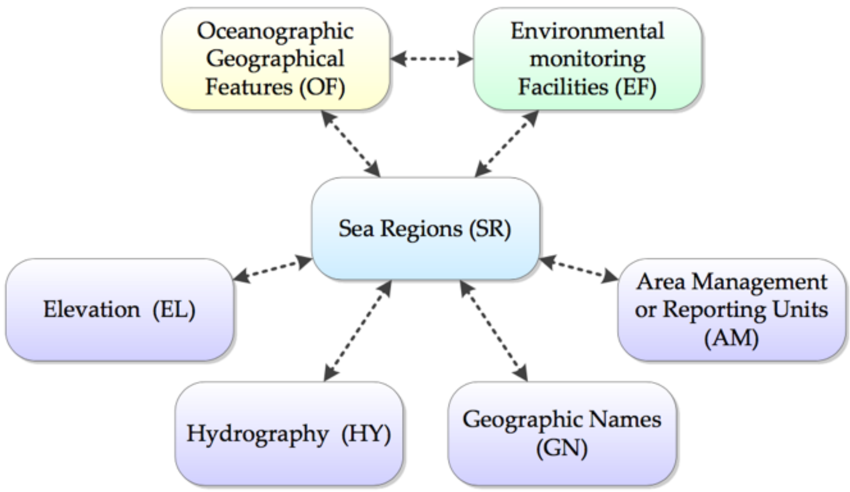

FIGURE 4.7: Links between selected INSPIRE themes

Figure 4.7 shows that some of the themes have relationships with each other and/or other non-marine specific themes. The connections are:

- **Oceanographic Geographical Features**
  - Oceanographic Geographical Features are derived from Environmental Monitoring Facilities (EF);

  - Oceanographic Geographic Features always contain information about Sea Region(SR);

- **Sea Regions**
  - Elevation (EL);
  - Main Sea Region class derives from Hydrography (HY);
  - Geographic Names (GN) are used for the named Sea Regions;
  - Geophysical observations: (described by the Oceanographic Geographical Features [OF] theme) are made within Sea Regions.

- **Area Management or Reporting Units**
  - Areas of the sea may be Area Management or Reporting Units (AM).

In general, the main sectors affected and focus is often on environmental information are the public and private sector. Marine spatial data infrastructure key stakeholders are related to government, industry, coastal tourism, marine resources, transportation, science and the general public. According to Nairn (2010) and GOOS (2013) they enclose environmental protection, coastal management, fisheries management, regional marine planning, hydrographic offices, oceanographic research, national meteorological and oceanographic agencies, offshore oil, gas and minerals exploration and industry, other marine and coastal industries, transport and post security, maritime safety and security, parties to international conventions, submarine cable and pipeline protection, indigenous interests, and policy makers.

4.4 Chapter Summary

This chapter highlighted coastal and marine management initiatives that aims to facilitate and coordinate the exchange and sharing of spatial information. It will provide an insight into SDI concepts and definitions in land and marine environments. It also highlights the role of SDI to improve management and administration of coastal and marine environments through better availability and applicability of spatial data.

These existing initiatives were used as a base to formulate holistic framework to integrate coastal and marine management and were adapted to the special needs of a Integrated Coastal and Mmarine Mmanagement.

5 Spatial Data Infrastructures

5.1 Introduction

Practitioners use information to build a realistic model of the world. This model is used for informative decision making. In order to achieve this, aim it is necessary that the information can be shared and accessed effectively. Information infrastructure allows effective information transmission and sharing. Information infrastructure consists of facilities, processes and standards to provide information to the users. Information infrastructure also creates new information from existing knowledge. Further, it enables information users to share knowledge with others, through information sharing and exchange.

Spatial information is a specific form of information and is a key commodity to the present day. Spatial information differs from other information forms. Spatial information is any information that can be linked to a geographic location. It is necessary to understand that spatial information is complex and while it can be included and managed in databases alongside other information, its coordination and maintenance require special skills. Spatial information enables the delivery of good governance and efficient business. As a result, spatial information must be accessible for analysis and use by decision-makers. SDI aims to facilitate the sharing, exchange and integration of multi-source spatial information through the provision of standards, policy framework, access and the establishment of partnerships and collaborations among spatial stakeholders.

SDI is a combination of technology, policies, standard and human resources that is necessary to facilitate and coordinate the exchange and sharing of spatial information between stakeholders of the spatial community.

5.2 Spatial Data Infrastructure Theory

Practitioners use information to build a realistic model of the world. Spatial information is a crucial and useful resource in many marine management and administration initiatives. This model is used for informative decision making. In order to achieve this aim, it is necessary that the information can be shared and accessed effectively. Information infrastructure allows effective information transmission and sharing. Spatial information is a specific form of information and is a key commodity to the present day. Spatial information differs from other information forms. Spatial information is any information that can be linked to a geographic location in a way that gives understanding and relativity to other objects or resources. This ability to visualise the location of resources enables planning and management of the exploitation of these resources, allocation of the rights to them, and creation of restrictions and responsibilities for the protection of these resources. Therefore, the utilisation of spatial information and spatial services is a suitable means to optimise the sustainable management of our resources (Muggenhuber, 2003).

Spatial information must be accessible for analysis and use by decision-makers to play a significant role in many social, economic and political decisions. Governments, business and the general public rely heavily on spatial information for their daily decision-making (Onsrud and Rushton, 1995).

They consider spatial information as a resource and also a part of fundamental infrastructure that needs to be coordinated and managed effectively (Ryttersgaard 2001). In response to this situation, over the last few years' spatial data infrastructure (SDI) has been emerged at different levels, which is driven by business needs and technological developments to support both the government and the rapidly expanding spatial information industry (Williamson et al., 1998). Use of spatial data and spatial information in any field or discipline, particularly marine administration, requires a SDI to link data producers, providers, and value adders to data users. SDI aims to facilitate the sharing, exchanging and integrating of multi-source spatial information through the provision of standards, policy framework, access and the establishment of partnerships and collaborations among spatial stakeholders.

SDI is a platform where there is a link between services, jurisdictions, organisations and disciplines. This platform can provide the access and the use of information to users in all aspects of the land and marine environments. This information through the platform is used to enhance decision making and supports the sustainable development. An effective SDI can save resources, time, and effort for users by eliminating the duplication data, updating the data, facilitating the maintenance and sharing the data with users.

5.2.1 Spatial information

Spatial information is another form of information. About 80% of all information utilised by decision-makers is spatial information (Masser, 2005; Ryttersgaard, 2001; Klinkenberg, 2003). Spatial information (also known as geographic information) is any information that can be geographically referenced. According to Rajabifard (2002), people need spatial data and its derived information to establish the position of identified features on the surface of the Earth, such as natural or constructed features, oceans and more. Spatial information is usually stored as coordinates and topology, and is data that can be mapped. Spatial information is often accessed, manipulated or analysed through Geographic Information Systems (GIS). Spatial information is used in many disciplines, by many different people, for many different reasons. Some of the oldest disciplines, land surveying and geography, are built on the spatial paradigm (Lees and Williamson, 2004).

The term spatial information is used almost interchangeably with spatial data, geospatial information or data and geographic information (Warnest, 2005). By organising data, it is turned into information, so that we can easily draw conclusions. Having information available is necessary to promote a good understanding and knowledge for a particular discipline as described by (Doody, 2003):

Data + Context = Information
Information + Analysis = Understanding
Understanding + Management = Possibility of sustainable action

Therefore, information has context. Data can also be turned into information by "presenting", such as making it visual or auditory (Cleveland, 1982).

Spatial information can now be stored and coordinated in databases, but the specific characteristics of spatial information make it a different form of information. Spatial information is scale-dependent. It is dependent on data models that are diverse and have many dimensions. The size of spatial information and the need for management of spatial and attribute information require a specific set of tools and arrangements (Egenhofer, 1993). Hence, understanding the collection, management, manipulation, integration, use, presentation and querying of spatial information requires special skill sets.

Spatial information is a key and integral component for the delivery of good governance, defence, promoting efficiency in business and supporting sustainable development. It provides enabling technology for modern societies. It is also recognised as fundamental for wealth creation and good decision making. Spatial information plays a significant role in promoting economic development, improving stewardship of natural resources, helping to protect the environment and political decisions.

5.2.2 Spatial Data Infrastructure (SDI)

5.2.2.1 SDI's birth

While it is difficult to pinpoint the origins of the SDI concept, it appears that the term "**National Spatial Data Infrastructure**" may have first been described by a Canadian, Dr. John McLaughlin, in 1991 (McLaughlin, 1991). However, the term appeared several times without definition in the US National Research Council Mapping Science Committee's 1990 report, Spatial Data Needs: The Future of the National Mapping Program (MSCNRC, 1993). Other early references to the SDI concept were made by Rhind, 1992, (MSCNRC, 1993),)(Tosta, 1994), (EC Communities, 1995), (Brand, 1995) and, in a comprehensive paper on building an SDI, by (Coleman and McLaughlin, 1997; McLaughlin, 1991; Nicholls and Leatherman, 1996).

The first formal adoption of the SDI concept at the national level occurred in the United States in 1994, with the issuance of *Executive Order* 12906, establishing the National Spatial Data Infrastructure (NSDI) (FGDC, 2008). In 2002, the NSDI was incorporated into one of the most important policy documents for the coordination of geographic information in the United

States, the *Office of Management and Budget (OMB) Circular A-16*. While not called an SDI at the time, it may be argued that the Netherlands had an even earlier start, with implementation of its National Geographic Information Infrastructure (NGII) beginning in 1992 (now the National Georegistry). Other early adopters of the SDI model at the national level included Australia (Australian Spatial Data Infrastructure, initiated in 1998), Canada (Canadian Geospatial Data Infrastructure, initiated in 1999) (Hall, 2002), and Germany (Geodaten-Infrastruktur Deutschland – GDI-DE, initiated in 2001). While there was some earlier movement towards the SDI model in other European countries (e.g., Sweden, Denmark and the United Kingdom), the first comprehensive efforts began in most countries with the adoption of the INSPIRE Directive in May 2007, which created a mandatory requirement for the implementation of national SDIs by all European Union (EU) Member States (EC, 2007).

In 1997, Tunisia started to develop the national SDI. A program called The National Geomatisation Program (GEONAT), has been started, with a view to coordinating geo-information management actions in Tunisia. As a first step, the initiative is envisioned as the elaboration of a National Geomatics Development Strategy, whereby a structured approach followed to plan the efficient contribution of geo-information management to the national economy, including the clarification of geo-information-related legal and institutional issues. Unfortunately, the project encountered several difficulties and it was stopped several times, there was a period of almost a decade between original ideas and execution.

In the mid-1990s at the global level, Global SDI (GSDI) initiative was formed with a special focus on promoting international cooperation and collaboration in support of local, national and international spatial data infrastructure developments that allowed nations to better address social, economic, and environmental issues of pressing importance.

The recognition of the importance of SDI for the governments was accompanied by the formation of the Federal Geographic Data Committee (FGDC) in 1990 (McDougall, 2006). Since then, the FGDC attempted to develop a coordination framework, standards and the documentation of best practices in accordance with the National SDI (NSDI) objectives in building a national digital spatial data resource.

5.2.2.2 SDI definitions

Masser (2006a) addresses the diversity of approaches to SDI definition and development and believes that SDI has developed in all shapes and sizes.

Several attempts to define national, international and global SDI have been carried through more recently by different actors. These different SDI definitions show the change in attitude and focus of the SDI movement. The early views of SDI were about producing, accessing and having spatial data. The other views recognise that the data is important as well as the infrastructure that provide the technology to allow and promote data sharing between stakeholders.

In addition, many of the countries around the world are developing SDI at different levels which lead to multitude of definitions for SDI. Within the SDI community there are differences in the understanding of SDI and its potential benefits (Grus et al., 2007). One of the most challenging obstacles for SDI assessment and development is the different view and definition of SDI. There is much confusion resulting from the lack of an agreed and unique definition of SDI, its components and the relationships between them. Table 5.1 shows a number of SDI definitions and perspectives.

TABLE 5.1: SDI definitions by different communities

Source	Definition
Federal Register (1994)	SDI means the technology, policies, standards and human resources necessary to acquire process, store, distribute, and improve the utilisation of geospatial data.
Coleman and McLaughlin (1997)	SDI encompasses the policies, technologies, standards and human resources necessary for the effective collection, management, access, delivery and utilisation of geospatial data in a global community.

Table 5.1 – *Continued on next page*

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Groot and McLaughlin (2000)	SDI encompasses the networked geospatial databases and data handling facilities, the complex of institutional, organisational, technological, human and economic resources which interact with one another and underpin the design, implementation and maintenance of mechanisms facilitating the sharing, access to, and responsible use of geospatial data at an affordable cost for a specific application domain or enterprise.
Executive Office US President (2002)	The technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and preserve spatial data
Rajabifard (2002)	SDI is fundamentally about facilitating and coordinating the exchange and sharing of spatial data between stakeholders in the spatial community.
Wiberg (2002)	The basic components in the SDI are: - Information, different data sets with specific focus on reference data sets that form the foundation on which other spatial data sets are built, meta data is another important part of the information - Legislative and institutional framework - Human resources, technical systems and processes - Strategies and action plans for interoperability, dissemination and use of the information
GSDI (2004)	SDI is a collection of technologies, policies and institutional arrangements that facilitates the availability of and access to spatial data.
Kuhn (2005)	An SDI is a coordinated series of agreements on technology standards, institutional arrangements, and policies that enable the discovery and use of geospatial information by users and for purposes other than those it was created for.

Table 5.1 – *Continued on next page*

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EC (2007)	SDI means metadata, spatial data sets and spatial data services; network services and technologies; agreements on sharing, access and use; and coordination and monitoring mechanisms, processes and procedures, established, operated or made available in accordance with this Directive.
GSDI (2008)	The term "Spatial Data Infrastructure" (SDI) is often used to denote the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data.
IHO (2010)	SDI is a term used to summarise a range of activities, processes, relationships and physical entities that, taken together, provide for integrated management of spatial data, information and services.
Tonchovska et al. (2012)	Spatial Data Infrastructure (SDI) is defined as a framework of policies, institutional arrangements, technologies, data, and people that enables the sharing and effective usage of geographic information by standardizing formats and protocols for access and interoperability.
Hendriks et al. (2012)	A spatial data infrastructure (SDI) is that structure of technology, policies, criteria, standards and people necessary for improved acquisition, sharing and use of spatial data.
Tóth et al. (2012)	SDIs should encompass the common spatial aspects constituting a generic location context for a wide variety of applications.
LINZ (2015)	SDI is the technology, policies, standards, and human resources necessary to acquire, process, store, distribute and improve the usability of geospatial data. Essentially, an SDI is the full framework supporting the use of geospatial information.

Table 5.1 – *Continued on next page*

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Wikipedia (2017d)	A spatial data infrastructure (SDI) is a data infrastructure implementing a framework of geographic data, metadata, users and tools that are interactively connected in order to use spatial data in an efficient and flexible way.

These attempts have resulted in slightly different definitions there are some common basic components within the models: to improve access and use of spatial data through enabling different people to share their spatial data products. These definitions also explain the interaction between spatial data stakeholders and spatial data through a number of technical and non-technical components including people, fundamental data, technology, metadata, standards, policies, institutional arrangements and financial resources.

SDI is a term used to summarise a range of activities, processes, relationships and physical entities that, taken together, provide for an integrated management of spatial data, information and services (IHO, 2011). The term:

- Covers the processes that integrate technology, policies, criteria, standards and people necessary to promote geospatial data sharing throughout all levels of the public sector;
- Embraces the structure of working practices and relationships among data producers and users that facilitates data sharing and use. It covers the set of actions and new ways of accessing, sharing and using geographic data that enable far more comprehensive analysis at all levels of government, the commercial and not-for-profit sectors and academia;
- Describes the hardware, software and system components necessary to support these processes.

5.2.2.3 SDI components

As can be seen, the aspects are already categorized which suggests the possible components of an SDI. For two of the aspects the GSDI Cookbook (Nebert, 2004) is giving more in-depth information in its comprehensive definition of the term. Firstly, it describes the beforehand mentioned users of an SDI more precisely as *"[...] users and providers within all levels of government, the commercial sector, the non-profit sector, academia and by citizens in general"* and secondly it specifies the organizational or policy aspect in the sense that an SDI *"[...] must also include the organisational agreements needed to coordinate and administer it on a local, regional, national, and or transnational scale."*

The findings so far align with the components of an SDI found in (Rajabifard and Williamson, 2001) and which can be seen in figure 5.1: people, data, access network, policy and standards.

This model proposes that the fundamental interaction between spatial data and the stakeholders (people) is governed by the dynamic technological components of SDI including access networks, policies and standards. The dynamic components mean that it can be updated or expanded with changing technology or user needs, or to include a new environment.

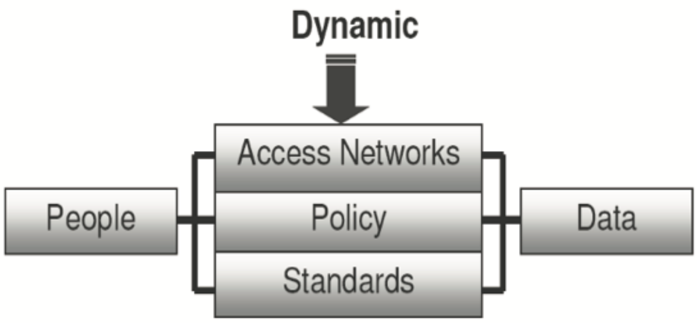

FIGURE 5.1: Components of SDI. (Rajabifard and Williamson, 2001)

But the GSDI Cookbook is digging deeper into the components of an SDI as it did with the other aspects mentioned (Nebert, 2004). It lists the components as:

- Metadata (geographic data and attributes, sufficient documentation);
- Catalogues and web mapping (discovery, visualization, evaluation);
- Access;
- Additional services for data application.

This leads to an extended view of the components of an SDI and results in the refined figure 5.2.

On the other hand, the Executive Office US President (2002) has introduced five components for US National SDI. The components of the SDI as can

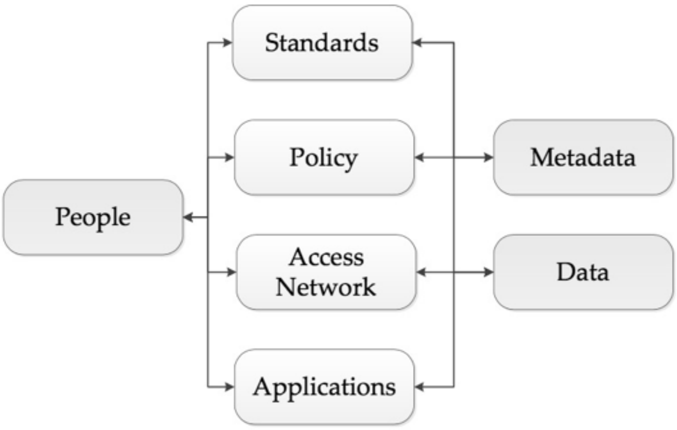

FIGURE 5.2: Components of an SDI expanded with aspects (Nebert, 2004)

be seen in figure 5.3 are fundamental data themes, metadata, the National spatial data clearinghouse, standards, and partnerships.

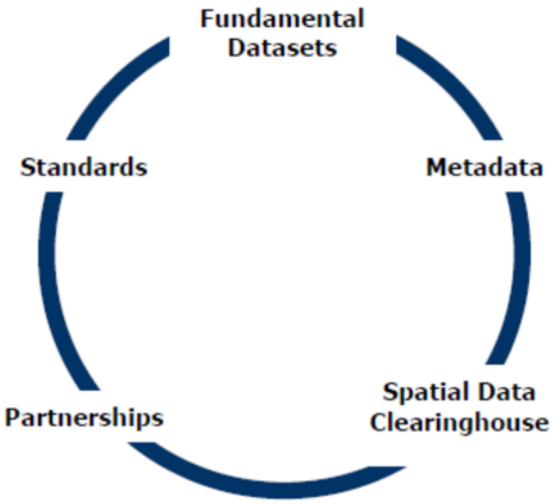

FIGURE 5.3: SDI components (Executive Office US President, 2002)

In Canada, the CGDI has identified five main components for Canadian SDI, including technology, policy, framework, standards (PCIDEA, 2013).

In general, as these examples show, the SDI components include spatial information, people, institutional arrangements, standards, metadata, access network, partnerships, governance and capacity building. These components are seen to be the tools which enable users and producers of spatial data to interact and cooperate with each other (Chan et al., 2001), reducing costs, both in terms of time and money, associated with the management and compilation of spatial data.

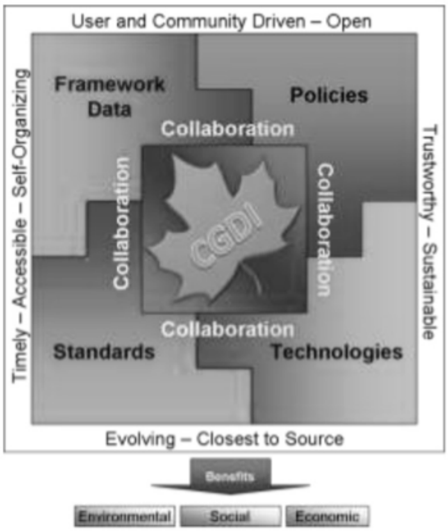

FIGURE 5.4: CGDI components and guiding (PCIDEA, 2013)

The concept and the development of the SDI framework have matured, in particular, capacity building, spatial data sharing, partnership and governance. Table 5.2 summarises the most important components of SDI.

TABLE 5.2: Major SDI components

Institutional Arrangements	The mechanisms created to enable key stakeholders to collaborate and engage actively in the planning and implementation of the SDI. These can take the form of legislation, regulations, policies or written agreements, or be developed through more informal negotiation.
Framework Data	The set of continuous and fully integrated spatial data that provides context and reference information for a jurisdiction. Framework data are expected to be widely used and generally applicable.
Policies	The strategic level instruments that help facilitate the development or use of an SDI. Strategic policies address high-level issues and set directions for organizations. Operational policies address topics related to the lifecycle of spatial data and help facilitate access to and use of spatial information.

Table 5.2 – *Continued from previous page*

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Standards	Spatial standards are technical documents that detail interfaces or encodings, which have been developed to address specific interoperability challenges. The more standards are the structure and content of information, the more effectively it can be accessed, exchanged and used by both humans and electronic devices. SDI-implementing organizations typically adopt international standards developed collaboratively by the International Organization for Standardization (ISO) and the Open Geospatial Consortium (OGC).
Technologies	The technological architecture of an SDI is composed of a network of physical servers that provide Web services and data. The Internet is the tool through which data and services are accessed so that users can produce and analyse spatial information to make informed decisions.

5.2.2.4 SDI classification

It has been recognised that SDI are hierarchically nested and inter-connected (Chan and Williamson, 1999). The SDI hierarchy model has been further extended to offer two views of the nature of relationships between the hierarchical levels – an umbrella view and a building block view (Rajabifard et al., 2000).

According to the theory of hierarchical spatial reasoning and its philosophical foundations in the work of Koestler (1969), an SDI is a holon i.e. something that is both a whole (i.e. an SDI in its own right) and a part (a sub-SDI within an SDI at a higher level of the hierarchy). From this perspective, governance of an SDI comprises the governance of the whole and the governance of the parts.

Hierarchical spatial reasoning further extends the theory of hierarchical SDI by attempting to represent the horizontal as well as vertical relationships between each hierarchical level (Rajabifard et al., 2000).

Central to hierarchical SDI models (Figure 5.5) aims to enable geospatial exchange and re-use between SDIs both horizontally (with SDIs on the same level) and vertically (with SDIs at higher and lower levels). SDI initiatives are developing at various political or administrative levels from local through state, national, regional to global. SDI is developed at each particular level or within each discipline to promote better decision-making and therefore better social, economic and environmental outcomes for that particular level (Rajabifard, 2002). In general, the various levels are a function of scale. Local government and state-level SDIs manage large and medium-scale data, leaving national SDIs to manage medium- to small-scale data, with regional and global SDIs adopting a small scale for their activities. In addition to the vertical relationships between different jurisdictional levels, complex horizontal relationships within each political or administrative level need to be analysed. The vertical and horizontal relationships within a SDI hierarchy are very complex because of their dynamic inter- and intra-jurisdictional nature (Rajabifard, 2002). Users of a SDI thus need to understand all the relationships involved in the dynamic partnerships it supports.

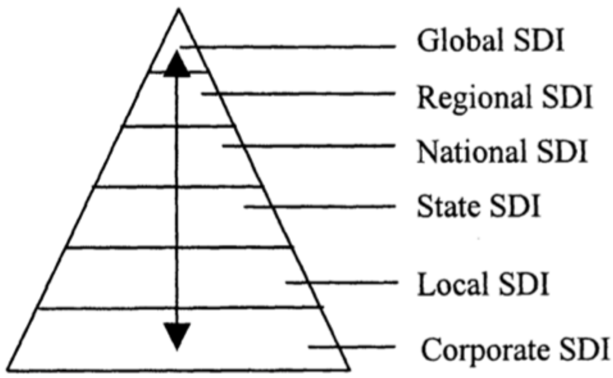

FIGURE 5.5: Hierarchical SDI models (Rajabifard et al., 2000)

In the umbrella view (Figure 5.6), the higher level SDI (e.g. Global or Regional levels) comprises the enabling components, such as institutional framework, human resources, standards and access network that support sharing of data held by lower level constituent SDIs (e.g. State or Local). This is a "top down" institutional perspective of SDI hierarchy as higher levels covers lower levels. In the building block view, SDIs at lower levels act as building blocks, providing geo-spatial data required by SDIs situated at higher levels of the hierarchy. This "bottom-up", "data-centric" perspective of SDI hierarchy emphasises the notion of SDI as a data sharing partnership. In the other way any level of SDI, for example the State level, serves as the building blocks supporting the provision of spatial data needed by SDIs at higher levels in the hierarchy, such as National or Regional levels.

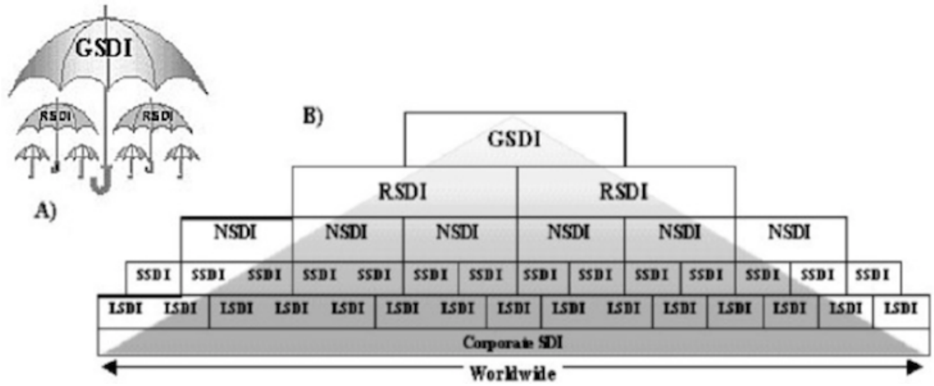

FIGURE 5.6: A- The umbrella view of SDI, B- The building block view of SDI (Rajabifard et al., 2000)

Associated with the recognition of hierarchical relationships between SDIs is the notion of multi-level SDI implementation (Masser, 2005). SDI initiatives tend to be implemented concurrently at multiple levels of the SDI hierarchy under varying degrees of coordination and governance.

However, Masser (2005) believes that although the properties and characteristics of the hierarchical system might be essential for the development of a consistent data structure, the absence of a strict hierarchical structure does not necessarily inhibit the implementation of SDI initiatives.

Spatial data integration and harmonisation have been identified as a major challenge for next generation of SDIs (Rajabifard et al., 2005b; Muggenhuber, 2003). Among current challenges of next generation of SDI, the integration of land and marine spatial data and building a holistic and integrated SDI that covers land and marine environments.

5.2.3 SDI and Data Sharing

SDIs are thought to have a dynamic structure. This is addressed by both change in the nature of SDIs and the external environment including the advancement in technology (Rajabifard et al., 2003). The dynamic environment of SDI presents uncertainty for the organizations involved (Omran, 2007a), which leads them to focus on cooperative relationships. One of these relationships is data sharing. Spatial data sharing has been defined as transactions in which individuals, organisations or parts of organisations obtain access from other individuals, organisations or parts of organisations to spatial data (Omran, 2007b). A coordinated approach to sharing spatial information will result in a number of benefits to participants, including:

- Reduction in the duplication of datasets, systems and processes
- Sharing the investment costs to make the data available to broader sector.
- Higher quality datasets
- Improved access to spatial data with security
- Development of partnerships across the entire spatial sector (public, private and academia).
- Interoperability by adoption of common standards for data;
- Broader coverage of data across multiple jurisdictions and sectors.

The capacity to meet such user needs and deliver services and tools within the spatial information community has gone far beyond the ability of single organisations (Rajabifard et al., 2005a). There is now a wide range of products and services available for a wide range of information technology applications, and hence the development of an enabling platform can facilitate access to data and sharing resources and tools among different practitioners (Omran, 2007a).

The sharing of spatial data involves more than simple data exchange. In order to facilitate the spatial data sharing, spatial stakeholders need to deal with many issues including the technical and non-technical aspects of data integration (Onsrud and Rushton, 1995). The appropriate focus for sharing data is data integration. Integrating data in a spatial system increases its effectiveness. Data integration facilitates the ability to share access to data sources or access common databases (Montalvo, 2003).

5.2.4 SDI and Interoperability

"Interoperability among components of large-scale, distributed systems is the ability to exchange services and data with one another." (Heiler, 1995) Interoperability is the base for SDI development, i.e. makes it possible. Peter (2009) states that interoperability has technical as well as organizational aspects which are depicted in figure 5.7. This figure also shows five elements that characterize interoperability:

(1) Directives and laws
(2) Standards and norms
(3) Profiles/Data modelling
(4) Data transfer/Services
(5) Semantic transformation

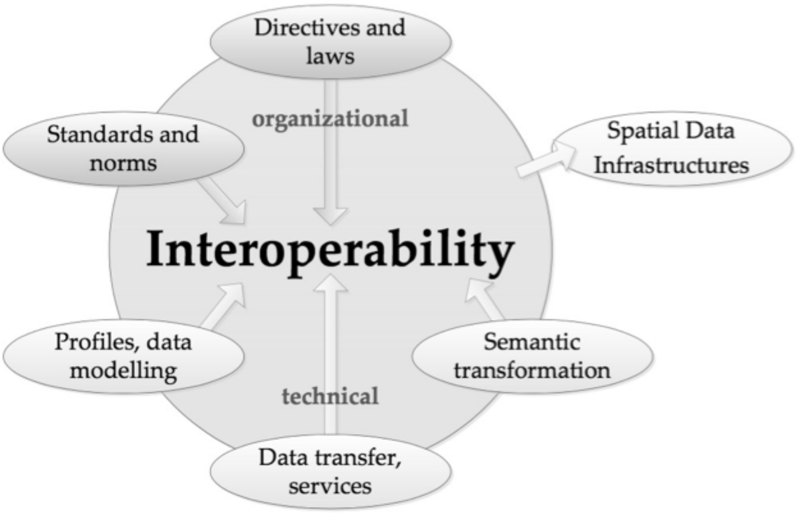

FIGURE 5.7: Interoperability (Peter, 2009)

An infrastructure with spatial data and a network of distributed nodes is called a spatial data infrastructure (SDI) and if the data sets handle spatial information in the marine domain it is called a marine (spatial) data infrastructure (MSDI). All these nodes use web services ([4] data transfer/services) so that the data owners do not have to push data files back and forth trying to keep track of which the current and most up-to-date version is. To make a SDI work the web services have to be able to communicate with each other. To achieve this web services, have to be based on standards ([2] standards and norms). Now that there are web services, standards for web services and nodes which are relying on web services, it must consider the architecture to compose the network of nodes. This can be modelled with the help of a reference model based on the ISO standard Reference Model of Open Distributed Processing (RM-ODP).

5.2.5 SDI and Data Integration

The value of a spatial dataset rests on its *"coverage, the strengths of its representation of diversity, its truth within a constrained definition of that word, and on its availability"* (Longley et al., 1999) and the integrability with other datasets (Rajabifard and Williamson, 2004). Backx (2003) has categorised spatial datasets into three major classes (Figure 5.8):

- **Known**: recognisable and findable;
- **Reachable**: available and payable;
- **Usable**: clear, handleable and reliable.

FIGURE 5.8: Spatial data usability model (Backx, 2003)

Moreover, there is urgent demand for harmonisation and integration services that harmonise data for optimised common use. In many cases, it is often difficult or even impossible for users to sensibly combine data from different sources (Ryttersgaard, 2001). Muggenhuber (2003) identifies the continuum of spatial data management within the context of SDIs. He explains the progress made and highlights the current challenges. In this progress, GIS played the main tools to implement the SDI. The current demand is to provide integrable and harmonised spatial data for broad and maximum use (Figure 5.9). This aim was highly dependent on institutional arrangements, which requires cooperation and partnership to share spatial data with other stakeholders.

The issues and obstacles associated with multi-source spatial data integration had been recognized for many years (Chrisman and Niemann, 1985), however there has not been a holistic approach to deal with these issues before the introduction of SDIs. One of the major international challenges of building SDIs is linking distributed heterogeneous spatial information resources from different data providers in an application-oriented and user-oriented way (Donaubauer, 2005).

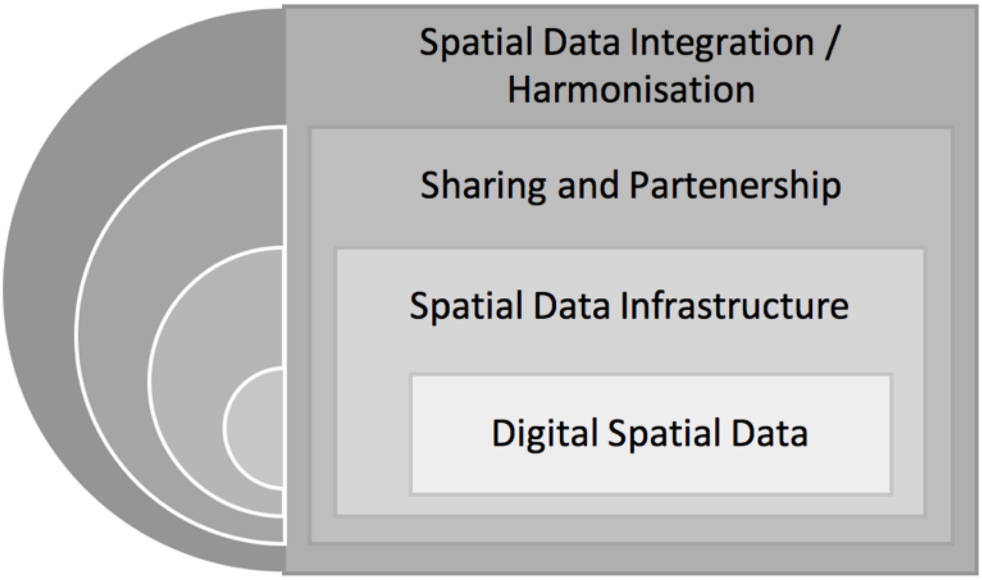

FIGURE 5.9: Spatial data management continuum

Effective spatial data integration can also be an identification and measure to show the success of an SDI. The assessment of SDI is difficult due to its complex, dynamic and ever-evolving nature.

Spatial data integration is claimed as one the most important aims and future directions of SDIs. Hence the degree of success in providing effective spatial data integration measures the success of SDIs.

5.2.6 SDI's challenges

In order to assist the spatial community, spatial information resources should be used widely by a broad range of citizens through SDI initiatives. In this regard SDI research should resolve the gaps in SDI advancement. Onsrud et al. (2004) highlight the social and the institutional issues as the most outstanding issues to focus on in future developments of SDI. Since the first establishment of SDI, SDI has faced many challenges and constraints almost in every SDI initiative. Therefore, it is important to study these challenges that happened around the world in order to avoid or overcome them before facing difficulties in implementing an SDI. There are some of the challenges that could be similar in most of the nations. These are (Alhubail, 2003; Arshad and Hanifah, 2010; GINIE, 2004; Manisa and Nkwae, 2007; Minh, 2009; Sen et al., 2006):

- Accessibility of the data;

- Availability of digital data;
- Need of Coordination (Institutional arrangements);
- Incompatibility of data (lack of standards);
- Lack of experts (knowledge and skills);
- Absence of technology infrastructure;
- Lack of Awareness;
- Funding limitation;
- Availability of Metadata;
- Need of Legal aspects;
- Difference in languages;
- Weak Cooperation;
- Long Term Benefits.

Masser et al. (2008) believe that the next significant step in SDI development is the spatial enablement of the government. They also urge that the future of SDIs is reliant on the ever-increasing involvement of the government in SDI development. There are many parallels between concepts based on which SDIs are developed and the vision of spatially enabling the governments. Spatial data integration and harmonisation have been identified as a major challenge for next generation of SDIs (Rajabifard et al., 2005b; Muggenhuber, 2003).

5.3 Marine SDI initiatives

The establishment of an SDI requires the collaboration of many parties. This collaboration can be based on voluntary agreements between the interested parties, or it can be more formally regulated, or even legally enforced, mandating the targeted organisations to fulfil the provisions of legal acts. Voluntary initiatives, such as GSDI and some national SDIs, are often coordinated by international and national associations or umbrella organisations.

According to Longley et al. (2011) there are over 150 SDI initiatives described in the literature. Most spatial information management and administration tools have focused on the terrestrial environment.

To meet the need to improve management and administration of the marine environment many countries launched some initiatives like Marine SDI, marine cadastre and marine spatial planning.

Management of the various Rights, Restrictions and Responsibilities (RRRs) is ideally achieved through the cadastre. In marine environment, there is marine cadastre that delineates, manages, and administers legally the off-shore boundaries. Nevertheless, the marine environment requires an overarching spatial information platform that facilitates coordinated use and administration of these tools.

SDIs is the best approach for maximum integration and security of data, effective resource use, and development of comprehensive information systems.

While the concept of Marine SDI is relatively important, the idea of supporting marine and coastal management through better access to spatial data or information is more established. Several countries and different jurisdictions are trying to improve their marine management through improving the accessibility and availability of spatial data. Often while these initiatives are not labelled "SDI" they share some of the objectives and concepts of SDI. Nebert in the SDI cookbook (GSDI, 2004) states that when developing SDI, the following areas need to be considered: definition, objectives, principles, rules and responsibilities, coordination, policies and guidelines.

Table 5.3 shows different perceptions and definitions of spatial information management initiatives in the marine environment.

TABLE 5.3: Examples of marine administration in the world

Country	**Marine Administration**	
Canada	MGDI	MGDI is described as spatial and temporal data infrastructure comprising data and information products, enabling technologies as well as network linkages, standards and institutional policies (Gillespie et al., 2000) and is critical to sustainable development, management and control of national marine, coastal and freshwater areas.
	Marine cadastre	Marine Cadastre is an information system that not only records the interests but also facilitates the visualisation of the associated rights, restrictions and responsibilities in the marine environment (Ng'Ang'A et al., 2002).
USA	Coastal SDI	Coastal SDI is a technology to facilitate discovery, collection, description, access and preservation of spatial data that should be widely available to the coastal zone management community .
	CMSP	Coastal and Marine Spatial Planning Data Registry (CMSP) by the NOAA "[...] *is a collection of Web-accessible NOAA geospatial data deemed essential for local, regional, or national-level CMSP processes."*
	Marine Cadastre	MarineCadastre.gov is an integrated marine information system that provides data, tools, and technical support for ocean and Great Lakes planning (Marine Cadastre, 2017).
Australia	Marine SDI	Marine SDI is an internet-based, customer focused view into data and information of interest to users of the marine environment (Finney and Mosbauer, 2003). Marine SDI has emerged to facilitate marine administration.

Table 5.3 – *Continued on next page*

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	Marine Cadastre	Marine Cadastre is a management tool that spatially describes, visualises, and realises formally and informally defined boundaries as associated rights, restrictions, and responsibilities in the marine environment (Binns et al., 2004).
UK	MAGIC / CAMRA	Multi-Agency Geographic Information for the Countryside (MAGIC) is a web map application that combines data on key environmental schemes and designations and which involves six government organisations. The atlas features a list of priority datasets including important coastal and marine habitats and species, as well as physical geography and relevant infrastructure. The Atlas is a web map tool offering access to a wide range of information on coastal and marine resources.
	MEDIN	The UK Marine Environmental Data and Information Network (MEDIN) is offering a framework for marine data management in the UK through clearing up terms and conditions for data use, coordinating marine survey and research activities, defining data specifications for improved data management and of course better access to data.
Europe	INSPIRE	INSPIRE (INfrastructure for SPatial InfoRmation in Europe) aims at making available relevant, harmonised and quality geographic information for the purpose of formulation, implementation, monitoring and evaluation of Community policy-making (Ryttersgaard, 2004).

The cadastral component and the SDI are fundamental to have competent marine administration by development and sharing the marine information (Figure 5.10). The marine cadastre was seen as a management tool that spatially describes, visualises, and realises formally and informally defined boundaries along with their associated RRRs in the marine environment. This tool, in turn, is central to the Marine SDI, facilitating the use of interoperable spatial information relevant to the sustainable development of marine environments.

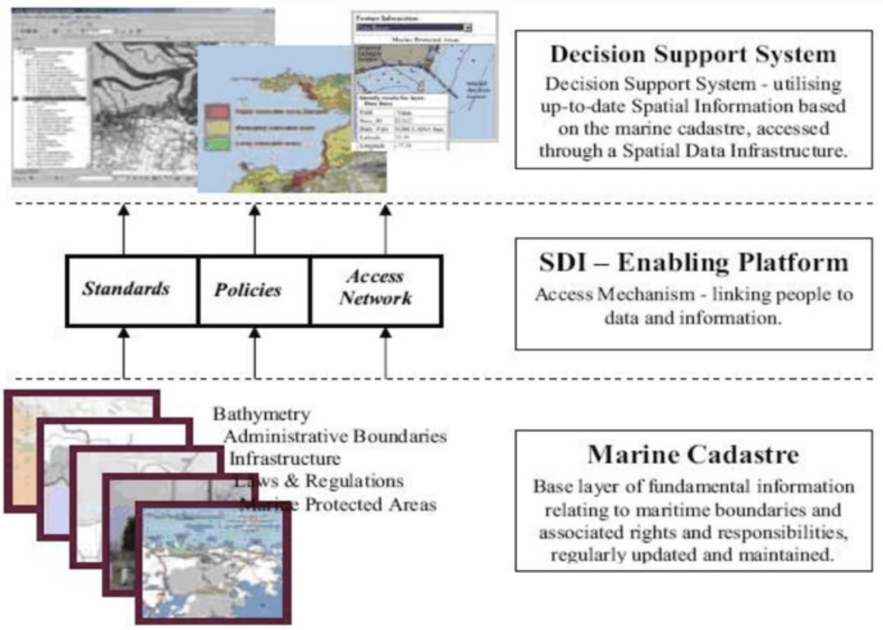

FIGURE 5.10: A marine cadastre and SDI are essential component of effective marine administration. (Rajabifard et al., 2006)

Marine SDI encompasses marine geographic and business information and covers the sea areas, inland navigable and non-navigable waters. It is a component of National SDI. This would typically include seabed topography, geology, marine infrastructure (e.g. bathymetry, wrecks, off-shore installations, pipelines and cables etc); administrative and legal boundaries, areas of conservation, marine habitats and oceanography (Ozborne and J.Pepper, 2007).

The different definitions of SDI (Table 5.1) can be expected due to the dynamic concept of SDI which can include new environments and a broad variety of information.

Current situation need for cooperation and collaboration between Global, regional and national effort in order to create an overarching spatial information platform that improves access and sharing of marine spatial data and facilitates coordinated use and administration in an integrated and holistic approach.

5.4 The Need for a SDI-ICMM Platform

All the SDI initiatives described above indicate the need for improving marine and/or coastal spatial data sharing. The main difference between all these initiatives is that some include the coastal zone as part of the Marine SDI and some others only focus on the marine environment, and have not yet considered including the coastal zone, but these operate as separate entities causing confusion and a lack of management at the coastal zone. Therefore, some countries are beginning to consider extending their land management systems to include the marine environment, while others are examining developing a different system to manage their marine area separately (Strain et al., 2004a). However, the separation between land administration system and marine administration system impedes the management of the coastal zone. This is the case for all countries.

The need to effectively manage the coastal zone as well as the need for integration of data between the three environments (land, coast, marine) requires a management system that incorporates them all (Strain, 2006). There is a need to make the land and marine infrastructures interoperable so that planning, management and solutions can be identified in a seamless and holistic way.

If two separate SDIs were created it would deepen the gap between these two administration systems and make coastal zone management more difficult. There is an opportunity for more research to be conducted into combining these initiatives and developing a SDI-ICMM that can include spatial data from all environments. Using common SDI standards, policies and access networks can ensure that this spatial data is interoperable, facilitating the design of a SDI-ICMM and thus improving decision-making and administration in the coastal and marine environments.

The idea of a holistic administration system that covers both the marine and terrestrial environments is generally accepted and non-controversial. A more integrated approach would be supported by the development of a SDI-ICMM. SDIs theoretically comprise networked, spatially-enabled databases or datasets that are accessible for downloading or manipulation using contemporary technologies, usually according to explicit institutional arrangements and are supported by policies, standards, and human capital (Rajabifard and Williamson, 2001; GSDI, 2004). It has been recognised that there is a need for a better and more comprehensive way to link different off-shore initiatives offering a more integrated understanding of the marine and coastal environments as there is a close connection between inland and marine coastal areas. SDI aims to facilitate the sharing, exchange and integration of land and marine spatial information through the provision of standards, policy framework, access and the establishment of partnerships and collaborations among spatial stakeholders.

A SDI-ICMM is an essential implementation strategy that allows integrated spatial management of interoperable data from both environments. This SDI should deliver an integrated and holistic model that creates a spatially enabled land - marine interface and bridges the gap between the terrestrial and marine environments (Figure 5.11).

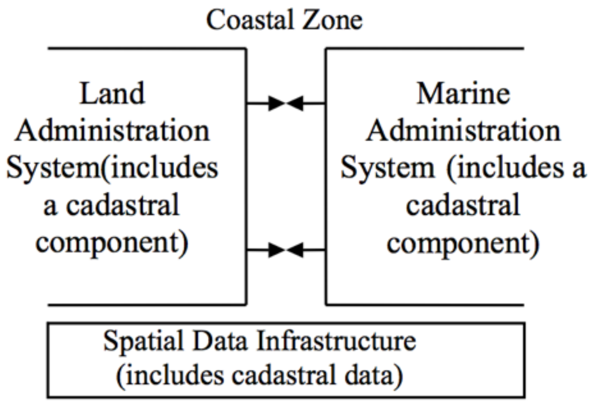

FIGURE 5.11: Combining Administration Systems: marine and land management (PCGIAP, 2000)

An essential requirement for the consistent and effective management of the marine and coastal environments is reliable, comprehensive and accurate spatial data. Nevertheless, the traditional SDIs is confined to the land-ward or marine-ward with little or no thought given to the interaction between these two environments. The reality is that the need for access and coordination of spatial data does not stop at the coastline.

The interactions between physical and institutional elements in the coast, makes it impossible to develop a Marine SDI in isolation from land-based initiatives due to the multiple physical and institutional spaces that exist within the coastal zone. Both the marine and terrestrial environments are tightly integrated systems in which all the parts are interrelated and dependent on one another. Furthermore, a holistic platform aids in facilitating more integrated and effective approaches to coastal zone management, dealing with problems such as marine pollution from land-based sources (Williamson et al., 2004b), climate change and the potential sea- level rises. Spatial data platform that enables a holistic approach let overcome many coastal management issues.

Despite the land issues such as immature institutional arrangements, data integratability and data interoperability, the marine environment are more issues due to the characteristic of boundaries (4D). The integratability and interoperability of marine- based and land-based databases and also the data gaps over the coastal zone, are the major issues within this region. Vaez et al. (2008) illustrate the entirety of these issues in land, marine and coastal environments (Figure 5.12)

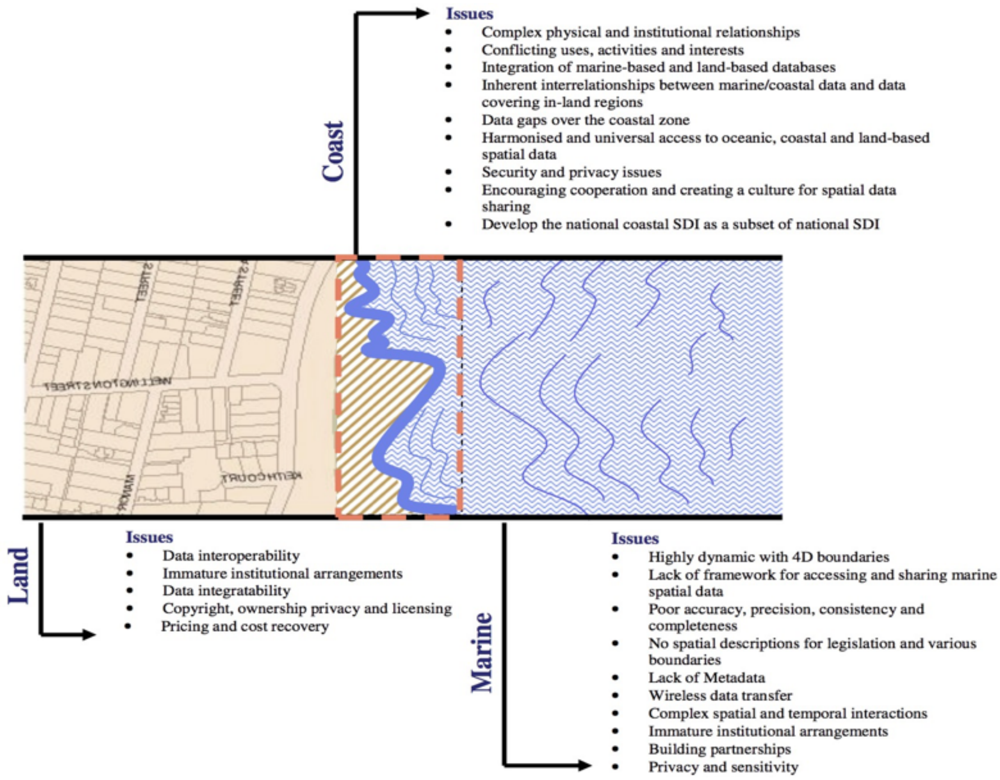

FIGURE 5.12: Issues of the land, coast and marine environments (Vaez et al., 2008)

Through development of a SDI platform we can improve management of the coastal zone by access to and interoperability of both marine and terrestrial spatial data. Ideally, this would result in a harmonised and universal access, sharing, and integration of coastal, marine, and terrestrial spatial datasets across regions and disciplines.

SDI-ICMM enable the utilisation of common boundaries across the coastal zone to ensure that no ambiguity exists. This infrastructure will become a powerful information resource for managers and improve decision making at all levels (fisheries habitat management, pollution monitoring and control, sea- level rise, shoreline erosion, global warming and tourism development). In this regard, the UN encouraged to develop a marine administration component as part of a SDI-ICMM covering both land and marine jurisdictions to ensure a continuum across the coastal zone.

5.5 SDI-ICMM Components

To describe land related spatial data and information, the researchers used recently the SDI concept. While these concepts might be applicable to improve marine administration, these components need to examine the ability to describe marine and coastal spatial data. There are some agencies and researchers have created their own NSDI components models based on their vision, goals, priorities, and the national requirements. A SDI is a platform that facilitates the interaction between people and data by providing required access channels, policies and standards (Rajabifard and Williamson, 2001; GSDI, 2004; Masser, 2006b) as illustrated in figure 5.13. All of these have their relevance and applications in the marine and coastal domains.

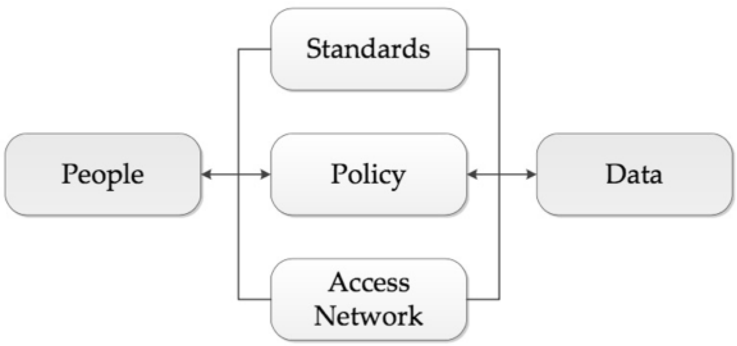

FIGURE 5.13: SDI and its components (modified after (Rajabifard and Williamson, 2001))

This section examines each component of SDI (fundamental datasets, standards, policies, access networks and people) and discusses its applicability to SDI-ICMM. It is important to note that the concept is dynamic, in that it provides an ability to be updated with changing technology or human attitudes or with the need for including new environments.

5.5.1 Data (Fundamental Datasets)

Arguably, the most important component of SDI is the information content which is available to users. Without content, expressed within a consistent coordinate reference system, SDI is of minimal use. At the core of this information is reference. Reference information may be defined as any geographic feature that is used as a location reference for application information, or can be used in geographic analysis.

The main objective of this component is to build datasets that offer a unique geo-referenced environment in order to ensure an easy transformation of the data between agencies. Also, the existence of such datasets will reduce the duplication and reduce the efforts that should be introduced in collecting and managing the data (Tosta, 1995).

The lack of accurate information seamlessly crossing the land – marine interface creates a serious obstacle for coastal zone managers. For decision-making, the managers need precise, accurate, and timely data. However, the marine environment is dynamic and multidimensional, providing a more difficult area for data collection and updating. Data is usually collected on a project-based approach and is rarely shared between different organisations (Strain et al., 2006b). A key issue is the availability of data. There is a substantial amount of data collected about the marine and coastal environments, but it is often not available to all users. The other issue is that if it is available, it may not be interoperable.

The need for specifically SDI are caused by the data requirements of coastal zone managers that go beyond of more terrestrially-focused or more marine-focused. For most Regional and Global SDI initiatives, there is not sufficient detail in specification of data elements to determine whether or not the needs of coastal and marine resource managers and researchers will be met (Bartlett et al., 2004).

INSPIRE Directive consisting of 34 spatial data themes required to successfully build environmental information systems. The integration of land and marine data is applicable to a number of themes in Annex I-III across the land and marine environments such as the elevation, hydrography/hydrology, transport networks, protected sides, buildings, land use, oceanographic geographical features, etc.

To have the possibility of harmonizing with such directives, SDI-ICMM model needs to cover all the fundamental datasets from land, marine and coastal environments.

Metadata is a file that has a format (XML) document that describes the content, quality and type of the data. In other words, it is the information used to describe data and its services. It can also be defined a summary document about the dataset, including the geographic area that the dataset covers, the custodian, who to contact to obtain a copy of the dataset and other useful information that helps people decide whether or not the dataset is useful for their particular purpose. The spatial data Metadata record usually includes core library catalogue elements such as Title, Abstract, and Publication Data; geographic elements such as Geographic Extent and Projection Information; and database elements such as Attribute Label Definitions and Attribute Domain Values.

Metadata needs to develop many procedures to implement a holistic seamless mechanism for all users of spatial digital data. Spatial Metadata is very important to serve the NSDI. Throughout the world, the users of NSDI have been utilizing the Content Standard for Digital Geospatial Metadata (CSDGM). The standards or policies of international Metadata should have the legacy and merge in community (FGDC, 2005).

5.5.2 Standards

Data would come from different sources; every source creates the data based on its needs and requirements. Thus, the integration, in case of using SDI with clearinghouse for data sharing, would become not trivial due to the differences in the structure of the data. Therefore, offering a unique standard data set structure will serve many users and give the data the ability for being shared. Standards are common and repeated rules, conditions, guidelines or characteristics for data, and related processes, technology and organisation.

There are two international standardization organizations work on the field of standardizing the digital geographic information. The first one is ISO/TC211 which is a standard technical committee constituted inside the International Organization for Standardization (ISO). Its work is similar to the second organization which is so-called Open GIS Consortium (OGC) but the latter is an international voluntary consensus. Both of them are responsible on creating international standards in geographic/ geomatics data (Marks and Bell, 2008). The standards are critical to developing a robust SDI approach. Any NSDI, in order to be successful in its aims, needs standard in many aspects: reference system, data dictionaries, data quality, data models, data transfer, and metadata (Williamson et al., 1998).

SDI must be based on interoperability (seamless databases and systems). Interoperability is an important part of sharing spatial data in a SDI (Smith, 2003). The differences in the marine and terrestrial environments in fundamental datasets, data collection and technology used in these environments will make interoperability between marine and terrestrial spatial data a big challenge. Standards are used to ensure interoperability and integratability of different datasets (Strain, 2006). The implementation of spatial standards at national level will assure that every institution and organisation creates spatial data in the same manner and it will ease spatial data sharing and exchange (Vaez et al., 2009).

In parallel with ISO, the IHO has an important role to play in developing the appropriate standards needed for its hydrographic and cartographic applications. IHO developed and maintained the S-57 (Special Publication No. 57) cartographic standard related to coastal and marine data. This standard is used for collection and exchange of hydrographic data among national Hydrographic offices globally. The development of S-100 (the next edition of S-57) has been a great step toward creating a SDI-ICMM. The next edition of S-57 standard will not be a standard just for hydrography, but will have manageable flexibility that can accommodate change and facilitate interoperability with other GIS standards. S-100 is being based on the ISO/TC211.

Another initiative that aims for interoperability between datasets from different custodians is the development of Extensible Markup Language (XML). The XML standard is a flexible way to create information formats and electronically share structured data via the public Internet, and via corporate networks. It is used to describe data. The main benefit of using XML is that it provides a common format to store data, and so allows data to be exchanged easily between providers, value adders, and users. SDIs rely on standards because they build on web services which – in the SDI world – were specified by the Open Geospatial Consortium (OGC, with standards such as WMS and WFS) in conjunction with the efforts of the International Organization for Standardization (ISO, technical committee 211).

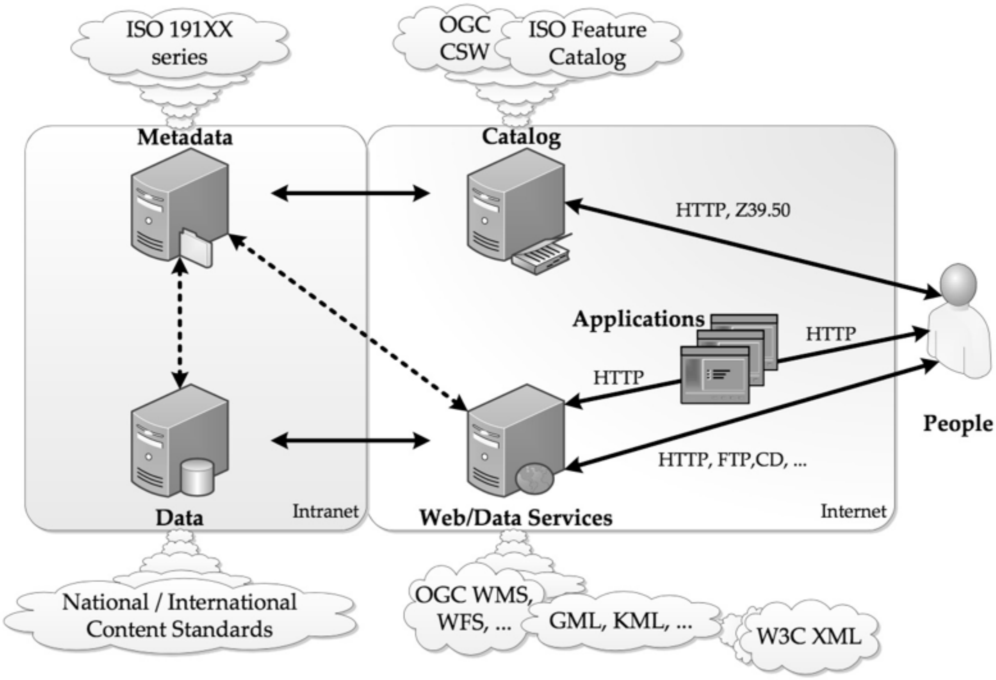

FIGURE 5.14: Components, their interaction and standards in SDI (Rüh, 2014)

As shown in figure 5.14, common standards (OGC, ISO, XML, etc.) and well documented metadata are essential for data discovery, management and compatibility within a SDI. Each user can have access to data from any environment through interoperability standards. These is the main purpose in developing a SDI-ICMM.

5.5.3 Policies (Institutional Frameworks)

A policy should exist to define the need to create information that is interoperable. This policy is often linked to a nation's or organisation's strategy for sharing and exchanging geographic information (e.g. INSPIRE in the EU). Policy and administrative arrangement that are utilized to create, maintain, access, and provide standards and datasets are defined by institutional framework (Williamson et al., 1998). Therefore, it can be divided into two major components that have different aspect. These components are: Policy and institutional structure or can be named institutional coordination.

Policy, Pricing, Copyright: One of the biggest challenges of the spatial data that are used by different agencies and sectors is the policy. So, the inconsistent policy would great a problem in sharing the data as many agencies have their own pricing mechanisms and policies. A conflict will probably happen in the policies through the process of sharing the data between these agencies. Therefore, a policy with any SDI initiative is important to facilitate the access to the data by all the users and to organize the sharing procedure and the agencies tasks.

Institutional Structure/Coordination: Spatial Data Infrastructure is based on the cooperation as many agencies define it as collaborative efforts. Coordination is the most important part in developing an SDI. Coordination is a mainstay of a successful SDI.

Policy is indispensable to create, sharing and exchanging geographic information. These policies are different for terrestrial, coastal and marine spatial data in terms of quality, access and privacy of the data. The quality of marine Data is more difficult to achieve at the same level as terrestrial data. It depends on collection, completeness, reliability of data and due to the complexity of the marine environment and the technologies used for data collection.

Privacy over spatial data in the marine environment is a concern with many countries reluctant to share spatial data relating to their marine jurisdictions. There may be a need to maintain the different privacy policies for off-shore data. Therefore, there is a need for an appropriate policy model to create a holistic infrastructure across jurisdictions.

5.5.4 Access Networks (Clearinghouse)

Crompvoets (2006) defined a clearinghouse as *"an electronic facility for searching, viewing, transferring, ordering, advertising, and/or disseminating spatial data from numerous sources via the Internet and, as appropriate, providing complementary services*".

From the definition, it can be understood that Clearinghouse is a number of servers connected with each other and it stores spatial data with their metadata. These data can be accessed by the use of internet through some processes of searching and querying in metadata. Some of the researcher and agencies name it: access network (Rajabifard and Williamson, 2001; Rajabifard, 2002), some clearinghouse (Crompvoets et al., 2004; Tosta, 1995), and some Clearinghouse Network (ANZLIC, 1998; FGDC, 2014). Despite the variety in naming this component of the SDI, the general concept of these different names is similar.

A Clearinghouse implies linking of spatial data producer, managers, and users electronically in a distributed network (Crompvoets et al., 2004; FGDC, 2014). By using clearinghouse, producers can know what data are existing, the status of these data, and how to access these data. Each dataset must be described in an electronic form (metadata) in order to be published by the producers. Then, the user can access the clearinghouse to find these data and to know who has what (Crompvoets et al., 2004).

Access networks comprise data warehouse, data portals, on-line atlases, etc. and include different mechanisms (distribution networks, clearinghouse, etc.) for getting spatial information to the stakeholders. To support this interoperable and coordinated data, access network must comply with SDI standards and policies.

One of the most important thing is what was mentioned by (Shariff et al., 2011; Tosta, 1994) clearinghouse is not a centralized warehouse or database of spatial data, but on the contrary it is a distributed network. It is a place where the users can get catalogued and organized data not a place where the data are put and stored only. It is simply a network transfer the spatial data among all the users and producers.

An opportunity in developing a SDI-ICMM is to enable all data to be available through one common portal. this SDI is the best way to facilitate access to terrestrial, marine and/or coastal spatial data. Decisions affecting marine and coastal environment need to be timely and based on a strategic interpretation of all available data, presented in an easy and accessible format.

5.5.5 People (Partnership)

Functional SDI requires willingness and practical cooperation between the various organisations that create, share and use information to implement the overall policy. All the components of an SDI depend on a creative partnership or, in other word, the cooperation between the people that are involved in a process of SDI. The people is one of the most important components of SDI. The people in SDI are the data providers, value-adders and data users. Moreover, all the decisions are made by people; all these decision need data to be made in the right way; the data cannot be exist without people. Relationships are built by an SDI to increase the ability of sharing information, developing, and maintaining standard datasets in a spatial data community (Tosta, 1995).

Therefore, by bearing in mind the meaning of data accuracy, sharing, security, and access are mostly based on the people relationship; good partnership increases the performance of any SDI model at a big deal (Rajabifard and Williamson, 2001).

In the marine environment these people will come from private industries such as shipping, defence, aquaculture and conservation, as well as from government at local, state and national levels. There will already be some degree of spatial data management that is occurring within these groups, even if only within or between organisations.

However, the partnerships between organisations involved in spatial information is the main key to success in any SDI and drive to development it allowing people to work together to achieve their respective goals.

In SDI-ICMM, there is an opportunity is to improve vertical communication between the different SDI levels – global, national and state. This communication can help coordinate these initiatives better in the marine and coastal environment.

Multiple reports internationally have highlighted the need for better coordination and integration between and within levels of government to improve coastal zone management (Hudson and Smith, 2002; Middle, 2002). Therefore, a challenge in developing a SDI-ICMM will be in encouraging cooperation and a culture for spatial data sharing between the institutions involved in marine and coastal spatial data collection and use (Rajabifard et al., 2003).

Through SDI-ICMM, the sharing and using common standards and a single access network encourage the cooperation and collaboration in the coastal and marine sector.

5.6 Challenges to creation of a SDI-ICMM

Since the first establishment of NSDI in U.S in 1994, NSDI has faced many challenges and constraints almost in every NSDI initiative. SDI creation can be a difficult and intimidating task, with both technological and organisational challenges Therefore, it is important to study these challenges that happened around the world in order to avoid or overcome them before facing difficulties in implementing an SDI. There are some of the challenges that could be similar in most of the nations. These are (Alhubail, 2003; Arshad and Hanifah, 2010; GINIE, 2004; Manisa and Nkwae, 2007; Minh, 2009; Sen et al., 2006):

- **Accessibility of the data and Availability of digital data**: One of the bases in SDI implementation is sharing the data and this can be difficult with non-digital data. Also, sharing has become easier with the advancement in the technology which can be done by using the internet.;
- **Need of Coordination (Institutional arrangements)**: Avoiding the duplication is one of the most important advantages of SDI. Without coordination the data may be collected by one of the agencies and as a result of absence of the coordination the same data collected again which duplicates the efforts and the money;
- **Data standardisation**: Collected data can be classified and organized in different ways, especially when using GIS databases, based on each agency needs and requirements. Hence, these data cannot be integrated and shared if there aren't data sets standards;
- **Knowledge and skills**: SDI system design and management needs experience and knowledge in order to put the concept of the institutions structure and policy in a network and database;
- **Lack of Awareness**: Many non-government agencies, public, and private sectors still have no information on GIS and SDI. These people are not cooperating due to their unawareness of the benefits of disseminating information to the public and the importance of sharing the data;
- **Funding limitation**: The lack of organization may duplicate the money that is spent on different projects for the same area;
- **Availability of Metadata**: The presence of metadata facilitates the ability of the users to reach its need rapidly and easily. Therefore, collection of a big size of data without metadata describe them would be like a mess;

- **Need of Legal aspects**: SDI is not only consisting of technical aspect. It is supported by policies and laws, and some of the agencies consider policies as the most important component of SDI. Policies of many organizations are not suitable for digital data. This usually happens through the process of moving from the use of paper maps to digital data which can be transferred by the networks (internet, intranet). When policies are to manage paper maps and traditional approaches, and they can no longer be used for digital forms;

- **Weak Cooperation**: The main pillar of SDI is Cooperation. The more cooperation in an SDI initiative the more successful will be;

- **Long Term Benefits**: Some of the stakeholders resist an SDI project in case that there is no evidence on short or medium term benefits because SDI projects need some time in order to show result or benefits.

All initiatives of SDI across terrestrial and marine environments and jurisdictions around the world show that building and maintaining a SDI is not an easy task. This difficulty due to dynamic and complex process at different levels of government and requires research and collaboration with academia and private industry. There are some specific problems related to coastal and marine geographic data management, that makes it difficult to extend the are covered for SDI implementations to include sea regions. Incorporation of marine and coastal regions within Global, National and Regional SDIs will bring substantial additional benefits of integration, standardisation and interoperability of technologies, enabling better policy formulation, monitoring and enforcement, often reaching beyond the coastal zone itself (Bartlett et al., 2004). The majority of users who work on resource management, planning, environmental studies, and regulation issues are need of land, coast, and marine spatial datasets. Therefore, there is a need for data integration both land and marine spatial data to build a holistic spatial data management throughout any jurisdiction. The diversity and number of mapping organisations and data providers are the most significant barriers for effective spatial data integration (Clarke et al., 2002). In order to implement spatial data integration efficiently, associated barriers and challenges should be investigated and identified. Some of this challenges that related to coastal and marine geographic data management are:

- The definition of the **coastline**, is the most evident problem to be solved when trying to merge in the same system sea and land geographic data. The border between the two worlds is not sharply defined, it is an especially fuzzy feature and there are different coastlines defined according to different criteria. In this topic, SDI approach offers the opportunity of publishing on the net the different definitions of coastline to make evident the differences, problems and inconsistencies existing;

- Some terrestrial **Spatial Reference Systems** (SRS), are not applicable to marine regions. The most usual projections (e.g.: UTM) are not very practical, and as far as a global datum is required (WGS84), and latitude, longitude is the most sensible coordinates system, the problem is the transformation of all the geographic data describing the land area of interest to this SRS to have a continuous solution;
- **Geographic Identifiers** are very useful and widely used to have a geo-reference of geographical names or any kind of Point of Interest (POI). It's not easy to extend this kind of Geographic Identifiers Systems to sea and coastal regions;
- **Vector models**, based on features with a well-defined geometry, despite the more implemented and used in practice, doesn't fit very well to the description of a continuous reality like the sea. Sometimes it would be more appropriate to use raster models and to manage data coverages to better represent marine information;
- The wide diversity of **data sources**, scales and conceptual models and the strong fractal and fuzzy character of coastal and marine related data, cause a high level of heterogeneity in the data of interest.

As stated by Syafi'i (2006) the integration of spatial data at national level encounters either technical or non-technical issues, however the non-technical issues are the most difficult issues to overcome.

5.6.1 Technical issues

Land and marine data products are incompatible in terms of scale, projection, datum and format (Gillespie et al., 2000) because spatial data come from various sources and data providers with different policies and methods of managing. This situation causes various issues in the step of integration due to disparities between scale, symbology and datum.

Interoperability issues related to reconciling these differences are heightened where shore-based and sea-based datasets meet in a coastal zone (Mackenzie and Hoggarth, 2009a).

Therefore, there is a need to make the land and marine infrastructure interoperable so that planning, management and solutions can be identified in a seamless and holistic way.

When integrating spatial data from various data sources, there are several technical issues among them:

- Differences in spatial reference system: Reference systems are not harmonised across borders;
- Differences in spatial data modelling (geometry, features name, attributes, field type, topology and symbology) (Gillespie et al., 2000; Gomm et al., 2004; Syafi'i, 2006; Mackenzie and Hoggarth, 2009a).
- There is a lack of metadata: Differences in feature or object definition;
- Currently a large variety of formats exist and these are not interoperable;
- Data sources are not consistent; Differences in data accuracies and in spatial data quality due to the differences of resolution or data acquisition method;
- Scales are not compatible; Differences in scale of data source;
- There are restrictions for data accessibility: Differences in storage format.

Table 5.4 shows an example of the differences on several aspects of two main data sources (Topographic Map and Nautical Chart) of Tunisia that should be considered when integrating land and marine spatial data.

TABLE 5.4: Different aspects of land and marine spatial data integration

Item	**Topographic Map**	**Nautical Chart**
Coastline	Mean Sea Level which is determined by modelling the topography	Mean Sea Level which is determined by modelling the topography

Table 5.4 – *Continued on next page*

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Horizontal Datum	Local Geodetic Datum	WGS84
Vertical Datum	Mean Sea Level for land elevation	Mean Sea Level for depth
Projection system	-Universal Transverse Mercator (UTM) -Lambert -NTT: New Tunisian Triangulation -STT: Tunisian Triangulation System	Mercator
Digital Storage Format	Various format (DWG, ARC, SHP, Hardcopy)	-Digital Nautical Charts: Raster (TIFF, ECW) -Electronic Navigation Chart: S-57 and S-100 -Hardcopy - Printed Charts -Various format (DWG, ARC, SHP, Hardcopy)
Scale	Systematically (1 to 10K, 25K, 50K, 100K, 250K)	Not Systematically (range from large scale to small scale)

Disparity of on-shore maps and off- shore charts in scales and storage formats and thus it is enable to accurately represent coastal features or processes that cross the land/water interface. These are other issues relevant to land and marine data integration. Land-ward data are captured at large scale and the sea-ward side at small scale. The result of this is a disparity in the features common to both zones, and a greater density of detail on the land compared with the sea.

The marine standards are not at the same level of completeness as the ISO TC/211 standards. The OGC/TC 211 implementation specifications were found to have deficiencies, particularly in relation to manipulating marine data types which typically have 3 or 4 dimensional components (e.g. latitude, longitude, depth, and/or time).

Shoreline is a fundamental boundary. The coastline is defined by the line of intersection between the land-mass and a nominated tidal place. Additionally, shoreline definitions typically relate to a water level, the shoreline is dynamic, changing over various temporal and spatial scales. Different representations of the coastline in marine and land datasets leads to data overlaps while most of the applications require a single layer without common features duplication. While most people will intuitively recognise the existence of the shoreline, it is virtually impossible to establish its absolute position at any given point in time (Bartlett et al., 2004). Current technical issues that impact on the consistent delineation of the coastline to remove current ambiguity in the tidal zone and create a single national cadastre covering the both on-shore and off-shore environments have been identified (Quadros and Collier, 2008). From this perspective, for any SDI-ICMMs to be functional, it is necessary to somehow translate this diversity of perceptions into some form of standardised conceptual data model for the shoreline that allows unambiguous representation of this feature within existing and future SDI databases. Table 5.5 summarises the described technical issues and their potential effects.

TABLE 5.5: Technical issues in integrating land and marine datasets and their consequent effects

Technical Issues	**Consequent Effects**
Different representations of the coastline	Data overlaps
Differences in spatial reference system	Lack of harmonise borders
Differences in spatial data modelling	Difficulty in integrating different datasets
Lack of metadata	Differences in feature or object definition
Difference between standards (ISO and OGC)	Difficulty in the interoperability between marine and terrestrial
Large variety of formats exist	Lack of interoperability of different datasets
Differences in data accuracies	Difficulty in integrating different datasets
Differences in scale of data source	Difficulty in integrating different datasets

Table 5.5 – *Continued on next page*

Table 5.5 – *Continued from previous page*

Differences in storage format	Difficulty in data accessibility
Differences in technology used to capture spatial data	Difficulty in achieving the same level of completeness, currency and reliability as terrestrial data

5.6.2 Non -Technical issues

The non-technical obstacles of data integration can be caused by institutional, policy and legal issues (Williamson et al., 2004c; Mohammadi et al., 2006; Burrough and Masser, 1998; Loenen, 2009).

5.6.2.1 Institutional issues

Each institution or organisation has different policies and rules on managing spatial data. Therefore, there is impediments to data sharing and developing a SDI-ICMM. In order to make the data available to others, it is required to set standards and policies conform to national or state level. Poor communication between different sectors presents another exiting barrier to be considered.

As a result of this issue there are conflicts between marine and coastal users. Most conflicts have at least some relationship with the multi- objective nature of demand for coastal resources. Many researchers have investigated institutional obstacles of spatial data integration. Some key findings are as follows:

- Inter and cross-organisational access, retrieval and display arrangements (Zaslavsky et al., 2004; Baker, 2005);
- Sharing data among organisations (Weaver, 2004; Baker, 2005);
- Different coordination and maintenance arrangements;
- High degree of duplication (Baker, 2005; Burgess, 1999);
- Weak collaboration (Baker, 2005);
- Uncoordinated specifications and standards across spatial stakeholders (Baker, 2005);

- Lack of central access gateway (single point of access) (Baker, 2005); and Building awareness and capacity (Clausen and Rajabifard, 2006).

The coastal zone is difficult to manage due to a complex array of legislative and institutional arrangements varying from local to global levels. Furthermore, there is currently confusion about the management of the land – marine interface. This means that is a strip of land between the two boundaries which is not within a management jurisdiction at all (Binns and Williamson, 2003).

However, it is believed that the above problems can be overcome through coordination arrangements and existence of a single management authority or forum for collaborative planning, and deficient legislation (Vaez et al., 2009).

5.6.2.2 Legal issues

The integration of spatial datasets raises a number of legal issues. It is obviously necessary to clarify the nature of datasets and the stakeholders and their particular rights in data (Burrough and Masser, 1998). In 1995, the European Umbrella Organisation for Geographic Information (EUROGI) commissioned RAVI, the Netherlands Council for Geographic Information, to conduct a survey on the legal problems:

- Different licence conditions (Donker and Loenen, 2006);
- Intellectual property (IP) and licensing (Baker, 2005; Donker and Loenen, 2006);
- Liability regimes (Donker and Loenen, 2006).

5.6.2.3 Social Issues

Many institutional and policy issues are caused by the social behaviours of jurisdiction for example the building collaboration among organisations. However, some explicit social behaviours directly hinder effective spatial data integration. for example, when certain departments or sectors do not wish to share information with others. Some People often resist sharing data across organisational boundaries due to loss of control, power and independence (Clausen and Rajabifard, 2006).

Many of the discussed issues are closely connected. Therefore, without considering all the issues (Figure 5.15) within a single holistic framework, effective spatial data integration cannot be achieved.

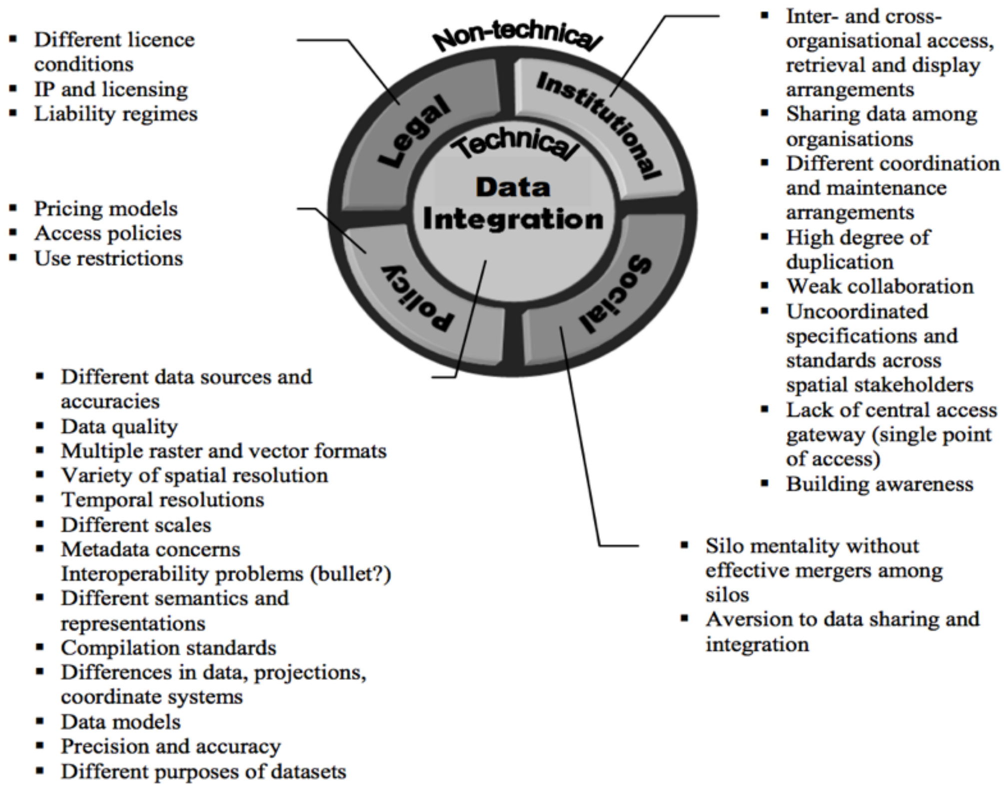

FIGURE 5.15: Technical integration and associated non-technical considerations. (Mohammadi, 2008)

The development of a framework such as a SDI-ICMM would aim to aid in facilitating decision making to respond to these technical and non-technical issues, to facilitate more effective management of the land – marine interface.

5.6.2.4 Policy issues

Many data producers are reluctant to allow their data to be shared due to sensitivity and quality of data. Non- technical barriers that are more difficult to address include lack of harmonised data access policies and exploitation rights for spatial information, particularly for data collected by public sector agencies. From a policy perspective, the diversity of involved organisations with different policy drivers and priorities affect the integration of land and marine environments. Some of the key issues are listed below:

- Access policies (Donker and Loenen, 2006): Concerning user requirements, users require both transparency of information policies and consistency in the access to policies throughout government;
- Differences in pricing, and liability regimes may result in confusion and ultimately limited use of the datasets (Donker and Loenen, 2006);
- Pricing models (Donker and Loenen, 2006): As a consequence, it is time consuming to explore a potential avenue to cost-recovery, among other things (Donker and Loenen, 2006);
- Use restrictions (Meixner and Frank, 1997; Donker and Loenen, 2006).

5.7 Chapter Summary

This chapter aimed to present the concept of Spatial Data Infrastructures (SDIs) as an enabling platform to facilitate sharing and access to up-to-date spatial data for all potential users. In this regard the continuum from information to information infrastructure and spatial data infrastructure is presented. It is accompanied by the diverse definitions of SDIs and SDI components within different communities. Hence, it discusses Spatial data sharing as one of the most significant components of SDIs.

Furthermore, this chapter examined the Marine SDI concepts at national and international levels. It showed that Marine SDI initiatives are developing in many countries, all with the aim to facilitate marine and coastal spatial information sharing to improve decision-making and management of the marine and coastal environments.

6 Design SDI-ICMM Model

6.1 Introduction

This chapter aims to present the design and development of the SDI-ICMM model. It proposes the conceptual model of SDI-ICMM by using Hierarchical Spatial Reasoning. The SDI-ICMM class and its inherited characteristics and properties will be discussed.

In addition to the conceptual phase, the development of a SDI-ICMM model also consists of two more stages: design phase and implementation phase. The design phase is presented based on Unified Modelling Language (UML) providing a graphical notation of the architecture of the system. The Use Case Diagram and Object Diagram of the Enterprise Viewpoint are developed.

The model proposed in the design phase is developed during the implementation phase. In this regard, this chapter presents SDI-ICMM guidelines as a necessary step by step approach to create a SDI-ICMM for any jurisdiction with a marine environment which might support and participate in a SDI-ICMM.

6.2 Formal SDI modelling efforts

Modeling is undertaken *"to capture and state requirements and domain knowledge so that stakeholders may understand and agree on them"* to support the design of a large complex system (Rumbaugh et al., 2004).

There have been significant efforts to develop a formal model to describe and characterise SDI using UML by inter alia the International Cartographic Association (ICA) Commission on Spatial Data Standards (Cooper et al., 1995; Cooper et al., 2003; Cooper et al., 2011; Hjelmager et al., 2008). Formal UML models of other aspect of SDI have recently been developed. Béjar et al. (2012) model SDIs as federations of autonomous communities while Vaez and Rajabifard (2012) propose the use of formal UML model to design a holistic terrestrial and marine SDI.

To date, ICA modelling efforts have focused on articulating specific viewpoints as specified in the ISO Reference Model for Open Distributed Computing (RM-ODP). Models related to enterprise and information viewpoints (Cooper et al., 2011; Delgado, 2004) and the computation viewpoints of SDI (Cooper et al., 2011). More recently, this model has been extended to include Volunteered Geographic Information (VGI) within SDI (Cooper et al., 2011). High level use cases articulated in the enterprise viewpoint by Cooper et al., 2003 reproduced in Figure 6.1 below, have been developed.

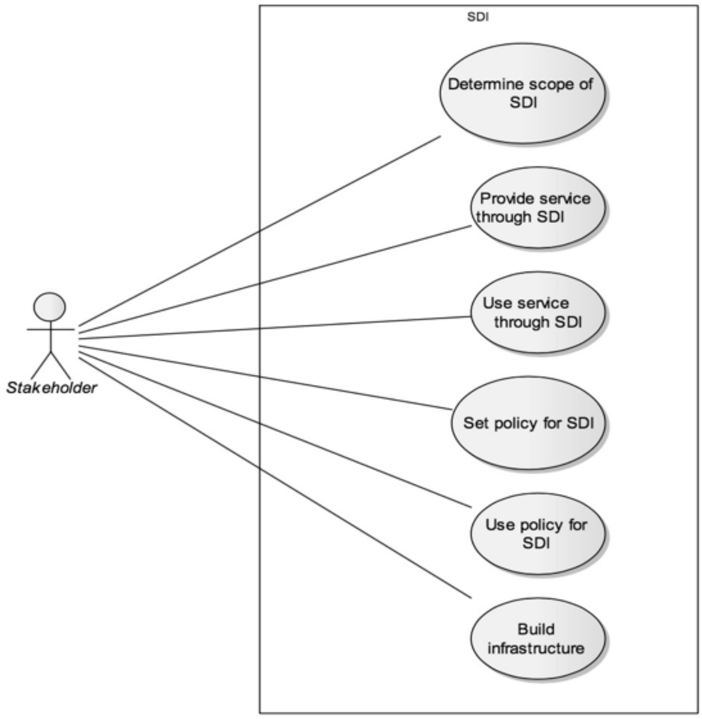

FIGURE 6.1: SDI Use Cases (Cooper et al., 2003)

6.3 SDI-ICMM Conceptual Model

Spatial data represents real world phenomena in abstracted form, which can be structured in data models. Within a stakeholder community, the concepts of the data models in use are well known, and are sometimes even formally agreed on.

Due to different problems during the management of coastal and marine area, there is a growing need to develop a SDI-ICMM that can include data from both land and marine environments which will improve access and sharing of data between these environments. This leads to a more integrated and holistic approach to management. With this in mind, the importance of understanding the link between land and marine environments (they cannot be treated in isolation) and the need for cooperation between nations as maritime. In order to have such an environment, there is also a need to identify technical, institutional and policy issues hindering the implementation of the SDI-ICMM model.

In designing the SDI-ICMM model many of the characteristics and components of SDI in general will be used adding other characteristics such as Seamless, Multi-purpose, Multi-users and Interoperable.

A critical success factor for any SDI-ICMM is its acceptance by the stakeholders. A bottom- up approach that creates a participatory environment in the specification development process foresees various interactions and feedback to the stakeholders' communities. Therefore, a collaborative model is needed that incorporates the safeguards necessary for consensus building processes.

Since a SDI-ICMM is usually composed of many data themes where cross-theme interoperability may be required, a robust framework should be established that drives the development process of the data component in a coherent way. In the European Union, INSPIRE has adopted a conceptual framework that consists of two main sections as shown in Figure 6.2:

- The Generic Conceptual Model;
- The methodology for data specification development.

The main role of the conceptual framework is to provide a repeatable data specification development methodology and general provisions for the data specification process, which is valid for all spatial data themes. The conceptual framework outlines a step-wise and iterative process for establishing the data component: work should start by defining the common parts that must be followed by theme-specific tasks. In other words, the specification process of the data themes can only begin when the conceptual framework is sufficiently developed.

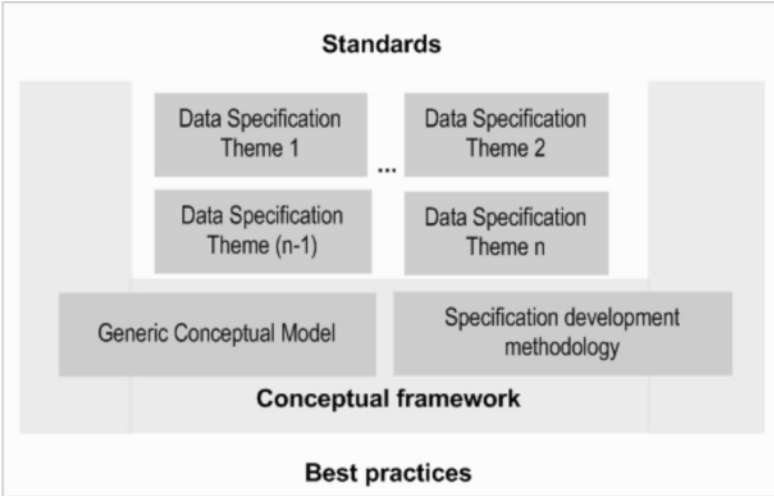

FIGURE 6.2: Relations of a conceptual framework. (Tóth et al., 2012)

The introduction of the conceptual framework is in line with the principle of reuse. In the context of SDIs, reuse relates not only to sharing data in different applications, but also to sharing knowledge, technical solutions, tools and components. Standards and examples of good practices of spatial data providers and user communities represent the basis for defining the conceptual framework and the data specification process. The complexity involved in arriving at agreements on interoperability grows with the number of data themes and with the number of participating stakeholders.

SDI-ICMM needs spatial data from land and marine environments which is a continuous spatial dataset including the coastal zone.

It should be possible to combine spatial data from different sources and share it between many users and applications. This platform would facilitate greater access to more interoperable spatial data and enabling a more integrated and holistic approach to management of the coastal zone.

The first step for implementing SDI-ICMM is developing a conceptual modelling to define the relationships between different components.

Conceptualization phase comes before implementation and design phase. It is the first step before design phase and drawing a Unified Modelling Language (UML) diagram. Conceptual modelling is modelling of real-world situations on a higher level of abstraction, before a detailed logical and physical design takes place (McFarlan, 1984). It helps to understand the entities in the real world and how they interact with each other.

Conceptual models provide the description of space that is closer to human conceptualisation and its semantics.

In order to develop a conceptual model, Hierarchical Spatial Reasoning (HSR) and Object Oriented Modelling (OOM) methods have been used. As demonstrated by Rajabifard et al. (2002) the principles and properties of HSR could be applied to SDI research to better understand their complex nature and to assist modelling of SDI relationships. The application of HSR to SDI research builds upon earlier work by (Eagleson et al., 2000; Eagleson et al., 2002; Eagleson et al., 2003) which applied hierarchical reasoning to the spatial problem of administrative boundary design. The main reason that a hierarchy concept is applicable to SDIs is that all properties and reasons for developing a hierarchical structure are applicable to the SDI concept (Williamson et al., 2004b).

Based on the Hierarchical Spatial Reasoning (HSR) and Object Oriented Modelling (OOM) method, several classes of SDI (land, coastal and marine), which have some properties in common, groups in to a more general super-class (Generalization).

The SDI-ICMM model can be postulated as one abstract class SDI at the higher level (parent level) with attributes and operations/methods designated to this class. A SDI-ICMM as a super-class specializes in to land SDI, coastal SDI and marine SDI (Specialization). The initiatives (MSP, ICZM, etc..) extend SDI when these initiatives can be called during the execution of the SDI (Dependencies). Each sub-class has same properties as well as special properties. Generalization extracts similar properties and characteristics of these three sub-classes (and SDI, coastal SDI and marine SDI) into a SDI-ICMM super-class. Figure 6.3 illustrates inheritance along a generalization hierarchy with the more general class at the top (SDI-ICMM class) and more specialized classes (land, coastal and marine SDIs) and dependencies classes at the bottom which may or may not be included in the SDI.

Properties which are common for SDI-ICMM super-class and these sub-classes would be defined only once (with the SDI-ICMM super-class) and inherited by the sub- classes SDI, but marine, coastal and land SDI sub-classes can have additional, specific properties and operations which are not shared by the SDI-ICMM.

Therefore, while land coastal and marine SDI classes would inherit

SDI-ICMM properties, they continue to have their specific characteristics and components at the same time.

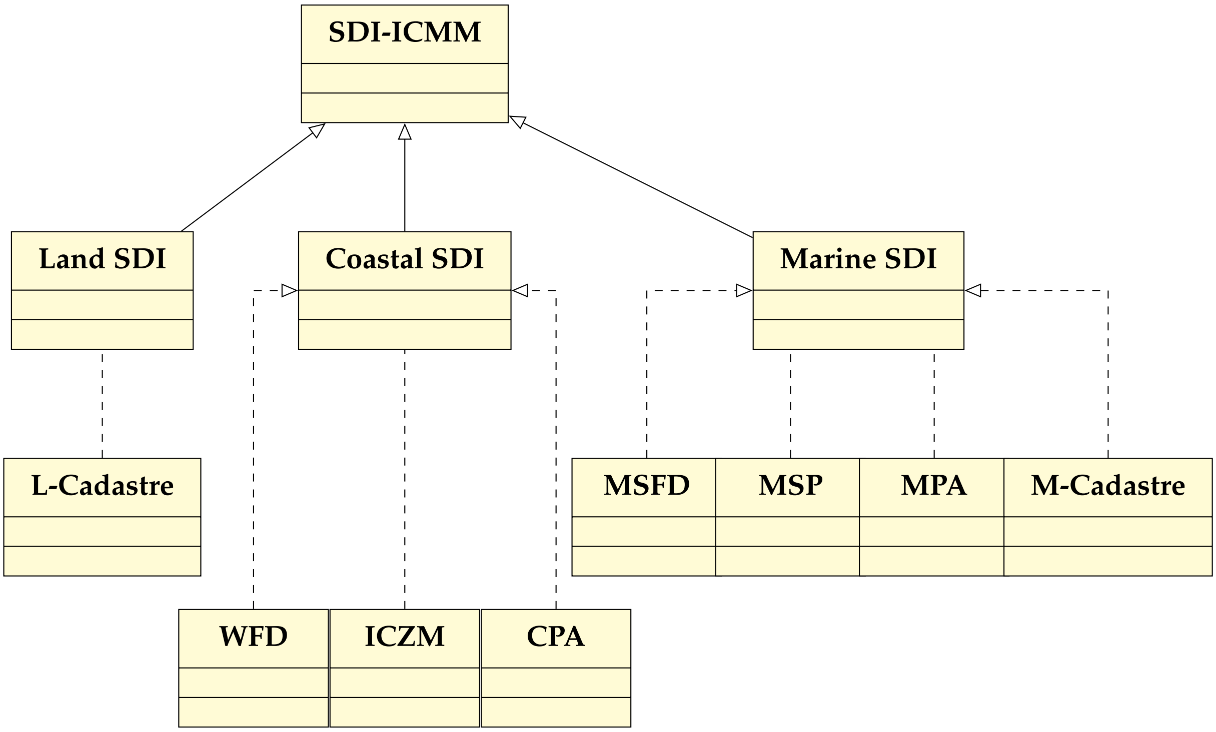

FIGURE 6.3: SDI-ICMM model

According to Timpf (1998), the most common function to build a hierarchy is the aggregation function. Classes of individuals are aggregated because they share a common property or attribute. This is the other reason that a hierarchical concept can be applied to SDIs since, different initiatives at a certain political/administrative level or in different environments can aggregate together to form the next higher level of hierarchy. This is the most common type of construction of hierarchy as introduced by Timpf (1998).

Figure 6.4 illustrates a conceptual view of holistic and seamless platform architecture. As demonstrated SDI-ICMM platform employs the components of SDI in general but the attributes of these components are different from existing platform. these SDI can be include some existing initiatives.

6.4 SDI-ICMM Design

Design phase is the next step of conceptualization which comes before the implementation phase. The list of requirements that is developed in the definition phase can be used to make design choices. The design phase

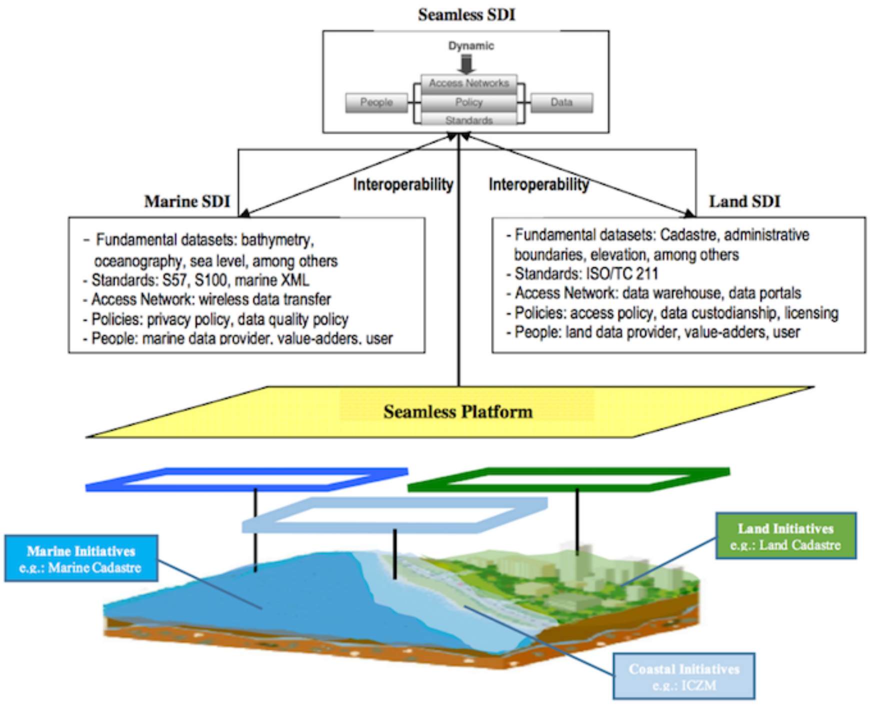

FIGURE 6.4: Conceptual model of SDI-ICMM platform (modified after Vaez et al. (2009))

deals with learning objectives, assessment instruments, exercises, content, subject matter analysis and lesson planning. In the design phase, one or more designs are developed, with which the project result can apparently be achieved. This section discusses the design of SDI-ICMM model. The design stage has utilized Unified Modelling Language (UML) in order to model the architecture, components and activities within the system. UML provides a unified model that acts independently from the development environment and allows developers to easily interpret the components and interactions between them (Bell, 2003). UML is probably the most widely known and used notation for object-oriented analysis and design. It is the result of the merger of several early contributions to object oriented methods. In this section we use it to illustrate how to go about object oriented analysis and design.

6.4.1 UML

The aim of UML (Unified Modeling Language) which is a standard specified by the Object Management Group (OMG) *"[...] is to provide system architects, software engineers, and software developers with tools for analysis, design, and* *implementation of software- based systems as well as for modeling business and similar processes."* The quote already indicates that UML has a very broad scope with many domains it may be applied to (OMG, 2011). Since the late 1990, with the emergence of object oriented analysis and design, the UML approach has gained in popularity. This is reflected by the variety of UML diagrams available. Diagrams give extensive information about a system in a graphical representation but in most cases this representation displays only part of the systems (a subset of its classes, components etc.) (OMG, 2011).

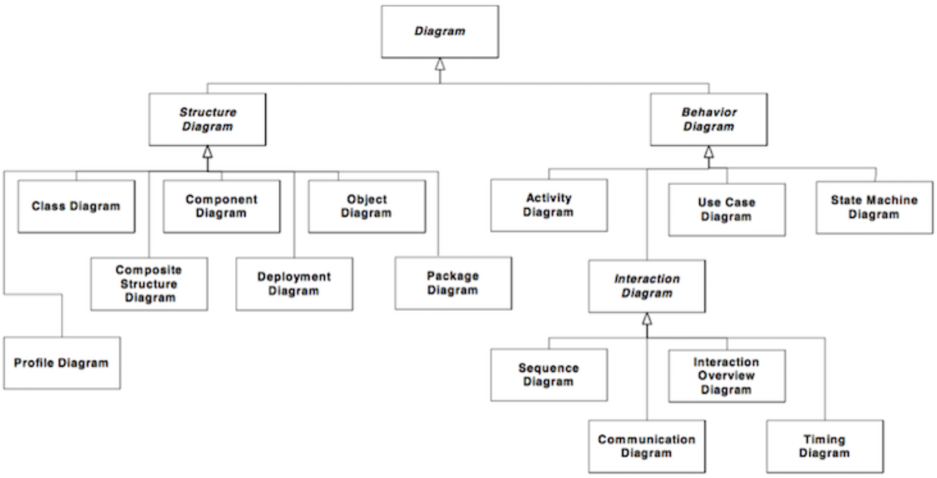

FIGURE 6.5: Class diagram of UML diagram types. (OMG, 2011)

As depicted in figure 6.5 the UML diagrams fall into two main categories: structure and behavior diagrams. In contrast to behavior diagrams which are dynamic, in the sense that they show interaction between elements, structure diagrams are static. Thus they only represent elements which are independent of time and which have to be available in the system being modelled. Taken class diagrams as an example for structure diagrams they specify the classes, their attributes and the relationships between the classes of the system (OMG, 2011). As already stated behavior diagrams are dynamic thus pointing out how the system changes over time. Taken use case diagrams as an example for behavior diagrams they describe the functionality of a system in regard to actors, their goals which are represented as use cases and relationships and dependencies between these use cases (OMG, 2011).

It is now becoming widely used and accepted. Its use is not limited to software systems, and it is being useful to use UML to model (or describe) SDI-ICMMs systematically.

UML is being used within the International Organization for Standardization's Technical Committee developing the international standards for geographical information and geomatics, namely ISO/TC 211, where it is used to encapsulate the essence of the standards, allowing their models to be harmonized. Since UML provides a standard notation for modelling and design, it ensures the ease of communication between designers and developers. SDI-ICMM efficiently being maintained and developed by using UML.

The Reference Model of Open Distributed Processing (RM-ODP) (ISO/IEC 10746) defines a framework comprising five viewpoints: Enterprise, Information, Computation, Engineering and Technology. RM-ODP has been used because it is a good base to facilitate understanding of SDIs; it is international standard already. RM-ODP (figure 6.6) allows describing complex distributed systems giving a framework of different levels of abstraction (Delgado 2004).

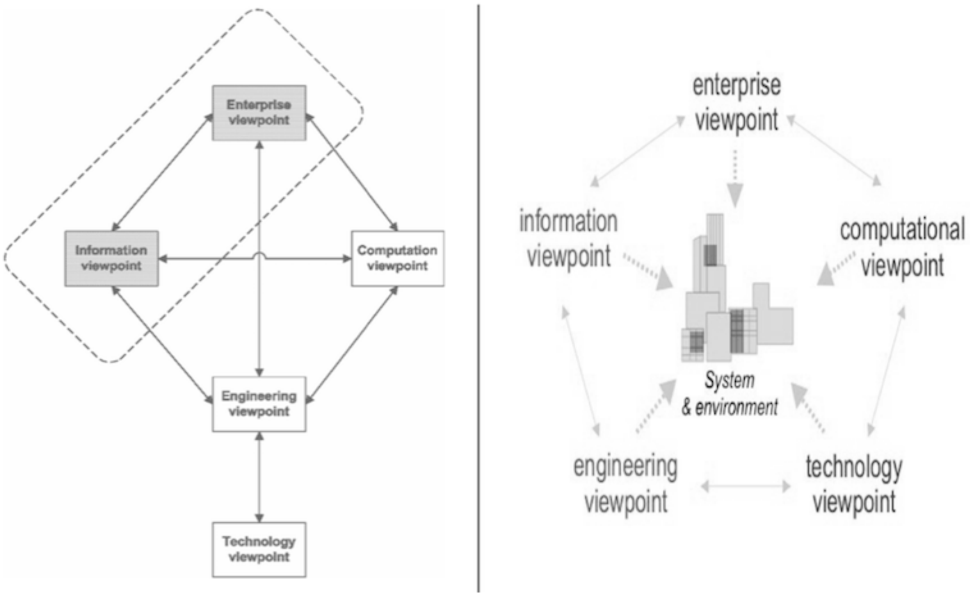

FIGURE 6.6: The RM-ODP model highlighting the two Viewpoints (Hjelmager et al., 2008; ITU, 2014)

Viewpoints as depicted in Figure 1 there are five generic and complementary viewpoints on the system to be modelled and its environment which (ITU, 2014) describe as:

- **Enterprise viewpoint** – *What for? Why? Who? When?*
  - Focuses on the purpose, scope and policies for the system;
  - Describes the business requirements and how to meet them

- **Information viewpoint** – *What is it about?*
  - Focuses on the semantics of the information and the information processing performed;
  - Describes the information managed by the system and the structure and content type of the supported data.
- **Computational viewpoint** – *How does each bit work?*
  - Enables distribution through functional decomposition on the system into objects which interact at interfaces;
  - Describes the functionality provided by the system and its functional decomposition.
- **Engineering viewpoint** – *How do the bits work together?*
  - Focuses on the mechanisms and functions required to support distributed interactions between objects in the system;
  - Describes the distribution of processing performed by the system to manage the information and provide the functionality.
- **Technology viewpoint** – *With what?*
  - Focuses on the choice of technology of the system;
  - Describes the technologies chosen to provide the processing, functionality and presentation of information.

This section presents a detailed introduction to UML methodology for a system design. UML consists of a number of diagrams for different aspects of modelling. UML diagrams are useful in different model development phases. The most useful, standard UML diagrams are:

- **Use Case Diagram**: used to gather the requirements of a system including internal and external influences;
- **Class Diagram**: used for visualizing, describing, and documenting different aspects of a system;
- **Sequence Diagram**: used to represent a scenario and shows the temporal ordering of events;
- **Activity Diagram**: used to show the message flow from one object to another;

- **Component Diagram**: set of components and their relationships;
- **Deployment Diagram**: used for visualizing the deployment view of a system.

Use Case Diagram and Class Diagram are used for SDI-ICMM design in this research. These models could be seen as a contribution towards the overall model of the SDI-ICMM and its technical characteristics.

6.4.1.1 Use Case Diagram

The Use Case Diagram models user requirements with use cases. It is a view of a system that emphasizes the behavior as it appears to outside users. A use case model partitions system functionality into transactions (use cases) that are meaningful to users (actors). Actors can be defined as something that interacts with the system. Actors can be a human user, some internal applications, or may be some external applications. Use case is the functional requirements of a system.

TABLE 6.1: Use Case Diagram components

Notation	**Description**	**Symbol**
Use case	A sequence of actions, including variants, that a system (or other entity) can perform, interacting with actors of the system.	
Actors	Actors are persons, organizations, or external systems that play roles in interactions with your system.	
System boundary	It is the boundary between the physical system and the actors who interact with the physical system.	

Table 6.1 – *Continued on next page*

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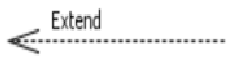
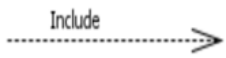
Associations	Solid lines are used in use case diagrams to indicate the associations between actors and use cases. An association exists whenever an actor is involved in an interaction described by a use case.	
Generalization	A taxonomic relationship between a more general use case and a more specific use case.	
Extend	A relationship from an extension use case to a base use case, specifying how the behavior for the extension use case can be inserted into the behavior defined for the base use case.	
Include	A relationship from a base use case to an inclusion use case, specifying how the behavior for the inclusion use case is inserted into the behavior defined for the base use case.	

6.4.1.2 Class Diagram

Class diagram describes the attributes and operations of a class and also the constraints imposed on the system. The class diagrams are widely used in the modelling of object oriented systems. Identifying a set of objects or conceptual classes is at the heart of data modelling. The identification of conceptual classes is part of an investigation of the problem domain. The following definitions of elements described in the diagram are summaries derived from (Gimenes and Barroca, 2002; Fowler, 2004; Larman, 2004).

TABLE 6.2: Class Diagram components

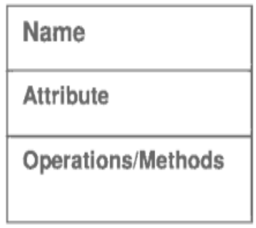
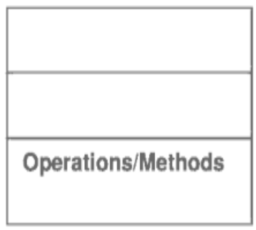
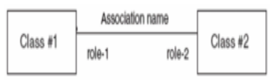
Notation	**Description**	**Symbol**
Class	A class is expressed by a rectangle with three parts inside (Figure 5.3). The first part is the class name. The second part contains all the attributes of the class. The third part contains all the operations within this class.	
Object	An object is an instance of a class, with specific values of the attribute and methods.	
Method	A method is a function or transformation type that is applicable to objects of the class. Only operations specified by the class can be applied to objects in that class. An operation may also involve objects of other classes, as specified by parameters of the operation signature.	
Multiplicity	Multiplicity defines how many instances of a class can be associated with one instance of another class. The multiplicity value communicates how many instances can be validly associated with another, at a particular moment.	
Associations	It is used to describe a relationship between two or more classes. It mirrors the different types of relationships: association, aggregation and composition.	

Table 6.2 – *Continued on next page*

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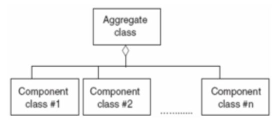
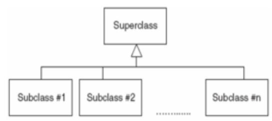
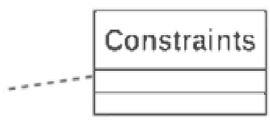
Aggregation	Relationship between two classes where one class plays the role of a container and the other plays the role of the contained entity.	
Generalization	It is a relationship between a superclass and the subclasses that may replace the superclass. The superclass is the generalized class, while the subclasses are specified classes.	
Composition	A strong aggregation, used when the objects representing the parts of a container object cannot exist without the contained object.	
Constraints	A constraint is a condition imposed on the elements of the model. Constraint is not behavior, but some other kind of restriction on the design or project. It is also a requirement, but is commonly called "constraint" to emphasize its restrictive influence. UML uses the brace notation to show constraints on the structural model.	

6.4.2 Modelling Spatial Data

For applications manipulating spatio-temporal data, conceptual modeling offers important advantages with respect to modelling approaches favoring a logical design directly related to the particularities of the GIS (Geographical Information Systems) software being used. First, users may express their knowledge about the application using concepts that are close to them, independently of computer concepts. As conceptual modeling is independent from the software tool on which the information system is implemented, the resulting design remains valid in case of technological change.

Conceptual modeling, by its readability, facilitates the exchange of information between partners of different organizations.

6.4.2.1 MADS model

MADS (Modeling of Application Data with Spatio-temporal features) is an object with relationship spatio-temporal conceptual data model. In this model, we assume that the real world of interest that is to be represented in the database is composed of complex objects and relationships between them; both characterized by properties (attributes and methods), and both may be involved in a generalization hierarchy (is-a links).

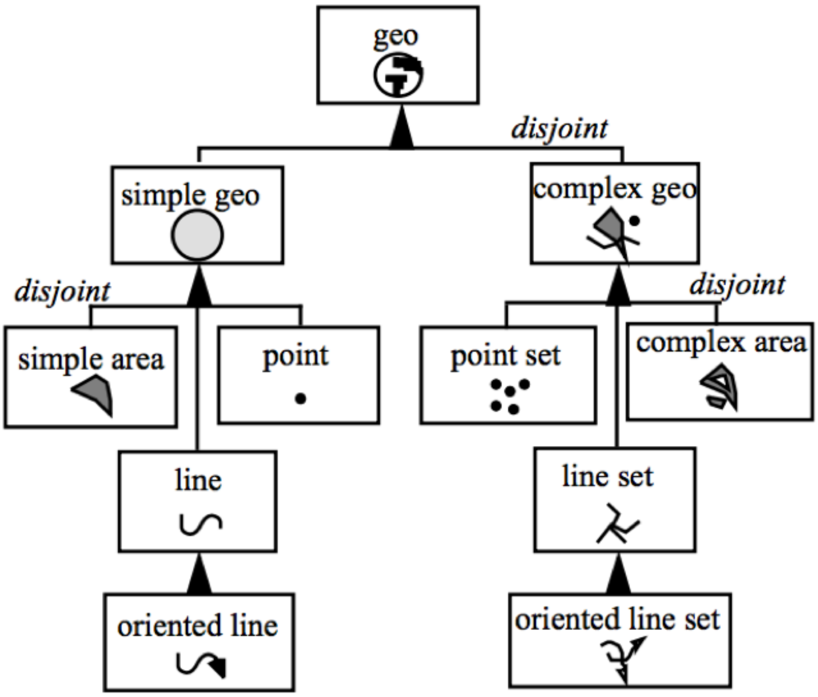


FIGURE 6.7: Modeling and manipulating multiple representations of Spatial Data. (Vangenot et al., 2002)

MADS structural dimension includes well-known features such as objects, attributes (mono-/multivalued, simple/ complex, derived), methods, integrity constraints, n-relationships, is-a links, and aggregation links.

Spatial dimension: MADS allows the modeling of phenomena:

- Discrete: objects located in space;
- Continuous: regions of space on the needs of variables and definitions as continuous fields of values. Modeled by a variable attribute.

Temporal dimension: For example, the attribute "population" of the object type "city" is variable over time. The temporality of an object or association relates to its existence / life cycle rather than its value: expected, active, suspended, dead. The "station" object has time intervals during which it is active and time intervals where it has failed.

Associations with constraint: The representation of time and space is not limited to properties of objects or associations. The constrained associations induce spatial or temporal constraints on the objects they bind:

- Topological: disjunction, adjacency, intersection, overlap, inclusion, equality. For example, the "confluent" association connects two adjacent river sections;
- Orientation;
- Metric;
- Synchronization: precedes, encounter, overlap, during, begins, finishes.

Causation Associations: It is important to be able to explicitly describe the evolution of objects. Causation associations offer users the opportunity to describe some changes and their causes.

Type of transition association

Object type change: an object is said to undergo a transition when it migrates from the population of one type of object to the population of another type of object, e.g. a "land section" which becomes an "underground section" during a regional planning.

Type of generation association

Emergence of new objects: An instance of a source object type generates an instance of a target object type. Allowed to model relations of filiation and temporality related to the appearance and the disappearance of entities in the real world, for example the division of parcels in the cadastral management.

6.4.2.2 Geographic data standards

Two major players in the standardization of geographic information:

- OGC Consortium (Open Geospatial Consortium)

- ISO TC / 211: International Standards Organization Technical Committee 211

Representation of data using a Geometry Object Geometry Schema

- ISO 19107: Geographic information – Spatial diagram
- ISO 19125-1: Geographic information - Access to entities

Standardized conceptual schemas for spatial characteristics will increase the ability to share geographic information among applications. These schemas will be used by geographic information system and software developers and users of geographic information to provide consistently understandable spatial data structures. ISO (2003) provides conceptual schemas for describing and manipulating the spatial characteristics of geographic features. Standardization in this area will be the cornerstone for other geographic information standards.

"Specifies conceptual schemas for describing the spatial characteristics of geographic features, and a set of spatial operations [...], It treats vector geometry and topology [...] It defines standard spatial operations for use in access, query, management, processing [...]"

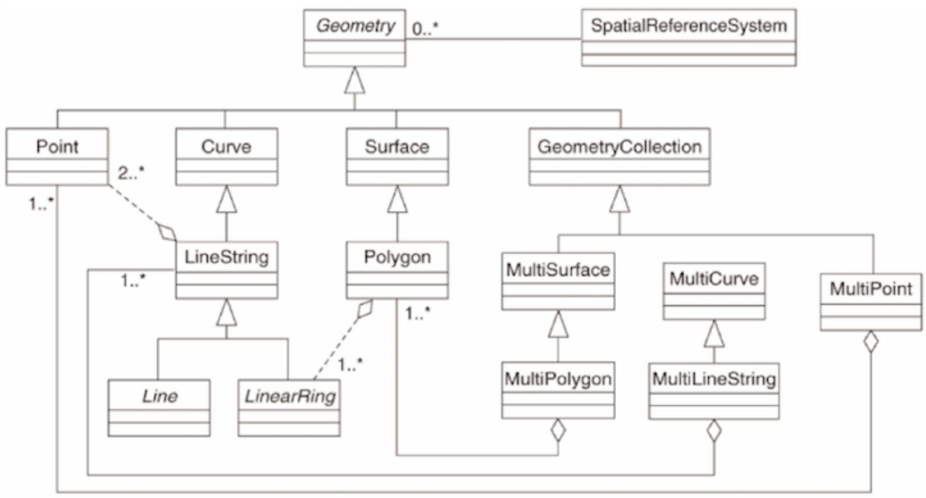


FIGURE 6.8: OGC/ISO Data Model. (Vangenot et al., 2002)

6.4.3 SDI-ICMM Use Case Diagram

Use Case Diagram allows for the specification of high-level user goals that the system must carry out for this reason that designers start usually by it. Use case diagrams are usually referred to as behavior diagrams used to describe a set of actions (use cases) that some system or systems (subject) should or can perform in collaboration with one or more external users of the system (actors). Each use case should provide some observable and valuable result to the actors or other stakeholders of the system. These goals are not necessarily tasks or actions, but can be a more general required functionality of the system (Visual Case, 2017). A use case collects scenarios. Each scenario is a sequence of steps that encompasses an interaction between a user and a system. The use case brings scenarios together that accomplish a specific goal of the user. A use case can be specified by textually describing the steps required and any alternative actions at each step. The Use Case Diagram allows the designer to graphically show these use cases and the actors that use them.

Applying this concept on SDI-ICMM, we have central circle that represents SDI-ICMM that interact (the arrows) with actors and a border for delimit a SDI and its neighborhood. Stakeholder (actors) is an individual or group with an interest in the success of a SDI in delivering its intended results and maintaining the viability of its products. Stakeholders either affect the SDI or are affected by it (Hjelmager et al., 2008). As can be seen in the Use Case Diagram (Figure 6.9), each stakeholder within a SDI-ICMM can be part of different use cases. For example, the same stakeholder (hydrographic office) participates in the building of SDI-ICMM, uses SDI services (using data for decision making), and builds the infrastructure used by the SDI-ICMM (networks, geoportal, etc.). Each one of these interactions then comprises a separate use case.

With the Use Case Diagram, it is possible to identify of required objects and relationships between them in a Class Diagram. The Class Diagram describes the attributes, the types of objects, relationships between the objects and the operations of a class and also the constraints imposed on the system.

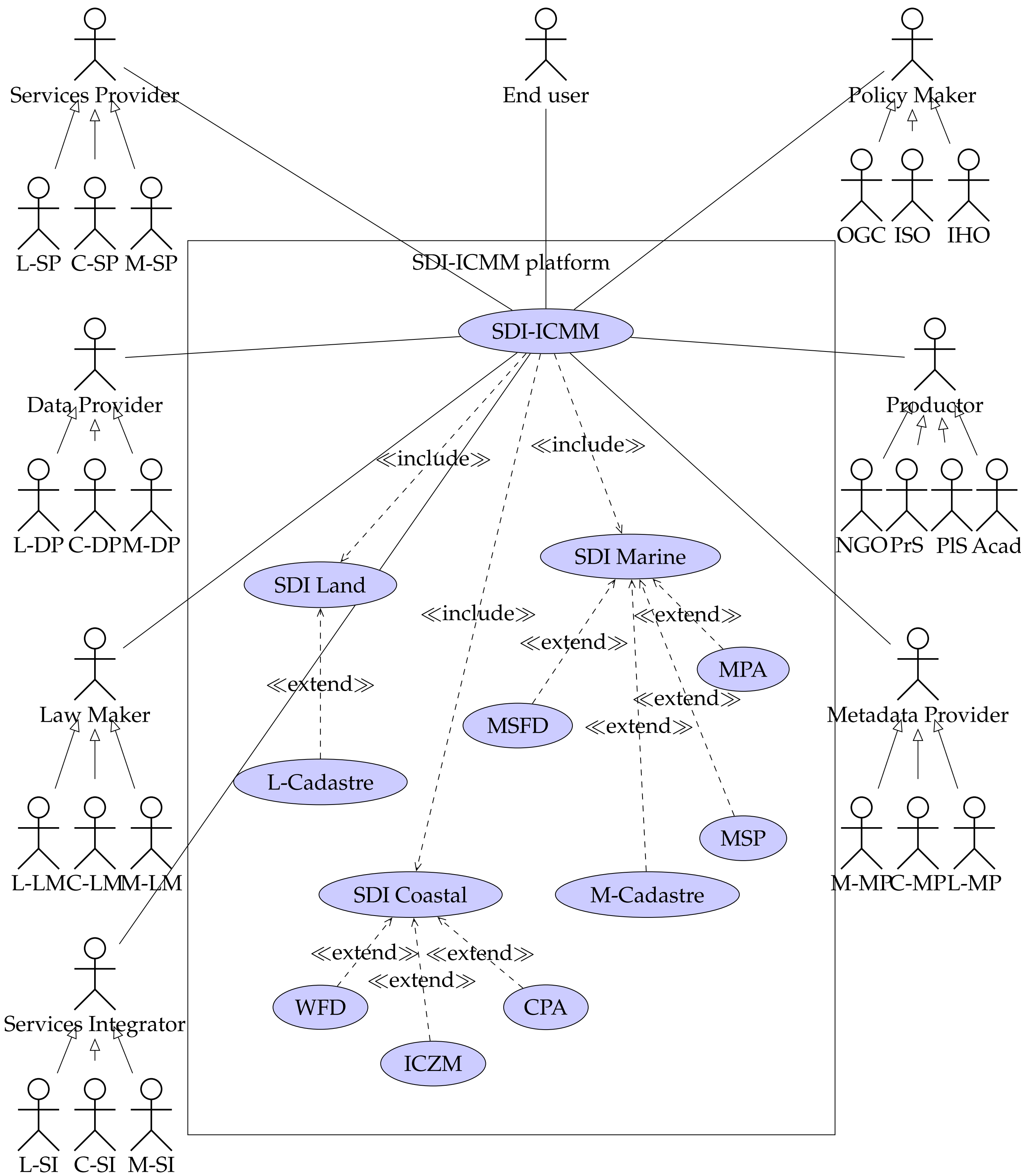


FIGURE 6.9: Use Case Diagram for Enterprise Viewpoint of SDI-ICMM

L: Land ; **C**: Coastal ; **M**: Marine
Pr: Private ; **Pl**: Public ; **Acad**: Academia

6.4.4 SDI-ICMM Object Diagram

Class diagram is basically a graphical representation of the static view of the system and represents different aspects of the system by showing the system's classes, their attributes, and the relationships between the classes. A collection of class diagrams represents the whole system. A Class Diagram partitions the system into areas of responsibility (classes), and shows "associations" (dependencies) between them. The purpose of class diagram is to model the static view of system. In an object oriented application, classes have attributes (member variables), operations (member functions) and relationships with other classes. The possible interaction between classes of objects are defined by links (Larman, 2004). Class Diagram for SDI-ICMM depicts different system's classes along with the relationships between these classes with SDI model. This diagram uses the most classes which develop SDI standards classes (IHO, ISO, OGC).

The core components of SDI-ICMM are digging deeper into the components than SDI, it can contain people, systems (application), policies, standards, services, data and metadata. The SDI-ICMM is also dynamic for that different categories can be formed based on the nature of their interactions.

The dynamic of system can be seen in policies, standards and services due to the rapidity with which technology develops and the needs change day by day. Therefore, an integrated SDI involves important issues regarding interoperability, policies and networks because to access the datasets must go through the technological components. These components need to set up appropriately to ensure interoperability.

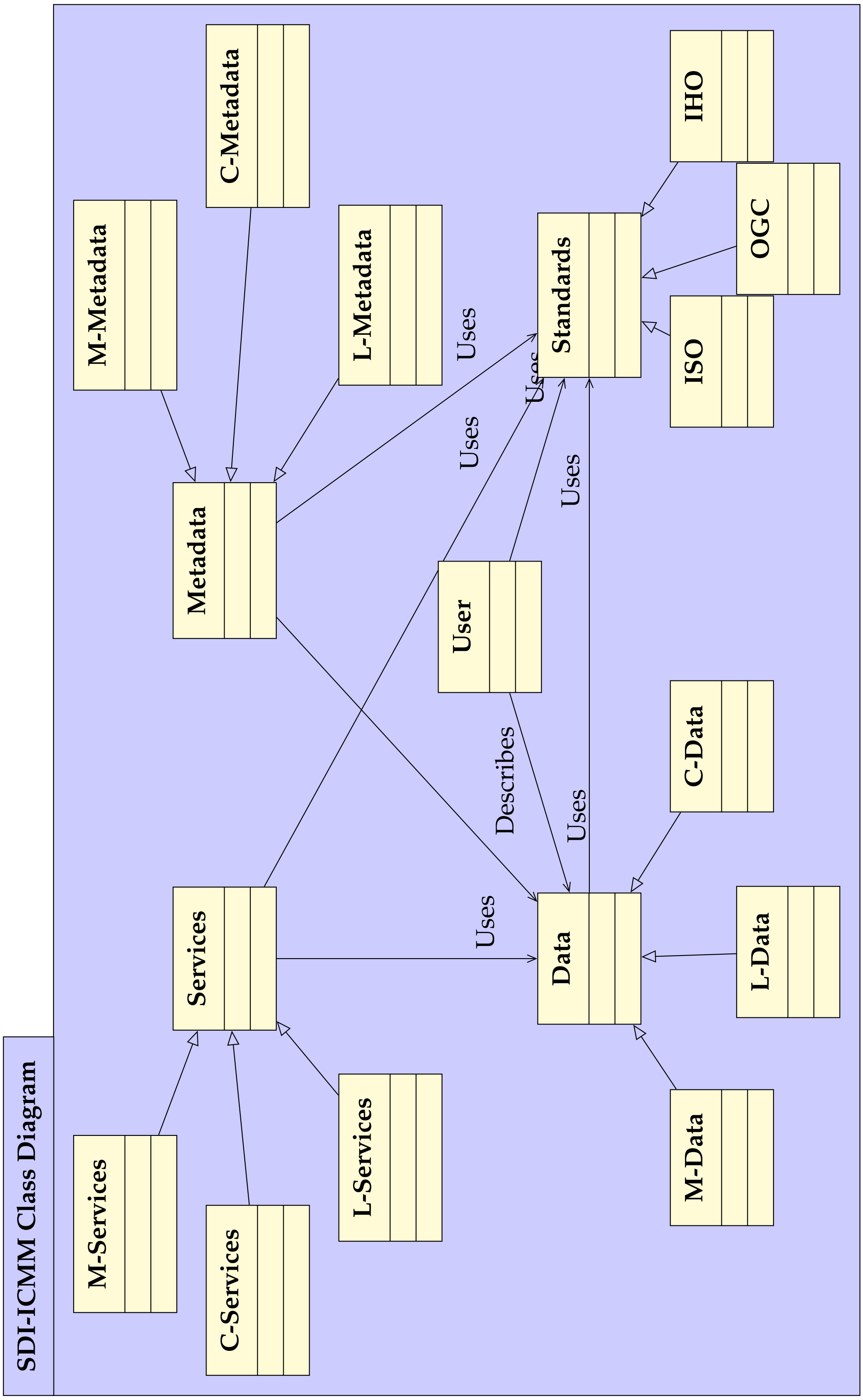


FIGURE 6.10: Class Diagram of SDI-ICMM

L: Land ; **C**: Coastal ; **M**: Marine

Due to the complexity of SDI-ICMM, the governance has an important aspect in the institutional framework necessary to support decision making. Further, there is need to develop appropriate governance arrangements to address SDI implementation challenges through giving top priority to the creation, understanding and accepting of appropriate SDI governance structures.

6.5 SDI-ICMM Governance Model

Closely associated with the institutional arrangements necessary for SDI initiatives is the establishment of a governance structure.

Over recent years, governance has gained an important role in SDI literature with calls to develop appropriate governance arrangements to address contemporary SDI implementation challenges (Kok and Loenen, 2005; Masser, 2005; Masser, 2006b; Box and Rajabifard, 2009). Similarly, in practice, the need for improved governance has been recognised (Kelly, 2007; Finney, 2007).

Nowadays, spatial data is framed within strategies that primarily aim to work towards a better government and improved living standards for society (Blakemore, 2004). Spatial data is also utilised within governance initiatives including e-government, e- society and e-democracy. Hence, spatial data and services evolve into a kind of nervous system for our planet throughout government and society. Spatial data and services will be able to take the pulse of the earth.

Wallace et al. (2006) articulate the Spatially Enabled Government (SEG) and state that a government can be named spatially enabled “where location and spatial information are regarded as common goods made available to citizens and businesses to encourage”. SEG and the society are part of a broader picture of e-government/e- society and e-democracy, and aim at building a better relationship between citizens and governments. The vision of SEG identifies the necessity to make data, information and related spatial business services ubiquitous in the daily conduct of government agency business and in the efficient and effective delivery of government services.

The implementation of the SEG vision leads to a number of significant achievements including informed and improved decision making, reduced cost of administration, consistent whole-of-government (WOG) outcomes and enhanced industry development opportunities (Rajabifard, 2007) together with effective interaction between citizens and government and better living standards for citizens.

In its most basic definition, governance is the act, process, or power of governing. The word "governance", when used in relation to fostering and maintaining SDIs, is usually applied to describe nationally specific political and institutional structures that have been established to govern or fund SDI initiatives.

Box and Rajabifard (2009) define SDI governance as "An overarching and enabling decision-making and accountability framework comprising authority structures, roles, policies, processes, and mechanisms that enable collective decision-making, and collaborative action to achieve common goals" Governance deals with collective decision-making and is clearly a function or aspect of organizational arrangements. However, given the typically large number and diversity of SDI stakeholders linked through multiple overlapping and interacting networks and the need to facilitate the rapidly evolving and increasingly collaborative approaches to SDI implementation, governance represents a significant challenge (Box and Rajabifard, 2009).

SEG builds on SDI initiatives that are an important and integral part of a country's infrastructure. SDIs aim at developing an enabling platform, including institutional, legal, governance and political arrangements. In simple terms SEG is about using SDI to improve the operation and processes of government, and deliver better policy implementation and decision making by extending the use of spatial information to the whole of government and society. SEG is also an important part of countries' ICT, e-government and information-sharing strategies as a key activity that fosters innovation. The focus of SEG is on the use of spatial information to achieve government policy objectives, though SDI is essential to achieving SEG outcomes (Williamson et al., 2004a).

While there is recent acknowledgement that governance plays an important role in developing and sustaining SDIs (Masser, 2006a), little detail has been presented in the literature on how formal governance models are being applied in this field. This is a significant gap if governance does have an appreciable effect on how SDIs are developed. It is suggested that appropriate governance models could assist SDI development in a number of ways by:

- Stimulating more rapid evolution of SDIs;
- Addressing current deficiencies in the application of standards;
- Helping to achieve an increase in public penetration of SDI related technology and services through more tightly integrating a user-perspective in both SDI design and operational management.

As noted by Masser (2005) some current SDI initiatives have evolved out of pre-existing coordination arrangements and in many cases are embedded within them. Early initiatives to coordinate geospatial information activities focused on the needs of central government mapping agencies. With the shift from product to process based SDI models (Rajabifard et al., 2003) came a shift in emphasis from concerns of the geospatial information producers to those of the users (Masser, 2006a) and a move from centralised organisational structures to decentralised and distributed networks (Masser, 2005). SDI operations have also been increasingly decentralised to local levels (Masser et al., 2008). With decentralisation, the increased role of the private sector and the need to involve a large group of diverse stakeholders in decision-making, legacy organisational arrangements reflecting the focus of early initiatives, are not necessarily the most appropriate mechanisms to enable SDI (Masser et al., 2008). These realities have led to attempts to develop improved governance models aimed at more inclusive, whole-of- industry approaches to SDI (Masser, 2005).

To achieve the aim of creation of appropriate SDI governance structures the simplest solution is to create hierarchical structures at national, state and local levels. Masser et al. (2008) note that hierarchical governance structures are required to enable the participation of national and local governments and the private sector addressing decision-making in the context of multi-level SDI implementation. Hierarchical structures are typically perceived as operating "***top-down***" (Georgiadou et al., 2006), with authority flowing from higher to lower levels and they refer the main to government initiated activities. However, SDIs are typically built at local levels from the "***bottom-up***" (Box and Rajabifard, 2009). They contrast with "bottom-up" approaches, which occur predominantly at the local level and which guide the development of application-specific and enterprise-wide activity. The hard fabric of the infrastructure is networking the community through by the deployment of applications and development of standards.

Conceptually, SDI governance can be characterised as having 'three + one' dimensions as depicted in Figure 6.11. This perspective on governance is based on Rajabifard and Williamson (2001) model of SDI conceptually recast to emphasise the role of governance in enabling cohesive evolution of the SDI components. The dimensions are:

- the **Who** – the key roles and relationships between of stakeholders and the collective organisational structures through which governance is exercises and in which they are embedded;
- the **What** – the scope of SDI resources under governance;
- the **How** – the mechanisms and processes to create, manage and support the implementation of agreements that tie together individual and collective efforts;
- the **When** – the cross cutting temporal dimension related to the evolving scope of governance.

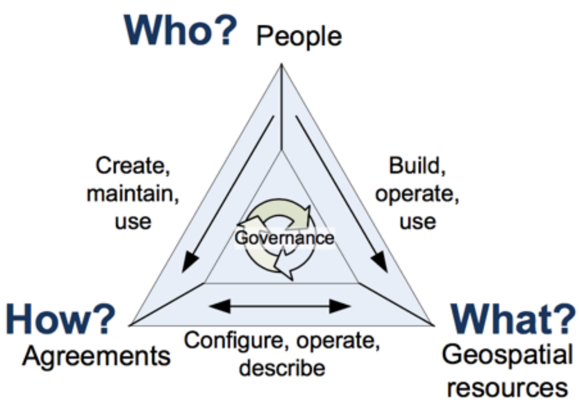


FIGURE 6.11: The three + one dimensions of governance (Box, 2013)

Change introduces a cross-cutting concern that lies at the heart of the governance model: "when". Who, what and how are all subject to decisions about implementation phases, and for the infrastructure to behave predictably, a client needs to be able to identify the status of every resource in the context of a process, and the stability of that resource. This "three + one" view of governance requires transparent process and status information to be an integral part of an evolving SDI. The technical governance of an SDI becomes more than a one-off design process; it becomes a primary source of information within the system. As such, there is an explicit requirement to link the governance model and the information model of an SDI.

The principles guiding the development of the SDI governance model are that governance solutions should be:

- Based on standards;
- Consistent with existing information infrastructure governance approaches;
- Commensurate with the scale of an SDI initiative, the volume of geospatial resources comprising the SDI and thus the scale of the governance challenge;
- Scalable and evolvable;
- Focused on the technical aspects of the SDI, namely agreements and their instantiations in the form of geospatial resources - geospatial data and services;
- Able to assist in reconciling the bottom-up and top-down governance processes and mechanisms that operate within the context of SDI initiatives as well as the broader governance realities within which SDIs are situated;
- Able to address complex independent change of multiple interrelated resources.

Therefore, it is recommended that a high-level strategic framework be established to provide a strong mechanism for collaboration between individual organisms in terrestrial and marine environments.

6.6 SDI-ICMM Guidelines

Hierarchical Spatial Reasoning (HSR) has been used to develop the conceptual model of SDI-ICMM and UML has been utilised for the design stage through Use Case Diagram and Class Diagram. These diagrams have been used to describe SDI-ICMM with its components.

Hence, the next step in the SDI-ICMM would be the implementation phase. This phase is based on the previous step to implement the requirements using appropriate tools. The implementation phase requires guidelines to facilitate the development process. These guidelines include the roadmaps, standards, policies and agreements in order to facilitate the integration of land and marine spatial datasets and sharing the data.

This chapter then provides guidelines of how to begin, given both the ideal situation/conditions, where there is wide support and adequate resources for developing SDI-ICMM. SDI-ICMM guidelines is a step-by-step approach that details the SDI framework for any jurisdiction with a coastal and marine environment.

It provides necessary information and discusses potential barriers and proposes available technical solutions and non-technical enablers. It provides guidance on how best to integrate the land and marine environment through coastal zone in a single coherent framework. Figure 6.12 illustrates the SDI-ICMM guidelines components.

An overarching framework for developing SDI-ICMM needs to be set out, based on the findings of and opinion garnered in the consultative phase. The programme should have a clear identity and a name that ensures it is widely supported. This framework is needed to provide direction and coherence to perhaps many projects, which would be undertaken in parallel, and over several years. Elements to be included within this framework are:

- A vision of what the programme will achieve, and the benefits SDI will bring;
- The principles on which it will be developed (e.g. partnership relationships);
- The identity of the lead agency;
- The institutional structures needed to ensure that there is ongoing consensus in order to have buy-in, at both technical and strategic. One may constitute a:
  - A steering body (this might be termed a “Steering Committee”, “Board”, “National Committee for Geo-information Infrastructure” etc.), most likely chaired by the lead agency committee, to provide ongoing guidance at a strategic level;
  - Technical working groups (focussing on policy, data standards, clearinghouse development etc.);
  - A stakeholder forum.

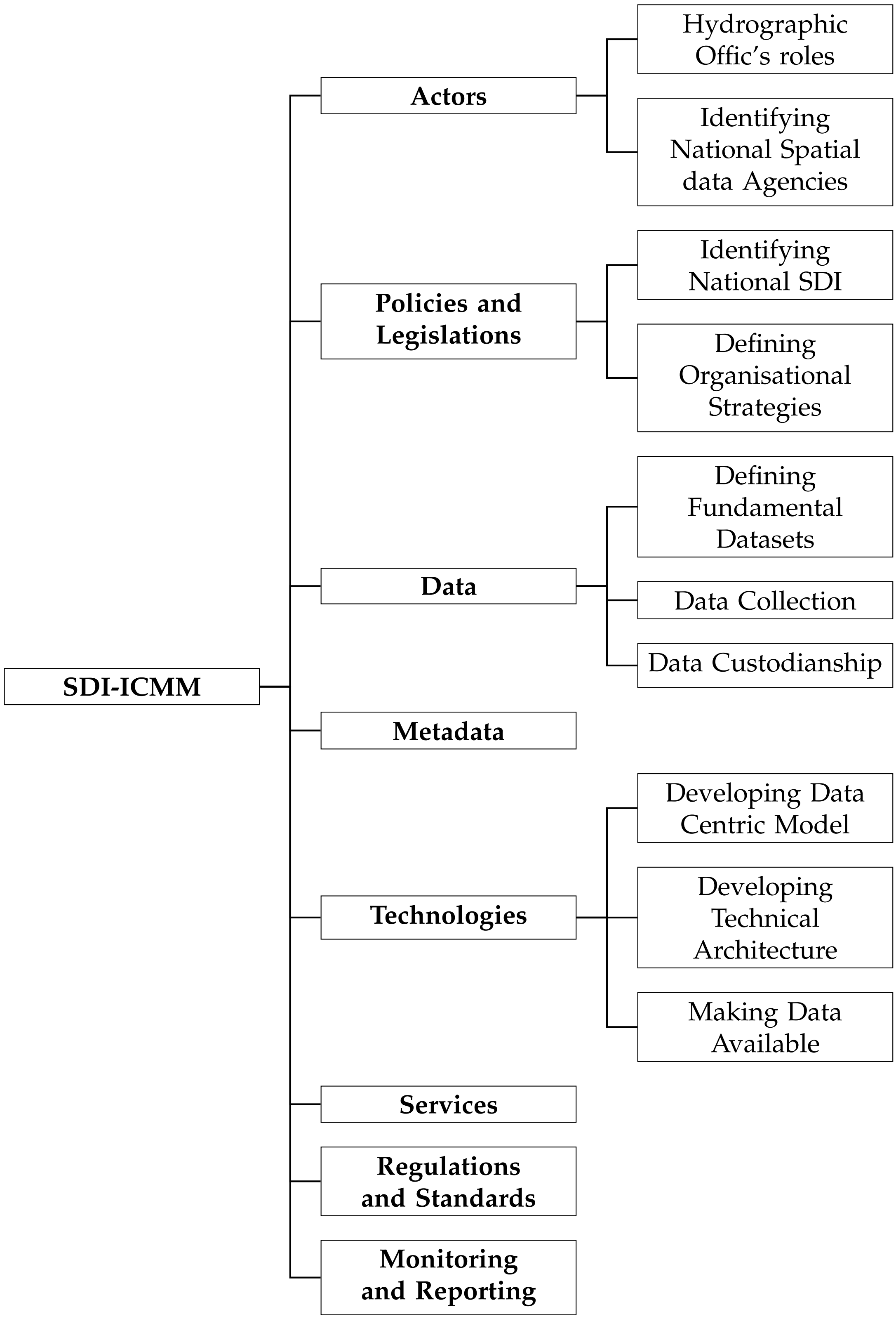


FIGURE 6.12: SDI-ICMM guidelines components

- How the programme is to be funded, or even how future fundraising will be tackled;

- Milestones to be achieved in SDI development, along with the associated timeframes.

6.6.1 Actors

The user, provider, manager or owner the data in land, coastal and marine environments are the key stakeholders of SDI-ICMM. Users should be as broad as possible, and not limited to the public sector. They can be corporate, small and large business or individuals, public and private sectors. Community of usage is the use and the management of a common resource by a community, that means the grouping of individuals and organizations interested in applying SDI-ICMM and interested to work in together: designers (both of components and standards); product manufacturers (implementing products that follow infrastructure standards); service providers; regulators; and users. All of these actors play a role, but no single type of actor can control the direction of the infrastructure, only shape parts of it (Hanseth and Lyytinen, 2009). There needs to be a willingness and practical cooperation between the various organisations that create, share and use information to implement the overall infrastructure.

There is a need to improve and encourage communication between agencies at government level, who are often the main collectors of spatial data, and all other stakeholders, both governmental, commercial and citizens (Longhorn, 2004). Partnerships are critical components of SDI development, which can be inter- or cross-jurisdictional (Williamson et al., 2003). In order to have effective SDI-ICMM, it is necessary to create well-coordinated partnership among land, coastal and marine environments users. These users can be governmental organisations, academic institutions, private sector and NGOs. It may become apparent that one will not immediately be successful in gaining the support or understanding of certain agencies, or senior decision-makers. Hence, there will not be adequate resources available for SDI-ICMM implementation, and it may not be possible to develop a widely-supported framework for SDI-ICMM development. In this case, it must be going with activities produceing results that makes other parties want to come on board. Developing an agreed interoperable seamless framework requires organisational collaboration and a clear use case and applications addressing interoperability cross borders and cross sectors (land–marine interface) scenarios.

In order to create a SDI-ICMM, national mapping and hydrographic charting agencies need to work under the same banner and their policies. Therefore, there is a need for a lead organisation or a "*champion*" to set out the access network, standards and policies and to encourage implementation of the common interoperable framework. In some countries this "*champion*" exists but it is mostly focused on terrestrial spatial data because for him the difference between marine and terrestrial SDIs can be seen as partly a result.

However, the problems in implementation of SDI can be overcome through coordination arrangements and existence of a single management authority or forum for collaborative planning, and efficient legislation. Promoting spatial data, sharing and using common standards and a single access network may help to counteract some of the unwillingness that exists, and encourage greater cooperation and collaboration in the marine and coastal sectors.

In order for the SDI-ICMM to operate at its optimum level, minimum requirements in terms of data management will be required. Data Management will probably include inputs such as policy and plans necessary to deliver metadata, data sharing and exchange mechanisms, levels of data interoperability, network services including "*discovery*", "*view*", "*download*", "*invoke*" and "*transform*" and other plans necessary to ensure compliance with SDI requirements (e.g. data licensing, digital rights management, pricing).

6.6.1.1 Hydrographic Office' roles

Hydrography forms the base spatial data layer for an SDI-ICMM in each state. Hydrographic Offices (HO) can be the competent authority concerning the provision of hydrographic and related data and it possesses an unparalleled data and knowledge resource for users at all levels according to IHO (2010) and most for them hold data to support nautical charting requirements.

Hydrography, with its subset of data themes, forms always the key "base reference" or "core geography" layer for the sea space in any jurisdiction and the HO is uniquely placed to play a central and leading role in the development of the marine component of SDI-ICMM. However, there are some challenges a HO may face when participating in a SDI-ICMM.

In below, there is a list of barriers, challenges and recommended actions to overcome these obstacles. This list is based on based on the questionnaire circulated to member states by the International Hydrographic Bureau (IHB):

- **Government Policy**: Communicate and collaborate to develop policies together;
- **Objectives counter to SDI**: Identify opportunities and benefits of SDI;
- **Business Model**: Demonstrate benefits of more inclusive and seamless approach;
- **Ethos/culture**: Training and communication;
- **Gaining the trust in other stakeholders**: Mutual respect through working together;
- **Security**: Demonstrate the benefit of release at appropriate resolution; define level of real risk;
- **Knowledge**: Training and capacity building;
- **Funding**: Cost benefit analysis through defining value and benefit of "joined up" approach;
- **Resources**: Demonstrate efficiency savings to achieve increased resources;
- **Value and benefit of SDI**: Efficiency savings and more effective way of doing things.

6.6.1.2 Identifying National Spatial Data Agencies

Another important stakeholder which should not be forget, it is the national spatial data agencies. The national spatial data agencies include national mapping agencies, cadastral agencies, coastal and land administration agencies. They play a key role in the execution of e-government policy plans and provide interactive tools to citizens. They are the leading agency in the national geospatial information policy development, commitment building and decision making process.

Cadastral and Land Administration Agencies are the lobbying institution for composing national standards, data sharing principles and portals, as well as legal and institutional arrangements in terrestrial domain. They can make institutional arrangements for SDI-ICMM regulations and play a leading role in decision making at the central governmental level.

One of the key elements for the role of Cadastral and Land Administration Agencies in SDI-ICMM is the fact that they provide and up to date the data and services to the development of SDI-ICMM. They stimulate the data integration and data sharing of fundamental datasets with other organisations in the public domain. These activities should be aligned with the SDI-ICMM institutional arrangements and national policy framework. Furthermore, encouraging the private sector and innovation in SDI development should be given high priority. Hence, identification of a champion to influence, lead and gain support for SDI-ICMM at the highest levels (ministerial and/or senior management level) of leadership is the basic requirement for any SDI-ICMM development.

6.6.2 Policies and Legislation

6.6.2.1 Identifying National SDI

In order to make an interoperable spatial information framework, there needs to be an appropriate policy or strategy in place. This is often linked to nation's or organisation's strategy for sharing and exchanging geographic information. Developing interoperability between datasets, harmonisation data and metadata standards, developing network services and sharing of public sector information, are important drivers of the creation of a SDI-ICMM. In this regard, a designated authority to develop policy/strategy along with partnerships with bodies/authorities including data owners and users required to be set up. In any jurisdiction with the marine environment, there is a need to prepare and define national marine policy in order to develop a SDI-ICMM.

One of the major concerns that should be defined in National SDI-ICMM policy is the access to detailed information about the marine and coastal environments due to concerns over national security. While the current fundamental datasets that relate to the land environment are often provided to anyone who wishes to use them, this may be more difficult to achieve with marine and coastal data. There is a need to develop an acceptable level at which data can be made available. This may involve data thinning or gridding to a level where data may be declassified.

6.6.2.2 Defining Organisational Strategies

Capacity is the power of something – a system, an organisation or a person to perform and produce properly. The conventional concept of capacity building has changed over recent years towards a broader and more holistic view, covering both institutional and country specific initiatives. As summarised by Williamson et al. (2003), capacity is seen as two-dimensional: capacity assessment and capacity development.

Capacity building is an important challenge for SDI implementation across both the land and marine environments and is especially important if the vision to spatially enable government is to become a reality.

There are different capacity factors that are important for the success of SDI implementation among them technological capacity, human capacity, and financial capacity. Some examples of capacity factors are: the level of awareness of values of SDIs; the state of infrastructure and communications; technology pressures; the economic and financial stability of each member nation (including the ability to cover participation expenses); the necessity for long-term investment plans; regional market pressures (the state of regional markets and proximity to other markets); the availability of resources (lack of funding can be a stimulus for building partnerships, however, there should be a stable source of funding); and the continued building of business processes (Williamson et al., 2004c).

6.6.3 Data

6.6.3.1 Defining Fundamental Datasets

The most important SDI component and of actual interest is the spatial information; Fundamental datasets are at the core of any SDI. Users need have immediate and easy access to up-to-date, accurate and data provided from land, coastal and marine sources. Data can be described in the following illustration (Figure 6.13).

- **Base Reference Information**: Geographic features that are used as a location reference for application information by a majority of users. Reference information is formed of base and associated reference information (e.g. topography and geology of the seabed).

- **Subject Information**: Any information that requires connectivity through a geographic reference of some kind (such as a chart, temperature and salinity) to enable the end-user to analyse, model and interpret the integrated information from different sources.

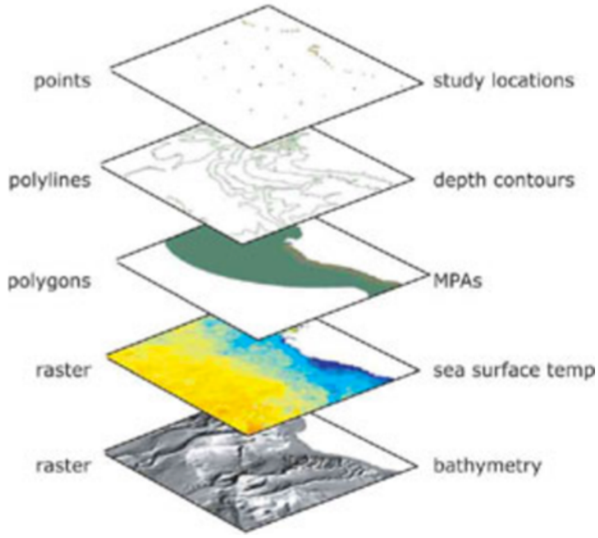


FIGURE 6.13: Fundamental datasets (Base Reference Information and Subject Information)

Much of the data that is considered fundamental in the marine and coastal environment is not available and most of the stakeholders were collecting it themselves. However, this data plays a determinant role in the development of coastal related planning and management strategies. Fundamental datasets exist in most SDI initiatives, but are generally related to the land environment. The datasets that could be considered fundamental in the marine environment are significantly different from those for the land. A suggestion to accommodate marine datasets in the current list of fundamental datasets is to extend them out into the marine environment. For example, in the USA, National SDI bathymetry is a sub-layer of the elevation fundamental dataset (Bartlett et al., 2004). This may be possible for some datasets. However, for other dataset it would need to be developed separately.

There is a growing need for better and harmonised data and information for the integrated management of the coastal and marine environment. Therefore, the common objective must be to better facilitate sharing of marine and coastal information.

Types of fundamental datasets within the marine environment may include:

- Bathymetry (e.g. DEM, TIN, Grid, points);

- Coastline;
- Tidal data (heights and streams);
- Oceanographic data (e.g. sound velocity, salinity, temperature, currents);
- Aids to navigations (e.g. lights, landmarks, buoys);
- Maritime information and regulations (e.g. administrative limits, traffic separation schemes);
- Obstructions and wrecks;
- Seafloor type (e.g. sand, rocks, mud);
- Constructions/infrastructure at sea (e.g. wind farms, oil platforms, submarine cables, pipelines);
- Shoreline constructions/infrastructures (e.g. tide gauges, jetties);
- Benthic habitat, flora and fauna;
- Boundary data, including physical boundaries and legal marine. boundaries

Marine Cadastre is considered as a base layer of a MSDI with fundamental information relating to maritime boundaries and associated rights and responsibilities, regularly updated and maintained (FIG, 2006). It is an important data layer for the user of marine environment in particular for the manager. However, Marine cadastre is one of the fundamental datasets using the common standards and policies and is available through a common access network and, as a consequence, development of SDI-ICMM. Hydrographic Office data which should be part of the SDI-ICMM includes any navigational or other water body data. Figure 6.14 illustrates the importance of hydrographic.

Fundamental datasets will allow potential data users to access geospatial data with known standards that they can use for their own purposes. These common standards have been adopted by data users can facilitate the interoperability of fundamental datasets which lead to better quality. The approach adopted to identifying fundamental datasets helps to balance ambitions and feasibility. If ambitions are too high, this may lead to complex specifications, which will be difficult and expensive to implement. Furthermore, if specifications are too complex, there is a risk that they will

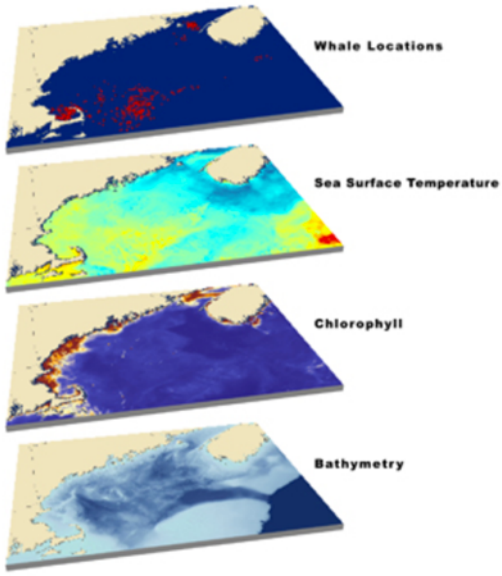


FIGURE 6.14: Example of Hydrographic datasets

not be supported by the data provider communities and that they will not be adopted by the users. However, overly simple data specifications may lead to insufficient interoperability, and the critical mass that makes the related efforts worthwhile may not be achieved, rendering the benefits of the infrastructure intangible. The main points of the challenge to be solved are illustrated in Figure 6.15.

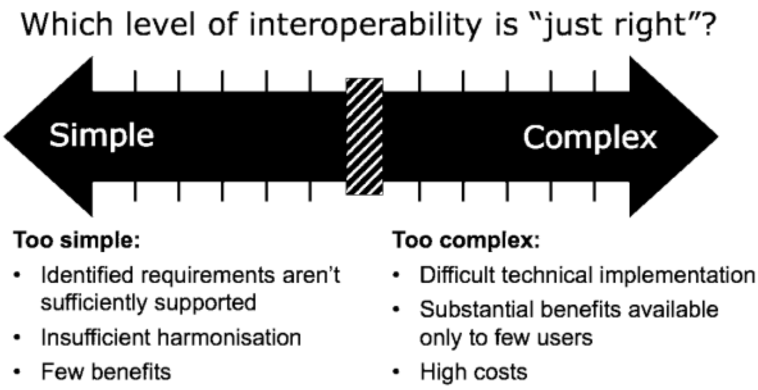


FIGURE 6.15: The challenge of finding a balance in the data specification process (Tóth et al., 2012)

A good approach to finding a balance is to apply two principles:

- The focus of activities should be on generating consistent spatial and temporal information for wider use;
- Extension mechanisms should be provided for the models and it should show how other spatial and non-spatial aspects can be linked to the

models.

SDI-ICMM bridges the land environment with the marine environment through the coastal zone. It allows users from many domains to build applications and decision-making. also, it promotes the sharing of data throughout all levels of government, of public sector, of private sector, of academia and of NGOs.

6.6.3.2 Data Collection

Data capture to obtain digital maps can be done in two ways:

- **Primary data collection**: New digital maps may be generated from aerial photography, remote sensed imagery, and field surveys. Primary data collection is done whenever existing maps are inaccurate, outdated, or unavailable;
- **Secondary data collection**: Existing analogue maps may be digitized. Secondary data collection is usually preferred when available analogue maps are accurate and up to date, and adequate data capture tools exist.

The fundamental datasets within land and marine environments aids to develop a holistic and seamless validated database of vector data using international standards, e.g. S-57 or S-100 feature data dictionary or data model in marine environment. Below are the steps regarding capturing digital hydrographic data:

- Scan manuscript documents into TIFF, GeoTIFF or JPEG format;
- Capture the data in vector format where possible;
- Ensure rigorous checking and validation is in place;
- Capture data as close to source scale or highest resolution as possible;
- Update the metadata search facility to identify raster or vector data availability.

6.6.3.3 Data Custodianship

Data custodianship are the means of ensuring accountability for the care and maintenance of fundamental datasets. The selection of custodians, in relation to fundamental datasets in the terrestrial environment, must be done in consultation with the broader spatial information community. This ensures a level of confidence in the data by users, as the custodians have been endorsed, accepted and hence trusted by the community at large. This is also needed in the selection of custodians for fundamental and business datasets in the marine environment.

The development of partnerships is one of the major factors in the successful implementation of the SDI-ICMM. The involvement of private sector companies as custodians of data fosters the development of such partnerships between not only the public/private sectors, but also between private companies, creating follow-on benefits for the development of the SDI-ICMM.

A distributed network of custodians within land and marine environments who retain full control of their respective datasets and commit to managing them and making them available is required. Land and marine spatial datasets custodians are responsible for data collection, maintenance and revision, standards development, quality, access, metadata, and privacy.

6.6.4 Technology

6.6.4.1 Developing Data Centric Model

In order to develop the SDI-ICMM database one option can be a data centric model. The merger of topographic and hydrographic data into a single database allows specialised products that contain a combination of relevant topographic and hydrographic features (e.g. products for coastal management) to be developed. Using a data centric model allows source objects to exist with an endless variety of representations, thus allowing the source data to be leveraged to create an endless variety of data products (Figure 6.16). As more source data are incorporated (such as hydrographic, topographic, aeronautical, cadastral, environmental, or biological data) better quality data products can be produced (Mackenzie and Hoggarth, 2009b).

Data centric model solutions can provide a mechanism for storing land and sea features in a single database, and can therefore facilitate the production of coastal zone maps that incorporate the relevant topographic and hydrographic features. The data model facilitates the storage of all the geospatial features in the database and how these features interact. Data

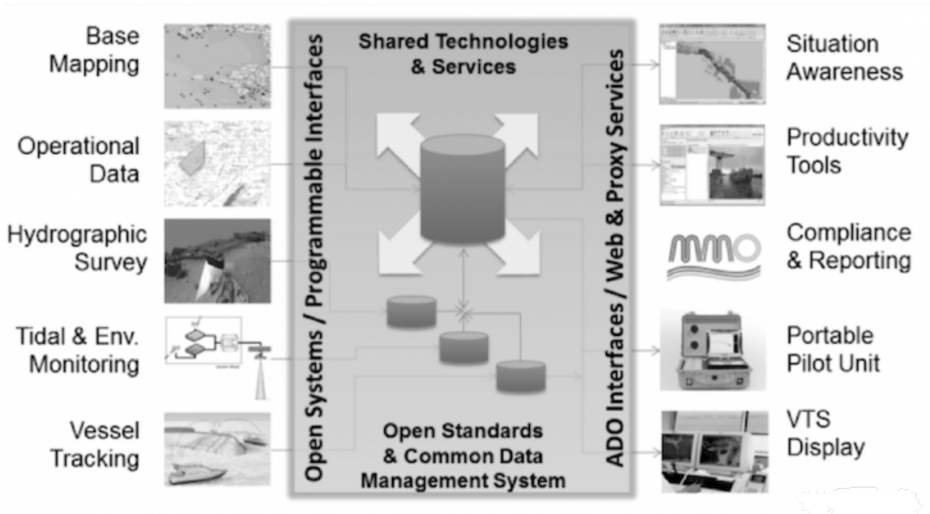


FIGURE 6.16: Data centric source (Ocean Wise, 2012)

dictionaries describing features and their attributes need to be conform to international standards. All the features in the data dictionary will require symbols, line patterns or area fills associated with them, depending on the geographic object type (point, line, area etc.). Figure 6.17 illustrates SDI-ICMM warehouse architecture. Land, coastal and marine spatial data are integrated into a single clearinghouse. The holistic and seamless datasets can be used for different applications and web services as well as metadata search engines. Updating and maintenance of this warehouse is another requirement.

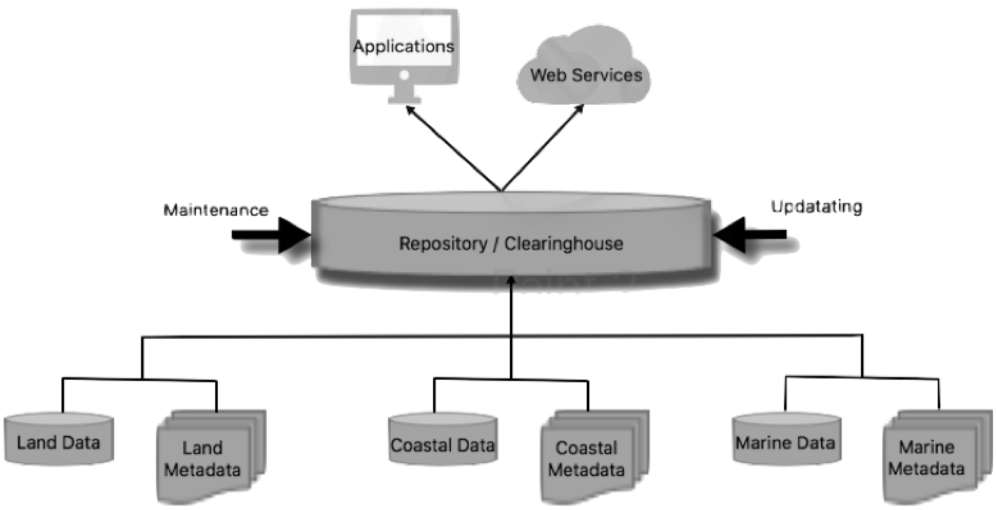


FIGURE 6.17: Clearinghouse architecture in SDI-ICMM

6.6.4.2 Developing Technical Architecture

Another requirement in building a SDI-ICMM is the provision of the technical infrastructure that will enable the delivery of data and services to allowing the viewing, transformation and downloading of information such as the ability to reference geodetic systems and transform data between such systems.

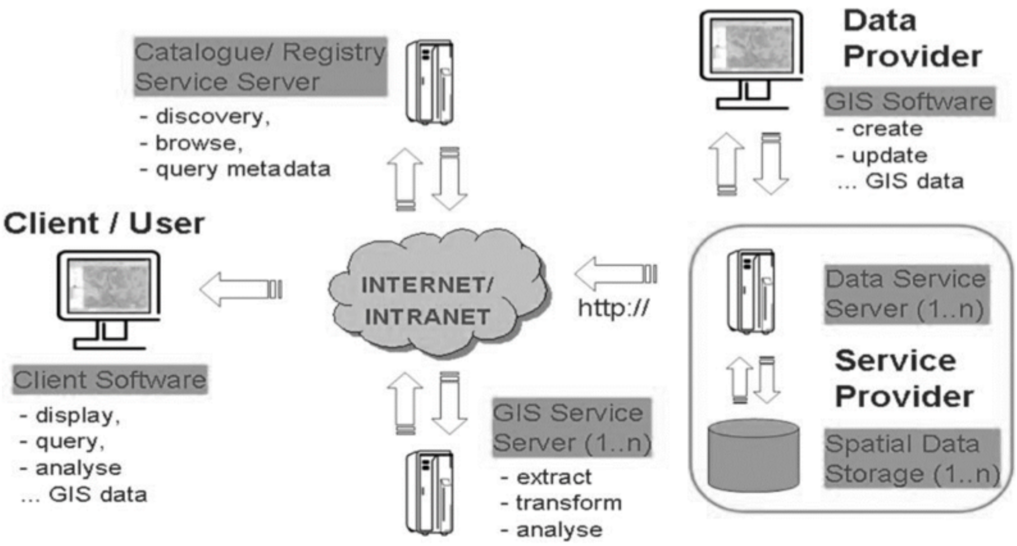


FIGURE 6.18: SDI-ICMM architecture (Steiniger and Hunter, 2012)

The SDI technology component includes hardware and software concepts such as web services, ontologies, geo-portals, catalogues and framework of minimum set of data (Souza and Delgado, 2012). Technology also includes hardware for data collection, ingesting, processing, storage, GIS user interface and output, as well as devices and systems for data transfer (Meaden and Aguilar-Manjarrez, 2013). The technology (Figure 6.18) enables the delivery of information for viewing, transformation and downloading (IHO, 2011). SDI-ICMM's basic software components are shown in figure 6.19. According to Steiniger and Bocher (2009) they consist of:

- A software client to display, query, and analyse spatial data (browser or Desktop GIS);
- A catalogue service for discovering, browsing, and querying the resources;
- A spatial data service allowing the delivery of the data via Internet;
- Processing services such as datum and projection transformations;

- Data repository for storing the data, e.g. in a Spatial database;
- A client or desktop GIS software to create and update spatial data.

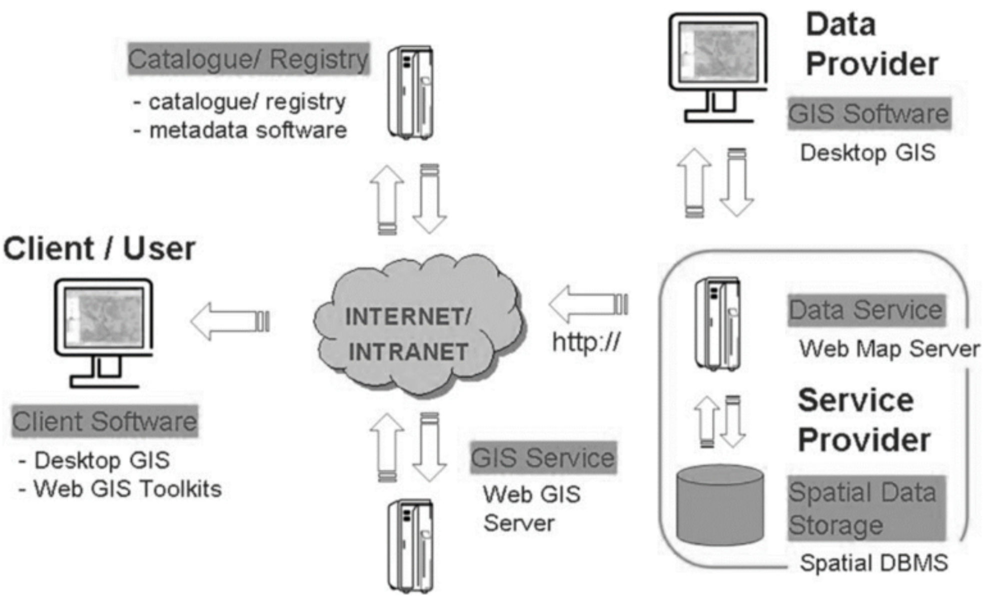


FIGURE 6.19: SDI-ICMM software needs. (Steiniger and Hunter, 2012)

Geospatial standards like WMS, WFS, GML, ISO 19115, data formats and internet transfer standards defined by the Open Geospatial Consortium (OGC), International Standardization Organization (ISO) and W3C consortium, are necessary to allow the interaction between the different SDI components of SDI-ICMM (Marine data, Coast data, Land data) to process vector and raster data, make maps and transfer data.

The need for handling, visualisation and interpretation is on 2-dimensional, 3D (depth) and 4D (dynamic), multi-dimensional, multi-sensor, multi-source, and, especially, hyper-temporal data (and data formats such as netCDF). In the land, the coast and the sea, there are lots of interrelated phenomena that give SDI-ICMM the ability of dealing with very large volumes of data.

6.6.4.3 Making Data Available

The technical infrastructure comprises not only technical tools including web services and single point of access, but also provide non-technical mechanisms including legal, social, policy and institutional considerations to facilitate data access and acquisition.

In some cases, the users know where is the data needed but they cannot find any channel to communicate and collect it. Easy access to an effective communication channel requires the provision of tools to link users to data providers including data dictionaries. The following are required steps in order to make the data available in SDI-ICMM:

- Develop download facilities for data sets;
- Develop automated search and download of data sets via web mapping services;
- Develop a holistic validated database of vector data using international standards;
- Where security of data is an issue, develop an acceptable level at which data can be made available;
- Facilitate automated search and download of data via web feature services.

6.6.5 Metadata

Metadata, commonly defined as “data about data”, is a structured summary of information that describes data (SEDAC, 2017). Metadata provides information on different technical and non-technical characteristics of spatial datasets. It includes information such as jurisdiction, custodian, data source, quality items, access channel and restrictions. Metadata is critical to document, preserve and protect agencies’ spatial data assets. In order to facilitate accessing of up-to-date fundamental datasets, metadata needs to be created and made searchable. An appropriate content of metadata can facilitate the integration of land and marine spatial datasets. Much of the information describing a dataset should be included in its metadata if present. Metadata, accompanying a dataset, are being held on readily accessible databases, allowing users to identify datasets suitable to their requirements.

However, in coastal and marine environments the main limitation for accessing marine and coastal spatial data is the lack of metadata for these datasets. The Lack of metadata remains one of the main problems coastal managers face frequently. Little or poor quality metadata makes it difficult for a potential user to assess the accessibility and applicability of the dataset.

Accurate and complete metadata will be needed in order to include marine and coastal spatial data within SDI-ICMM.

Ensuring interoperability between land and marine SDIs requires agreement on metadata schemas and formats, data models and encodings, and service interfaces for accessing both data and discovery metadata (GSDI 2008). The minimum set of metadata required for data discovery for marine requirements should describe information about the identification of the data, the extent of data, the quality of the data and the spatial/temporal reference systems used for the data.

Spatial application must be flexible to extract and update spatial metadata automatically because SDI-ICMM (land, coastal and marine datasets) has huge amount of spatial information must be generated. By contrast, in current applications, the extract and update process is undertaken manually, making changes to spatial metadata relatively more difficult and expensive (Kalantari et al., 2009). Therefore, there is a need for consistent and automated Metadata. Metadata contains a rich source of information on different characteristics of spatial datasets. This rich and consistent content can greatly facilitate different spatial data use, evaluation, coordination and integration. Effective data integration requires data evaluation (Mohammadi, 2008). However, many metadata items including quality are descriptive and most target the manual use of metadata rather an automated approach (Kalantari et al., 2009). In creating a SDI-ICMM, metadata should:

- Provide data producers with appropriate information to characterise their geographic data properly;
- Facilitate discovery, retrieval and re-use of data so that users will be better able to locate, access, evaluate, and utilise their geographic resources;
- Enable users to apply geographic data in the most efficient way by knowing its basic characteristics;
- Provide optional metadata elements to allow for more detailed description of geographic data;
- Use the ISO 19115 as the standard to ensure full interoperability.

6.6.6 Services

Services are accessible through network interfaces allowing users to evoke behaviours using standardized protocols. Three types of services are fundamental to SDI-ICMM: data catalogue services, on-line mapping services and access services. A broad range of other spatial services exist. The OGC Service Framework (GSDI, 2008) groups spatial services into five categories:

- Application Services, which are for human interaction with spatial information;
- Catalogue Services, which are for the management of metadata;
- Data Services, which are for the management of spatial data;
- Portrayal Services, which are for human interaction with spatial information;
- Processing Services, which are for processing of spatial information.

Many fundamental SDI services are related to data management and accessing data (GSDI, 2008) including: discovery and catalogue services, web-mapping, electronic commerce, authentication, payment confidentiality, public key infrastructure, delivery and packaging, compression, sub-setting and sub-selection, container-based delivery systems, data subscription, data and file transport, HTTP, FTP, SMTP/MIME. Higher level services are related to data analysis, usage and value-adding including: geo-processing, distributed computing, COM, and a multitude of value-added spatial services related, among others, to environmental, economical, industrial, social, juridical and political applications and to specific sub-fields like meteorological research or fisheries policy taking the advantage of spatial information.

6.6.7 Regulation and Standards

Most SDIs will soon converge around a Service Oriented Architecture (SOA) using Information Technology (IT) standards promulgated primarily by the Open Geospatial Consortium (OGC) and ISO Technical Committee 211. There are very few examples of these types of architected SDIs in action (Finney, 2007).

In theory, central to any SOA initiative is the concept that services will be business aligned, re-usable, durable, discoverable, interoperable, composable (i.e. designed such that one service can be incorporated readily into another or be part of a service chain), loosely-coupled, and relatively coarse-grained (Marks and Bell, 2008).

In the past few years, the geospatial community, mainly lead by the OGC and the ISO Technical Committee 211 for Geographic Information/Geomatics, has embraced the SOA model but developed alternate standards that are designed specifically to deliver or discover geospatial data payloads. For example, instead SOA components (UDDI and WSDL), the OGC has developed a registry interface standard, the OpenGIS Catalogue Service (CS-W) and three types of web services with their own messaging formats, the Web Maps Service (WMS) Web Feature Service (WFS) and Web Coverage Service (WCS). These web services and other spatially-based standards are expressed in GML (Lake et al., 2004), an XML-based language tuned for representing spatial objects.

Standards are relevant to SDI-ICMM in terms of interoperability, data format, metadata, thesaurus and vocabulary (Figure 6.20). Standards define technical data management in order to allow interoperability of data and services. For example, it is important to use the ISO 19115 standard to ensure interoperability between the SDI-ICMM, GIS, Remote Sensing and other processing systems. The Open Geospatial Consortium's (OGC) work on data content modelling, transport and web services are critical to developing a robust SDI approach (IHO, 2011).

Framework data should be maintained for common goods and it consists of data layers for transportation and utilities networks, hydrography, cadastral, administrative boundaries, elevation, aerial etc. imagery and geodetic control points.

6.6.8 Monitoring and reporting

SDI-ICMM aims to manage human activities in the land, coastal and marine zone. It requires multiple stakeholders at the table, including government, community, private sector and academia. This user provides the data in some time with Shortcomings. Therefore, the need for efficient feedback

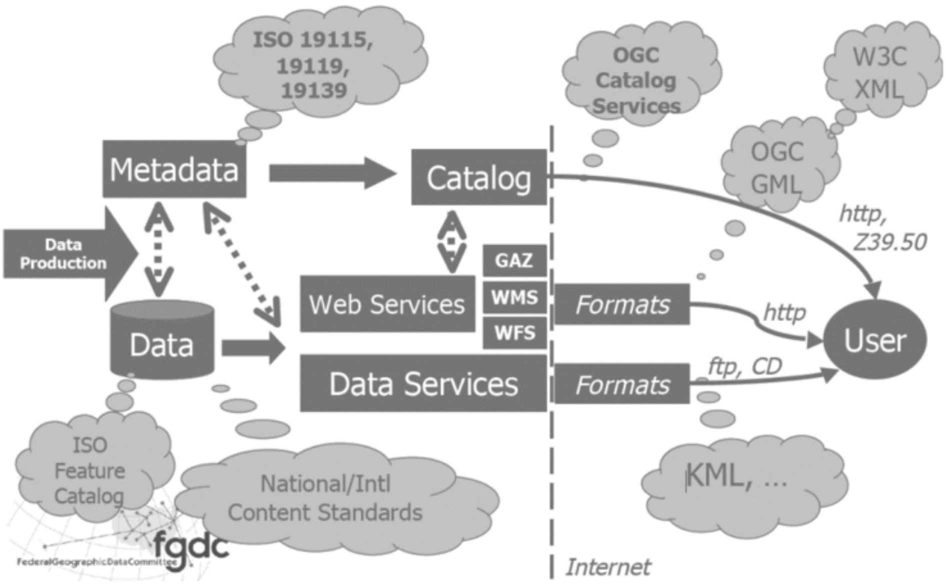


FIGURE 6.20: Activities and standards in SDI-ICMM (Nebert, 2009)

mechanisms is very important component for SDI-ICMM. This feedback plays a key role on the quality of available services.

Each component of the SDI-ICMM as highlighted in bellow (policies, standards, access network, people and data) can be considered as separate criteria for evaluation of this model. For example, the data component can be evaluated by assessing the data models, the creation of fundamental datasets, data capture methods, data maintenance, etc.

When data is defined in integrated and transparent ways (content, quality, accuracy) so that they can easily and readily be shared among different stakeholders. Other components of SDI-ICMM may be considered as the main evaluation areas based on the predefined indicators. Minimum requirements in terms of data management is required to operate a SDI-ICMM. Figure 6.21 illustrates a SDI-ICMM data management flow diagram.

A report including information on the coordinating structures, on the use of the infrastructure for spatial information, on data-sharing agreements and on the costs and benefits of implementing the SDI-ICMM, must be prepared and submitted periodically.

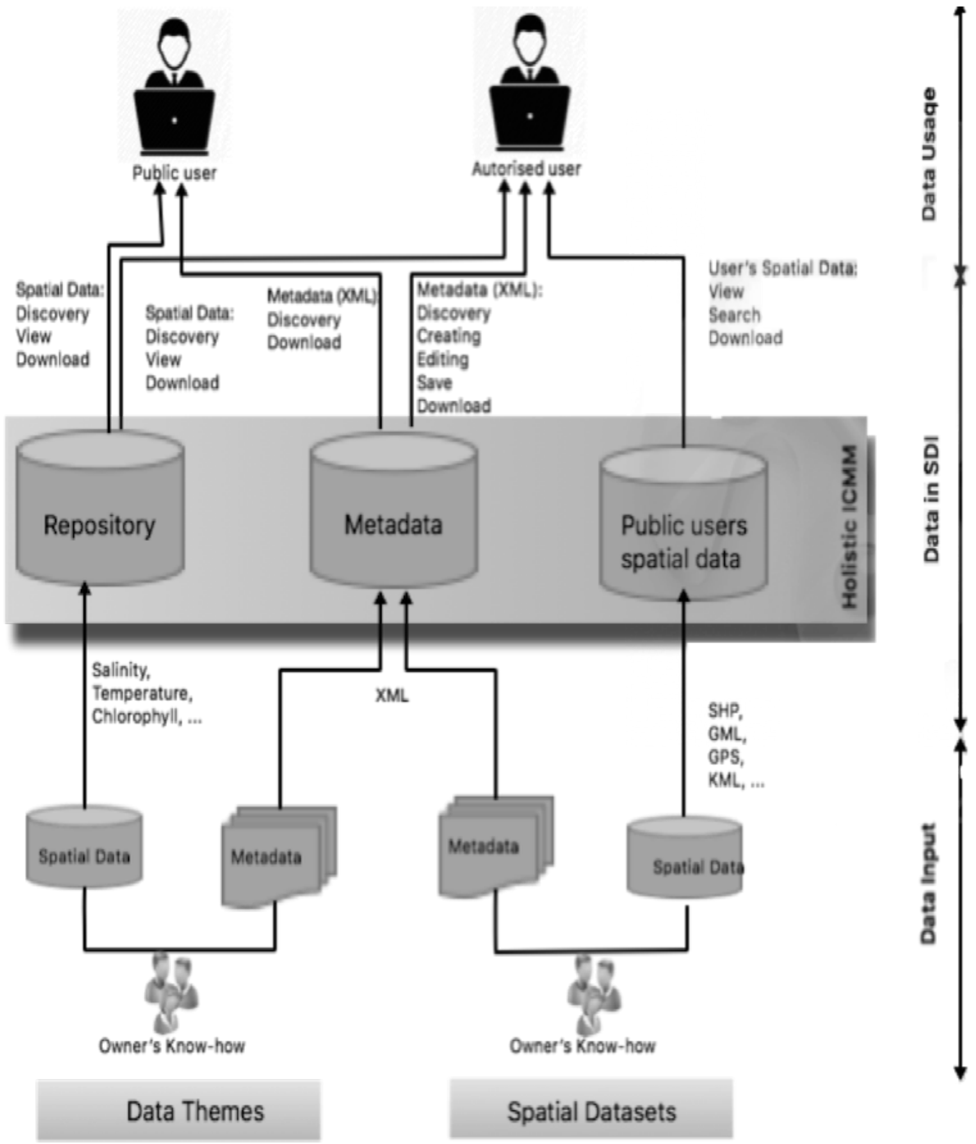


FIGURE 6.21: SDI-ICMM data management diagram

6.7 Chapter Summary

In order to design and implement a SDI-ICMM, we need a conceptual model of a SDI-ICMM. In this chapter, the Use Case Diagram and Class Diagram have been developed for the SDI-ICMM design. These models could be seen as a contribution towards the overall model of the SDI-ICMM and its technical characteristics. The Use Case Diagram shows the stakeholders and their role within the SDI-ICMM. It also helps the identification of required objects and relationships between them in a Class Diagram. In order to see how the different parts of the use cases fit together, an initial view Object Diagram for SDI-ICMM has been developed. The Class Diagram describes the types of objects in the system and the static relationships between the objects. These diagrams described the SDI-ICMM systematically and its context, users, providers, services and so on, necessary to establish them.

In implementing the SDI-ICMM model for any jurisdiction, guidelines have been outlined. The SDI-ICMM guidelines detail the key considerations for effective land and marine spatial data integration. The guidelines discuss the potential technical and non-technical barriers as well as available solutions. The guidelines provide necessary information for practitioners in order to deal with the complexity of creating a SDI-ICMM. It includes the roadmap, standards, policies and agreements that are developed within each SDI to facilitate the coordination of spatial datasets.

7 Research Design & Case Study

7.1 Introduction

This chapter charts the development of the project's research design. It returns to the underlying research problem and explains how the findings of the background chapters were used to generate a research hypothesis. The chosen case study approach is outlined and justified.

The chapter also introduces and outlines the current management and administration framework of Gulf of Gabes marine and coastal areas.

The second part of the case study analysis aims to evaluate the availability, accessibility and interoperability of spatial data in the case study area and outlines the justification for holistic and seamless information. This is achieved by testing the integration of different datasets.

The third part of the case study analysis investigates use, management and sharing of spatial data about Gulf of Gabes from the perspective of the people involved in managing this area. The results of the questionnaire collected from the respondents are presented.

Consequently, the results of the case study lead to the demonstration of the limitations and opportunities of integrating terrestrial, coastal and marine data and the need for a holistic platform between land and marine areas to enable effective management of the coastal zone

7.2 Research design

The scientific method is an organized way of fi guring something out modernised by Kuhn (1962). The steps of the scientific method are:

1. Ask and define the question;
2. Gather information and resources through observation;

3. Form a hypothesis;
4. Perform one or more experiments and collect and sort data;
5. Analyse the data;
6. Make conclusions;
7. Form a final or finished hypothesis.

The scientific method involves identifying a problem and then generating theories or hypotheses to best explain why the problem is occurring or how it may be overcome (Figure 7.1). The hypotheses are then applied to more specific research objectives, which leads to the definition and testing of measurable variables (McDougall, 2006). This deductive approach provides a framework for the study and an organizing model for the research questions and data collection procedures (Creswell and Habib, 2009). Each of these stages and their application to the research are now discussed.

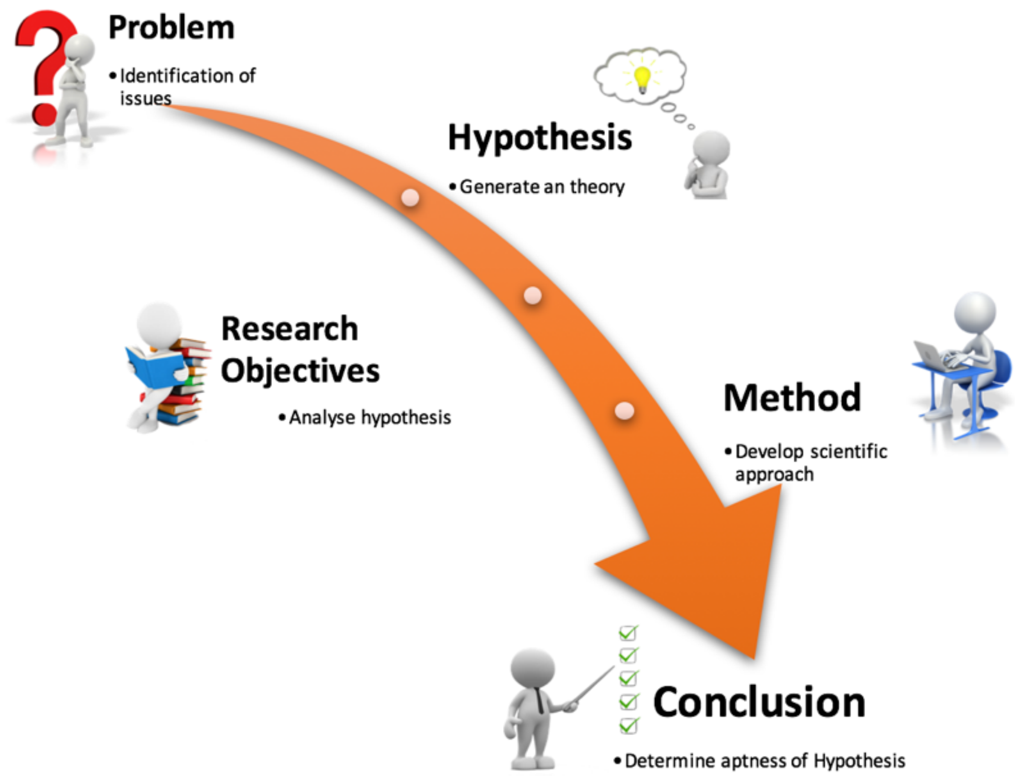


FIGURE 7.1: Scientific Method

7.2.1 Research problem

This step can also be called "*research*" or “*observation*”. It is the first stage in understanding the problem. It explains how the problem is clearly articulated and identified and provide definitions of the subject. As stated in the introductory chapter, the research problem was articulated as: With climate change, rising sea levels, shoreline erosion, population growth, pollution, overfishing and loss of biodiversity, the inability to integrate marine and land based spatial information is an increasing problem in many countries because the current SDI design is focusing mainly on the access and use of land related datasets or marine related datasets.

> The most SDI initiatives stopping stops at the land-ward or marine-ward boundary of the coastline, institutionally and/or spatially. As a result, a gap exists between the land management and the marine management. Consequently, there is a lack of harmonised and universal access to land, coastal and marine datasets. This leads to the creation of inconsistencies in spatial information policies, data creation, data access, and data integration across the coastal zone that limits sustainable management and development of the coastal zone.

7.2.2 Formulating the hypothesis

The second stage of the scientific method involves the proposal of a hypothesis. A hypothesis is an educated guess about how things work. It is an attempt to answer the question and resolve the problem with an explanation that can be tested.

In the context of this research, the marine and coastal management issues, described in the first stage "research problem", provides the best starting point. The hypothesis is based on the necessity of having a holistic information across the land – marine interface.

Most SDI initiatives stop at the land-ward or marine-ward boundary of the coastline, institutionally and/or spatially. With this in mind the research hypothesis was generated:

> The development of a holistic platform covering the land and marine environments in order to avoid the gaps between the land management and the marine management and to facilitate the access to more interoperable spatial data and information across the land – marine interface enabling a more integrated and holistic approach to the coastal and marine zone management.

7.2.3 Articulating the research objectives

The third stage of the scientific method involves designing the steps that will test and evaluate the hypothesis to develop a set of research objectives. In the context of this research the objectives which relate directly to the hypothesis as follows:

1. Investigate and justify the need for holistic information across the land-marine interface in support of better management of the coastal and marine zone and avoid the gaps between the land management and the marine management;
2. Investigate and understand current land and marine SDI initiatives and concepts;
3. Investigate the characteristics and components for the design of a SDI-ICMM model;
4. Develop and propose a SDI-ICMM model and associated guidelines;
5. Test the SDI-ICMM on Tunisia's marine jurisdictions.

7.2.4 Designing the experiments

The fourth stage of the scientific method involves designing experiments to answer the research objectives.

In the context of this research, qualitative research methods could be used to answer all of the research objectives. Qualitative methods would facilitate greater understanding of the existing land and marine SDI models in terms of their attributes and underlying infrastructure. The opportunities and barriers for combining land and marine components could all be identified and used to inform the design of a new SDI model.

There are many types of qualitative research; however, consideration is now given to the type applicable in this research: the 'case study' approach. Case studies use multiple data collection methods interviews, surveys, legislation, strategic plans, management reports, operational procedures, reports relating to the public and private organisations.

The case study approach is appropriate when the phenomenon under study is not readily distinguishable from its context and when there is a need to define topics broadly and rely on multiple rather than singular sources of evidence (Yin, 1993). Indeed, the case study approach is the only way to understand the broad field of SDI.

In the context of this research, case studies, particularly the 'descriptive' form, appeared highly relevant for a number of reasons:

- **Firstly**, it would allow for analysis and description of coastal and marine management framework;
- **Secondly**, as outlined by Yin (1993), there was a need to define topics broadly: coastal and marine interests, their management and impact were seen as very broad;
- **Thirdly**, case studies allow multiple sources of evidence to be studied. It was anticipated that data would be gathered from a range of sources including interview material, legislation, government policies and literature produced by non-government groups;
- **Fourthly**, the coastal and marine management could be studied in their normal settings.

7.2.5 Case Study Location

The selection of the case study area was based upon a number of criteria:

- **Firstly**, the jurisdiction needs to have a coastal and marine environment.
- **Secondly**, the jurisdiction needs to have a defined management framework.
- **Thirdly**, it needs to represent a heavily used and heavily populated coastal and marine environment.
- **Fourthly**, the jurisdiction needs to be accessible to the researcher.

Gulf of Gabes which is located in South of Tunisia was the chosen jurisdiction (Figure 7.2). It extends over a length exceeding 260 km, or about 20% of the Tunisian coast. The Gulf of Gabes - a Mediterranean area with abundant biological resources and rich coastal, marine and freshwater ecosystems - is specially exposed to anthropogenic factors (overfishing, deep-sea trawling and pollution from sewage Urban and industrial) which alter its natural performances. The Gulf of Gabes is under severe constraints linked to anthropogenic activities and especially to industrialization in the areas of Sfax, Skhira and Gabes, linked to the development of urban, industrial, tourism and above all related to the pollution generated, In particular by the dumping of large quantities of phosphogypses from phosphoric acid plants and chemical fertilizers on shorelines and at sea for more than fifty years. Since the early 2000s, the Tunisian government, fully aware of the difficulties and potential of this area, has emphasized the importance of adopting a pragmatic and integrated approach to conserving natural resources, including soil conservation and Water, while mitigating proven or potential threats to biodiversity; It also sought to address social and environmental concerns, while contributing to greater harmonization of planning with other investment programs and projects.

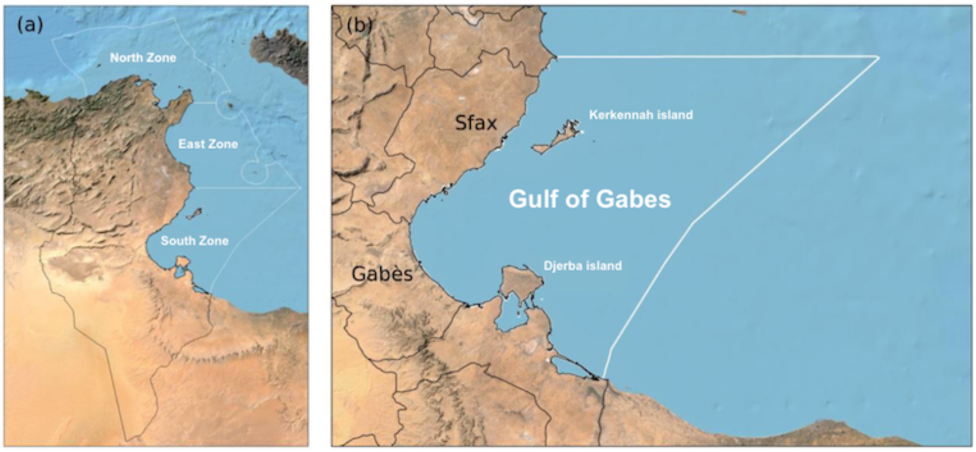


FIGURE 7.2: Geographical situation of the Gulf of Gabes: (a) Tunisian EEZ (b) Gulf of Gabes

7.2.6 Processing results and making conclusions

The fifth and final phase of the scientific method involves analysing the results, answering the research objectives and consequently making conclusions. This is a summary of the experiment's results, and how those results match up to the hypothesis. The answers to each of the research objectives are presented in Chapter 2, 3, 4, and 5. However, the answers were tested or checked through the case study analysis. The implementation of a case study as part of the overall project will enable theoretical ideas and concepts to be tested and evaluated. The case study relies on identifying the responsible for managing in Gulf of Gabes, and collecting the available spatial data. This case study was used to complete the assessment of the potential for a SDI-ICMM through examining Marine SDI as a state/ local level. In the context of this thesis, the major objectives of the case study are:

1. Identification of governing bodies and relevant legislation operating over the case study area (Gulf of Gabes);
2. Investigation of the current management framework of Gulf of Gabes including manager, regulator, planner, stakeholders and users of spatial data over the area;
3. Examining availability, accessibility and interoperability of spatial data within Gulf of Gabes through collecting the available data;
4. Justification of the need for holistic information across the land - marine interface by integrating all available datasets;
5. Identification of the current use, access and sharing of spatial data in Gulf of Gabes from the perspective of the selected stakeholders responsible for managing this area;
6. Examining common problems and limitations in use, access and sharing of spatial data from the interviewed stakeholders' point of view.

7.3 Assessing Management and Planning Framework

The Gulf of Gabes or *"Small Syrte (petite Syrte)"* located in the eastern basin of the Mediterranean and in the south of Tunisia (Figure 7.3), is probably among the most affected Mediterranean ecosystems by global change. It extends over a length exceeding 260 km, about 20% of the Tunisian coastline. Indeed, a recent analysis of the intensity and distribution of the cumulative impacts of 22 anthropogenic pressures on the whole Mediterranean basin (including fishing activities, climate change, biological invasions, coastal erosion, pollution, etc.) has shown that the Tunisian continental shelf and more particularly the Gulf of Gabes is an area with multiple influences (Micheli et al., 2013).

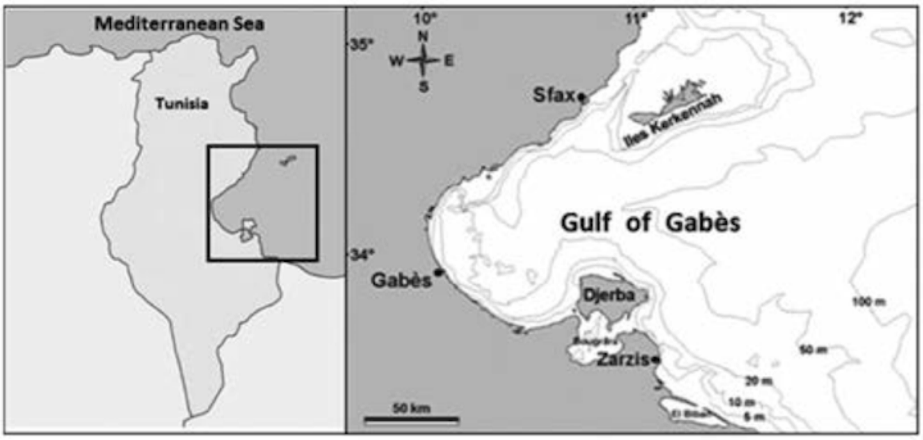


FIGURE 7.3: The study area: The Gulf of Gabes (Central Mediterranean Area)

The Gulf of Gabes subtitled with strong constraints related to:

- Anthropogenic activities and especially industrialization in the areas of Sfax, Skhira and Gabes;
- Development of urban, industrial, fishing and tourism activities;
- Pollution caused in particular by the discharge on shorelines and at sea, large quantities of phosphogypse.

All these disturbances, especially overexploitation, pollution and invasions of exotic species, have led to a great evolution of biological assemblages since the late 1970s (Quignard and Ben Othman, 1978). This makes the Gulf of Gabes an archetypal ecosystem where all threats are present and, as a consequence, a model for potential studies of more generalized trends affecting marine ecosystems at the Mediterranean level.

The first part of case study analysis is dealing with assessing Gulf of Gabes (GG) management and planning framework. Gulf of Gabes is managed by national and local governments.

Local governments have jurisdiction above low water mark; however, in some municipal councils, jurisdiction is extended seawards to 600m from the low water mark to include jetties, marinas, breakwaters and other coastal infrastructure. The National government is responsible for the area off-shore: the waters and seabed.

The planning and management framework of Gulf of Gabes is made up of a number of key agencies responsible for:

- Ownership of the land or waters;
- Management of the land or waters;
- Planning the way in which the land or waters are to be used;
- Regulating activities on land and waters.

To understand the planning and management framework, it is important to recognise who owns the asset, who is charged with direct management of the land or waters, and who is responsible for planning and regulating the way in which the land or waters can be used at a local or regional level. It is also necessary to consider Gulf of Gabes in terms of its waters, coastal foreshore land and its regional catchments. Activities in the broader catchments have a direct impact upon the marine environment of Gulf of Gabes. The coastal foreshore includes both public and private land that forms the important land and water interface of the Bay.

7.3.1 Legal tools

At international level, the number of international conventions ratified by Tunisia regarding the coastal zones, the sea and biodiversity in general, are numerous and are interested in various aspects of the valorisation of these spaces. In addition to the national level, the protection of coastal and marine natural areas is ensured by numerous legislative texts among which mention should be made of those dealing directly with coastal areas and their protection (Figure 7.4).

The veritable protection and management of the coastal and marine area started after the establishment of the Coastal Protection and Management Agency (APAL) in 1995 following the recommendations of the Med 21 Conference on the Implementation of the Agenda 21 for the Mediterranean (APAL establishment - Law 95-72 of 24 July 1995). It is responsible for the execution of State policy in the field of coastal protection and management in general and maritime public domain in particular. Its main areas of intervention concern the management of coastal areas and the monitoring of development operations; The regularization of existing land real estate situations; The development of studies on the protection of the coastline and the development of natural areas and the development of research; Observing the evolution of coastal ecosystems through the establishment and operation of GIS.

APAL as one of the key stakeholders is uniquely placed to play a central and leading role in the development of the marine component of SDI-ICMM. APAL with these local offices can be invited by the national government to be involved in the development and management of National SDI-ICMM.

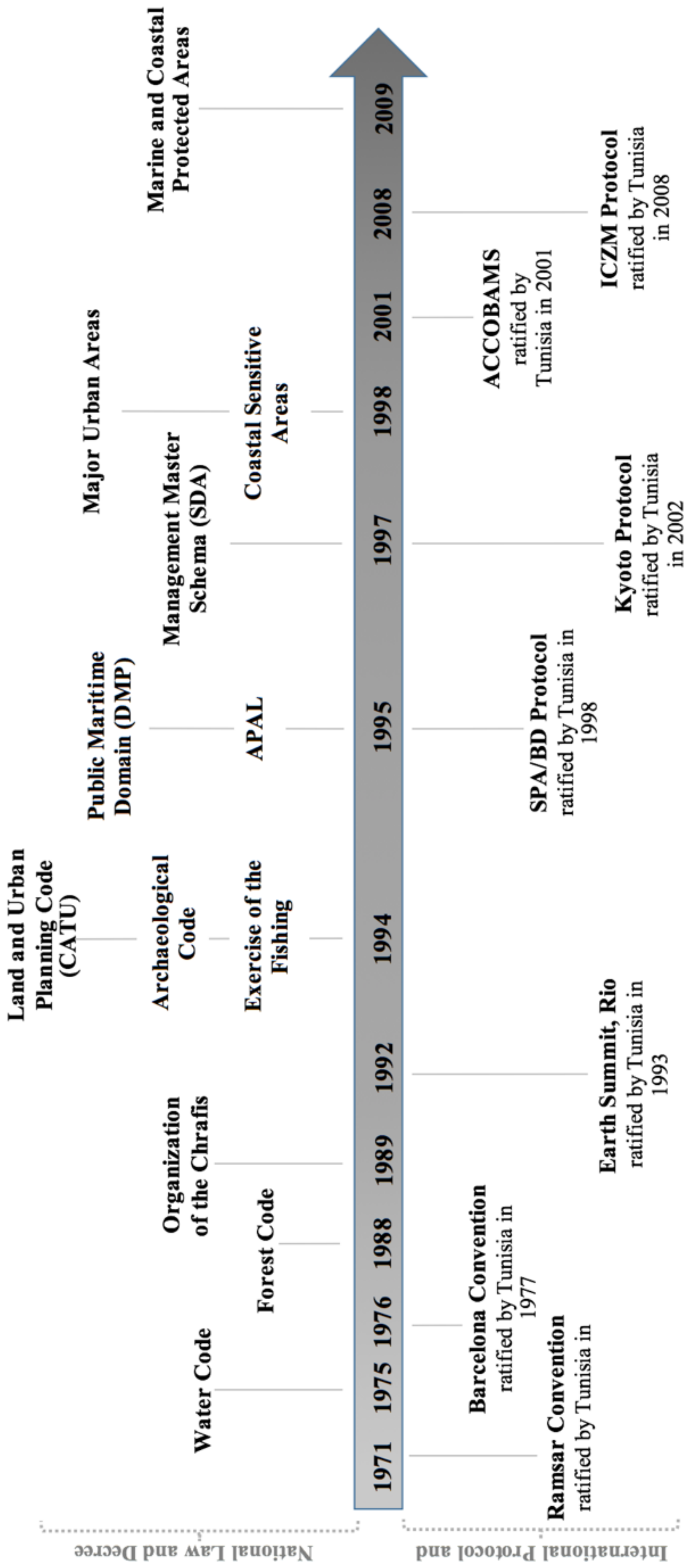


FIGURE 7.4: Main national and international legislations applicable to coastal and marine zones

7.3.2 Institutional tools

The establishment of a SDI-ICMM could provide some leadership in ensuring good governance of the coastal and marine environment and management the land ward, marine ward and coastal-marine interface through legal and institutional tools. The SDI involves all stakeholders in the exploitation, management and planning of coastal and marine areas.

The SDI can reflect the commitment of the public authorities to a partnership with national associations and organizations. A multitude of institutions and organizations involve in the coastal and marine space either through a transversal and integrated spatial planning and management or through a sector exploitation strongly influencing the use of the space and its resources natural.

Three main ministries are particularly concerned with coastal and coastal ecosystems, namely the Ministry of Environment and Sustainable Development (MEDD), the Ministry of Infrastructure, Habitat and Spatial Planning (MEAT) and the Ministry of Agriculture, Water Resources and Fisheries (MARH).

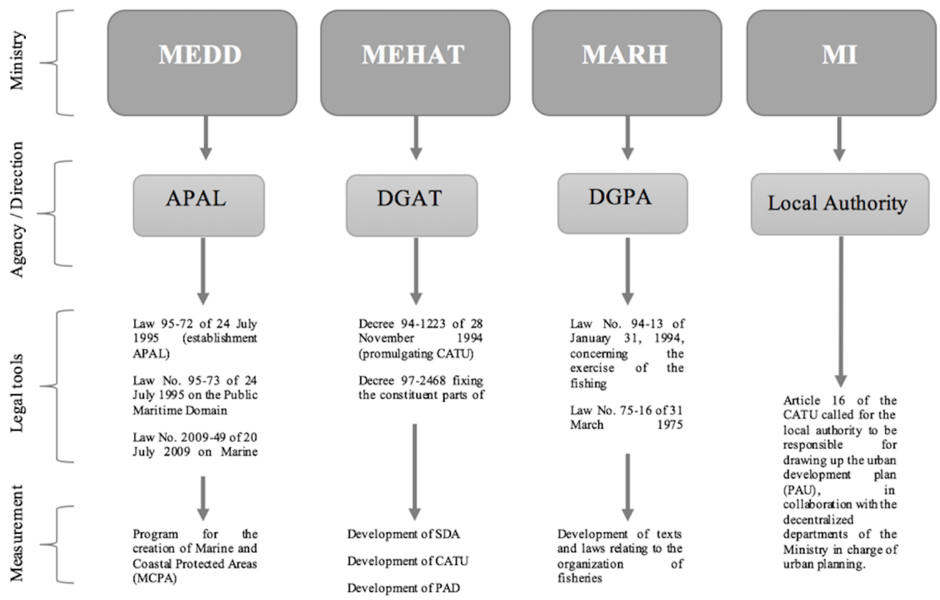


FIGURE 7.5: Main institutions involved in the protection, management and management of coastal and marine areas

Figure 7.5 shows the main institutions involved in the protection, management and management of coastal and marine areas.

7.3.2.1 State and regional planning

A description of these institutions and their missions related to the planning, management and exploitation of coastal and marine areas in Tunisia is presented below.

- Ministry of Environment and Sustainable Development (MEDD)
  - Coastal Protection and Management Agency (APAL)
  - Coastal Observatory
  - National Agency for the Protection of the Environment (ANPE)
  - Tunisian Observatory on Environment and Sustainable Development (OTEDD)
- Ministry of Equipment, Habitat and Spatial Planning (MEAT)
  - General Direction for Urban Planning
  - General direction of Air and Maritime Services
- Ministry of Agriculture, Water Resources and Fisheries (MARH)
  - General Direction for Forestry (DGF)
  - General Direction for Fisheries and Aquaculture (DGPA)

7.3.2.2 Local planning

At a local level, planning for coastal is undertaken on a site specific basis by the delegated land managers in their role as committees of management. These land managers include Local Authority, Municipal Councils and committee of management composed by some regional managers.

While a Local Authority may be a committee of management for land and coastal area, all local councils are also responsible for planning decisions. The planning scheme includes a State Planning Policy Framework which embraces state-wide policy objectives including coastal issues. State Government regulates activities on waters and both public and private land in the Bay, foreshore and catchment though a variety of agencies.

Many different local, regional and national government agencies are responsible for different aspects of the management and different uses of the Gulf of Gabes. It is evident that these stakeholders come from land, coastal and marine environments with different rights, interests, or responsibilities for management of this area. These rights and responsibilities regularly overlap, creating the need for interaction between a wide range of stakeholders and activities. The task of efficiently and effectively managing all stakeholders is complicated by the fact that their rights can often overlap which gives rise to the need for cooperation between agencies.

Table 7.1 represents all the institutions that can be involved in the SDI implementation as well as the role that can play each of them in the coastal, marine and terrestrial area.

TABLE 7.1: Institution that have a role in coastal and marine management

Ministry	Management Agency / Direction	Owner			Manager			Planner			Regulator		
		L	C	M	L	C	M	L	C	M	L	C	M
Ministry of the Environment, Sustainable Development	Coastal Protection and Management Agency		X			X	X		X	X		X	X
	National Agency for the Protection of the Environment							X	X	X	X	X	
	General Direction for Environment and Quality of Life								X			X	X
	National Office of Sanitation	X			X	X							
	National Agency for Waste Management	X			X			X			X		
	Tunis International Centre for Environnemental Technologies							X	X	X			
	Tunisian Environment Observatory for Sustainable Development							X	X	X			
Ministry of Agriculture and Hydraulic Resources (MARH)	General Direction for Forestry	X			X			X			X		
	General Direction for Fisheries and Aquaculture									X			X
	Regional Office of Agricultural Development				X			X			X		
	General Direction for Water Resources										X		
Ministry of Equipment and Urban Planning (MEHAT)	General Direction for Urban Planning				X			X			X		
	General direction of Air and Maritime Services					X							X
Ministry of Industry	Industry Real Estate Agency	X			X			X			X		
Ministry of Health	Direction of Environmental Hygiene and Environmental Protection							X	X		X	X	
Ministry of Culture,	Agency for Development of Heritage and Cultural Promotion	X	X	X	X	X	X						

Table 7.1 – *Continued on next page*

Table 7.1 – *Continued from previous page*

Youth and Recreation	National Institute of Heritage							X	X	X	X	X	X
Ministry of Higher Education	National Institute of Marine Science and Technology									X			X
	INAT, FST, FSB, FSS, etc.							X	X	X			
Ministry of Tourism	Tunisian National Tourist Office							X	X		X	X	
	Tourism Real Estate Agency	X	X		X	X							
Ministry of Transport	Office of the Merchant Marine and Ports		X			X			X			X	
Ministry of Defence	National Army of the Sea			X			X						
Ministry of the Interior	Municipality council	X	X		X	X		X	X		X	X	
	Marine Guard											X	X
Associations and NGO	World Wild Fund for Nature							X	X	X			
	Regional Activity Centre for Specially Protected Areas							X	X	X			
	Kerkennah Islands Integrated Management Unit							X	X	X			
	Agricultural Development Group				X	X							

L: Land Area; **C:** Coast Area; **M:** Maritime Area

7.4 Analysing Available Spatial Data

The second part of the case study analysis involves obtaining available spatial data of Gulf of Gabes and examining and analysing this data. In this regard, a search was conducted to establish the available datasets for the marine and coastal areas of Gulf of Gabes. This involved searching various data directories. This was done to provide an audit of all available data for the case study area at national, state and local scales (Table 7.2).

In collecting the available datasets within the case study area, the main impediment to obtaining data was that there are some general datasets available, but there is a limited data that is specifically related to Gulf of Gabes. When planners, managers and decision-makers need data for a particular area it will generally be collected on a once-off basis, used and then rarely used again. This project-based data is not available for re-use by someone else (example the data about artificial reefs).

Metadata is also another important part of assessing the availability of spatial data. Some of the datasets did not come with metadata (Table 7.2) and this makes it very difficult to use the data. Other aspects of the data such as the scale, reference frame and accuracy are critical in using the data, and need to be documented in the metadata. This part of case study revealed that data producers in the marine environment did not always produce or supply metadata with spatial datasets.

The only way in which users are able to make effective decisions is through knowledge of the accuracy and limitations of the data that they use. Metadata provides such knowledge, and would need to be provided for any dataset used within a SDI-ICMM. This is especially so for fundamental and business datasets, although this would be part of any custodian's role.

TABLE 7.2: Available datasets for Gulf of Gabes and their availability of metadata

Available Datasets	**Custodians**	**Metadata**
Watershed	DGRE	No
Hydrographic Network	DGRE	No
Wetlands	APAL	Yes
Dam	DGRE	No
Lan Use	CRDA	No

Table 7.2 – *Continued on next page*

Table 7.2 – *Continued from previous page*

Bathymetry	Nautical Chart	No
Coastline Data	APAL	Yes
Swell	EANM	Yes
Tide	EANM	Yes
Marine Depot	APAL	Yes
Geological Data	Geological Map	No
Floor	CRDA / DGGR	No
Water table	CRDA	No
Vegetation	CRDA / DGF / ANPE	Yes
Coastal Erosion	CERES	Yes
Contour	Topographic Map	No
Slope	OTC	Yes
Side Points	Topographic Map	No
Port Zone	EANM / APIP	No
Tourist Zone	ONTT / AFH	No
Industrial Zone	API	No
Population	INS	Yes
Aquaculture Farm	DGPA / CTA	No
Dump	OTED	No
Water Rejection	APAL	No
Marine Protected Area	APAL	Yes
Coastal Protected Area	APAL	Yes
Sensitive area	APAL	Yes
Administrative Boundary	Ordnance Survey Map	No
Name Place	Ordnance Survey Map	No
Built Area	DGAT	No
Roads	DGAT	No
Aerial Photography	CNCT	Yes
Oil and Gas Facilities	ETAP	No
Pipelines	ETAP	No
Marine Vegetation Classification	INSTM	No
Vessel Tracks	DGPA	No
Defence Areas	MD	No
Marine Boundaries	CNCT/DGPA/APAL	Yes

In order to investigate the need for seamless information, each dataset was assessed and included in the GIS. There were quite a few datasets available that had information about Gulf of Gabes, and that only few of these datasets could not be used because of interoperability issues. Interoperability is the ability of a computer system to run application programs from different vendors, and to interact with other computers across local or wide-area networks regardless of their physical architecture and operating systems (Business Dictionary, 2017).

In order to assess the interoperability of datasets within the case study area, the characteristics of data as format, licensing, pricing, scale and reference frame have been further analysed. Table 7.3 shows the results for the datasets for Gulf of Gabes.

TABLE 7.3: Interoperability of few datasets for Gulf of Gabes

Dataset	**Format**	**Scale**	**Reference**
Arial Photography	Image	Variable scale	WGS84
Bathymetry	shp / ASCII / Raster	Variable scale	WGS84
Topography	shp / ASCII / Raster	1:25 000 / 1:50 000	Lambert
Coastline	shp	1:250 000	WGS84 / Lambert
Marine Boundaries	shp	1:10 0000 / 1:250 000	WGS84
Tourist Zone	shp	1:10 000	NTT
Lan Use	shp	1:25 000 / 1:50 000	Lambert

Table 7.3 shows that different data formats and scales limit the data interoperability and data integration of datasets within the main stakeholders of Gulf of Gabes. The majority of data is not accessible to all users; they are either stored in personal datasets or in a geo-portal through intranet. Considering all the limitations and issues regarding interoperability of datasets, the analysis of data demonstrated the importance of not only making spatial data available, but of also having common standards and policies to make the data interoperable.

After the data collection step it arrives the step of the refinement and integration of data. Initial data refinement was based on spatial extent, appropriate scale and relevance to the coastal zone. Each dataset was individually assessed to ensure the scale was of sufficient resolution, its spatial extent encompassed gulf of Gabes or surrounds, and its attributes were relevant to the coastal zone. Interoperability issues were then resolved where possible including varying projections and datum; data was refined and modified to geographic coordinates (WGS84) as a base standard. All datasets were converted to shapefile in order to facilitate the management with GIS software desktop. Throughout integration, metadata for each dataset (where available) was checked, and features were appropriately attributed where possible.

Investigation of spatial datasets in the case study highlighted a number of coastal management issues due to the lack of seamless information across the land – marine interface. For instance, figure 7.6 shows that there are discrepancies in datasets, mainly in the coastal area where the coastline datasets are available (APAL data, DGPA data and DGAT data) showing that the coastline are slightly different. Different organisations and agencies can delineate the same spatial feature in separate datasets without agreement on boundary location.

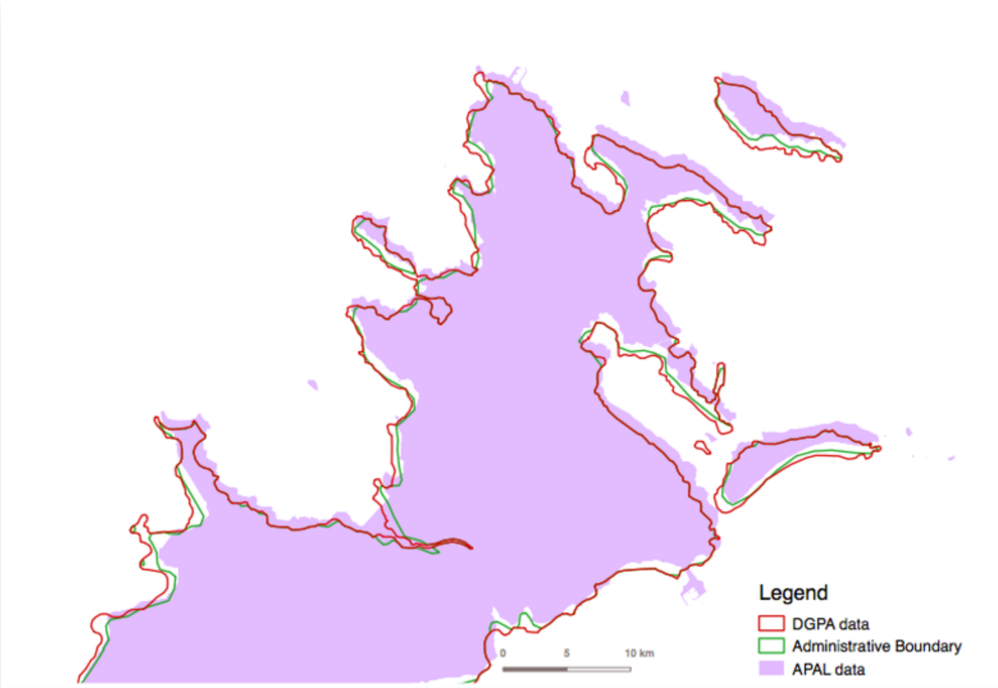


FIGURE 7.6: Coastline Differences in Island Kerkennah (Gulf of Gabes)

The coastline data from DGAT was more generalised (covers the entire country); it simplified the coastline by ignoring smaller detail. The APAL shoreline data showed much more detail and included more islands because the main role of APAL studied the coastline. As well as, the difference is due to the scale and accuracy and to the large positional uncertainty of one dataset.

There exists another discrepancy between the terrestrial based and marine based data sets over the coastal zone. This is illustrated where the terrestrial based topography and marine based bathymetry. A SDI-ICMM platform would enable the utilisation of common boundaries across the coastal zone to ensure no ambiguity and no areas unaccounted areas over the coastal interface.

This part of the case study highlighted the limitations of integrating spatial data over the coastal zone. The lack of metadata and standard for data collection and maintenance is the major problem of integration the coastal and marine data. Standards, policies and procedures involving spatial data need to meet in unique SDI to effectively integrate and manage the coastal and marine zone. If such a holistic system were adopted across the area many of these issues could be resolved or reduced through holistic and integrated management.

The next section of this chapter assesses the level of implementation of the SDI-ICMM and examines the accessibility and usability of spatial data from the point of view of stakeholders in Gulf of Gabes.

7.5 Centralization and sharing of data

Much of the effort of the thesis was to collect, standardise, and centralise the data and documents available. This data was added to geo-portal SDI-ICMM (Figure 7.7) that contains coastal and marine geographical data. This sample of website has been set up in a localhost domain just to give an example of SDI-ICMM.

The most of data and metadata were provided by APAL. A large number of data probably available in vector form but not accessible was identified during the documentation work, notably the excellent work of Etienne Etienne (2014).

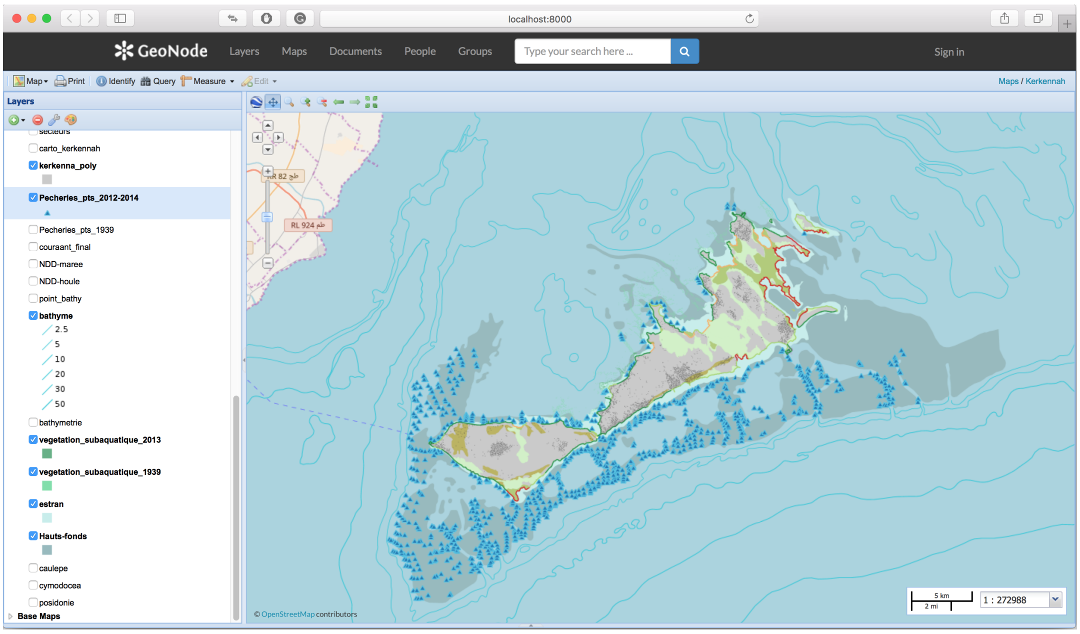


FIGURE 7.7: Prototype of geoportal SDI-ICMM

7.6 Survey with Gulf of Gabes Management Authorities

Due to their complex, dynamic and evolutionary nature coastal and marine SDI assessments are difficult. The objective of the third part of the case study analysis was to examine the different components and sub-components of SDI-ICMM, to assess the level of implementation, and to identify current use, management and sharing of spatial data about Gulf of Gabes from the perspective of the people involved in managing this area.

7.6.1 Adopted Methodology

For this study, a multi-view SDI assessment framework as proposed by Grus et al. (2007) was adopted. The main idea of multi-view SDI assessment framework is that it acknowledges the multi-faceted character of SDI, and assesses the SDI from different viewpoints. Five viewpoints were established and these are:

- Policy and Legal issues;
- Technical issues;
- Funding;

- People;
- Data.

A set of twenty (20) more specific indicators were formulated which are based on the five viewpoints.

7.6.2 Questionnaire Survey

A questionnaire is a commonly used method of collecting information from respondents. It is convenient for collecting data over large geographical distances and can be very useful in exposing the reality of the situation and identifying current problems.

The respondents were chosen from the various stakeholders according to roles (owner, manager, planner, and regulator) are coordinating institution, nodal agencies, government, private organizations, academia and NGOs. The purpose of the questionnaire is:

- To examine the different components and sub-components of SDI-ICMM;
- To assess the level of implementation of the SDI-ICMM;
- To identify some problems encountered in the implementation of the SDI-ICMM.
- To identify the existing spatial data.

The main points of reference for the questionnaire are the viewpoints identified in the adopted methodology (Policy and Legal issues; Technical issues; Funding; People; Data) and broken down into a set of seventeen indicators (Figure 7.8).

The Information was compiled to establish scores against the indicators (Table 7.4). For all possible indicators, there were six possible responses namely: Absolutely True; Fairly True; Slightly True; Slightly False; Absolutely False;Not Sure.

In addition to these close ended questions, a provision was made for open ended comment at the end of the questionnaire. For purpose of ranking: Not Sure = 0; Absolutely False = 1; Slightly False = 2; Slightly True = 3; Fairly True = 4; Absolutely True = 5;

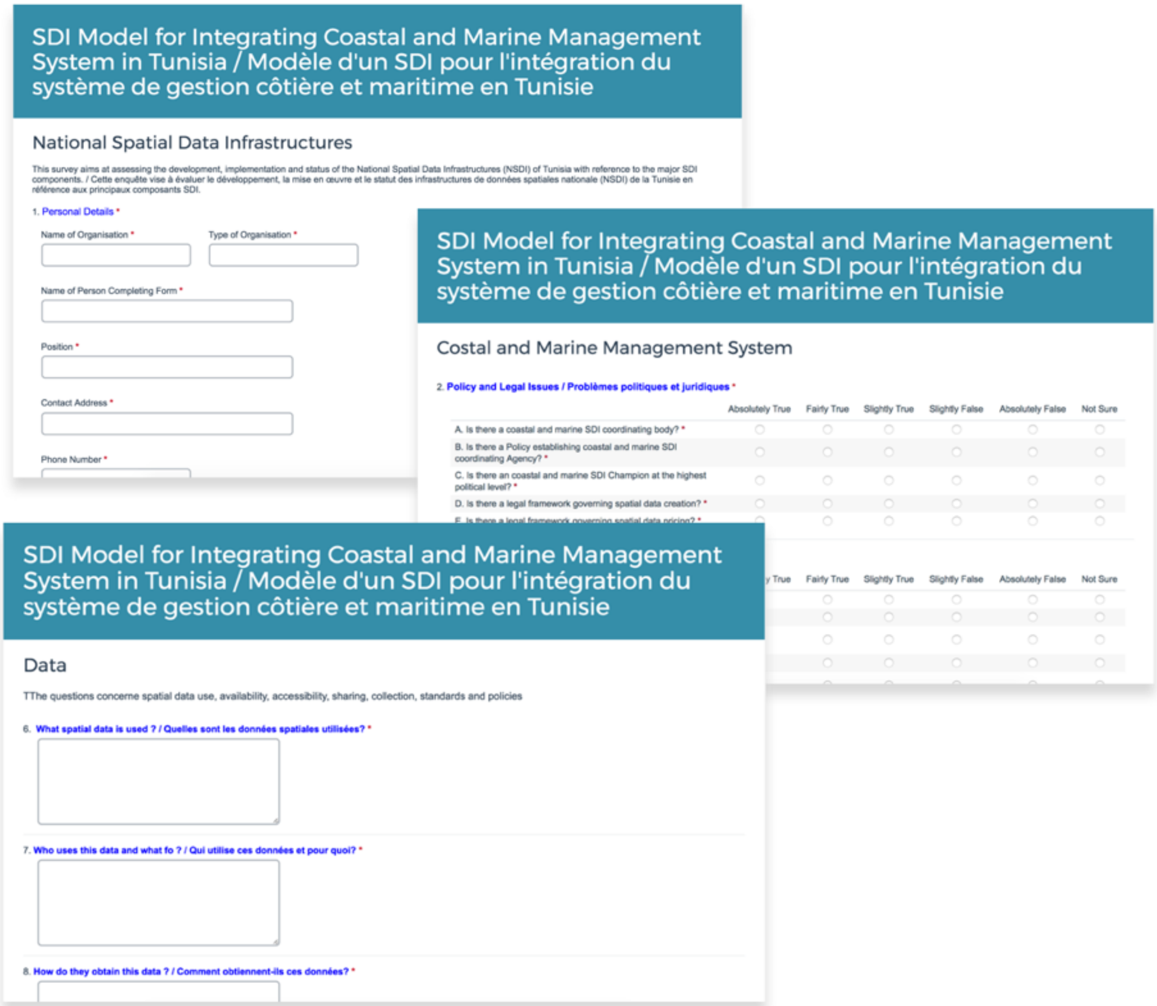


FIGURE 7.8: Sample of the questionnaire

A total of 20 questionnaires were sent out for this survey. The questionnaires were sent to the stakeholders and users of geo-information in Tunisia, both in government and private sectors; producers and users; within the central and local administration; NGOs and academia. There were significant limitations observed during the data collection process between December 2016, and January 2017. One of them was hesitance on the part of the government officials to respond on questions which involve government or which they perceive should be answered by their senior officers. Some higher officers meanwhile delegated their junior officers to respond to the questionnaire. Attempt to overcome this problem was made by removing personal information section from the questionnaire and resending them. Response increased by more than 25%. The other major problem was how to reach the potential respondents. Some of the potential respondents were not reached because their email addresses were no longer functioning.

7.6.3 Results

The results of the questionnaire collected from the respondents are presented in table 7.4. The questionnaire was sent to 20 people in Tunisia by email. Out of these total, 9 questionnaires were returned which is 45% of the questionnaire sent out, while the other 4 questionnaires are done with a face-to-face interview (20%). Moreover, the respondents are from relevant people and are here considered as a true representative of the population.

TABLE 7.4: Scores by the indicators

	Policy Issues					**Technical**						**Funding**			**People**			**Score**
	A	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**	**F**	**A**	**B**	**C**	**A**	B	**C**	
1	2	3	5	3	2	5	3	5	5	1	1	3	1	1	3	3	4	58,8%
2	5	3	5	4	4	3	5	4	5	3	2	3	4	4	1	4	5	75,3%
3	5	5	5	2	1	1	3	2	3	2	1	4	2	1	2	2	4	52,9%
4	5	5	5	3	1	0	1	3	0	1	2	2	4	2	1	2	4	48,2%
5	5	5	1	3	1	1	3	3	3	0	1	3	4	1	0	3	5	49,4%
6	3	5	1	4	4	1	2	2	1	2	1	4	4	4	2	2	4	54,1%
7	5	5	4	4	4	4	4	4	4	4	5	3	4	4	2	3	5	80,0%
8	5	5	5	0	0	1	2	5	1	0	1	5	4	1	1	5	5	54,1%
9	5	0	3	0	0	5	1	1	1	1	0	1	0	0	0	1	1	23,5%
10	0	0	0	0	1	4	1	1	1	0	0	1	0	1	0	1	0	12,9%
11	1	1	2	1	0	5	1	0	1	0	0	1	1	1	2	2	0	22,4%
12	5	3	5	3	4	4	4	2	1	4	1	1	1	1	2	3	1	52,9%
13	4	4	2	3	5	5	4	4	3	3	2	3	2	3	3	2	3	64,7%

The raw result is presented in table 7.4 after which the data are analysed from different perspectives. In table 7.4, the scores from the respondents are presented against the indicator classes. The respondents which are thirteen in number are represented by numbers 1-13. Each indicator class is divided into specific indicators represented by alphabets. Each of these alphabets represents and corresponds to a question in the questionnaire. The response from each respondent for each specific indicator is scored on a scale of 0-5.

The scores of each respondent for all the specific indicators in all the indicator classes are summed and converted to percentage. This percentage now represents the total score given to the SDI-ICMM by the respondent.

The aim of the second part of the questionnaire is to identify critical factors in implementing spatial data sharing in Tunisia's land, coastal and marine organisations. The objectives of the questionnaire are:

1. To identify the level of GIS implementation in the organisations;
2. To identify critical factors in implementing GIS;
3. To identify the relationship between these critical factors.

The questionnaire consists of three parts:

(a) Information on respondent's background;

(b) Information on GIS implementation in the organisations;

(c) Level of spatial data sharing implementation.

The questions using a Likert Scale (Wikipedia, 2017b) to measure the extent of agreement describe by each item. The scale ranged from 1 to 5, where:

1 = Strongly disagree

2 = Disagree

3 = Fair

4 = Agree

5 = Strongly agree

Cronbach's Alpha was conducted to measure the internal consistency of the research instrument. Suppose that we measure a quantity which is a sum of K components (K-items or testlets): $X = Y_1 + Y_2 + \cdots + Y_K$. Cronbach's α is defined as (DeVellis, 1991):

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K} \sigma^2_{Y_i}}{\sigma^2_X}\right) \tag{7.1}$$

where

σ^2_X is the variance of the observed total test scores

$\sigma^2_{Y_i}$ the variance of component i

To analyse correlation from the questionnaire, the inferential analysis was selected were Spearman's Rho analysis (Wikipedia, 2017e) to analyse the correlation from the Likert scale question and Pearson Chi- Square

(Wikipedia, 2017c) to analyse the correlation of nominal data.

$$r = \frac{\sum(X - \bar{X}) * (Y - \bar{Y})}{\sqrt{\sum(X - \bar{X})^2} * \sqrt{\sum(Y - \bar{Y})^2}} \tag{7.2}$$

The Spearman correlation coefficient is defined as the Pearson correlation coefficient between the ranked variables (Myers and Well, 2003).

For n raw scores X_i, Y_i are converted to ranks $\operatorname{rg} X_i, \operatorname{rg} Y_i$ is computed from:

$$r_s = \rho_{\operatorname{rg}_X, \operatorname{rg}_Y} = \frac{\operatorname{cov}(\operatorname{rg}_X, \operatorname{rg}_Y)}{\sigma_{\operatorname{rg}_X} \sigma_{\operatorname{rg}_Y}} \tag{7.3}$$

where

> ρ denotes the usual Pearson correlation coefficient, but applied to the rank variables.
>
> $\operatorname{cov}(\operatorname{rg}_X, \operatorname{rg}_Y)$ is the covariance of the rank variables.
>
> $\sigma_{\operatorname{rg}_X}$ and $\sigma_{\operatorname{rg}_Y}$ are the standard deviations of the rank variables.

The generally agreed value of the lower limit for Cronbach's alpha is 0.70 (Wikipedia, 2017a). The analysis was performed separately for the items of each factor, the summaries of the reliability analysis given in table 7.5. All items show the results higher than 0.70 therefore it is reliable.

TABLE 7.5: Reliability test results

	alpha
GIS	
- Geospatial Data	0.8507
- Technologies	0.8844
- Human Resources	0.9248
SDI	
- Data User	0.9793
- Data Provider	0.8619
- Data exchange	0.9532
Collaboration	
- Within organisation	0.9234
- Between organisation	0.7877

7.6.4 Analysis

7.6.4.1 Analysis by Respondents

The responses to each specific indicator vary greatly across respondents, across position rank, across sectors of the economy and across geographical location.

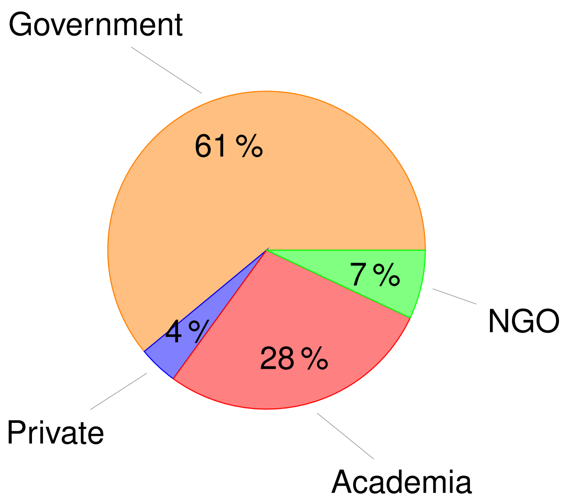


FIGURE 7.9: Analysis by Sector

61% of the respondents are from the government sector, 4% from the private sector, 28% from the academia and 7% from NGOs. SDI-ICMM mainly concerns the government stakeholders; therefore, the participants are mostly people working in public sector. The respondents are mostly drawn from government establishments. Even though the government policy makes room for public-private participation, the reality is that the people that constitutes the geospatial data creators' disseminators and users fall within government sector.

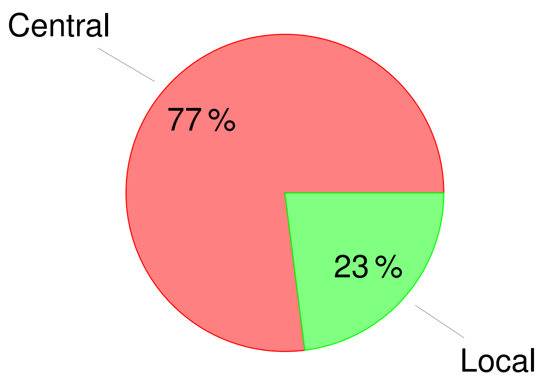


FIGURE 7.10: Analysis by Location

77% of respondents are working in ministry and central administration, while 23% of the respondents are outside (local). The administrative data of Tunisia are strongly tinted of centralization. This state of affairs means that existing competences appear only in terms of the competencies traditionally reserved for the centre, that it competences exercised by the State or by national public institutions. So structurally and functionally, the central public administrative institutions play a role preponderant. All the ministries are located in the capital city Tunis.

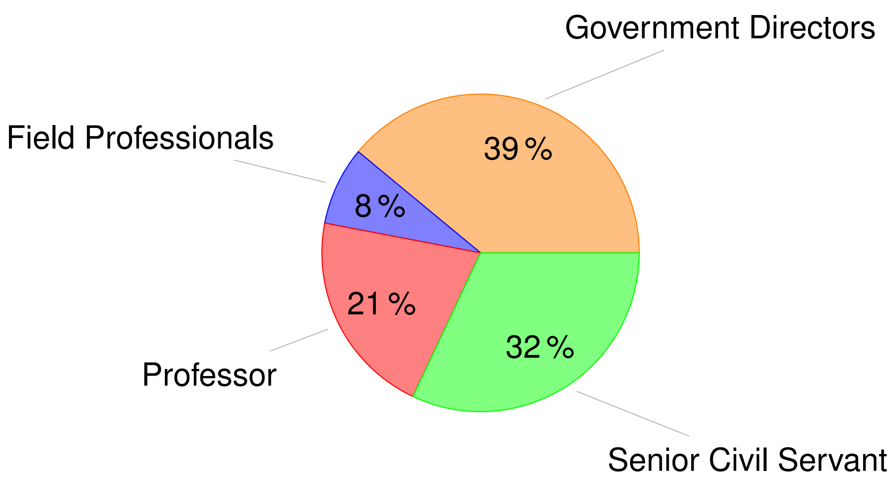


FIGURE 7.11: Analysis by Position Rank

Most government decisions are taken in the headquarters of the ministries. Though the questionnaire is sent nationwide, the subjects at Tunis seems to be more informed of SDI-ICMM, as most people from local administration did not respond.

The respondents consists of directors from government (39%), university professor (21%), senior civil servants (32%), and field professionals (8%).This is more or less an equitable distribution of respondents.

The scores of each respondent are added up and normalized to 100% to give what we can call here SDI score of the respondent (Figure 7.12). The SDI Score herein after known as the Score of the respondent represents the assessment value of the SDI from the perspective of the respondent. In this study it is assumed that each specific indicator has equal weight and therefore the summation of the scores will give an indication of the status of SDI from the point of view of the respondent. The score ranges from 12.9% to 80% and are divided into three classes: 12-42%, 42.1-50%, and 50.1-80%.

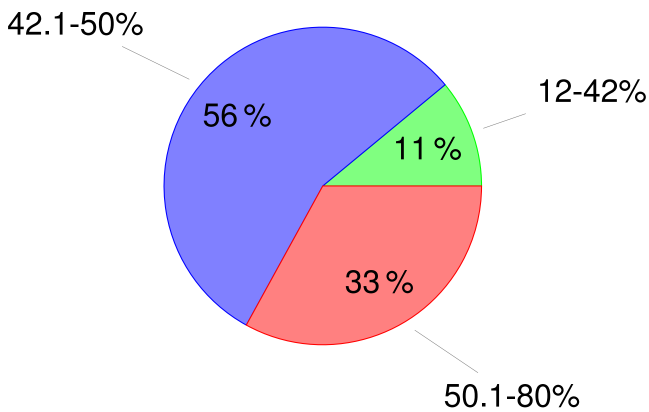


FIGURE 7.12: Analysis by Scores

12-42%: There is only one respondent whose score is in this class, a government director by rank, from regional location. This suggests that the SDI awareness is very limited in some parts of Tunisia outside the capital city. Respondents here are distributed across government, private sector and NGO.

42.1-50%: This is both the modal class and the class that contains the median. three respondents are in this class. In qualitative terms, respondents in this class gave a medium score in the overall of SDI. Respondents here are distributed across government (geospatial dataset users), NGO and academia.

50.1-80%: The respondents in this class gave a high score to SDI-ICMM project. seven respondents are within this group. four is from government (representative of one project manager, and three responsible of geospatial datasets) and one from the private sector and two from academic field. It is obvious that these respondents are mainly users of coastal and marine data.

Participation of the private sector here is weak and may be doing some constraint in SDI-ICMM implementation.

7.6.4.2 Analysis by Indicators

Here an analysis of the results based on responses to each specific indicator is made. Table 7.6 summarizes how research subjects responded to each specific indicator. Each alphabet on the left column of the table represents a specific indicator (question in the questionnaire), while the figures inside the table represent the number of respondents that scored the SDI-ICMM a particular ranking. For instance, in specific indicator, "A" in Policy and Legal Issues component class, nine respondents answered '*Absolutely True*' in the questionnaire (69%), while two respondents answered '*Fairly True*' and two respondents each answered '*Slightly False*' and '*Not Sure*' respectively. This means that there is certainly the presence of the variable which specific indicator "A" is assessing. The table 7.6 is represented and analysed in the following charts and paragraphs respectively.

TABLE 7.6: Summary of respondents to each specific indicator

	Absolutely True	**Fairly True**	**Slightly True**	**Slightly False**	**Absolutely False**	**Not Sure**
Policy & Legal Issues						
A	69%	15%		8%		8%
B	54%	8%	23%	8%		8%
C	23%	15%	31%		15%	15%
D	15%	15%	15%	23%	8%	23%
E		38%		23%	23%	15%
Technical						
A	15%	15%	8%	8%	46%	8%
B	8%	15%	31%	8%	38%	
C	23%	23%	23%		15%	15%
D	8%	8%	31%	15%	23%	15%
E		31%		23%	23%	23%
F	8%	23%	8%	15%	38%	8%

Table 7.6 – *Continued on next page*

Table 7.6 – *Continued from previous page*

Funding						
A	8%	15%	23%	8%	38%	8%
B		15%	38%	15%	23%	8%
C		38%	15%	8%	31%	8%
People						
A	8%	8%	8%	23%	23%	31%
B	15%	23%	31%	8%	23%	
C	31%	31%	31%			8%

7.6.4.2.1 Policy and Legal Issues Analysis of the result of questionnaire on the Policy and Legal Issues component class indicate that SDI-ICMM can started well with this component.

There is almost unanimous agreement on the necessity of creation a national coastal and marine SDI coordinating body. The response to the specific question on the SDI at highest political level was scored well. Here we mean a politician in the National Assembly pioneering and pushing for SDI awareness, funding and law.

On the legal framework for spatial data creation and pricing, the respondents scored it poorly. Actually there is policy framework guiding these activities but they are not signed into law yet.

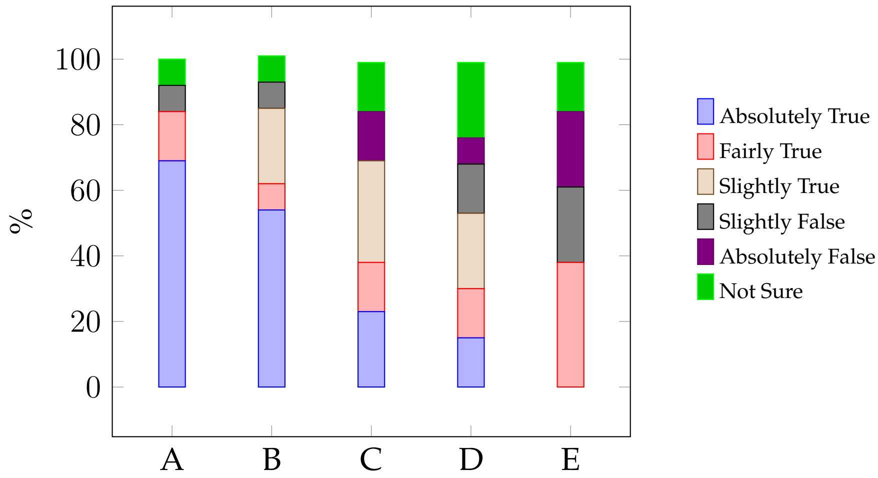


FIGURE 7.13: Policy and Legal Issues Indicator Class

7.6.4.2.2 Technical The technical aspect of any coastal and marine SDI system is the pivot on which its data sharing rotates. With respect the SDI access network, the intention is to put in place a high-speed and high bandwidth backbone carrier as the main gateway and master server and implement a database server at each mode. This is not available in reality yet. The bad shape of access network facilities notwithstanding at public administration level, the analysis from the questionnaire responses indicates weak accessibility to geospatial data through geo-portal. There is an equal good effort towards interagency coordination of spatial data creation. Metadata capturing is also scored highly by few respondents.

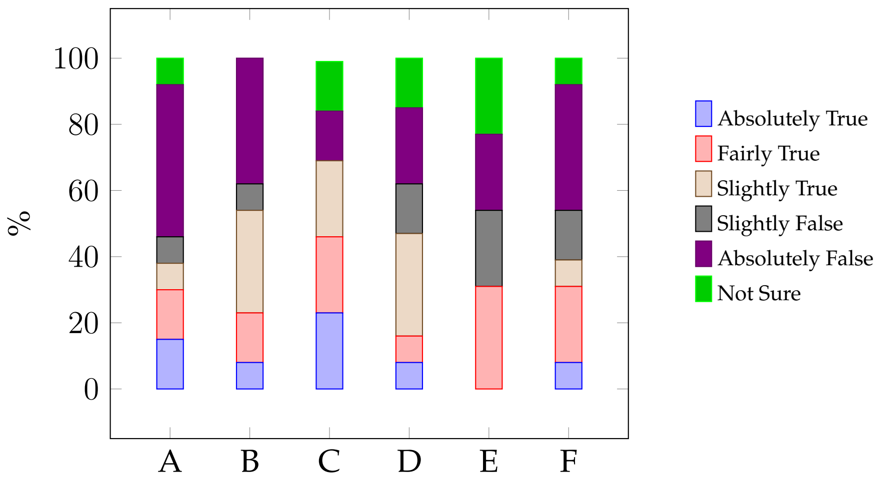


FIGURE 7.14: Technical Indicator Class

The responses (Figure 7.14) however show lack of standardization in spatial data creation and absence of clearinghouse. Data is acquired and stored for own use and applications, with the difficulties of unnecessary overlaps and duplication, lack of accessibility, and varying standards and formats.

7.6.4.2.3 Funding Figure 7.15 highlighted the policy statements on coastal and marine SDI funding. But that have not been fulfilled probably due to lack of SDI Directive. And funding is earmarked as major problem in the SDI-ICMM implementation.

The responses of the subjects to this component class are not very encouraging. The major source of income for SDI implementation is from national budget.

There is an effort towards fund generation from access charges and data sales, but this is not viable yet. In addition, Tunisia has received several international grant through WWF, Global Environment Facility (GEF), UE, etc. but in the context of specific project (ICZM, climate change, etc.). Even there is no agreement on the existence of policy for spatial data pricing.

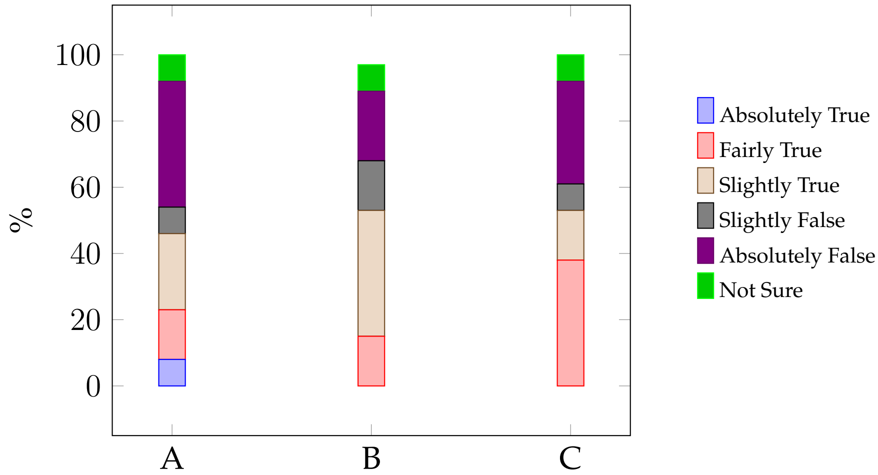


FIGURE 7.15: Funding Indicator Class

7.6.4.2.4 People There is sound organizational framework for the SDI-ICMM implementation. Responses from the questionnaire however indicates that there is not enough public- private participation. The major stakeholders, predominantly government however participate in the implementation.

On the specific component of skilled personnel, there is reasonable number of skilled personnel to man the coastal and marine SDI implementation. Though availability of skilled personnel especially in technical areas is still a problem.

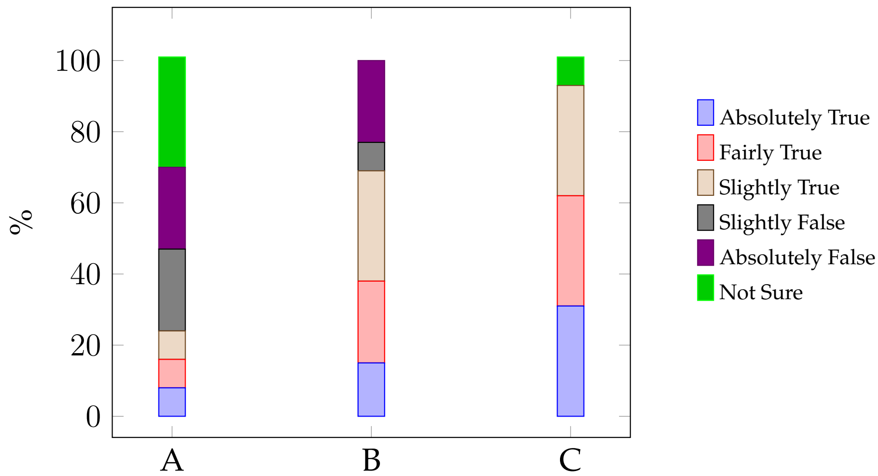


FIGURE 7.16: People Indicator Class

7.6.4.2.5 Data Spatial data plays an important role in aiding planning and management decisions in both the terrestrial and marine environments. The issues of access to and requirements of such data are well documented for land, but less so for the marine environment.

However different activities are involved in the management and administration of the marine and coastal environments which will require access to spatial information for better decision-making. Therefore, a common theme from many of the initiatives that aim to improve coastal and oceans management is the desire for access to appropriate and reliable spatial information to support these initiatives. Often the various spatial datasets are collected and stored by different organisations which can make them difficult to determine their existence and access.

In order to assess the current use and management of spatial data several organisations involved in management of Gulf of Gabes were selected to assess the nature of their responsibilities as well as their level of spatial data usage (Table 7.7)

TABLE 7.7: Main stakeholders of Gulf of Gabes and their use of spatial data

Main Stakeholders	**Nature of the Work**	**Use of Spatial Data**
Coastal Protection and Management Agency (APAL)	- Management of the public maritime domain. - Management of coastal. - Development of studies of expertise and research relating to the protection of the coastline. - Management of natural coastal areas and sensitive areas.	Yes
National Agency for the Protection of the Environment (ANPE)	- Combat sources of pollution and to ensure compliance with environmental regulations. - Development of research of coastal and marine environment.	Yes

Table 7.7 – *Continued on next page*

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National Office of Sanitation (ONAS)	- Control of sources of water pollution. - Development and implementation of integrated projects on wastewater treatment and storm water drainage.	Yes
Tunisian Environment Observatory for Sustainable Development (OTEDD)	- Produce statistics and indicators on the environment. - Develop and implement information systems relating to the environment and sustainable development.	Yes
General Direction for Fisheries and Aquaculture (DGPA)	- Development of research programs and preserving and ensure the sustainability of fisheries and aquaculture resources.	Yes
General Direction for Territory Development (DGAT)	- Implement the guidelines of rational land management and sustainable development.	Yes
General direction of Air and Maritime Services (DGSAM)	- Delimit and protect the maritime public domain. - Management the maritime public domain. - Protect the coastal against marine erosion.	Yes
Agency for the Development of Heritage and Cultural Promotion (AMVPPC)	- Restoring sites and monuments in urban or coastal areas. - Protect and conserve Tunisia's natural environment and cultural heritage.	Limited
Office of the Merchant Marine and Ports (OMMP)	- Identify and analyse the risks and the assessment of the possible consequences on the environment.	Limited
Municipality Council (MC)	- Regulate activities on the coast and on both public and private land.	Limited

Table 7.7 – *Continued on next page*

Table 7.7 – *Continued from previous page*

National Institute of Marine Science and Technology (INSTM)	- Conduct research programs in fields directly or indirectly related to the sea and its resources. - Contribute to solving problems related to the development of urban and economic activities on the coast and in territorial waters.	Yes

As illustrated by Table 7.7 most of the main stakeholders in Gulf of Gabes consider spatial data as an essential or important part in their day-to-day business activities while the other agencies such as Municipality Council shows that there is still a limited level of spatial data sharing and use.

The questions in the servey were concerned with spatial data use, availability, accessibility, sharing, collection, standards and policies. Table 7.8 describes the issues identified regarding spatial data accessibility, sharing, collection, standards and policies within the organisation.

TABLE 7.8: Issues with spatial data use and sharing within Gulf of Gabes

Stakeholders	Access Network	Standards/ Policies	Sharing	Issues
APAL	- Contact custodian directly - Collect internally	- Privacy policies - Use metadata - Standards based on project needs for other data	- Rarely - Share data in intranet	- Updating data - Different technologies - Different data formats - Compatibility - Data currency
ANPE	- Contact custodian directly - Collect internally	- Privacy policies - Use metadata	- Rarely - Share data in intranet	- Updating data - Different technologies - Different data formats - Compatibility - Data currency
ONAS	- Internal data	- No defined standards or Policies - No metadata	- Rarely - Share data in intranet	- Different technologies - Compatibility - Data currency
OTEDD	- Internal data	- Privacy Policies - No metadata	- Rarely	- Updating data - Different technologies - Compatibility - Data currency

Table 7.8 – *Continued on next page*

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DGPA	- Internal data - Contact custodian directly	- No defined standards or Policies - No metadata	- Don't share data	- Need large scale Data - No resources for improving data sharing - Different technologies - Different data formats - Compatibility - Data currency - No budget for making data available
DGAT	- Internal data - Contact custodian directly	- No defined standards or Policies - No metadata	- Rarely	- Lack of availability of data - Compatibility - Data currency - No budget for making data available
DGSAM	- Internal data	- No defined standards or Policies - No metadata	- Rarely	- Updating data - Limited funding and resources for improving spatial data use and collection

Table 7.8 – *Continued on next page*

Table 7.8 – *Continued from previous page*

AMVPPC	- Internal data	- No defined standards or Policies - No metadata	- Don't share data with other organisations	- Need large scale Data - No resources for improving data sharing - Compatibility of technology and data
OMMP	- Internal data - Collected for a project	- Privacy policies - Use metadata	- Rarely	- Need large scale - Different technologies
Municipality Council	- Internal data - Contact custodian directly	- No defined standards or Policies - No metadata	- Don't share data with other organisations	- Inconsistent formats - Compatibility - Data currency - No budget for making data available
INSTM	- Contact custodian directly - Collect internally	- Privacy policies - No metadata - Standards based on project needs	- Rarely	- Updating data - Different technologies - Different data formats - Compatibility - Data currency

The results of this analysis shows that while the stakeholders in Gulf of Gabes all want better access and sharing of spatial data, there are poor interoperability between and within the stakeholders involved in management of the case study area. These issues are listed below:

- Most of them have problems with data availability;
- There is a range of accuracies, standards, data formats, completeness and consistencies within the different spatial datasets which creates a lack of interoperability because different datasets are collected by different agencies;
- There is no one central authority or database containing all the available spatial data;
- If there is a sharing of the data, it is not on the web but through intranet;
- Often the datasets do not have metadata as spatial data was collected and used for in-house without appreciation of metadata;
- Availability of the data is due to the difficulties in collecting: some spatial data is readily available, while, other data is much more difficult to collect;
- Lack of budget within these agencies to make the data and metadata available or for further data maintenance, updating or conforming to certain standards;
- Spatial data is usually collected for a specific project and is collected at standards that are the best for that project. The same data will not be collected again unless another project requires it;
- Lack of GIS specialists who work in these agencies.

Overall these results have shown some of the limitations for the development of a SDI-ICMM, or a SDI that can accommodate data from terrestrial as well as marine and coastal environments. The results of this analysis demonstrate the common limitations and problems facing by each of the stakeholders in the development of a SDI-ICMM. The responses to each specific indicator vary greatly across respondents, across position rank, across sectors of the economy and across geographical location. This is expected as SDI is a complex and dynamic concept, with each respondent approaching it from where it matters to him most. However, the result of the analysis will yield some interpretations and conclusions which will answer the research questions of the thesis. This further supports the findings regarding the barriers against implementation of a SDI-ICMM model which have been discussed in chapter 5 and chapter 6.

Analysis of the questionnaire was divided into three main categories; Respondent's background, GIS implementation in the organisation, and implementation of spatial data sharing.

7.6.4.3 Respondent's background

Respondent's background focusing on respondent's experience in using GIS in the organisations. Table 7.9 shows the general background of the respondents such as user type, number of years using GIS and GIS function being used by respondents.

TABLE 7.9: Respondents background in using GIS

	n	%
Background of respondents in using GIS		
- Less than one year	1	7.7
- One to two years	1	7.7
- Two to five years	2	15.4
- More than five years	9	69.2
Respondent's GIS user type		
- Data User	4	30.8
- Data Provider	1	7.7
- Both (Data User and Provider)	8	61.5
Respondent's GIS functionality		
- View information	1	7.7
- Collect data	2	15.4
- Analyze information	1	7.7
- Integrated with other system	1	7.7
- View, Collect and Analyze	8	61.5

Results from table 7.9 show that, the respondents were mostly using GIS for more than five years, most of the respondents were both data user and data provider, and using most of GIS functions. From these results, it can conclude that the respondents have knowledge of GIS background. But according to their specialties (university diploma) they have other training (e.g. geologist, hydrologist, agronomist) that is to say they are not real GIS specialties.

7.6.4.4 GIS implementation in the organisation

GIS implementation discusses about the respondent's knowledge and experience in handling GIS, and the important aspect of GIS that need to have in the organisations. Analysis was based on three main components of GIS; data, personnel and software, hardware and network.

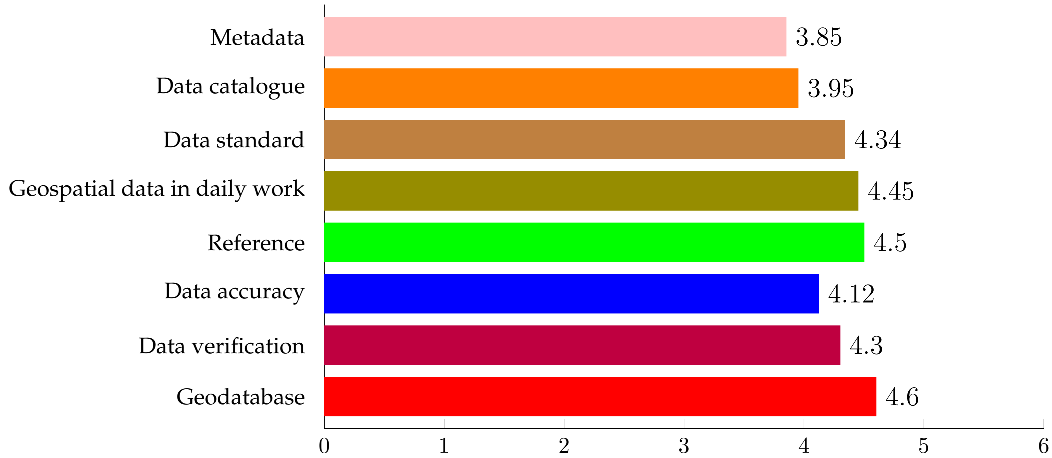

FIGURE 7.17: Importance of spatial data components by GIS personnel

Figure 7.17 shows the mean for GIS personnel understanding of the importance of spatial data components. Figure 7.18 shows the mean of organisations or people factors in succeeding spatial information system implementation in the organisations.

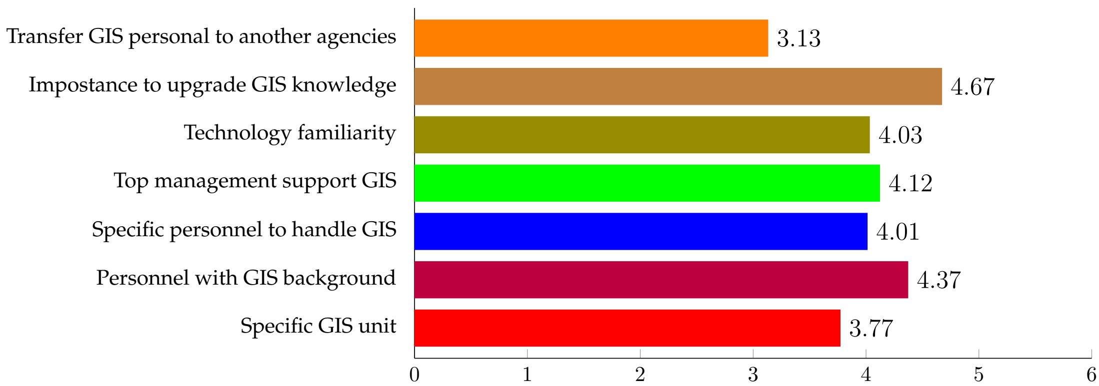

FIGURE 7.18: Organisations or people factors in succeeding SDI-ICMM implementation

From the results, it shows most of the respondents are aware of the GIS components. The mean of the answer was mostly above 4, which indicated the respondents agreed with the importance of each component.

7.6.4.5 Spatial data sharing implementation

Implementation of spatial data sharing discussed on the knowledge of respondents in spatial data sharing, limitation in implementing spatial data sharing correlation between knowledge of GIS and SDI in the organisational (Land, Coastal and Marine) implementation of spatial data sharing. For descriptive statistical analysis, three analyses were done.

1. The first analysis is to understand the knowledge on cooperation on spatial data exchange in the organisation;
2. The second analysis is to understand the cooperation for GIS implementation in the organisation;
3. The third analysis is to understand the opinion on collaboration in enabling spatial data sharing between all organisations (Land, Coastal and Marine) implemented in SDI-ICMM.

Table 7.10 shows the summary of the descriptive analysis

TABLE 7.10: Descriptive analysis

Factors	**Mean Score**
Knowledge on cooperation on spatial data exchange	
- Get data from other unit/division to assist processing	4.37
- Give data to other divisions to assist other divisions	4.31
- Get spatial data from other agencies	4.13
- Give spatial data with other agencies	4.15
- Integrate system with other divisions	4.03
- Integrate system with other agencies	2.19
Cooperation for GIS implementation	
- Geospatial data collection	4.53
- Geospatial data upgrading	4.23
- Cooperation on developing GIS	4.11
- Cooperation on upgrading GIS	4.04

Table 7.10 – *Continued on next page*

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Opinion on collaboration in enabling spatial data sharing between organisations	
- Frequent meeting facilitating geospatial data updating	4.18
- Frequent meeting facilitating geospatial data sharing	3.28
- Formal collaboration for spatial data sharing	4.27
- Collaboration to improve GIS	4.49

The hypothesis was constructed based on three main criteria; the knowledge and implementation of GIS in the organisation, the knowledge and implementation of spatial data sharing in the organisations, and the collaborative process in enabling spatial data sharing between organisations. To understand the correlation between the three main criteria, these hypotheses have been listed:

- There is correlation between duration using GIS in the organisation with personnel knowledge in GIS
- There is a correlation between GIS user in the organisation with the personnel level of knowledge in GIS
- There is a correlation between GIS knowledge on spatial data with GIS technologies
- There is a correlation between spatial data sharing implementation with knowledge about GIS
- There is correlation between knowledge about spatial data sharing with knowledge, spatial data sharing implementation

For the **first hypothesis**, Spearman's rho analysis was used to determine the relationship between duration using GIS and knowledge on GIS. There was a positive correlation, which was statistically significant, r = 0.339, $p<0.05$.

For the **second hypothesis**, A Pearson Chi-Square test was used to determine whether there was significant correlation between types of GIS user in the organisation with the personnel level of knowledge in GIS. There was no significant correlation between types of GIS user with a level of knowledge on GIS, X^2 = 23.76, DF = 13, $p>0.05$.

The **third hypothesis** using Spearman's Rho analysis, to determine the relationship between respondent's knowledge on GIS data with knowledge of GIS technologies and GIS management. There was a positive correlation, which was statistically significant between respondent's knowledge on GIS data with knowledge of GIS technologies, r = 0.728, $p<0.05$. There was also a positive correlation between respondent's knowledge of GIS technologies with GIS institutional management, r = 0.362, $p<0.05$.

The **fourth hypothesis** was used Spearman's Rho analysis to determine the relationship between respondent's knowledge on GIS with the implementation of spatial data sharing. There was a positive correlation with statistically significant, r = 0.335, $p<0.05$, which indicate that to successfully implement spatial data sharing, the knowledge on GIS in important.

The **last hypothesis** was analysed using Pearson Chi-square analysis, to determine the correlation between respondent's knowledge of spatial data sharing with the spatial data sharing implementation, where there was also a significant correlation between the two components, X^2 = 60.31, DF = 13, $p>0.05$.

From the inferential statistical analysis, the findings show:

- There is a correlation between personal knowledge of SDI-ICMM component in the SDI implementation in the organisations.
- There is a correlation between personal knowledge of SDI-ICMM with the implementation of spatial data sharing in the organisations.
- There is a correlation between spatial data sharing with SDI-ICMM implementation.
- There is a correlation between cooperation in the organisations with spatial data sharing implementation.
- There is a correlation between collaboration with other organisation with spatial data sharing implementation.

7.7 Overall Findings

The analysis of results has shown some of the limitations and problems for the development of a SDI that can contain data from terrestrial as well as the marine and coastal environments.

The first part, assessment of management and planning framework, demonstrated the complexity of the management framework. The stakeholders of land, coastal and marine environments have different rights, interests, or responsibilities of this area. The task of efficiently and effectively managing all stakeholders is complicated by the fact that their rights can often overlap which gives rise to the need for cooperation between agencies. However, these problems can be overcome through coordination for collaborative planning. There should be proper regulation to enforce that all spatial data providers should be involved in and contribute to the development of a SDI-ICMM.

The second part investigated the availability, accessibility and interoperability of spatial data within Gulf of Gabes through collecting all available data. The biggest impediment to interoperability was that not all organisations used the same data format, and so their data could not be integrated with other data. The lack of interoperability of different dataset from custodians is the most significant problems found during the integration of land and marine spatial data. The other problem It would like to mention is the differences in scales, quality and coverage of spatial data and the lack of or poor quality of metadata. An issue that was brought up in this part was the need for interoperability across the land – marine interface. The stakeholders in Gulf of Gabes are responsible for managing not only marine and coastal areas, but also terrestrial areas, and activities (i.e. tourism, etc.) that may cover all of these environments.

Lastly, the third part examined the responses to each specific indicator vary greatly across respondents, across position rank, across sectors of the economy and across geographical location. This is expected as SDI is a complex and dynamic concept, with each respondent approaching it from where it matters to him most. This part of case study also analysed the current use, access and sharing of spatial data from the perspective of the selected stakeholders responsible for managing this area. It highlighted the fact that marine and coastal spatial data is used by many different organisations and sectors and comes from different environments land and marine).

The lack of a formalised approach to data collection, maintenance and sharing in the marine and coastal environments showed a lack of interoperability from different data formats.

Determining what data is available is difficult because there is no one organisation or authority that holds all spatial data and this data is usually collected for a particular project, and is rarely made available for other organisations to use.

From the analysis, it shows that several issues and opportunities need to be managed to improve SDI-ICMM implementation and to enable spatial data sharing between land, coastal and marine administration and management in Tunisia. It can be summarised as:

- Spatial data need for planning for standardised spatial data collection, storage and distribution with proper metadata to simplify data sharing process;
- Spatial data also need to be verified, have information on its concurrency, accuracy and level of completion;
- A proper geoportal (GIS hardware, software and access network) is essential to facilitate in spatial data sharing;
- In organisational aspect, specific GIS personnel and GIS unit were needed to handle GIS;
- Knowledge on GIS should be improve for GIS personnel and top management in the organisation;
- Awareness on the importance of integration of GIS and other system related should be increased;
- Knowledge of spatial data sharing need to improve for GIS personnel and organisation's top management;
- Cooperation between organisations was needed in developing GIS before upgrading GIS data and functionality;
- Formal collaboration between organisations with proper lead organisation, the committee and frequent meeting are needed to enable spatial data sharing.

From the findings, the results then were grouped into three main groups: issues in GIS planning and development, issues in enabling spatial data sharing, and issues in collaboration between organisations to enable spatial data sharing. To improve coastal and marine spatial data sharing in Tunisia's organisations, several strategies need to be applied, based on the three issues, marine GIS strategic planning, marine spatial data sharing strategies and collaboration strategies as shown in figure 7.19.

FIGURE 7.19: The key components to improve SDI-ICMM in Tunisia

The survey highlighted that there is much duplication in collecting spatial data in Gulf of Gabes and that the stakeholders in this area are becoming more open to the idea of sharing spatial data within a common framework and many of them believed that improvements could be made if there is a formal and common approach.

This further supports the need for a common and holistic platform which leads to the promotion of data sharing and communication between organisations thus facilitating better decision-making involving marine and coastal spatial information.

7.8 Chapter Summary

This chapter explained the scientific method by identifying the problem and then generating hypotheses to best explain why the problem is occurring or how it may be overcome. The hypotheses are then applied to more specific research objectives. In order to respond to these objectives, a case study used to complete the assessment of the potential for a SDI-ICMM through examining Marine SDI as a state/ local level. The case study involved three parts:

- **Part 1:** Assessing Gulf of Gabes management and planning framework;
- **Part 2:** Analysing/ examining available spatial data about Gulf of Gabes;
- **Part 3:** Interviewing relevant stakeholders of Gulf of Gabes about sharing and use of spatial data;

After this analysis the resulting set of answers were compiled and the hypothesis tested.

This chapter described in second part the case study that were undertaken within this research project. The aim of the case study was to describe and examine the limitations and barriers to development of a SDI-ICMM. While the research was based on a case study of a small part of Tunisia, the results and principles can be applied generally with the outcome being extended model for the whole country. The chapter examined availability, integratability, accessibility and sharing at the state and local jurisdictional level, identifying the current limitations and opportunities from the perspective of the main stakeholders responsible for managing Gulf of Gabes.

The case study showed that spatial data is an integral component for the many organisations that manage Gulf of Gabes. While all organisations are collecting their own data and using their own standards and sharing policies.

8 Conclusion

8.1 Introduction

This research investigated the potential issues of, challenges and barriers to integrate the coastal and marine information in a unique platform to facilitate marine and coastal zone administration. by studying the most SDI initiatives in the world, a conceptual model of Spatial Data Infrastructure for integrated coastal and marine management (SDI-ICMM) have been developed and associated guidelines proposed.

This chapter examines the outcomes achieved during this research, highlights the significance of the research project to theory and practice, reflects on the original research problem and suggests directions for future research efforts.

8.2 Research Summary

As highlighted in first chapter, the research problem was defined as:

> *"Most SDI initiatives stop at the land-ward or marine-ward boundary of the coastline and most of them focuses on access to and use of the land datasets or marine datasets. Consequently, there is a gap between the terrestrial and marine environments due to lack of a holistic framework of spatial information. This leads to the need to develop Spatial Data Infrastructure for Integrated Coastal and Marine Management (SDI-ICMM) that enables the access and sharing of spatial information of land, coast, and marine zone."*

The overarching hypothesis of the research was therefore:

> *"The development of a holistic platform as Spatial Data Infrastructure for Integrated Coastal and Marine Management (SDI-ICMM) covering the land and marine environments would facilitate greater access and share to more interoperable spatial data."*

The major aim of this research has been:

> *"The aim of this research is to design, develop and test an SDI-ICMM model that integrates marine, coastal and land-based spatial information in a unique platform."*

The research has also fulfilled its objectives. The objectives of the research includes five objectives that represented in the next section.

8.3 Objectives

8.3.1 Objective 1: *Justify the need for SDI-ICMM covering the land and marine environments*

Section 1 has investigated and justified the need for Spatial Data Infrastructure for Integrated Coastal and Marine Management. Chapter 2 identified major coastal and marine issues around the world such as global warming, sea-level rise, shoreline movement, overfishing, pollution with the primary focus on Tunisian marine and coastal management regimes. Chapter 3 examined the management and administration of rights, restrictions and responsibilities in Tunisia's coastal and marine environments and analysed the gaps in the regulatory and institutional framework.

However, the research in section revealed major issues related to the coastal. These issues due to the natural pressure and regulatory gaps. Consequently, there is a need to build holistic approach. This led to the justification of the need for SDI-ICMM covering the land and marine environments.

8.3.2 Objective 2: *Understand the concepts of current land and marine SDI initiatives*

A review of SDI literature from research and practice was undertaken to determine what was currently understood about SDI. Several important insights were gained from this review. Chapter 4 gave an overview of some examples of spatial information initiatives that focus on the marine or coastal environments and highlighted initiatives issues due to the separation between Land, coastal and marine zone.

The research showed that there is a need for a better and more comprehensive way to link different initiatives as there is a tight connection between inland and marine coastal areas.

This research further confirms that Marine SDI cannot be developed in isolation from Coastal SDI and vice versa.

8.3.3 Objective 3: *Investigate the characteristics and components for the design of a SDI-ICMM model*

This research has investigated the characteristics and components of the design of an SDI-ICMM model and identified the potential barriers for adding the marine and coastal dimension in Chapter 5.

This was fulfilled through the evaluation of technical, institutional, policy and legal spatial data integration issues and problems associated with effective land and marine data integration.

8.3.4 Objective 4: *Develop and propose an SDI-ICMM model and associated guidelines*

Chapter 6 proposed the conceptual model of an SDI-ICMM by using Hierarchical Spatial Reasoning. Use Case Diagram and Class Diagram have been developed.

In implementing the SDI-ICMM model for any jurisdiction, guidelines have been outlined. The SDI-ICMM guidelines as a necessary step by step approach detail the key considerations for effective land and marine spatial data integration.

The guidelines discuss the potential technical and non-technical barriers as well as available solutions.

8.3.5 Objective 5: *Test the SDI-ICMM through case study (Gulf of Gabes, Tunisia)*

A scientific method has been used to identify the problem and then generating hypotheses to best explain why the problem is occurring. Then, the hypotheses have been applied to more specific research objectives in chapter 7.

In order to respond to these objectives, a case study approach has been used to test the limitations of developing an SDI-ICMM. The availability, integratability, accessibility and sharing of spatial data has been examined in chapter 7. The case study showed that spatial data is an integral component for the many organisations that manage Gulf of Gabes. This further supports the need for a common and holistic platform which leads to the promotion of data sharing and communication between organisations thus facilitating better decision-making involving marine and coastal spatial information.

8.4 Contribution to the field

The outcomes of this research have highlighted the need for a holistic approach included land, coastal and marine information in SDI-ICMM. This was achieved by:

- ***Firstly***, describing the major marine and coastal issues such as global warming, sea-level rise, overfishing, pollution. Then, examining the management and administration of rights, restrictions and responsibilities in Tunisia's coastal and marine environments. This is an essential component in order to know the rights and responsibilities of multiple users of this space. The investigation of SDI initiatives leads to the identification of the commonalities and differences between land and marine based SDI initiatives along with influential treaties and conventions driving the development of an SDI-ICMM.
- ***Secondly***, this research introduced the concept and definition of the SDI-ICMM and generally highlighted its characteristics and components. building SDI-ICMM shows that there are several technical and non-technical issues, however, the non-technical issues are the most difficult problems to overcome. Development of an SDI-ICMM conceptual model and implementation guidelines is

the major contribution of this research. The conceptual model of SDI-ICMM has been proposed by using Hierarchical Spatial Reasoning and the SDI-ICMM class and its inherited characteristics and properties have been discussed.

- ***Finally***, the SDI-ICMM guidelines need to be tested and evaluated in different jurisdictions. A case study has been used to demonstrate the complexity of managing the coastal and marine environments in Gulf of Gabes due to the different rights, interests or responsibilities for the management of this area. These rights often overlap and creating competing rights, restrictions and responsibilities. This gives rise to the need for cooperation between agencies to resolve the difficulties of integrating terrestrial, coastal and marine data, therefore, the need for a holistic platform for integrated costal and marine management. The case study showed that the biggest problem is the lack of interoperability of different datasets from different custodians in Gulf of Gabes. This problem due to the differences in data format, scales, quality, coverage of spatial data and the lack of metadata. The case study highlighted the same problem with data sharing including a lack of interoperability and lack of common data standards and policies.

The result of the research is a SDI-ICMM conceptual model and its implementation guidelines that covers both land and marine environments and can be used by jurisdictions to create an enabling platform for the use and delivery of spatial information and services. This development aims to meet the initial needs of stakeholders in the coastal zone in line with the sustainable development (economic, environmental and social) goals of the region. The holistic enabling platform provides more efficient and effective decision-making capabilities across both the marine environment and land – marine interface.

8.5 Recommendations for Further Research

The outcomes of this research have highlighted a number of areas that require further research. Hence, future research efforts could take into consideration that Spatial Data Infrastructure for Integrated Coastal and Marine Management model presented in this research is not the ultimate and unique model of SDI but provides useful tools for developing a systematic model of holistic SDI. As well as, the application of the SDI-ICMM guidelines requires further investigation in different jurisdictions because each jurisdiction has its own considerations and its guidelines for developing their SDIs.

Note also that the Use Case Diagram and Object Diagram of Enterprise viewpoint were not fully developed. The UML was used to describe the different elements that make up the SDI-ICMM, both physical and conceptual. In the case of fully developed diagrams, there are need all classes with all associations. The resulting model is a preliminary model of a SDI-ICMM.

A Appendix

- **Stages and Summer schools**
  - Stage: *"Tropical marine ecology"* High Training and Research Centre, 20 -29 October 2015, Magoodhoo (Maldives)
  - Summer school: "*How to govern marine environment: Baltic Sea and sediment services as a case study*" 10 - 21 September 2017, Hamburg (Germany)
- **Seminars and Conferences**
  - **Khorchani, A.** (2016), "Artificial reefs as tools for coastal resource management", Proceedings of *International Seminar on Biodiversity and Natural Resource Management*, 19-21 April 2016, Souk Ahras (Algeria).
  - **Khorchani, A.** (2016), "Kerkennah island: Growing vulnerability and fragile environment: Extension of the Sebkhas, retreat of the coast and urban spread", Proceedings of *International Soil Seminar*, 5-6 December 2016, Hammamet (Tunisia).
- **Papers**
  - Kies, F., De los Rios, P., Elegbede, I.O., Gbolahan, A., **Khorchani, A.**, Monge Ganuzas, M., and Corselli, C. (In revision) (2017), "Trophic and hydro-morphological dynamics of The Mediterranean Estuary and its Adjacent Waters", *Revista de Biología Marina y Oceanografía Journal*.
  - **Khorchani, A.**, Kies, F., and Corselli C. (submitted), "Exploratory study on SDI-ICMM implementation in Tunisia", *Journal of Spatial Information Science*.

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