3D MARINE ADMININSTRATION SYSTEM, BASED ON LADM

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Abstract: Maritime environment, acknowledging the precedence of the terrestrial boarders, needs to be organized and precisely determined whereas the interests involved are complex and wide. The registration of marine boundaries is a necessary condition for the protection of an alive organism, which flows, changes, reverses itself, but it is not limitless.

The research has confirmed that the common pattern of people land relationships exists in the marine environment. Also the marine cadastre concept suggests that the complexity of interests in marine space is similarly encountered in land. The extension of cadaster functions from land to marine space is considered reasonable.

The main objective of this paper is to organize the RRRs included in marine space and to develop a marine administration model, based on LADM, followed by the database implementation.

Keywords: Marine Administration System, LADM, 3D modeling, 3D cadastre

1. INTRODUCTION

The interests of every state are not limited to the terrestrial and maritime borders; they are also within the maritime environment [Williamson et al., 2010]. This summarizes the important issue dealt with in this paper. Maritime environment, acknowledging the precedence of the terrestrial boarders, needs to be organized and precisely determined whereas the interests involved are complex and wide. The maritime environment has always been a place for different activities and uses, involving various parties; however for most countries its space needs to be properly managed, in order to be sustainable within the international framework. Hence, each government should be responsible for providing appropriate management of the maritime space, whereas a number of legislative rules and restrictions result from a complex framework of local, state, national legislation and international conventions, the global environment movement and maritime practices that have been implemented.

Over the last two decades, countries with extensive coastlines and confined marine space, where they exercise sovereignty and powers, archipelagic states inclusive, have dealt with the concept of Marine Administration System (MAS). Among others Australia, Canada, the Netherlands and the United States developed systems for the administration of marine interests and the sustainable management of marine resources. Their efforts are at a development stage, looking fro best practices in the fields of marine cadastre and marine Spatial Data Infrastructure (MSDI).In addition, the international geomatics community has increased its research efforts towards the development of MAS, including technical, institutional, and legal issues to be considered. [Sutherland & Nichols, 2002; Binns et al., 2003; Barry et al., 2003; Fraser et al., 2003; Binns, 2004; Rajabifard, et al., 2006; Fulmer, 2007; Abdullah et al., 2014;].

For defining a MAS, certain issues need to be addressed: hat type of information should a MAS contain? What is the relationship between subject-right-object in the marine environment? What types of law define the interests? What types of interests exist in marine environment? Which is the property/ tenure object? Who are the stakeholders and which are the entities with statutory duty to assign rights and control the implementation? Is the 3D registration of interests in fact required? What is the framework for representing and visualizing these interests interacting with one another, capturing the inherent 3D nature of marine interests? What is the basic reference unit and how this can be defined and delaminated? [Ng'ang'a, et al., 2004; Sutherland, 2004].

The answer to the above raised questions is under discussion recently. The existence of different MASs shows the different perspectives of the various jurisdictions. The absence of common standards is apparent. However, there are common elements that must be taken into account, when defining a MAS. As key points, the majority of marine interests exist because they are implemented by the law. Furthermore, the three dimensional volumetric nature of marine environment (with rights on the surface, water column, seabed, and subsurface) requires 3D cadastral representation, where even the 4–dimensional nature of the person-space relationship needs to be registered (rights and interests within a legal framework that change over time).

The most challenging part when considering the ideal MAS is a functional 3D registration and visualization of the legal objects and their physical counterparts. Simultaneously, this constitutes one of the crucial requirements in the development of land cadastral systems, in order to serve multiple 3D applications such as land and property taxation and public communication [Aien et al., 2013a; Aien et al., 2013b]

In the conceptual level, different land cadastral data models (2D & 3D) have been developed by jurisdictions, organizations and software developers [Aien et al., 2013a]. However, LADM constitutes the most solid common ground in land administration, as an officially International Standard ISO 19152. Standardization supports the design and development of an administration system and can be considered a a requirement for the development of a National Land Information System. As Lemmen (2012) states "in spite of the available basic standards (for modeling the UML), exchanging structured information (XML) and ISO generic geo-information standards, there is still one important aspect missing: a standard and accepted base model for the land administration domain". LADM may deal with this problem by providing a conceptual description for land administration based on common grounds. Its core packages are related to (1) parties, (2) basic administrative units, rights, responsibilities and restrictions, (3) spatial units and the spatial extension of them, through surveying and spatial representation sub-package. It constitutes a generic domain model, which is expandable. The question arises as to whether the different land/cadastral data models are adequate to model marine space.

This paper is structured as follows. In Section 2, the various Marine Administration concepts are examined along with the developments in the different jurisdictions in terms of web applications in the public domain. Section 3 outlines the complex issues surrounding the marine environment and elaborates on the classification of marine interests, in regard to the law that also defines their spatial dimension. Section 4 briefly provides different initiatives in the domain of cadastral data modeling, and investigates, based on literature, how these structures may be extended to the marine environment. The conceptual classification of the marine entities and relationships, based on LADM, are presented in Section 5, followed by the database implementation. Finally selected cases are visualized, using ArcScene and Google Earth.

2. MARINE ADMINISTRATION SYSTEMS

2.1 Basic Concepts

The concept of marine cadastre evolved to bring coherence in the various approaches [Williamson et al., 2010]. Given its stage of development, it has many definitions, as Nichols et al. (2006) extensively described. It can be broadly defined as "an information system that records, manages and visualizes the interests, and the spatial (boundaries) and non-spatial data (descriptive information about laws, stakeholders, natural resources), related to them".

The marine cadastre delivers the fundamental datasets that are especially vital to marine management. The functionality of a cadastre in supporting the MSDI is recognized after a protracted debate about how to use and adapt land-based tools to service marine needs. In modern theory, the cadastral component and the SDI are fundamental to the way marine information is developed and shared, and ultimately for competent marine administration. Most ocean and coastal management problems are of a spatial nature and therefore, the development of a marine component to national and regional SDIs is imperative to the effective management of the marine environment [Williamson et al., 2010]. MSDI must be based on 'interoperability' (seamless databases and systems). International standards' organizations are addressing the development of standards for both land-based and marine-based spatial data and technologies. Important standards developments relating to coastal and marine data include the S-100 - Geospatial Information Registry, which provides important compatibility for data sharing in the hydrographic information community (S-100 is being based on the ISO/TC211 base standard) [Ward et al., 2009].

A multidimensional management of marine space requires for additional types of information concerning the spatial extents of marine cadastre. This includes scientific information (e.g. geology, hydrology, biology etc.) and the physical objects of legal registrations, in case of underwater tunnels, pipelines, utility networks, submerged archaeological cities or even underwater luxury hotels and facilities - a growing trend in tourist destinations. Such a system, is implemented by using GIS tools, interactive mapping applications, marine and coastal data and metadata. in order to support decision making processes in the marine environment..

2.2 International Initiatives

The marine cadastre concept in Geomatics' related research and literature is growing since 1999 [Griffith-Charles & Sutherland, 2014). These efforts mainly focus on the development of unique cadastral systems for the sustainable management of marine resources within a range of jurisdictions. An overview of online mapping and cadastre approaches that support integrated coastal and marine planning for USA, Australia and Canada is briefly presented below. Despite developments in MASs, seafloor may be three-dimensionally presented, but the visualization of interests remains 2-dimensional.

In the USA, NOAA and BOEM have developed a web-based integrated marine information system that provides data, tools, and technical support for ocean planning, named marine cadastre. The base data on this site focuses on providing a legal framework for authoritative data. Over time the project included many other types of data [NOAA & BOEM, 2010]. Geoscience Australia created the Australian Spatial Information System (AMSIS), a web based interactive mapping that contains over 80 layers of information and provides legal information for the visualized boundaries. Issues in the use of natural rather than geometric boundaries to define jurisdictional limits were considered, as well as expanding the Australian SDI to develop and support a marine cadastre. Custom queries are possible [Geoscience Austalia, 2010]. In 2008 ACZISC, supported by Geoconnections Canada, developed the Coastal and Ocean Information Network for Atlantic Canada (COINAtlantic). A search utility locates marine and coastal datasets and offers the user the option to add and display datasets in a graphic map interface. Data displayed can be queried by point-and-click methods and delivers text/attribute data results directly from linked spatial databases [COINAtlantic, 2009].

3. REGISTRATION OF LEGAL OBJECTS

3.1 Legal framework

The interests, that have to be registered in a MAS, concern the activities taking place in the marine environment and affect it. The common component of all marine interests is that their existence is based on the law. So in order to develop a MAS, the registration of laws is considered reasonable.

United Nations Convention on Law of the Sea (UNCLOS), concluded in 1982, formed the cornerstone of the legal mechanism and balanced the interests of States. One of the ways established was through the division/classification of marine space into different maritime zones. Coastal States enjoy sovereignty or sovereign rights over the maritime zones in the waters adjacent to their coasts and thus the jurisdiction to establish their laws and policies, in compliance with UNCLOS guidelines. According to Cockburn et al. (2003), UNCLOS influences a ratified nation's MAS in several ways, like breadth, depth, what rights can be included in the ocean areas and hence what spatial information is contained therein and has an effect on the evidence that can be used for boundary demarcation and delineation. UNCLOS has created a complex three-dimensional mosaic of private and public rights [Ng'ang'a et al., 2004].

In this mosaic, a number of marine[1] policies are added (regulations and directives) provided by the European Union for Member states, as Greece. Some of the prevailing EU directives refer to: maritime spatial planning (Directive 2008/56/EC, Regulation EU No 1255/2011), Integrated Maritime Policy (the Blue Book) which highlight that all matters relating to Europe's oceans and seas are interlinked, and that sea-related policies must be developed in a joined-up way.

Within this framework and in accordance to the above international provisions, each member state is entitled to determine its national legislation either incorporating the international developments or retaining its exclusive right to define specific rights, restrictions and responsibilities of sovereign areas.

3.2 Type of RRRS

UNCLOS defines thoroughly the rights of each state in marine spaces. The kind and the extent of sovereign rights depend on different marine zones to which they refer. However, it is important to note that referring to state rights in inland waters, sovereign rights are differentiated from the freehold ownership of terrestrial space. For our understanding, we may use it in a similar way in the present paper but we should bear in mind that sovereign rights involved with the marine space are exercised under specific conditions excluding the wide power and free-

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[1] IOC, NOAA and DEFRA use the term marine spatial planning, while EU argues that maritime spatial planning underlines the holistic cross-sectorial approach of the process

dom of a freehold ownership. In short, marine space is a place for various transactions but it cannot be conveyed. Regardless this particularity, sovereign rights involve a variety of powers and rights that should be recorded by MAS.

Public Interests: Public rights refer mainly to the constitutional right of every citizen of the state having an unlimited without obstacles access statewide (terrestrial and marine space). Interrelated with this, is the right of personality.

Environmental Interests: We refer to provisions relevant to the protection and conservation of water resources, places of protected beauty and cultural heritage. These places are pre-determined by the law and the rights involved are of supreme importance and mandatory, in comparison to the following functional rights.

Functional Interests: The term functional is used in order to highlight the particularities of the marine environment and the kind of different transactions that can be found in the marine space. Progressively functional rights tend to acquire a private nature, associated with individual stakeholders, that coexist with the state rights. In a wide sense, this term sets the limits of rights, which involve mainly the different ways of use, management and appropriation. In other words, in the marine environment the rights are limited in terms of space, duration and most importantly the extent, the content that refers only to the different kind of uses and management. The stakeholders are not owners but only beneficial "users". Functional rights are granted either by leasing contracts or through licensing. It has to be said that the power of granting remains national and no freehold ownership is involved.

3.3 RRRs requiring 3D Registration and Representation

Few marine activities take place on the ''surface'' of the water. Nearly every marine activity takes place in a volume of water [Ng'ang'a et al., 2004]. Marine environment has an inherent volumetric nature involving the exercise of rights to the surface, water column, seabed, and subsoil.

Regarding the spatial reference of marine interests, three kinds of RRRs can be distinguished:

- Exclusive use that their physical presence exclude any other rights from being present in that space so the visualization of this indicates the restriction boundaries for any other interest.
- Time based, as some rights and restrictions may be in effect only during certain periods of time. So the coexistence of two different rights, like mooring and fishing is allowed in different times.

- Without geographic location; opportunities may be tied to simply holding a license or being owner or operator of a licensed fishing vessel.

Table 1. Interests in marine space and their spatial extend

Interests	Spatial extent	Specializations	Presence			Representation boundaries of legal objects	
			Permanent		Temporal	2D	3D
			Physical	Non-Physical			
Sovereignty and jurisdictional rights	Shoreline			•		•	
	Internal waters			•		•	
	Territorial Sea			•		•	
	Contiguous Zone (if exists)			•		•	
	EEZ (if exists)			•		•	
	Continental Shelf			•		•	
Environmental rights	Marine protected areas	Ecologically sensitive areas, preservation of sea birds and marine fauna and flora		•			•
	Natura 2000			•			•
	Archeological Sites		•				•
	Heritage areas		•				•
	Shipwrecks		•				•
Functional powers (state and private rights through grants, leases, licenses or concessions)	Exploring and exploitation of minerals			•			•
	Areas of seismic surveys				•	•	
	Exploring and exploitation of natural resources	Fishing (commercial and recretional)			•		
		Aquaculture		•			•
	Utility Networks	Oil and gas pipelines	•				•
		Telecommunications cables	•			•	
		Electricity cables	•				•
	Sand mining areas				•	•	
	Marine energy parks		•				•
	Underwater resorts	Hotels	•				•
		Facilities	•				•
	Coastal construction areas	Harbours	•				•
		Shipyards	•				•
		Mooring areas			•	•	
	Organized swimming areas				•	•	
	Areas for watersports			•		•	
	Submarine touristic tours				•	•	
	Drilling platforms		•				
	Artificial islands		•				
	Artificial platiforms		•				
	Spatial Planning areas		•	•			•
	Special rights	Military Exercise Areas			•		•
		Areas of scienific research		•			•
Public rights	Navigation	Innocent Passage			•	•	
	Swimming areas			•		•	

3.4 Basic Reference Unit

Modern cadastral systems consider land unit (cadastral parcel - to which unique property interests are attached) as the basic reference unit for collecting, storing and disseminating information. Respectively, in a marine cadastral system a basic unit is necessary to be defined, regardless the complexity of precise descriptive and spatial definition of marine parcel, as Ng'ang'a et al. (2004) stated. Particularly, having in mind that the coexistence of marine activities in time and space is frequent, individual ownership of a parcel cannot be considered as the norm. In addition, a variety of activities can occur in the same longitude and latitude, but in different depth. The inherent volumetric 3D nature of marine space is apparent and subsequently its appropriate presentation is needed. The delineation of marine boundaries presents certain legal, technical and scientific problems. The basic issue involved is the dynamic nature of the marine environment that renders the implementation and the physical demarcation of legally defined marine boundaries impossible [Ng'ang'a et al., 2004]. Additionally, land water interface is ambulatory and most boundaries and limits follows the motions of that traditionally interface.

A succinct descriptive definition of marine parcel could be: "A confined space having common specifications for its internal, mainly used as reference to locate a phenomenon. A marine parcel facilitates the distinction between contiguous territories and provides information concerning this phenomenon through appropriate codification" [Arvanitis, 2013].

Spatially the basic reference unit, could be defined as: a multidimensional marine parcel or a series of (special purpose) volumetric marine parcels [Ng'ang'a et al., 2004] or as sea surface objects, water volume objects, seabed objects, and sub seabed objects [Rahman et al., 2012] or as a single piece of marine space deriving from the determined and standard division of the maritime surface using a grid of specific dimensions and subdivisions if needed. It is specified by geodetic coordinates of the surrounding boundaries. This method is already in use for defining the blocks in the domain of minerals exploitation. The combination of these methods is feasible.

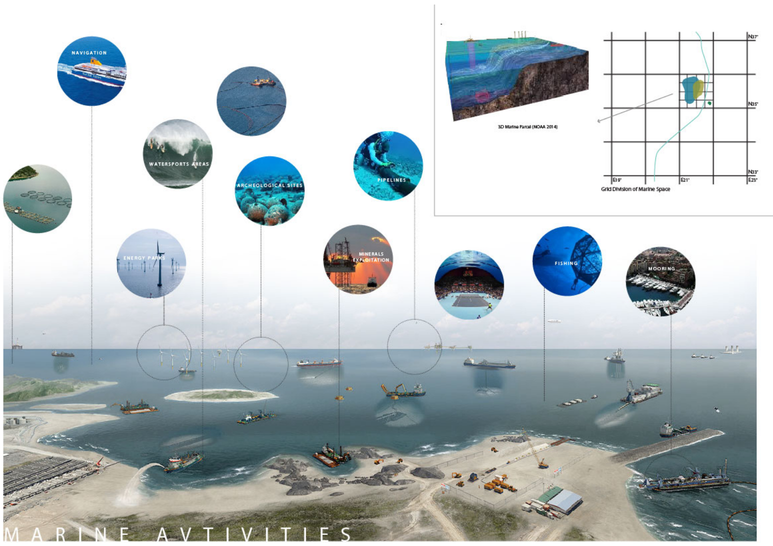

Fig. 1. Marine activities and marine parcel

In LADM the more generic term of Basic Administrative Unit (BAUnit) is introduced, in order to allow the association of a unique and homogenous right to a combination of spatial units, with unique identifiers. Respectively, in the marine environment it could be a unit with common specifications for its internal, which spatially can be described by the UNCLOZ zone it belongs, the physical layer and the responsible port authority or by the coordinates of the grid it belongs (according to the reference system of the country).

4. MODELING APPROACHES

The development of a MAS can be termed as a “combinatory play”. It has several parts (as every system): a data model for the information itself, the data format to support the data model, a database to manage data, and visualization tools for communicating, exploring and representing the information [Shojaei et al., 2013]. This paper focuses on the data modeling aspects of a marine administration system and more specifically examines the implementation of LADM to marine space.

Data modeling development is a repetitious and cyclical process used to create a perfect model of the real world, which aligns the seemingly random jumble of stuff into entities with relationships. The first step in the data modeling process is to define the overall scope and content of the model. It starts from mapping the concepts and their relationships of the real world to a conceptual model, through the UML and ER model. The conceptual data model is then translated into a logical data model, which records in detail the structures of the data that can be implemented in a database. The last step in data modeling involves transferring the logical data model to a physical data model that organizes the data into tables [Aien et al., 2013]. The abstraction is increased as one goes from human-orientation to computer-orientation. The physical design of the database specifies the physical configuration of the database on the storage media. This includes detailed specification of data elements, data types, indexing options and other parameters residing in the DBMS data dictionary.

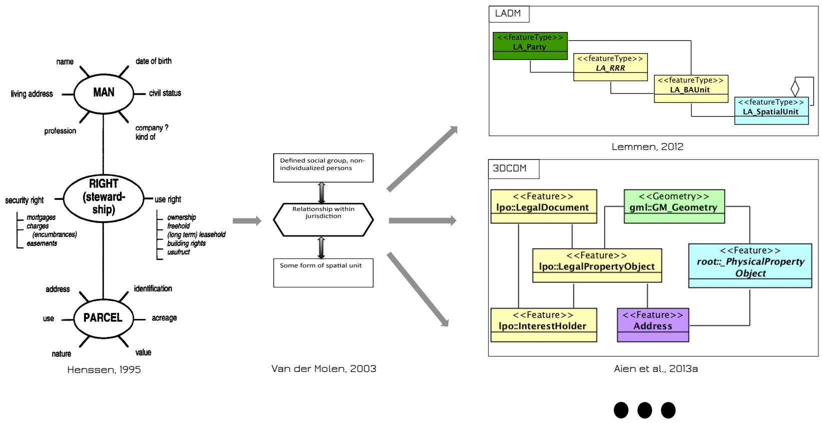

Fig. 2. Cadastral data models

Starting point of data modeling in land administration can be considered the visualization of the triple Object – Right – Subject, as introduced by Henssen (1995) and that pattern embodies the most solid common ground in land administration until today [Lemmen, 2012; Lemmen & van Oosterom, 2013).

Different initiatives in land cadastral data modeling have been developed, since the administration requirements differ among the various jurisdictions. The endeavor for the development of 3D cadaster is increased

4.1 3D data models for land administration

From the 3D perspective, LADM supports both 2D (LA_BoundaryFaceString) and 3D objects (LA_BoundaryFace) and it makes distinction between legal and physical objects by introducing external classes for BuildingUnit and UtilityNetwork. It covers only the legal space and the physical counterparts are not directly created in LADM. At the semantic level, legal entities are not enriched by classifying data in relationship to each other [Aien et al., 2013a]. Futhermore, LADM through VersionedObject class provides the attributes beginLifespanVersion and endLifespanVersion, allowing the recreation of a dataset at a previous point in time leading to a 4D visualization of the cadastre [Griffith-Charles & Sutherland, 2014].

Another initiative, the 3D cadastral data model (3DCDM) aims to achieve a conceptual framework for 3D cadastres. It was developed to support integration of legal and physical information that are required for 3D cadastral applications. The 3DCDM utilizes the concepts and terminology of LADM, but the primary focus is on geometrical 3D spatial units and the combination of legal and physical objects together in the data model. In addition 3DCDM only supports spatial units that are surveyed in a define coordinate system [Aien et al., 2013].

Current deliberations have focused on the incorporation of 3D legal and physical objects. The integration of data on legal spaces and on physical features is critical to occur also in marine environment, since the coincidence of boundaries of legal and physical spaces, is very rare if ever existent. Taking as a reference the underwater tunnels, pipelines, utility networks, submerged archaeological cities or even underwater luxury hotels and facilities - a growing trend in tourist destinations.

Integration enables to reuse geometrical data in different domains in general and to define legal spaces based on physical constructions in specific [Rönsdorf et al., 2014].

The modeling of 3D physical objects can be achieved by using 3D city models such as CAD files CityGML [Groger et al., 2012]. The adjustment of these models to marine space and the integration with marine cadastral model, need to be further investigated.

4.2 Extension to marine environment

In marine environment, despite the fact that a number of jurisdictions have shown interest in the development of MAS and the academic community has dealt with the marine cadastre concept focusing on varying technical, institutional, legal and stakeholder issues, there is a lack of literature to deal with marine data models in terms of data objects and the relationships among them [Griffith-Charles & Sutherland, 2014].

The question arises as to whether the LADM is adequate to model required data and their relationships, relevant to marine spaces. And if yes how can LADM be used as a basis for MAS development.

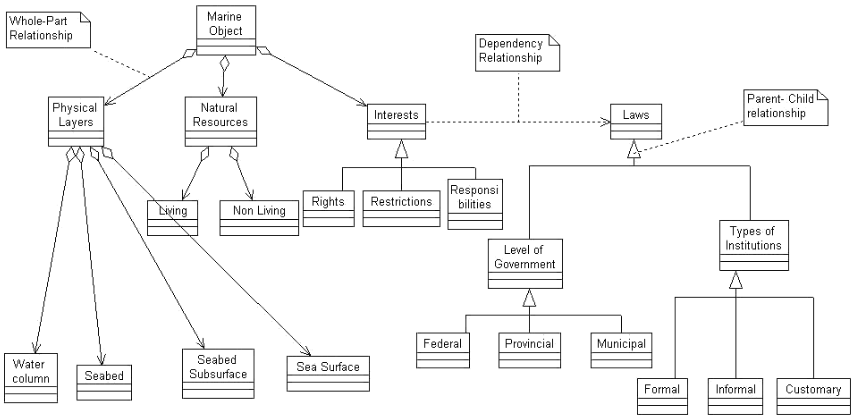

Fig. 3. Marine Property Data model (Ng'ang'a et al, 2004)

Ng'ang'a et al. (2004) describe a marine property rights data model, "which provides a standard way to capture the laws that facilitate the allocation, delimitation, registration, valuation and adjudication of marine property rights; the interests that are allocated; the resources that the interests refer to; and their 3D spatial extent." The authors argue that there exists a marine parcel object as base for data collection, storage, and retrieval on marine interests. Lemmen (2012) based on the above proposal, states "With some imagination the laws (formal or informal) can been seen as parties; in fact the laws allow people to have interests in "marine objects". The interests are RRRs and the MarineObject corresponds with the SpatialUnit in LADM Version C. So it is expected that LADM can be used to marine space." The application of the LADM to the marine environment highlights the differences that can arise in the application of the concept to different jurisdictions. The main issues are in the decisions regarding the visualization of the basic administrative units and any derivative spatial units, and in the linking or interfacing of the land based cadastre with its own existing standards with newly defined standards in the marine space [Griffith-Charles & Sutherland, 2014]. Duncan & Rahman (2013) advocate the integration of marine blocks with land volumes.

5. APPLYING THE LADM TO MARINE ENVIRONMENT

5.1 Conceptual description of proposed model

This paper proposes a marine cadastral data model, based on the LADM structure, which allows the registration of:

- the marine interests (RRRs) that are allocated,
- the legislation that recognize these interests,
- the different stakeholders that hold rights,
- the 3D spatial extend of interests,
- the natural resources that the interests refer to.

In the marine space the common relationships' pattern "people – land" is valid. The basic difference from land is the resources property object, which can be spatially defined. The proposed data marine model contains various adjustments, compared to LADM. The model's design is presented in this section. Every class in the model, except of sources inherits the attributes from VersionedObject, which leads to a 4D visualization of marine cadastre.

Non-Spatia

The non spatial part of the model consists of the Party and administrative package. In marine environment the party can be a stakeholder or most likely a group of individuals or companies. The party can also be the state. In the proposed model, the additional attribute of the level of responsible government is introduced. It specifies who has the supervisory control to exercise a RR according to relative law and its registration is compulsory.

Rights are divided to private and state rights. The MA_StateRight refers to the sovereign and administrative interests. In the MA_PrivateRight, the rights, which are granted by the State to natural or non-natural entities are recorded. The model proposes the registration of administration sources and laws in different classes. The fact that all different rights find their base in some kind of transacting document is represented by the association between MA_RRR and MA_AdministrativeSource and this transacting document is recorded in the latter class. However in marine environment the existence of rights may be not emerged through the transaction, but from the law implementation.

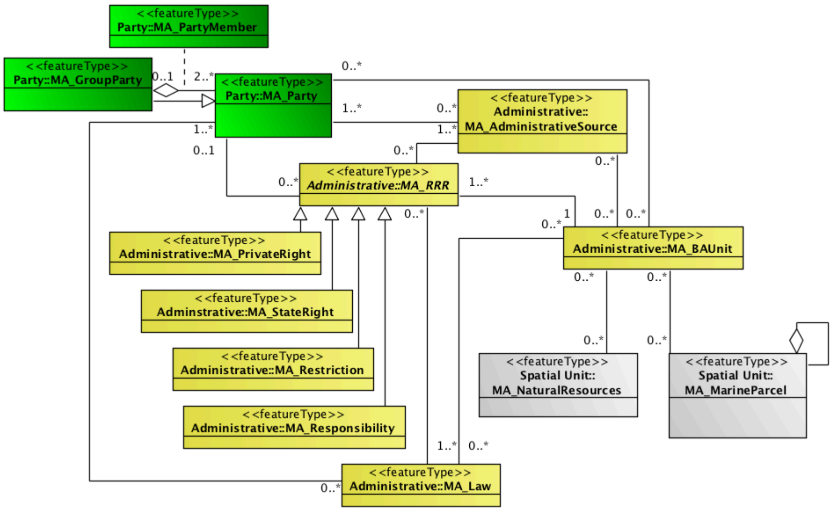

Fig. 4. Party and administration package

Respectively, in the marine environment the BAUnit is a unit with common specifications for its internal, can be spatially described through the MA_MarineParcel. MA_BAUnit can be wind energy park, aquaculture area, archeological site, shipwreck, artificial island e.tc.

Spatial

The MA_MarineParcel is the core class of Spatial Unit package. In order to spatially define MA_MarineParcel additional attributes are introduced. The unclosZone, with possible values - territorial sea and EEZ, the physicalLayer, the seaType (in Greece for example, the sea is divided in 8 different pelages) and the port authority – the values of these attributes are from proposed code lists. Furthermore the marineBlockCode is added, which is defined as "N°$_{WGS84}$, E°$_{WGS84}$/codeOfSubdividedGrid".

When defining a RR in marine space, and the MA_BAUnit this RR refers to, the registration of the natural resource that falls within its spatial extend is needed in a MAS, and this occurs through the class MA_NaturalResources.To make the model comprehensive, a wide range of spatial units can be supported. The specializations of MA_LegalSpaceUtilityNetwork and MA_LegalSpaceBuildingUnit (a growing trend in marine space) are maintained by LADM. The model introduced the specialization MA_LegalSpaceTunnel of marine parcel with its own attributes and structure.

External Classes

The LADM provides stereotype classes for external datasets. The classes of extPrivateEntities, extState, extLevelofResponsibleGovernment are associated to class MA_Party. The class extArchive is for the external registration of sources, according to LADM and is associated with the MA_SpatialSource, MA_AdministrativeSource and MA_Law. Additionally, the classes extPhysicalSpaceBuildingUnit and extPhysicalSpaceUtilityNetwork, extPhysicalSpaceTunnel are associated with the respective specializations of MA_MarineParcel. Finally the class extPhysicalSpaceConstructionUnit is associated with MA_MarineParcel in case the legally defined object contains constructions. (their physical registration is outside the scope of this paper).

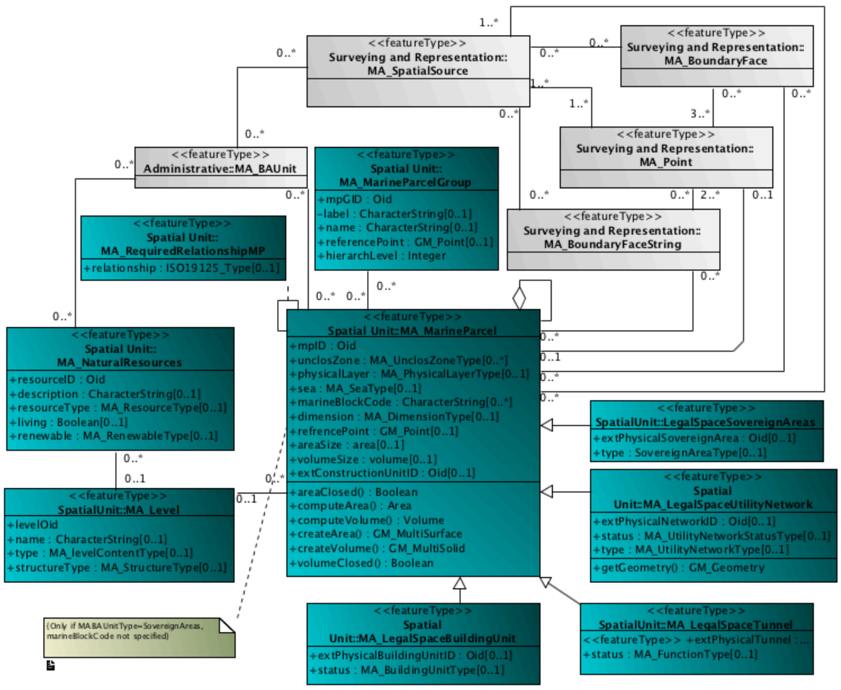

Fig. 5. Spatial package of proposed model

5.2 From Conceptual to Technical

Having structure the ER data model, the automatic physical design of the database was achieved through PgModeler software (PostgreSQL Database Modeler). The ER model was designed following limitations and capabilities of the PostgreSQL, by making use of PgModeler. The schema was implemented and populated using PostgreSQL, combined with PostGIS, which supports spatial functions. PostGis adds support for geographic objects allowing location queries to be run in SQL. The comparison and the validation of the methodologies are outside the scope of this paper.

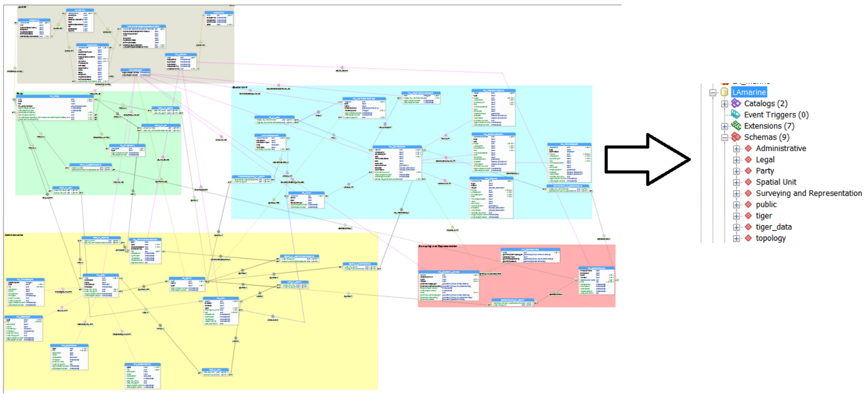

Fig. 6. Entity Relationship model and physical design

The Table 2 illustrates the assignment between the UML and the PostgreSQL. The following step was the registration and visualization of spatial data in a 3D GIS environment and in the second case study in Google Earth. Firstly, a study area was chosen and the digital terrain model was generated manually, using open data.

Table 2. Assignment between the UML and the PostgreSQL.

UML (LA marine)	PostgreSQL/PostGIS
Package	Schema
Codelist	Datatype
Oid	Oid
Fraction	Double
Relationship M-N	Create an intermediate table to reduce cardinality to 1-N
Class	Tables
BoundaryFaceString	Geometry (MULTILINESTRING),
BoundaryFace	Geometry(MULTIPOLYGON)
Constraints - Multiplicity	Constraint -functions

5.3 Case studies

This section presents examples of practical usage of the proposed data model for marine space. The dataset registered in the database, are shown In Figure 7, in ArcScene environment. We have to point out that the data are not real, however they are in accordance with the restrictions set by Greek legislation.

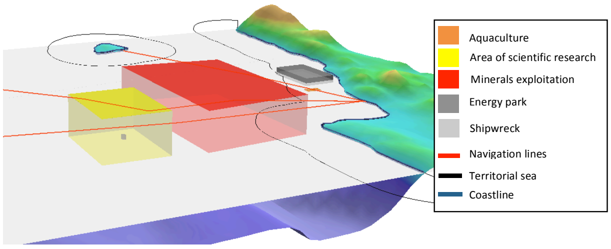

Fig. 7. The 3D representation of the legal objects registered in the database.

Case Study 1: A gas pipeline traversing a space defined for minerals exploration and exploitation

In first analyzed instance presents the registration of a leased Unit for hydrocarbons exploration and exploitation, and in the same space the existence of a pipeline. A spatial relationship should be verified between the pipeline and the underlying marine block.

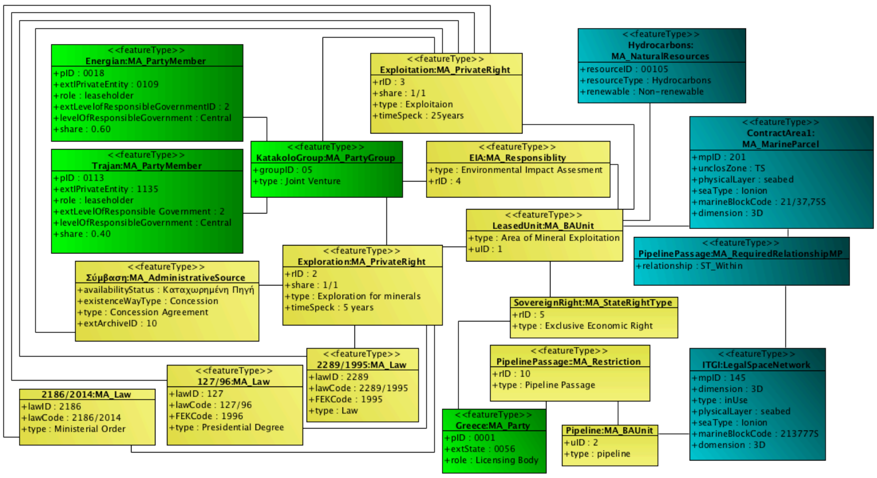

Fig. 7. The structure of relationships between objects at the instance level, according to the proposed model

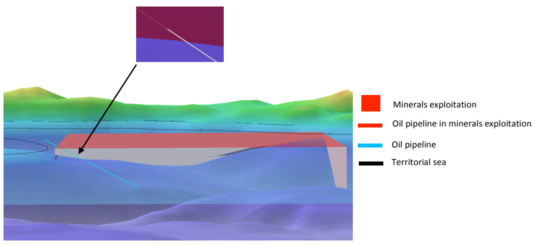

Fig. 8. The proposed 3D registration of marine rights in the system

Case Study 2: Navigation line within aquaculture area

The specific case concerns granted areas for the purpose of aquaculture and the construction of Wind-energy Park. Across this area navigation lines are provisioned. A 3D visualization of the confined places will precede (through querying) and subsequently the navigational lines will be amended in cases where they coincide with other uses and rights for a specific period. In this way, the role of MAS as a decision making tool is identified.

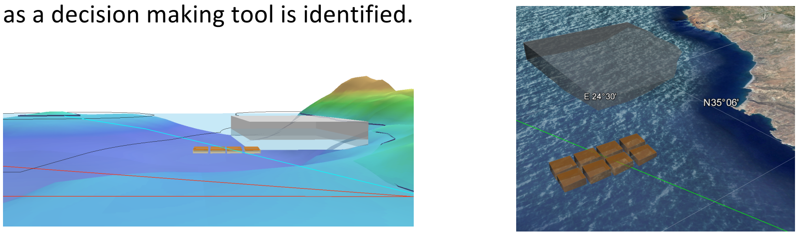

Fig. 9. The navigation line, which intersects with the marine parcel of aquaculture.

Conclusions

The model described in the present paper serves as a proposal for the management of the legal object of the marine space, including the possibility of a 3D data record. The establishment of such a managing tool could contribute to a sensible use and optimization of the marine space and its resources. The design of the model in accordance with international standard LADM offers a common language for all parties involved, interoperability of data and simplification of the procedures.

The use of a unique code of identification for each marine parcel, as developed by the attributes of the class MA_MarineParcel is considered necessary for the establishment of a single management system. The use of WGS84 UTM allows a smooth transitioning between the land cadastre and marine cadastre and constitutes a standard coordinate system for the Earth, being also the reference used by the GPS.

The integration of physical and legal objects by virtue of international standard models (LADM, CityGML) needs to be subjected to a further research. It is proposed to associate the cadastral marine parcel unit with the module of Water Body in CityGML, the LegalSpaceBuildings with the module Buildings, and the MA_LegalSpaceTunnel with the module Tunnel.

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