

# **Toward the Development of LADM-based Marine Cadastres: Is LADM Applicable to Marine Cadastres?**

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**Key words:** LADM, ISO 19152, Marine Cadastre, Marine Information Data Model

## **SUMMARY**

Hoogsteden and Robertson (1998; 1999) were among very few early publications that supported the idea that consideration is to be given to the extension of “on-land” cadastral system into the offshore. It was circa 2001 that the terms “marine cadastre” or “marine cadastral” were first explicitly used in scholarly media and at professional conferences (Fowler and Tremi 2001; Collier, Leahy and Williamson 2001; Hirst and Robertson 2001; Ng'ang'a et al, 2001; Sutherland, Nichols and Monahan 2001; Todd 2001). Most publications, since then, that addressed the marine concept cadastre concept, acknowledged the obvious 3-dimensional (3D) marine spaces and support the need for marine cadastres to multipurpose in function (Ng'ang'a, Sutherland and Nichols 2002; Binns and Williamson 2003; Binns et al, 2004; Ng'ang'a et al, 2004; Fulmer 2007). From a literature review by the authors of this paper, no publication sufficiently addressed any ascription to an appropriately applicable data standard for marine cadastres. The Land Administration Domain Model (ISO 19152: 2012) (LADM) conceptual standard has been referenced in scholarly and professional works to have explicit relevance to 3D cadastres in exposed land- and built environments. These sources, however, only cursorily make reference to LADM's applicability to marine cadastres (Lemmen et al, 2005; Lemmen and van Oosterom 2011; Lemmen 2012; de Almeida, Ellul and Rodrigues-de-Carvalho 2013; Tjia 2014; Eftychia 2015). Canadian Hydrographic Service & Geoscience Australia (2016) presents the most comprehensive modelling, to date, that refers to LADM in relation to marine cadastres. The authors propose an extension of the S-100 IHO Universal Hydrographic Data Model into the development of the S-121 IHO standard, to handle maritime limits and boundaries. However, the proposed S-121 standard is not a pure LADM-based data model but seeks to build some components that would conform to ISO 19152. This paper attempts to the question “How applicable is LADM, as a published cadastral data standard, to marine cadastres?” The given answers are based on a list of reasonable criteria, developed from relevant literature reviews, and used to assess the LADM standard. It is concluded that LADM is indeed applicable, as published and as a whole, to marine cadastres. This can be good news to those jurisdictions who are seeking to develop marine cadastres in that they can reasonably trust the LADM as an applicable data standard.

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## **1. GENERAL REVIEW OF MARINE CADASTRE PUBLICATIONS**

Land Administration Domain Model (ISO 19152: 2012) (LADM) has found justified accepted applications in the international construction and implementations of 3D cadastres related to non-submerged lands and built environments. The standard is also said to be applicable to marine cadastres. However, very few papers that make links between LADM and marine cadastres have to date been published in scholarly or professional journals/magazines. Some of these publications include: Lemmen et al (2005); Lemmen and van Oosterom (2011); Lemmen (2012); de Almeida, Ellul and Rodrigues-de-Carvalho (2013); Tjia 2014; Eftychia (2015); and Canadian Hydrographic Service & Geoscience Australia (2016). Additionally these publications generally and implicitly accept the relevance of LADM to marine cadastres. A search of the literature has not to date revealed published acceptance of LADM's relevance to marine cadastres, based on developed or listed criteria. It is a reasonable academic exercise, therefore, to seek answers to the question "How applicable is LADM, as a data standard, to marine cadastres?", and base the answers on developed or listed criteria.

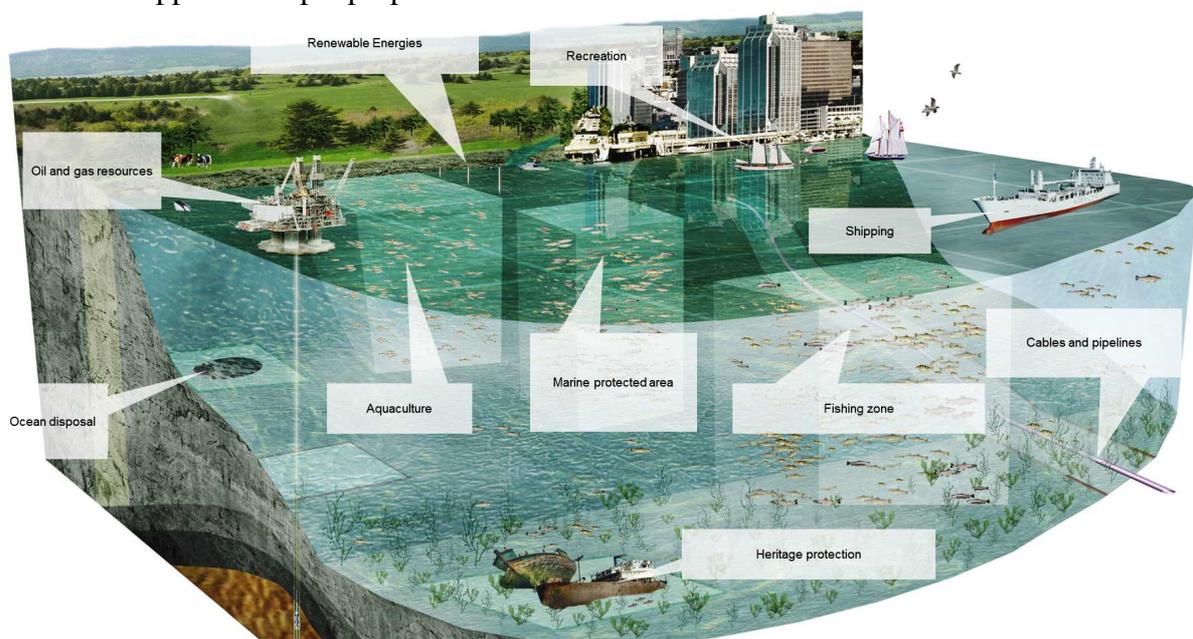
In ascribing to LADM as a standard that is generally applicable to marine cadastres, it is logical and reasonable that criteria are defined and the standard assessed against same. Such criteria are addressed in Section 3, which are developed from literature and projects reviewed in Section 2. Section 4 then offers a review of LADM-related marine cadastre publications so as to underscore the point that the authors of this paper have found no literature that explicitly assessed the LADM as applicable to marine cadastres, based on established or defined criteria. Section 5 then interrogates the LADM based on the defined criteria so as to offer an answer to the question "How applicable is LADM, as a data standard, to marine cadastres?"

## **2. GENERAL REVIEW OF MARINE CADASTRE PUBLICATIONS**

Publications containing cadastral issues related to the marine environment began appearing in the body of scholarly work circa 1998, with Hoogsteden and Robertson (1998; 1999) proffering ideas to deal with the extension of "on-land" cadastral system into the offshore. It was circa 2001 that the terms "marine cadastre" or "marine cadastral" were first explicitly used in scholarly media and at professional conferences. For instance, Fowler and Tremi (2001) in discussing marine cadastral data underscored the facts that cadastral components such as adjudication, survey elements such as boundaries and datum considerations, and descriptions of ownership rights are also applicable to ocean spaces. These concepts are supported by Todd (2001). Collier, Leahy and Williamson (2001) referred to marine-related rights and responsibilities held by diverse groups and individuals that are subject to a "complex web of government legislation", and supported the idea that a marine cadastre, as part of a spatial data infrastructure, can facilitate the management of rights, restrictions and

responsibilities. The authors also implied that a marine cadastre may have to manage overlapping rights and boundaries, some of which may be affected by the ambulatory nature of some marine-related boundaries which must be well-defined and accurate. Hirst and Robertson (2001) outlined the importance of a marine cadastre accommodating various types of boundaries, not necessarily cadastral in nature, such as those that are associated with the United Nations Convention on Law of the Sea (UNCLOS) (1997) that are expressly administrative in nature. This is also supported by Todd (2001), Ng'ang'a et al (2001), and Sutherland, Nichols and Monahan (2001). All sources ascribed to the benefits of marine cadastral data and information to increased efficient management of marine resources and spaces.

After 2001, a number of publications addressed the marine concept cadastre concept, with most authors acknowledging the obvious 3-dimensional (3D) nature of the space to be managed and modelled. Ng'ang'a, Sutherland and Nichols (2002) stated that in modelling and constructing a marine cadastre, and apart from the obvious data needed (i.e., in relation to rights, responsibilities, restrictions, and boundaries), other attribute information necessary for good governance of marine spaces must also be accommodated and managed: living and non-living resources; water quality; seabed characteristics etc. The authors also state that the construction of a marine cadastre must also facilitate data integration and visualization. Confirming the need for a marine cadastre to service multiple needs and address multi-dimensional issues (i.e., legal, technical, institutional, economic, environmental, social etc.) Binns and Williamson (2003) underscored the need for a marine cadastre to be part of a spatial data infrastructure and to handle complex and possibly overlapping rights is an obvious 3D/4D space. Binns et al (2004) supported this position, as well as the need for a marine to support multiple purposes.



**Figure 1. Complex marine and maritime rights. From Peyton, Kuwalek and Fadaie 2016**

Some authors have specifically addressed marine cadastre data conceptual visualization of complex 3D marine/maritime boundaries (Figure 1) so as to underscore the nature of the environment that has to be modelled and managed (Binns and Williamson 2003; Binns et al, 2004; Ng'ang'a et al, 2004; Peyton, Kuwalek and Fadaie 2016).

Some authors and jurisdictions have reported on, published, or proposed Web-mapping interfaces and systems such as CARIS Spatial Fusion, ArcIMS and ArcGIS Server that were used to manage and visualize marine cadastre data (Ng'ang'a, Sutherland and Nichols 2002; Sutherland 2008; Commonwealth of Australia 2009; Sutherland and Nichols 2009; National Oceanic and Atmospheric Administration 2016). Most, if not all, proponents of the marine cadastre have done so from a multipurpose perspective (Ng'ang'a et al, 2004; Fulmer 2007).

## 2.1 Publications on marine cadastre data models

Very few explicit data models specifically relevant to marine cadastres have been found by the authors in searches of the literature (scholarly or professional). One such source is Ng'ang'a et al (2004) who took an initial step in designing a “Marine Parcel Data Model” (Figure 2). The model sought to incorporate and encapsulate environmental, legal, and institutional elements associated with a marine parcel. The design was predicated upon the fact that rights, responsibilities, restrictions and interests in marine spaces are explicitly 3D/4D in nature, relating to the sea surface, water column, seabed, and seabed subsurface. The design also sought to acknowledge that rights, responsibilities, restrictions and interests are associated with various types of stakeholders, and can be formal or informal. Curiously, components that would incorporate these stakeholders are missing from the graphical representation of the model.

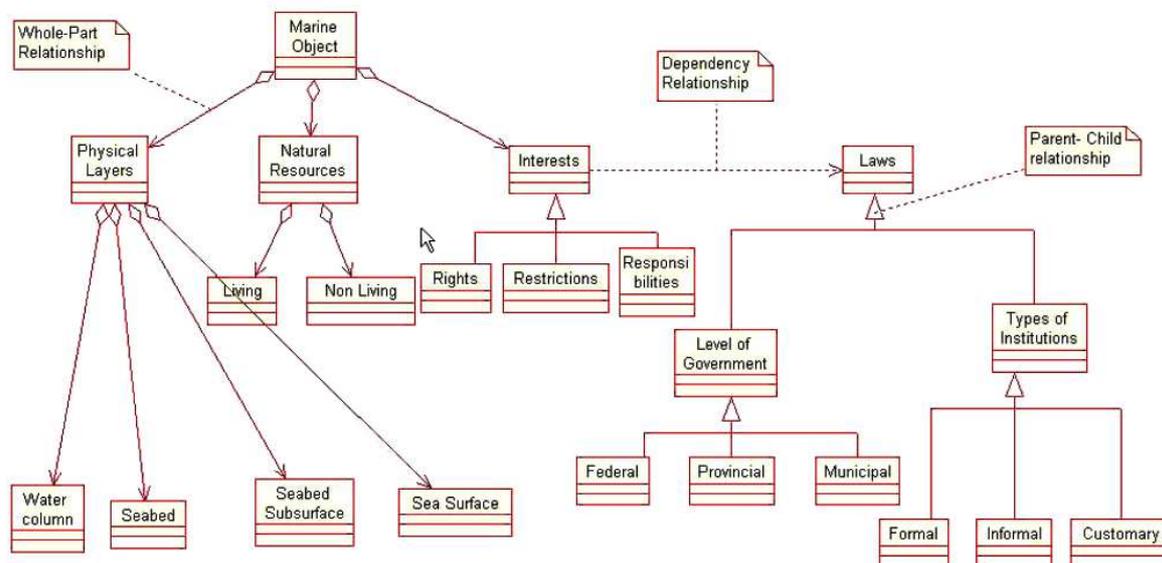


Figure 2. A marine parcel data model (Ng'ang'a et al, 2004)

Canadian Hydrographic Service and Geoscience Australia (2016) present a model that refers to, in part, the LADM and marine cadastre. The authors propose an extension of the S-100 IHO Universal Hydrographic Data Model into the development of the S-121 IHO standard, “built upon the Object Oriented structure of S-100” to handle maritime limits and boundaries. The S-100 IHO Universal Hydrographic Data Model is an extension of the International Hydrographic Organization (IHO) S-57 Hydrographic Data Transfer Standard. The development of S-100 was motivated by limitations inherent in the S-57 standard, such as its inability to handle gridded bathymetry or temporal changes in information, and the fact that it was developed to primarily facilitate the exchange of data between ENC databases. S-100 was developed to better handle the management of hydrographic spatial and non-spatial data and information, including imagery and gridded data, 3-D and time-varying data (x, y, z, and time), and new applications that go beyond the scope of traditional hydrography (for example, high-density bathymetry, seafloor classification, marine GIS, etc.)” (Ward and Greensdale 2011). The IHO S-121 standard on Maritime Limits and Boundaries is a further development based on S-100, and is being designed to incorporate the management of UNCLOS objects or any UNCLOS composed objects, beyond the management of maritime limits and boundaries. The IHO intends to base all hydrographic-related product specifications, e.g., marine limits and Boundaries, marine cadastre, and Marine Spatial Data Infrastructure (MSDI), on S-121 (Canadian Hydrographic Service and Geoscience Australia 2016).

Apart from Canadian Hydrographic Service and Geoscience Australia (2016), which is not formally published in scholarly literature but is in fact a proposal, and from the perspective of marine cadastre logical and physical data model development, none of the sources reviewed referred to, or attempted to adhere to, a marine cadastre relevant data model standard based on reasonable universally defined criteria. Section 3 below outlines such criteria, developed from the literature reviewed in this section.

### **3. MARINE CADASTRE DATA MODEL AND STANDARD CRITERIA**

Marine spaces are obviously 3D in nature. What then are the criteria necessary to be met in developing marine cadastre logical and physical models, against which a marine cadastre data model may be assessed for sufficiency of multipurpose function, and which are to be incorporated in the design of an applicable data model standard? According to the review of sources in Section 1 of this paper, a marine cadastre data model (and by implication a marine cadastre relevant data standard) should at least facilitate the management of marine spatial information relating to:

- The existence, creation and termination of various and overlapping types of formal and informal rights, restrictions, interests, and responsibilities that affect multiple purposes and objectives jurisdictions;
- Diverse groups, individuals, and legal persons to whom rights, restrictions, interests, and responsibilities are ascribed;
- Various and overlapping types of 3D formal and informal boundaries and limits that relate to sea surfaces, water columns, the seabed, and the seabed subsoil, some of which can change in space and time due to:
  - Transfers of, or changes in, rights, restrictions, interests, and responsibilities;

- The ambulatory nature of some marine related boundaries;
- Various types of metadata, and other spatial information and surveying/mapping elements, such as datum, projections, data acquisition methodologies etc. that are attributable to defined 3D spatial extents;
- Various types of non-spatial information (e.g., ecological, political, social, economic etc.) attributable to defined 3D spatial extents;
- Complex levels of overlapping government laws, legislations, regulations, policies, treaties, conventions etc. that affect behaviours in defined 3D marine spatial extents;
- Possible integration of the marine cadastre datasets with other datasets in a spatial data infrastructure.

These foregoing criteria are used in this paper to assess whether the LADM is truly applicable to marine cadastres. In other words, and for instance, can a marine cadastre logical data model be designed using only LADM constructs and rules? However, to underscore the point that this issue has not explicitly been addressed in scholarly literature to date, Section 4 below reviews literatures that refer to LADM and marine cadastres.

#### **4. LADM-RELATED MARINE CADASTRE PUBLICATIONS**

This section is brief because there is not yet a lot of literature that explicitly and fully addresses the implications of LADM on marine cadastre development. Since the advent of the LADM, scholarly works have explicitly (or by implication) referenced the ISO 19152 conceptual standard, including in relation to marine cadastre. Some sources imply that ISO 19152 has utility in managing cadastral units in marine spaces but these implications remained as such, without any detailed discussions on the matter. Other sources focus on LADM's application to cadastres dealing with exposed land, and only cursorily mention marine cadastres (Lemmen et al, 2005; Lemmen and van Oosterom 2011; Lemmen 2012; de Almeida, Ellul and Rodrigues-de-Carvalho 2013; Tjia 2014; Eftychia 2015).

Canadian Hydrographic Service & Geoscience Australia (2016), referred to in the final paragraph of Section 2, presents the most comprehensive modelling with reference to LADM and marine cadastre. However, the proposed S-121 standard that is the focus of the proposal is not a pure LADM-based data model. Instead it is proposed to incorporate into the S-121 structure some elements inspired by ISO 19152. As can be understood from the foregoing, none of the literature reviewed in this section appear to explicitly assess the relevance of LADM to marine cadastres, based on reasonably defined criteria. Section 5 below uses the criteria outlined in Section 3 to test whether LADM constructs are sufficient, wholly within the context of the standard, to support the design of a marine cadastre data model.

#### **5. IS LADM WHOLLY APPLICABLE TO BASED MARINE CADASTRES?**

This section offers an examination of LADM from the perspective of criteria outlined in Section 3, so as to make a determination as to whether the data standard is as a whole applicable, as published, to marine cadastres. LADM packages, sub-packages, and relevant classes are presented in Figures 3 and 4.

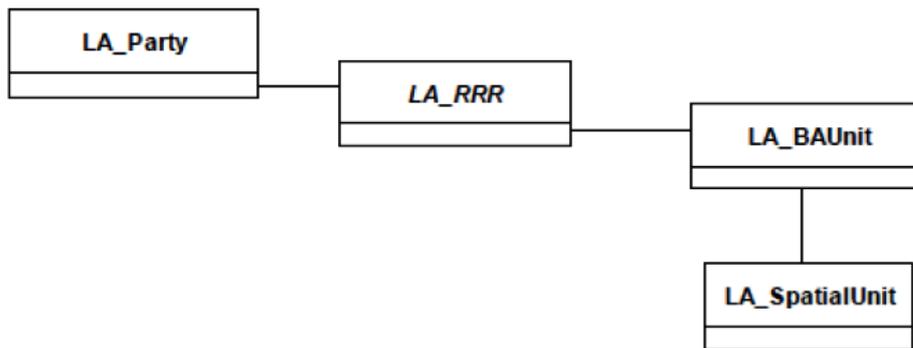


Figure 3. Land Administration Domain Model Packages (ISO 19152: 2012)

Figure 4. Land Administration Domain Model Sub-Packages and Respective Classes (ISO 19152: 2012)

### 5.1 The ability to accommodate complex marine rights

Many authors of academic and professional publications have underscored that, regardless of the jurisdiction, marine spaces comprises many varied, complex, and overlapping rights. A general classification of these includes, but is not limited to (Done 1989; Hirst and Robertson 2001; Binns et al, 2004; Sutherland 2005; Sutherland and Nichols 2006; Fulmer 2007):

- Sovereign rights;
- Administrative rights;
- Jurisdictional rights;
- Public rights;
- Private rights;
- Customary and traditional rights;
- Aboriginal rights;
- International rights;
- Treaty rights;
- Convention rights.

The relevant conceptual schema, packages and sub-packages of ISO 19152: 2012 are the Administrative Package, and its classes and sub-classes:

- class LA\_RRR (rights, responsibilities, restrictions);
  - subclass LA\_Right (ownership right, tenancy right, possession, customary right, or informal right);
  - subclass LA\_Restriction (formal or informal restraint from doing something);
  - subclass LA\_Responsibility (formal or informal obligation to do something);
- class LA\_BAUnit ('basic administrative unit' - an administrative entity consisting of zero or more spatial units against which one or more rights;

The foregoing constructs appear to be able to manage and model various types of rights, responsibilities, and restrictions, especially considering that ISO 19152: 2012 declares that LADM is a generic model that is expandable in terms of additional attributes, operators, associations, and classes as needed.

The overlapping nature of rights and interests in marine spaces is well documented. LADM must be able to accommodate and manage this characteristic of the rights and interests. According to Paasch et al (2015):

*In LADM a representation of overlapping tenures is possible. The LADM functionality as presented in “RRRs: formal, customary and informal in the LADM” section seems to be sufficient and specific classifications/types can be added by extending the various code lists of the relevant RRRs.*

It appears, then that LADM is relevant to marine cadastres, from the perspective of accommodating various types of overlapping rights, responsibilities, and restrictions.

## **5.2 The ability to accommodate information on stakeholders in marine spaces**

The literature on marine cadastre is clear regarding the existence of multiple types of stakeholders who have interests and rights in marine spaces. These stakeholders are international, regional, state/provincial, municipal, private, public, traditional, customary etc., and often, as discussed in the previous section, their rights overlap. A marine cadastre must accommodate these situations and stakeholders so as to assist in effecting good governance of marine spaces (Collier, Leahy and Williamson 2001; Sutherland and Nichols 2006).

An observation of LADM Party Package and the classes seems to confirm that LADM is capable of accommodating this aspect of marine cadastre modelling:

- class LA\_Party: persons, or groups of persons, or juridical persons, that compose an identifiable single (legal) entity;
- class LA\_GroupParty: any number of parties, forming together a distinct entity;
- class LA\_PartyMember: a constituent of a party or group party.

## **5.3 The ability to accommodate and model complex overlapping marine boundaries**

The literature on marine cadastre, as reported in Section 2 of this paper, is clear that one complexity in marine spaces that marine cadastres should address is the obvious 3D nature of the natural environment, and the 3D nature of spatial extents (i.e., volumes, not polygons) existing in the pelagic, benthic, and seabed subsoil environments to which various stakeholders have often overlapping rights (Ng'ang'a et al, 2001; Todd 2001; Ng'ang'a, Sutherland and Nichols 2002). A marine cadastre also ought to be able to accommodate changes to some marine/maritime boundaries that change because of their ambulatory nature or through transfers of/changes in rights, restrictions, interests, and responsibilities. Some projects have avoided 3D modelling by implementing 2D web-based marine cadastres (or marine information systems) (Ng'ang'a, Sutherland and Nichols 2002; Sutherland 2008; Commonwealth of Australia 2009; Sutherland and Nichols 2009; National Oceanic and Atmospheric Administration 2016).

LADM is constructed to manage 2D and 3D modelling of cadastral data and information. This is implementable through the Spatial Unit Package and its sub-classes:

- class LA\_SpatialUnit (e.g., text, point(s); line(s); area(s)/polygon(s); volume(s):
- class LA\_SpatialUnitGroup (spatial units within an administrative)
- class LA\_Level (geometric or thematic coherence: urban/rural type; point type etc.)
- class LA\_LegalSpaceNetwork ()
- class LA\_RequiredRelationshipSpatialUnit ()
- Subpackage Surveying (management of data collected from surveys)

- class *LA\_Point*
  - *LA\_PointType*
- class *LA\_SpatialSource*: Observations made during surveys
  - *LA\_Source*:
  - *LA\_SpatialSourceType*:
- class *LA\_InterpolationType*
- class *LA\_Transformation*
- Subpackage Representation (management of data collected from surveys)
  - class *LA\_BoundaryFace* (instances of 2D and 3D representations of spatial)
  - class *LA\_BoundaryFaceString* (instances of 2D/3D representations of spatial units)

Versioned objects can be used to manage changes in spatial dimensions. It appears that LADM, from the perspective discussed in this section, is applicable to marine cadastres.

#### **5.4 The ability to incorporate other relevant spatial information components**

Often in marine cadastres, as in other types of cadastres, metadata and other spatial information and surveying/mapping elements, such as datum, projections, data acquisition methodologies etc. are required components. They support fitness for use and perceptions accuracy when data and information are being interpreted, or used to support various types of decision making processes relating to defined marine spaces (Binns et al, 2004; Ng'ang'a et al, 2004). LADM Spatial Unit Package (Figure 4) seems relevant to the aspect of marine cadastre discussed in the previous paragraph.

#### **5.5 The ability to incorporate relevant non-spatial attributes**

The most appropriate class of LADM to address issues of relevant non-spatial attributes is the Administrative Package. The classes and sub-classes listed in Figure 4 do not explicitly offer solutions to this required aspect of marine cadastre (i.e., as a complete marine information system). However, as stated in Section 5.1, ISO 19152: 2012 declares that LADM is a generic model that is expandable in terms of additional attributes, operators, associations, and classes as needed. The necessary classes can therefore be created to satisfy this requirement.

#### **5.6 The ability to associate marine parcels with complex legal regimes**

Complex levels of overlapping government laws, legislations, regulations, policies, treaties, conventions etc. were attempted to be modelled by Ng'ang'a et al (2004). This is necessary in using a marine cadastre as a marine information system to support decision making and multiple objectives of good governance, because laws, legislations, regulations, policies, treaties, and conventions etc. determine the nature of rights associated with defined spatial extents, and serve to control behaviours in those spaces. As outlined in Section 5.5, the Administrative Package is relevant, with classes created as is necessary.

#### **5.7 The ability to facilitate marine cadastre's data intergration in SDIs**

Spatial data infrastructures (SDI), e.g., Marine Spatial Data Infrastructure (MSDI), facilitate the sharing of data among stakeholders to support holistic decision making, especially in relation to spatial extents where many rights and interests overlap. The ideal situation is that all stakeholders subscribe to the same data (and other) standards; this would make data

sharing much easier. However, in less than ideal situations where various standards are in employ, aspects of data structures can share key information (e.g., parcel ID) that can serve to link databases. LADM is capable of incorporating such data, and therefore it is reasonable to assume that LADM can support data integration in SDI.

## 6. LADM-BASED MARINE CADASTRE CONCEPTUAL MODEL

Based on the discussions in Section 5, a LADM-based marine cadastre conceptual schema may be constructed as presented in Figure 5. Created classes are shaded. The design is based on the assumptions:

- There are approximately eight maritime zones relevant to marine cadastres:
  - Internal waters;
  - Archipelagic waters;
  - Coastal waters;
  - Territorial seas;
  - Contiguous Zone;
  - Straits;
  - Exclusive Economic Zone (EEZ); and
  - Continental Shelf;
- Maritime zones may or may-not contain spatial units or administrative units, and may or may-not contain marine resources;
- Maritime zones will always be associated with maritime layers: UNCLOS rights are defined according to zones and marine layers (i.e., sea surface, water column, seabed, and seabed subsoil);
- Marine layers will always be associated with maritime zones.
- Spatial units will always be associated with a maritime zone, and with marine layers;
- Marine layers may or may not contain marine resources, or spatial units; and
- Marine resources may or may not be found in maritime zones and marine layers.

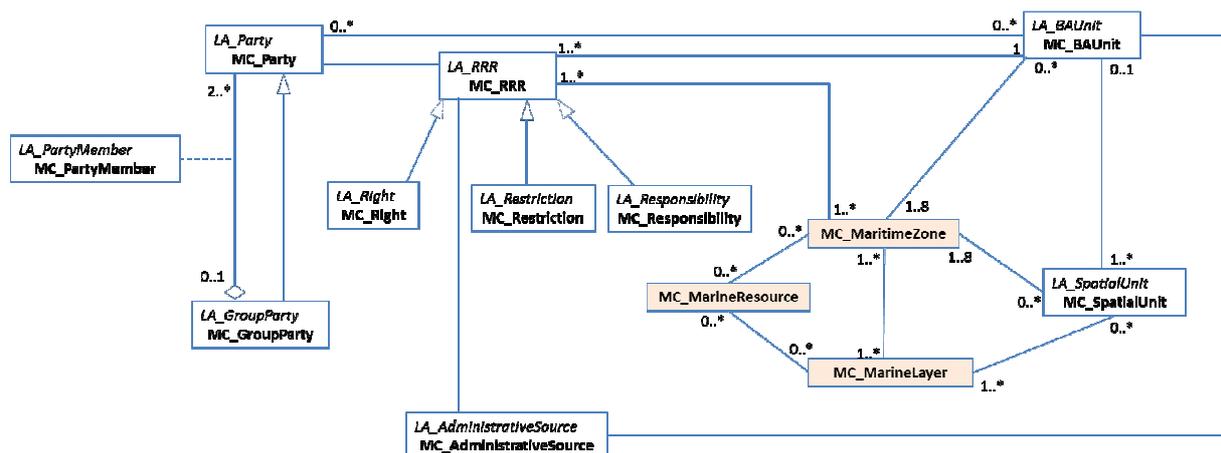


Figure 5. Land Administration Domain Model Based Marine Cadastre Conceptual Schema

## 7. CONCLUSIONS

Publications dealing with the marine cadastre concept were reviewed and criteria defined therefrom so as to support an assessment of whether the LADM standard is as a whole applicable, as published, to marine cadastres. The discussions in Section 5 seem to suggest a positive response to this query. It can therefore be reasonably assumed that a purely LADM-based marine cadastre can be developed and implemented. This can be good news to those jurisdictions who are seeking to develop marine cadastres – they can reasonably trust the LADM as an applicable conceptual standard.

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