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LADM extensions to maritime domain in multi-register environment - Case study Croatia

Veljko Flego [a,*], Miodrag Roić [b], Irena Benasić [c]

[a] Teh Line Ltd., Mate Balote 53, Rijeka, 51000, Croatia
[b] Faculty of Geodesy, University of Zagreb, Kačićeva 26, Zagreb, 10000, Croatia
[c] State Geodetic Administration, Riva 16, Rijeka, 51000, Croatia

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ABSTRACT

Traditional land administration key registers are established for the onshore area and after been developed and technologically improved during many decades, nowadays they are in a stable and mature evolution phase. Registers covering the administration of offshore spaces, i.e. the maritime domain, are usually extended from onshore registers or developed for a single purpose, creating a multi-register environment with many administration challenges and issues caused by many actors involved and by complex registration processes.

In this paper, an analysis of maritime domain registration in Croatia has been performed by using Unified Modeling Language class models. The analysis includes two close connected key land registers, Cadastre and Land book, as well as: other authoritative data from Territorial units/Address register; Utility cadastre; Register of concessions on maritime domain; spatial plans, and a series of registers dedicated to natural resources exploitation, nature and cultural heritage protection. Redundant data and cross-registration is present in all basic Land Administration Domain Model (LADM) classes contained in the registers, as well as 3D overlapping of spatial extent of registered spaces and tenure.

The basic LADM classes were semantically identified in class diagrams of registers and compared to LADM using a schema matching methodology on the object level, with emphasis on required registration in different registers. Shared classes were identified and a possible upgrade and extension of the current model is proposed to facilitate the registration process.

1. Introduction

The first regulations related to marine activities in, were related to navigational and fishing rights. Over centuries, increased activities in marine areas created a layered scene with a multitude of parties and temporal and complex spatial extents of rights, restrictions and responsibilities (RRRs). Regulation and, subsequently, registration of marine areas and related parties and interests are an important part of any sovereign state's efficient and integral land administration.

With defining of the extent of national jurisdiction and sovereignty on the seas and oceans, the widely accepted United Nations Convention on the Law of the Sea (UNCLOS) allowed the sovereign states to extend and enforce their laws and public administration instruments to their marine area. Inclusion of marine areas in national governance caused some integration issues which should be resolved.

Generally, three phases in the development of administration tools in marine areas can be identified:

- Determination of marine areas, their boundaries and limits;
- Establishing of marine registers;
- Incorporating of marine registers in national land administration.

The first step is the proper spatial identification of marine spaces which is not always straightforward because of their distinct features as uncertainty, mobility in space and time and difficulties in demarcation (Sutherland, 2005). Boundaries are established according to agreement between stakeholders, purpose, presence and evidence on the ground, existence in time, and their graphical and textual representation (Bennett et al., 2009). Typical for the marine environment is that borders have numerical definitions based on coordinates, maps, imagery and GPS data instead of visible natural or artificial borders.

Marine cadastres as stand-alone registers emerged in coastal states

* Corresponding author.
E-mail addresses: veljko.flego@ri.t-com.hr (V. Flego), mroic@geof.hr (M. Roić), irena.benasic@dgu.hr (I. Benasić).

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and some distinct issues also emerged. The use of existing digital data in the USA revealed the lack of proper geographical and legal definition of marine spaces (Fowler and Treml, 2001). In South Korea, multiple institutions and complex competences were detected as significant obstacles in establishing of an efficient marine cadastre (Lee and Shin, 2010). Latvia identified the need of better coastline determination (Stāmure et al., 2017). Malaysia started with an analysis of the existing legal framework and the needs of local and regional authorities (Abdullah et al., 2014), in Israel the use of marine cadastral blocks as basic unit is proposed (Srebro, 2015). Indonesia relied on experiences in existing marine cadastres (Astor et al., 2017). In Europe there are some documents and policies dealing with marine cadastre, but none of the countries established a full-fledged marine cadastre (Balla and Wouters, 2017).

Integration of marine data in National spatial data infrastructures (NSDI), Integral coastal management (ICZM) initiatives and using of marine data in Marine spatial planning (MSP) revealed more integration issues (Roić, 2016). Extending the competences of onshore (land) institutions to offshore (marine) areas (Ng'ang'a, 2006) leads to a more consistent and integrated system (Vaez, 2010), but this extension should be approached with caution considering the differences in legal status, competent institutions, boundary definitions and social component (Gazzola et al., 2015).

2. Methodology

The registers considered in this study are defined by relevant laws and regulations and can be considered as key registers, bearing distinct features like legal foundation, obligation of use for official purposes, institutional responsibility for the data, publicity, etc. (Bakker, 2009). A line-up of registers used in registration in maritime domain is indispensable as the first step of the analysis. The roles of registers are depicted in a Unified Modeling Language (UML) use case diagram. Subsequently, all relevant registers are modeled using standard UML class diagrams.

In order to analyze the behavior of registers of authoritative marine data in a complex administration relying on multiple registers, and to investigate the possibilities of using Land Administration Domain Model (LADM) in such an environment, the next step was to review the possibilities of LADM in modeling registers other the cadastre and cadastre-alike ones.

For model comparison, models correspond to schemas so schema matching methodology is used because it is suitable for identifying correlations of schemas in process of data integration (Alwan et al., 2017). Schema matching can be done on various elements and schema levels, using different levels of automation depending of amount of data. Models of registers of maritime domain were analyzed using manual schema matching in structure level and element level (Rahm and Bernstein, 2001). Since there is no common terminology used in registers, a semantic identification between classes was performed.

The main feature typical to multi-register environment is the cross-connection of authoritative data between registers, which should be noticeable as relation between classes of UML models. LADM in this case can be used as a core reference model (Hess and Schlieder, 2006) using the basic LADM classes, *LA_BAUnit*, *LA_Party* and *LA_RRR* to compare the registers. An additional element of a class or feature belonging to another register was included in schema matching tables. For three basic LADM classes, a matrix of cross-connections between registers was made.

As a final step, after identifying the repeating, cross-connected and redundant classes, a generalization of most common classes was made, resulting in new linking LADM classes which may be used to better modeling in a multi-register environment.

3. Registration of maritime domain in Croatia

Croatia never established a dedicated marine cadastre and the registration of administrative units, parties and RRR's relies on existing registers, mostly the same ones as onshore, or dedicated to a specific maritime feature.

The discussion about the coastline definition, which can be seen as the division line between onshore and offshore spaces, is often brought in the context of marine cadastre (Seet et al., 2014). However, the spatial extents of registers are not legally limited by the coastline, nor generally limited by any other physical feature, but rather by the extent of state sovereignty. Considering that, and the certain vagueness of coastline definition, the identification of marine areas cannot rely entirely on physical location and should consider all other elements in registers, like attributes and descriptions, which can indicate the belonging to marine space (Flego and Roić, 2018a).

The source for identification of relevant registers and other sources containing records related to marine spaces are laws and regulations published in the Official Gazette and accessible to public on internet. From the available land related registers only the relevant ones were included in this study, and those that are clearly irrelevant, such as the Vineyards cadastre, Forrest management registry, Arkod (Land Parcel Identification System) and others, were omitted. As well, the State property register is not included, because of the nature of marine spaces in Croatia to which the ownership regime does not apply, so they cannot be of the state property. The registration process is showed in a standard UML use case diagram (Fig. 1). Relevant registers are represented as actors, connected to a proper registration action showed as ellipse. Cross-connections between registers and registration actions are showed using dashed lines connectors.

Generally, if there is a cadastral parcel established, the registered marine space belongs to real property registration system. Protected areas are established by a relevant establishment act. Special uses of marine spaces are granted by concessions. Other marine spaces are parts of administrative subdivision, defined by law as fishing zones or defined by an intended purpose in spatial plans. Marine spaces, areas and objects are registered in one or more relevant registers, they are shown on official maps or plans, or they are defined and described by a relevant law.

The registers currently in use rely on spatial definitions common in the time of registers establishment, which means that the usual registration units are defined as 2D areas and very seldom having a third dimension element, in the marine spaces usually expressed as depth.

Completeness of data has been early pointed out as an important element of spatial data quality (Brassel et al., 1995). Marine registers and marine cadastres are supposed to contain a wide range of data to record various types of marine spaces use (Barry et al., 2003) and to fulfill institutional and legal demands (Dawidowicz and Źróbek, 2014). In the case of registers in Croatia, all the relevant registers are detected and considered in this study.

There are three main types of registration: parcel based, concession based and registration related to environmental and heritage protection. Aside from that, some objects are registered on nautical publication, and the administrative borders are registered in Address and territorial units register.

3.1. *Parcel based registration – real property*

Real property registration is based on cadastral parcels and relies on two closely related registers, Cadastre, under the control of the State Geodetic Administration (SGA) and Land book, under the control of the Ministry of Justice. Cadastral parcel is the main registration spatial unit in both registers, with a higher level unit of cadastral district. Cadastre is in charge of spatial definition of parcel and its use, with records of current tenants, Land Book registers ownership data and RRRs. When required by spatial planning, cadastral parcels can be established on the

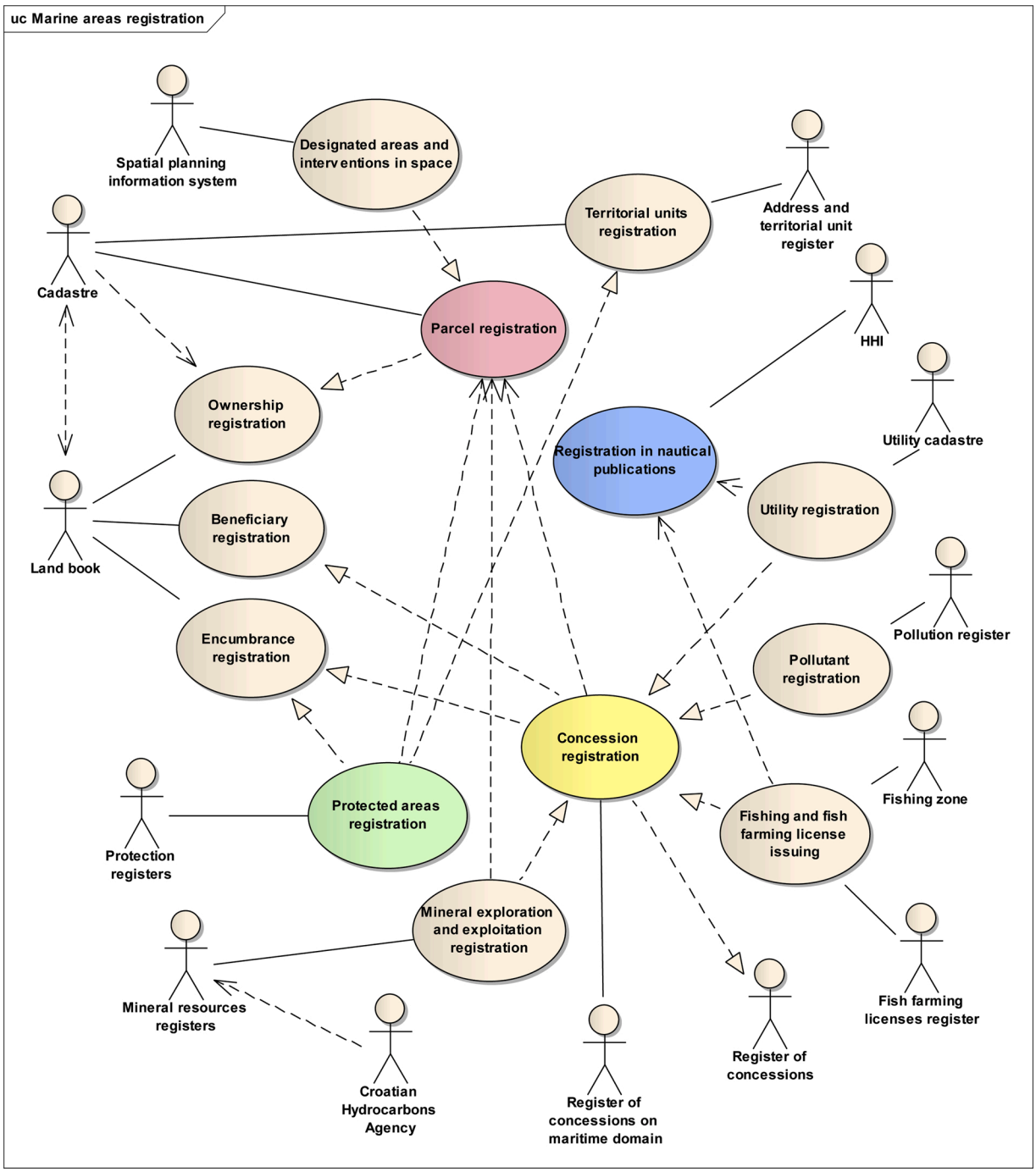

Fig. 1. Maritime domain registration UML use case model.

sea (Fig. 2), can be physically connected to land or standalone and hierarchically belong to the cadastral district onshore.

The Land Book keeps records of several types of rights, responsibilities and restrictions under the condition that the RRRs are related to an established cadastral parcel or to a registered physical or legal person.

Since there are no ownership rights on the maritime domain, the owners name on parcels is registered as *Maritime domain*.

3.2. Concessions

Maritime domain is a public good, ownership rights cannot be established and cannot be subject of real property transactions. By laws, it extends at least six meters inland from coastline to the limits of territorial sea, includes seabed, subsoil, physical features, buildings, structures and facilities (Official gazette, 2003). Concessions on maritime domain are granted by competent authorities in accordance with regional spatial plans and within a determined border of maritime domain, whose onshore part is registered in the Cadastre and Land book. Concessions are registered in a range of registers, depending on the concession provider, competent institution, resource type, scope and the object of concession. Register of concessions on maritime domain is a general register containing records on granted concessions on ports, harbors, marinas, pipelines, cables, shipyards, commercial activities, gravel and sand extraction, salt production, beaches, sports and leisure facilities and other ways of regulated usage of marine areas. Concessions

Fig. 2. Cadastral parcel on the sea (URL 1).

are granted by the Government, regional authorities or local authorities, resulting with three levels of registers and independent local databases which are kept by competent authorities.

With the growth of marine related activities, the need for registration led to emergence of several stand-alone registers created according to specific needs of competent institutions. To keep records on exploration and exploitation of mineral resources the Ministry of economy, business and trade established the Integral information system on mineral resources which includes two registers, the Register of approved mineral resources exploration spaces and the Register of established mineral resources exploitation fields, with a collection of accompanying documents and an auxiliary register of mining businesses subjects. Depending on the type of mineral resources, the competence of registers is divided between the Ministry and the regional government. Croatian Hydrocarbons Agency is a stakeholder in the management of hydrocarbons resources and keeps the register of contracts regarding exploration and exploitation of hydrocarbons, geothermal waters and liquefied natural gas storage.

Register of granted privileges for fish and other marine organisms farming is kept by the Ministry of agriculture in a form of aquaculture database. According to concluded concession contracts, the Ministry issues the privileges for fish and other marine organisms farming, related to parts of maritime domain granted for concession or for the onshore space where farming takes place.

Utility cadastre is maintained by SGA and includes both onshore and offshore utility lines and facilities. Laying of cables, pipelines and other utility objects on the sea bottom is carried out after a concluded concession contract.

Environmental pollution register is an information system containing information about activities that discharge waste substances in the environment, in marine environment they are represented mostly by underwater outlets, which activity is subject to concession. The register is maintained by the Croatian environment and nature agency.

Financial agency (FINA) holds the Register of concessions, a public register of all granted concessions in the Republic of Croatia. The main focus of register is revenues and it does not contain any spatial information except the location name.

3.3. Protected areas

Protection measures are applied to natural values and cultural heritage which are in competence of two ministries and registered in two registers. Register of protected areas keeps records of protected natural values and is kept by the Ministry of environment and energy. Registration is based on a Registration Act issued by the competent authority, depending on the level of protection. Records about protected areas include several space related data, like territorial location (including city/municipality and county), area, boundaries description, a list of cadastral parcels included in the protected area and a digital map.

The register of cultural heritage is a public register kept in the Ministry of culture. Marine areas can be identified as immovable cultural property of types "underwater archaeological site" and "underwater archaeological zone". The register itself consists of several lists, containing records about the county, city/municipality, location, address, toponym and coordinates of the protected property.

3.4. Marine spaces not registered in a register

Some important areas related to marine activities are not registered in a form of an official register. Fishing zones and subzones are hierarchically structured and defined in relevant official regulations. They are determined by prominent geographic elements such as promontories, rocks, cliffs, by the border points of the territorial sea, by geographic coordinates, azimuths and headings intersections. Restricted waters are closely related to fishing zones, defined in relevant bylaws with a descriptive area definition. Fishing zones and subzones are recorded in

the fishing privileges connected to fishing vessels and their owners and recorded in the Register of issued fishing privileges.

The Spatial planning information system contains a variety of data regarding spatial planning, zoning, intended use, building acts and documents. It is kept and maintained by the Ministry of construction and physical planning. Besides of the state border on the sea, there is no other explicitly marine feature. The intended use of maritime areas, conditions and restrictions, or the planned interventions in space can be detected only by physical location in regards to the coastal line (Fig. 3).

Nautical charts and pilots officially issued by Hydrographic institute of the Republic of Croatia (HHI) are a means of registration for objects and facilities important for the safety of navigation, including aquaculture facilities, navigation and observation buoys, underwater constructions, underwater cables and pipelines. HHI is also competent for determination and mapping of Croatian international borders.

3.5. *Territorial units and address register*

Register of territorial units and addresses is kept in the SGA and its regional offices and contains data on Croatian administrative subdivision (counties, cities, municipalities), statistical and census units, settlements, streets and house numbers (the address model), jurisdictional subdivision, mail delivery areas and protected areas. The register itself is composed of maps, lists of territorial units and collections of documents. Boundary lines of local administration on the sea are for informative purposes only and do not represent the legal borders. The actual belonging of islands, islets and rocks to onshore local administration is shown through attribute identifiers.

4. LADM in maritime domain modeling

LADM has been recognized as an appropriate model far beyond its original purpose of describing land administration and cadastre-alike registers, which include building information modeling (BIM) and valuation (Van Oosterom et al., 2019), cultural heritage (Gogolou and Dimopoulou, 2015), fiscal purposes (Kara et al., 2018), or integrating the needs of a juridical, fiscal and marine cadastre (Griffith-Charles et al., 2018). With allowing of customization of core model by adding user defined classes, and with the possibility of connection of external classes with common keys (ISO, 2012), LADM opened the way to many possible applications.

As a natural spatial and administrative extension of land, maritime domain is the first to be included in the same model with its onshore counterpart. Standardization is the first step towards a mature land administration system, with the ultimate goal of a networked cross sector approach placing all the relevant information in public service (Van Oosterom et al., 2009). Since most of registers used in maritime domain LADM are either extended or derived from onshore based registers, LADM as description of people-to-land relations is an appropriate modeling tool.

LADM right out-of-the-box, without further customization, is applicable for marine environment. Some emphasis should be put on classes and packages important to marine areas. Complex interests in the marine areas can be described using *LA_RRR* class, including the relevant sub-classes; stakeholders in marine spaces can be accommodated in *LA_Party* class; borders and limits of marine spatial units can be modeled either as 2D or 3D borders; metadata and data sharing is included in the model. Marine domain tenure often relies on non-spatial data, laws, regulations, conventions, agreements and other, so an extension of

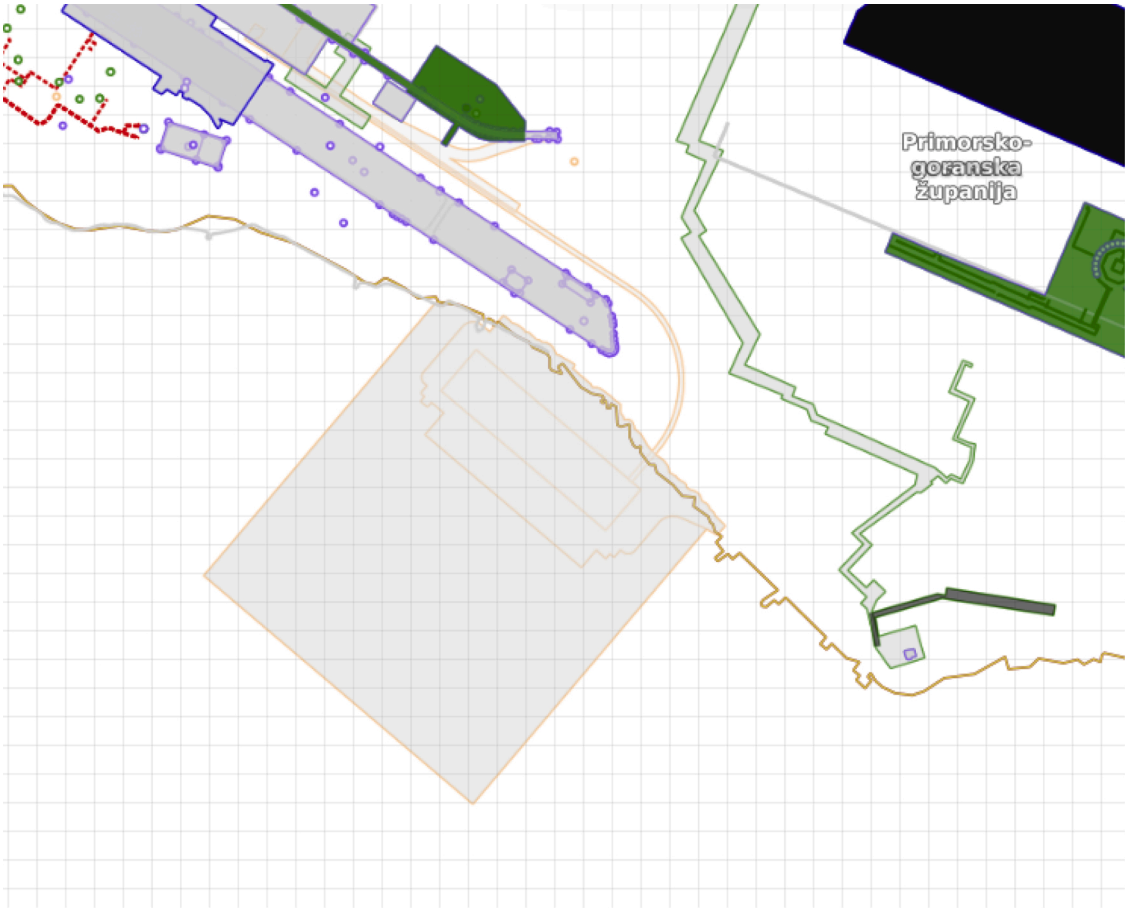

Fig. 3. Intended marine area (URL 2).

Administrative package could contribute to better modeling of tenure on the marine areas relies (Sutherland et al., 2016).

Marine activities have a distinct 3D character, reflecting the 3D character of marine spaces and the 3D nature of tenure on maritime domain. Public laws and restrictions are an important factor in defining legal 3D spaces (Kitsakis and Dimopoulou, 2017) since marine spaces and the relevant tenure are mostly established by laws rather than real property transactions. In investigating the possibilities of fine adaptation of LADM to marine needs, some new classes regarding marine administration have been already proposed. Marine rights can be expanded by two new specialization classes, *MA_StateRight* (marine state right), referring to state sovereign interests and *MA_PrivateRight* (marine private right), referring to granted rights. The proposed *MA_NaturalResorces* class includes natural resources, both movable and unmovable. Complex spatial 3D relations can be better described in models using *MA_LegalSpaceTunnel* class (Athanasiou et al., 2017a).

The most distinct feature related to tenure on marine spaces in Croatia is their public nature and they are rarely related to ownership and private rights. Some of proposed new types of specialized rights are applicable for closely defining the tenure on marine spaces. *Latent right* (Paasch, 2012b) is a type of timed encumbering of beneficial rights that have not been realized yet and are waiting for their execution, when they become a registered RRR. Typical examples are intended spaces in spatial planning, or the concluded concession contracts that are not yet legally valid. Public regulations (Paasch, 2012a) are the most important mean of defining marine spaces and especially of establishing RRRs on marine spaces and their elaboration leads to a range of new suitable classes describing public regulations features. In the case of marine spaces, where they are established and managed with a public document, spatial plan, or a regulation, the concept of public regulations is an important factor to consider. In cases of traditional tenure, the classes *Customary right* and *Informal right* (Paasch et al., 2015) can further expand the marine administration model to tenure that has not been formalized or registered in the form of an official register.

Although not a register, nautical charts and nautical publications are an important element in registration of marine objects and features. Beyond the original purpose aiming at navigation and hydrography, nautical charts and publications, in their electronic form, serve as a spatial register of all marine related objects, including physical features, limits and borders, and extending to marine administration and legislation. The International hydrographic organization (IHO) S-100 standard already includes LADM based information about marine limits and boundaries, and the emerging S-121 standard includes additional LADM classes and packages regarding spatial objects, parties and administration packages, with the possibility of further expanding and customization. S-121 standard was tested in marine administrations of Greece and the Trinidad and Tobago (Athanasiou et al., 2017b). Marine limits and boundaries, legal descriptions of marine objects, 3D legal and physical objects were used for modeling, resulting in extensive code lists related to marine environment for both countries, useful in future development of national marine administration systems.

5. Analysis of the multi-register environment

Multi-register environment is a reality for any registration domain and maritime domain is not an exception. In establishing of new registers, the existing ones were rarely structurally analyzed, and almost never institutionally and technologically linked. Competent institutions belong to different ministries and sometimes the substantially same register is maintained physically separated on different organizational levels. Depending on the institution and the actual technology in time of establishing, the technologies used for registers range from simple datasheets to complex GIS based structures. The connection between registers can be sometimes achieved using a common key (Mađer et al., 2015), although the linking is not always straightforward, especially in complex spatial relations.

5.1. Modeling of individual registers

Registers are modeled using UML according to their definition in laws and regulations. Main classes, relevant attributes and relations between classes are identified and represented in the form of UML class diagrams. In this research the emphasis is on the connections with related registers which are pointed out in the model. Twelve register models are made. The example shows the class model of the Register of concessions on maritime domain (Fig. 4). Two party classes, *HR_ConcessionProvider* and *HR_ConcessionBeneficiary* and one RRR class *HR_Concession* are connected to Land book model and the *HR_CadastralParcel*class when a part of *HR_ConcessionArea* as basic administrative unit belongs to Cadastre class model.

5.2. Schema matching

In the first step, basic model classes were compared against basic LADM classes, which showed that on the structure level the registers follow the core LADM schema and contain classes representing parties, administrative units and RRRs. The basic LADM classes can be identified although there is a substantial terminological diversity among registers. Schema matching on element level compared semantically identical classes between model classes and LADM classes. It showed up that most of the registers contain classes that originally belong to other registers.

Schema matching between LADM *LA_BAUnit* class and the correspondent administrative unit classes from registers (Table 1) shows that cadastral parcels and concession areas are the most common linked administrative units from other registers.

Matching of LADM *LA_Party* class and the correspondent party classes from registers (Table 2) shows that there are additional parties registered, in the case of Land Book, it is a party that holds an interest besides ownership. Other parties are part of provider – beneficiary relation or they represent a detailed elaboration of the main party.

As for other main classes, besides the main RRRs registered in registers in *LA_RRR* class specializations (Table 3), registers include records about other RRRs belonging to other registers. The most common are concession and administrative rights.

5.3. Cross-connections

The most distinct feature of a multi-register environment are the cross-connections between registers. When observing the registers on class level as LADM structures, the most important connections exist between administrative units, parties and RRRs.

The analysis of cross-connected basic administrative units (Table 4) shows that the administrative units from Address model/Territorial units register are used in every register, which is expected because of the nature of that register. On the other hand, the Register of concessions on maritime domain registers the most of basic administrative units (*LA_BAUnit* class) from other registers, which is also expected because of mostly concession related interests on maritime domain.

Parties (*LA_Party class*) are registered mostly in the Land Book and in Register of concessions on maritime domain as owners or as holders of some other right, concession beneficiaries or concession providers (Table 5).

Similar to parties, RRR classes matched to *LA_RRR* LADM class are registered in the Land Book (Table 6). Protection legal regimens are also recorded on relevant cadastral parcel in Cadastre. Register of concessions on maritime domain contains records of granted concessions form specialized registers.

5.4. Linking classes

The registration of maritime domain spaces in multi-register environment usually shows a pattern involving two sides, concession granting and benefiting of concession rights. The required procedure of

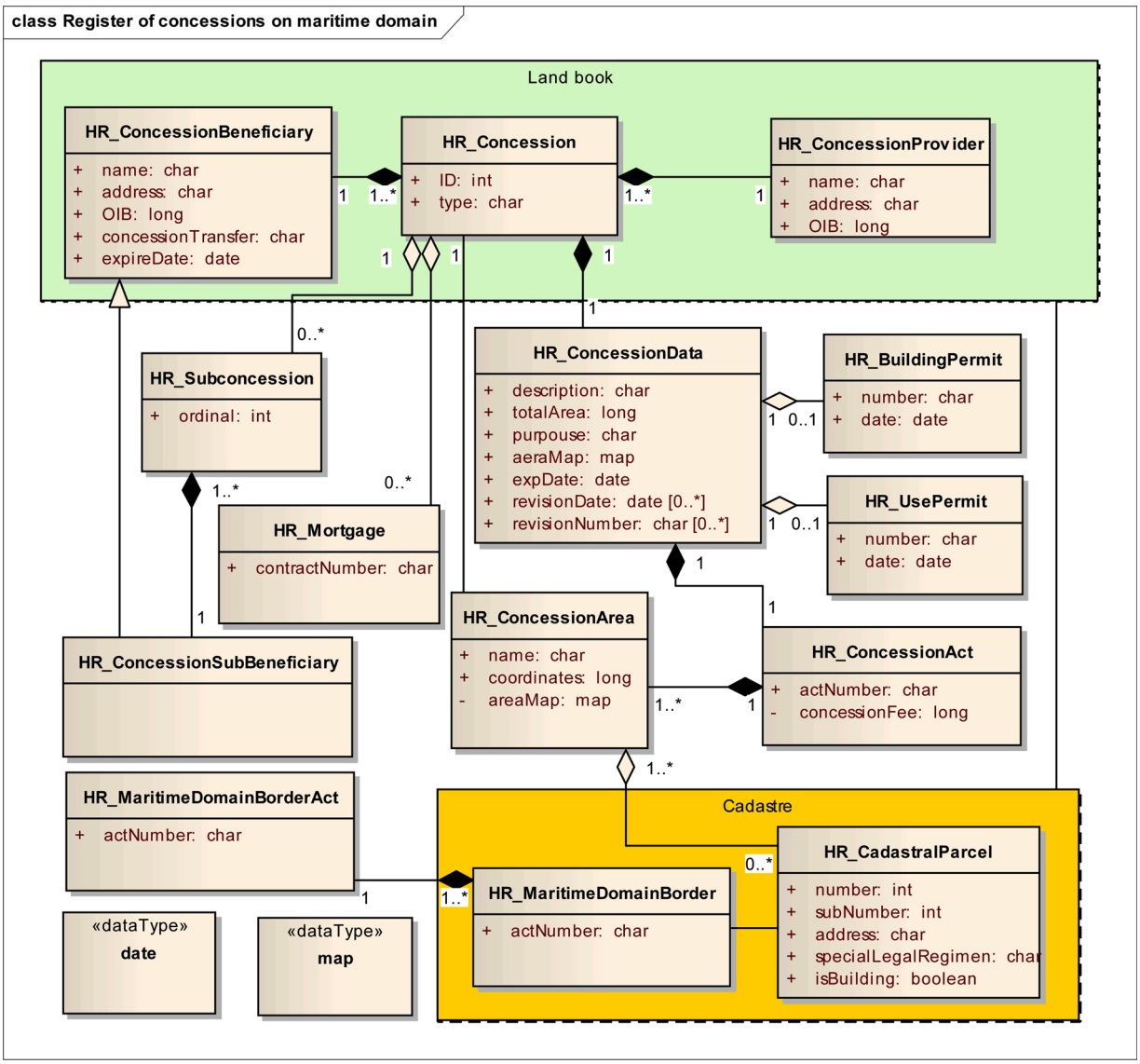

Fig. 4. Class model of Register of concessions on maritime domain.

registration prescribes the registration of related parties and RRRs in two or more registers. In the registration of administrative units, there is often more than one administrative unit involved, belonging to another register. Linking of registers using the same basic LADM class instances could be easier with extending of LADM with linking classes.

Five linking classes are used for LADM extension (Fig. 5). Classes *LA_RightBeneficiary* and *LA_RightProvider* are specializations of *LA_Party* class and classes *LA_OriginalRight* and *LA_GrantedRight* are specializations of *LA_RRR* class. Secondary administration unit is represented with *LA_SecondaryAdministrationUnit*, which is a specialization of *LA_BAUnit* basic LADM class. All classes contain an attribute that indicates the competent register they belong to, RRRs and parties contain a standard LADM type attribute. *LA_GrantedRight* class contains also a *timeSpec* attribute to specify the active time of a grant.

UML associations show the connection between elements. *LA_RightProvider* class is connected to its appropriate right, *LA_OriginalRight*, related to the basic administration unit. Classes *LA_RightBeneficiary* and its appropriate right, *LA_GrantedRight*, are related in the same way. Secondary administration unit *LA_SecondaryAdministrationUnit* is connected with an aggregation relation to the *LA_BAUnit class*, which can include one or more secondary administration units or none at all.

6. Discussion

This study showed that the current state of marine registers in Croatia includes several competent registers having a strong cross-connection component, creating a complex multi-register environment. The complexity of multi-register environment in maritime domain of maritime states can be observed in other coastal states. In the case of Turkey (Baser and Biyik, 2016) there is an important role of cadastral registration in the coastal zone, and a complex institutional structure administering various aspects and spaces in UNCLOS defined maritime zones. The paper is focused on institutional cooperation and partnership as a crucial task, with the need of a better law regulation of coastal activities and a system of data exchange between all the relevant institutions. The South African legislative and administrative framework, depicted as "horrendogram" (Taljaard et al., 2019), shows a multi-institutional environment dealing with marine related issues and defined by a series laws, conventions and standards. Cross-sectoral governing mechanism is proposed as a solution to such complex environment. In Netherlands, the institutional and organizational complexity emerged too, when solving large coastal dune protection projects (Aukes et al., 2020). Cooperation and consensus of all involved parties is pointed out as a key factor for success.

Table 1
Basic administrative units matching.

Register	Administrative unit	Class	Linked class from another model
Cadastre	cadastral parcel	*HR_CadastralParcel* *HR_CadastralDistrict* *HR_MarineCadastralDistrict*	*HR_ProtectedAreaUnit*
Land Book	cadastral parcel	*HR_CadastralParcel* *HR_OldCadastralSurvey*	
Territorial and address register	territorial unit	*HR_TerritorialUnit*	*HR_ProtectedAreaUnit* *HR_CadastralDistrict* *HR_MarineCadastralDistrict*
Utility cadastre	infrastructure object	*HR_Infrastructure*	*HR_CadastralDistrict* *HR_LocalAdministrationUnit* *HR_ConcessionArea*
Concessions on MD	concession area	*HR_ConcessionArea*	*HR_CadastralParcel*
Exploration areas	exploration area	*HR_ExplorationArea*	*HR_CadastralParcel*
Exploitation fields	exploitation field	*HR_ExploitationField*	*HR_CadastralParcel* *HR_ConcessionArea*
Protected nature	protected natural value	*HR_ProtectedNaturalValue* *HR_PreventiveProtectedArea*	*HR_CadastralParcel*
Cultural heritage	cultural property	*HR_CulturalProperty*	*HR_CadastralParcel*
Pollution	pollutant	*HR_Outlet*	*HR_ConcessionArea*
Fish farming	fish farm	*HR_FishFarm*	*HR_ConcessionArea*
Fishing zones/permits	fishing zone	*HR_FishingZone* *HR_RestrictedAquatorium*	

Table 2
Parties matching.

Register	Party	Class	Additional class
Cadastre	right holder	*HR_LandRightHolder*	
Land Book	owner	*HR_Owner*	*HR_RRRHolder*
Territorial and address register	competent authority	*HR_CompetentAuthority*	
Utility cadastre	administrator	*HR_InfrastructureAdministrator*	
Concessions on MD	concessionaire	*HR_ConcessionBeneficiary*	*HR_ConcessionProvider*
Exploration areas	beneficiary	*HR_ExplorationApprovedPerson*	
Exploitation fields	beneficiary	*HR_ExploitationApprovedPerson*	
Protected nature	competent authority	*HR_PublicAuthority*	
Cultural heritage	conservation authority	*HR_ConservationDepartment*	*HR_CulturalPropertyOwner*
Pollution	operator	*HR_Operator*	*HR_OrganizationUnit* *HR_WasteWaterOperator*
Fish farming	Trade legal person	*HR_Trade*	
Fishing zones/permits	beneficiary	*HR_FishingLicenseHolder*	*HR_FishingVessel*

Table 3
RRRs matching.

Register	RRR	Class	RRR from another register
Cadastre	property/ tenancy RRRs	*HR_LandRight* *HR_SpecialLegalRegime*	
Land Book	Property RRRs	*HR_RRR*	land rights
Territorial and address register	administration	*HR_AdministrationRight*	protection
Utility cadastre	administration	*HR_AdministrationRight*	concession
Concessions on MD	right of use	*HR_Concession* *HR_GrantingRight*	land rights
Exploration areas	exploration	*HR_ExplorationRight*	
Exploitation fields	exploitation	*HR_ExploitationRight*	concession
Protected nature	restrictions	*HR_ProtectionRRR*	administration
Cultural heritage	restrictions	*HR_ProtectionRRR*	administration
Pollution	right of use	*HR_UseRight*	concession
Fish farming	permission	*HR_FarmingRight*	concession
Fishing zones/ permits	permission	*HR_FishingRight*	

From the previous examples it can be concluded that successful spatial planning and environment protection relies on institutional cooperation, including the use of existing spatial data kept by competent institutions. Since the uncoordinated development of individual registers led to a multi-register environment with its typical features, achieving of the interoperability of registers is indispensable. Cross-registration is an issue that can affect the reliability of data, so it has to be identified and examined. Modeling of relevant registers gives an overview of internal register structure, but by modeling of relations between registers, it is possible to identify the interconnections between relevant register classes. In the case of marine multi-register environment, the identified pattern of interconnections can be represented by five new LADM classes, which can facilitate the proper identification of the institutions competent for the particular data set and to help the modeling of future data interchange systems.

On the geometry level, introducing of 3D spaces can greatly improve the unambiguity of registered spaces and contribute to separation of registers competence. Introducing of a new LADM class of secondary administration unit will support the modeling of complex registration systems with addressing the proper institutional competence of registered areas.

7. Conclusion

A multi-register environment is an inevitable reality for any present-day land administration system. Keeping all the registers up-to-date in

Table 4
Administrative unit cross-connections.

Is also registered in ↓	Administrative unit from → Cadastre	Land Book	Territorial and address register	Utility cadastre	Concessions on MD	Exploration areas	Exploitation fields	Protected nature	Cultural heritage	Pollution	Fish farming	Fishing zones/ permits
Cadastre	×		●									
Land Book		×	●									
Territorial and address register	●	●	×						●			
Utility cadastre	●		●	×								
Concessions on MD	●		●	●	×		●			●	●	
Exploration areas	●		●			×						
Exploitation fields	●		●				×					
Protected nature	●		●					×				
Cultural heritage	●		●						×			
Pollution			●							×		
Fish farming			●		●						×	
Fishing zones/ permits												×

Table 5
Parties cross-connections.

Is also registered in ↓	Party from → Cadastre	Land Book	Territorial and address register	Utility cadastre	Concessions on MD	Exploration areas	Exploitation fields	Protected nature	Cultural heritage	Pollution	Fish farming	Fishing zones/ permits
Cadastre	×	●										
Land Book		×		●	●		●			●	●	
Territorial and address register	●		×						●			
Utility cadastre				×								
Concessions on MD				●	×		●			●	●	
Exploration areas						×						
Exploitation fields					●		×					
Protected nature								×				
Cultural heritage									×			
Pollution										×		
Fish farming					●						×	
Fishing zones/ permits												×

such an environment is a demanding task, especially considering uncoordinated competencies and vague regulations, which lead to arbitrary maintenance practices. Moreover, establishing of public accessible spatial infrastructure portals and web GIS information systems gives more importance to actuality and source relevance of available linked data.

Typical features of multi-register environment include:

- registration process is defined by several laws and regulations;
- registers are structurally, institutionally and technologically heterogeneous;
- registers are established separately and independently, for a dedicated purpose;
- regulations require records of features not unique to competent register, creating redundant records;
- consistency of records between registers is not regulated;
- 3D aspect of marine spaces is often neglected.

Table 6
RRRs cross-connections.

Are also registered in ↓	RRRs from → Cadastre	Land Book	Territorial and address register	Utility cadastre	Concessions on MD	Exploration areas	Exploitation fields	Protected nature	Cultural heritage	Pollution	Fish farming	Fishing zones/ permits
Cadastre	×	●						●	●			
Land Book		×		●	●		●	●	●	●	●	
Territorial and address register			×									
Utility cadastre				×								
Concessions on MD				●	×		●			●	●	
Exploration areas						×						
Exploitation fields					●		×					
Protected nature								×				
Cultural heritage									×			
Pollution										×		
Fish farming					●						×	
Fishing zones/ permits												×

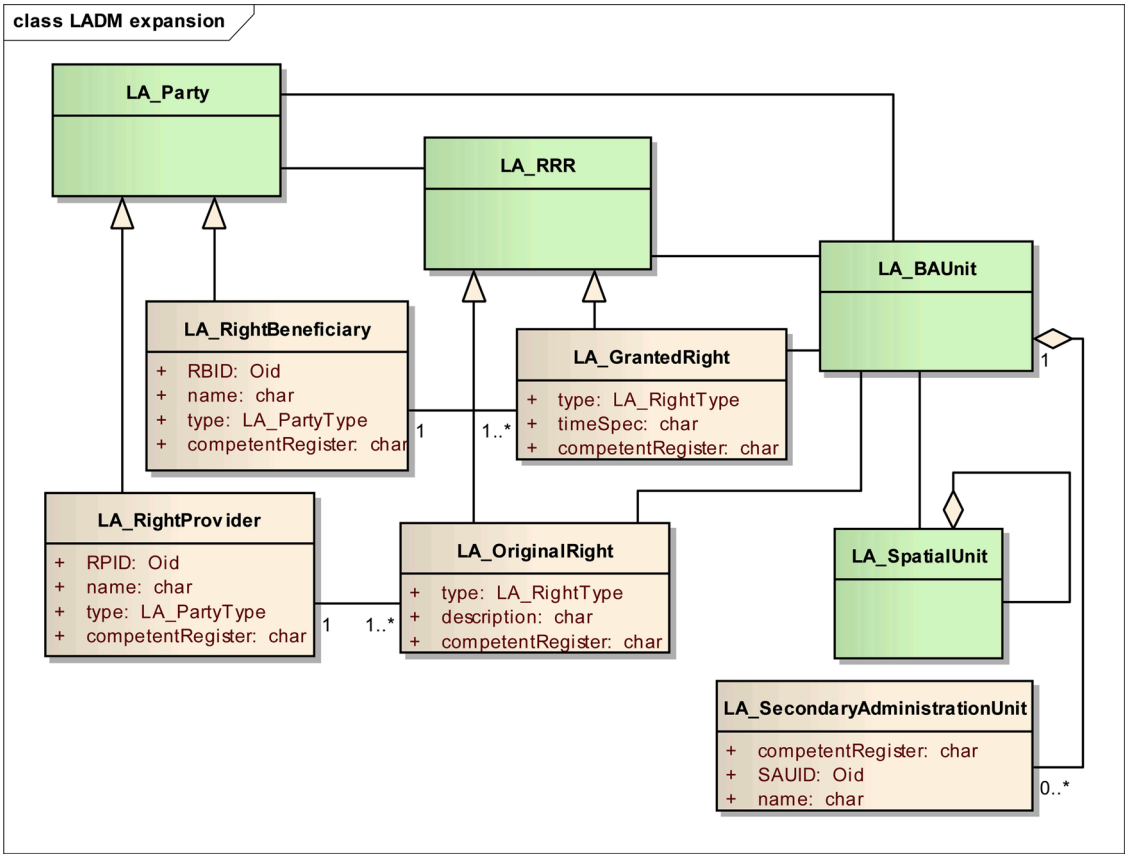

Fig. 5. LADM linking classes extension (Flego, 2018).

Maritime domain multi-register environment in Croatia, but also generally, is particular because of the lack of private ownership and because of the key role of competent institutions in marine space management. The consequence of such relationship is that the most of registers are related to concession granting or benefiting. Because of the heritage of existing land registers, a lot of registrations include records of basic administrative units belonging to other registers.

The LADM structure involving parties, administrative units and RRRs

is applicable to all relevant registers used in maritime domain registration, although some of registers are not typical land administration registers. Expansion of LADM by introduction of linking classes with competent registers as attribute will be useful for modeling purpose in multi-register environment. Specializations of *LA_BAunit*, *LA_Party* and *LA_RRR* classes here presented target the maritime domain environment, but are not limited to it and can be a concept for defining interconnections in other multi-register environments.

CRediT authorship contribution statement

Veljko Flego: Conceptualization, Methodology, Formal analysis, Writing - original draft. **Miodrag Roić:** Conceptualization, Supervision, Resources. **Irena Benasić:** Investigation, Formal analysis.

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Further Reading

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URL 2: Spatial planning information system, https://ispu.mgipu.hr/, (23.04.2020.)