Developing 3D Marine Cadastre Data Model within Malaysian LADM Country Profile – Preliminary Result

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Key words: marine cadastre; data model; three dimensional (3D); land administration domain model (LADM); marine rights, responsibilities and restrictions (RRRs)

SUMMARY

Cadastre in marine environment is still quite unclear due to separate working systems between land and marine areas. Coastal and maritime spaces with multiple usages often lead to conflict in overlapping rights in the water surface, water column and seabed as well as conflict in technical, legal and stakeholder management. 3D marine cadastre may improve the governance and information system of coastal and marine areas by portraying accurate representation of rights. Currently, most publications address the concept of marine cadastre, however, the real implementations on three dimensional (3D) are still lacking. This concept of 3D marine cadastre has been applied by several countries such as Canada and Greece but lacking on integration of physical and legal objects part. The same concept could be developed for Malaysia where marine cadastre data model could help marine administration by integrating spatial and non-spatial components in 3D marine cadastre. In this particular paper, the preliminary result of 3D Marine Cadastre Data Model (MCDM) will be presented. The model consists of three (3) major components, namely, spatial, ownerships and administrative. The spatial component – data and attributes for marine parcels or resources including fishing sites, aquaculture areas. The ownerships component – people and organizations. The administrative component - responsibilities, restrictions and rights. The proposed model will be linked with the Malaysian LADM Country Profile. This 3D marine cadastre data model illustrates the *classes of marine resources* within coastal zone, the integration of data between *legal spaces and spatial unit features* through external classes as well as *administrative sources*. We attempt to develop a prototype to prove the data model concept and visualize the associated rights, restrictions and responsibilities of the marine objects. In the near future, this marine cadastre data model would facilitate coastal space for 2D and 3D applications and management needs in the country.

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1.0 INTRODUCTION

In recent years, marine and coastal areas became the country's interest in term of welfare, communities and regions. This is because, these areas approximately covered two-thirds of the earth's surface and become the crucial areas that associated with each other and humanity of common living areas. A vast variety of marine wealth such as marine properties (e.g. tourism, resort, petroleum platforms), marine natural resources (e.g. fishing areas, oil, natural gas) including the marine properties that lying through seabed (e.g. cables and pipelines) become as part of the contributors for economic earnings. In order to administer its marine resources, many coastal countries have implemented marine cadastre including Malaysia. Malaysia is divided by South China Sea into two parts (can be seen on Figure 1) where is consisting of 11 states in Peninsular Malaysia and two states in the island of Borneo (Sabah and Sarawak). The total length of Malaysia's coastline is 4800km which made the coasts are one of the country's most important natural resources. To handle all the natural resources, marine cadastre has been applied.

Figure 1. Malaysia Map (*accessed from Encyclopædia Britannica, Inc.*)

Marine cadastre deals with right, restriction and responsibility (RRRs) on marine objects that lies within coastal zone, littoral space, and three nautical miles from the shoreline zone as reported by several authors such as Arof & Abdullah (2015), Nazirah et al. (2016), Omar (2019), and Hassan (2020). The same scenario has been discussed in other parts of the world

such as in Australia by Binns et al. (2004), in Greece by Anthanasiou A. et al. (2017), in Trinidad & Tobago by Athanasiou K. et al. (2017), and in Canada by Sutherland et al. (2016). Since some parts of marine area are considered as land space, there were several studies on marine's RRRs within land administration e.g. Land Administration Domain Model (LADM). The LADM standard has been established as ISO 19152 in December 2012 which was initiated by Lemmen and Oosterom as reported in GIM International 2013. Then, several initiatives were adopted by many National Mapping and Cadastre Agencies (NMCA) including Malaysian NMCA (Department of Surveying and Mapping Malaysia - JUPEM) as pilot case study in 2017. This pilot case study utilized LADM Edition I. The same edition has been adopted by other national agencies in other parts of the world (Indonesia, Korea, China, Poland, Australia, Greece, Trinidad & Tobago, Serbia, Turkey, and Croatia) as reported by Zulkifli et al. (2014), Greece by Kalantari et al. (2017), Trinidad and Tobago by Griffth-Charles & Edwards (2014), Croatia by Mader et al. (2018) and Turkey by Alkan et al. (2019). Most of these initiatives were based on two approaches – holistic and focused as reviewed by Kalogianni et al. (2019). The two approaches basically focuses on the following applications – archaeological, underground utilities, immovable properties, natural resources, marine spaces, agriculture land usages, cadastral, and land administration. The applications reveal that LADM meets the requirements of the agencies and achieve sustainable utilization of land, air, water, and other related natural resources.

Thus, this paper attempts to develop a 3D Marine Cadastre Data Model within Malaysian LADM Country Profile including 3D elements. The existing LADM model hardly addressed the complexity of properties within marine environment as mentioned recently by Kalogianni et al. (2019). The introduction of class marine resources into the LADM standard supported by various countries such as Trinidad & Tobago as reported by Athanasiou K. et al. (2017), Greece (Athanasiou A. et al., 2017), Turkey (Baser & Biyik, 2018) and Canada (Sutherland M. et al. 2016) as a step to cover the marine and maritime legal objects.

2.0 MARINE CADASTRE

Marine cadastre helps to record, manage and visualize the spatial information in marine environment including the descriptive information such as stakeholders, rights; restrictions; responsibilities (RRRs) and legislation. Multiple developments around the coastline e.g. resorts for tourism, triggered the jurisdictions to deal with a system that can handle those situations. Marine cadastre is a system that able to handle the following issues - type of interest exists in marine area that need to be identified, the best way to capture and register those interests, the RRRs that need to be defined, the ways legislation can be included in managing related RRRs.

In early year of 2000, United States, Canada and Australia have implemented marine cadastre as information system encompassing both nature and spatial extent of interests in properties, values and marine areas usages. Then, followed by Malaysia in 2012 plus Athens and Greece in 2014 as reported by Arvantis A. et al. (2016). Marine administration and authorities in Malaysia is separated between the state and federal jurisdiction (Abdullah et al. 2014). State is responsible for area within three nautical miles (5.6km) from the shoreline as mentioned in

Section 4 Emergency (Essential Powers) Ordinance, No 7/1969. P.U (A) 307A/69 and addressed in Territorial Water Act (2012) meanwhile federal authorities cover the Territorial Zone from 3nm to 12nm offshore until Exclusive Economic Zone (EEZ). The marine area begins at Lowest Astronomical Tide (LAT) where the land stopped at Highest Astronomical Tide (HAT). Currently, there is no jurisdiction involved between HAT and LAT area – known as littoral zone as mentioned by Omar A. H. (2019) and Hassan M. I. (2020). This area tends to have some developments such as water based resort which is generally involved on land and marine space. For land registry management, Peninsular Malaysia has applied Ordinary Cadastre – known as Torrens System to register the land under ownership document and it is tradable. All the land and title records will be under government responsibility. Aside from Malaysia, the other countries such as Australia, Canada, New Zealand, Ireland, Singapore, Indonesia and Philippines also have adopted Torrens System as their land registry system. Seeing some of marine areas are considered as land region, several researchers, (Sutherland M. et al. 2016); (Athanasiou A. et al. 2017); (Athanasiou K. et al. 2017); (Lemmen C. et al. 2019); (Bilgi C. et al. 2019); (Baser V. & Biyik C. 2019); (Sweeney V. & Corbin C. 2019); (Flego V. et al. 2021) believed that the possibilities of adopting land administration concept within marine cadastre. Extending of onshore contexts to offshore regions lead to a more cohesive and integrated structure, however, this expansion should be adressed properly according to the country's administration as aggreed by Flego V. et al. (2021).

2.1 Needs of Marine Cadastre

Internationally, whole range of professional fields within global surveying, geomatics, geodesy, and geo-information community are supported by International Federation of Surveyors (FIG) which is known as premier international organization in representing the interests of surveyors worldwide. Multiple commissions have been developed to work on various practices including marine cadastre. One of the commissions which is commission 4 has been assigned in managing hydrographic information. A Working Group 4.4 deals with policy issues such as development of institutional policy and framework, conceptual and technical standards, guidelines and practice, land and sea governance for a marine cadastre, and development of indigenous marine management systems as reported by Omar A. H. (2020). Essentially, it has been accepted that marine space is meant for general use and individuals, public as well as for reserve purposes. On the other hand, a joint commission 3 (spatial information management) and 7 (cadastre and land management) deal with the concept of 3D Cadastres including 3D parcels for water spaces (above and below surface).

Currently, in Malaysia, the state authorities have the rights in handling the marine spaces including sea surface, water column as well as seabed. The stakeholders are not the permanent owners of the marine properties however they are part of the beneficiaries through leasing or licensing contracts. The interest individuals or stakeholders need to request the right for marine activities through a license called Temporary Occupation License (TOL) as reported by Arof & Abdullah (2015). By definition, the TOL license allows the holder to occupy certain areas granted by the state authorities for a limited period and renewed annually. This TOL concept is similar to the marine registry. Other issues in marine environment as reported by Rajabifard et

al. (2006) are dynamic spatial and temporal relationships, precise and efficient updating of marine spatial data and marine interests registration. Presently, 3D marine data is hardly available as reported by Yatim et al. (2018). In marine environment, variety of aspects such as the location of the marine properties, the information of elevation or depth, stakeholders information as well as 3D spatial object attributes need to be considered for a precise data. Defining a marine parcel on the basis of the sea surface does not give an accurate view for all the existed rights in that region. Almost all the marine activities or resources take place in the water column which made 2D representation is imprecise. Thus, 3D elements need to be considered, in order to have an accurate marine rights portrayal.

2.2 Three-Dimensional (3D) Marine Cadastre

Activities involving sea surface, water column and seabed need to be treated in a proper way (3D environment). Geometric parcels in the marine environment need to define the rights, interests and value of the properties as reported by Steudler, D. (2014). The report describes various aspects of 3D cadastre – overlapping properties, 3D storage and visualization, more standardized and interoperable both nationally and internationally. Figure 2 portrays the example of overlapping marine activities or properties. Most marine rights such as aquaculture area, fishing site, marine protected area and resort are essentially 3D in nature, which legally makes 2D representation is insufficient to handle those rights. Not only on the water surface level, but at some point, far below, in the water column, even underneath the seabed, any two marine rights e.g. cables and pipelines are likely to meet.

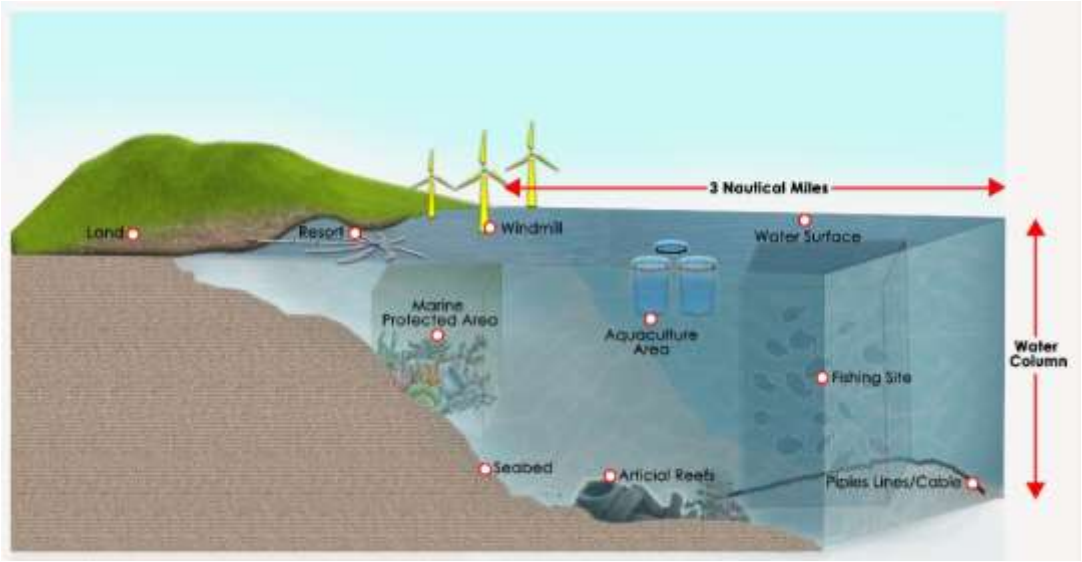

Figure 2. Overlapping marine rights as represented in 3D view

Amsyar et al. (2011) believed that marine areas can be registered through their attributes. The identification of semantic attributes can be an efficient way to classify marine regions if the attributes are consistently organized and documented. The required analysis may consist of a simple description or, a more complicated analysis is required depending on the number of

attribute types and the amount of data. To work with these 3D attributes, land administration practice seems applicable since the current practice of marine alienation follows almost the same protocol as that applied onshore. Currently, the land standard that has been applied in most of the countries is Land Administration Domain Model (LADM) and this standard is applicable for 3D attributes.

3.0 MOTIVATION TO UTILIZE MALAYSIAN LADM COUNTRY PROFILE

Land Administration Domain Model (LADM) is an international standard for the land administration. This concept is being adopted by several countries including Malaysia to enable cross boundary land transaction and acquisition. Referring to the basic packages presented in LADM standard, Zulkifli et al. (2014) has adopted the standard for Malaysia land administration. The basic packages (can be seen on Figure 3) encompass: parties (people and organizations); basic administrative units, rights, responsibilities and restrictions (RRRs); spatial units (parcels, and the legal space of buildings and utility networks) with a sub package for surveying, and representation (Lemmen C. et al. 2013).

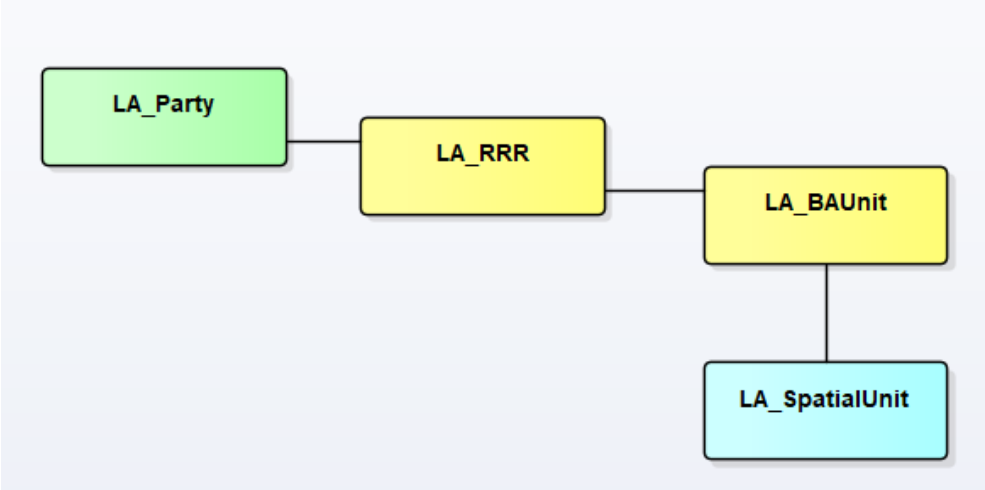

Figure 3. Basic packages in LADM (Lemmen C. et al. 2013)

The basic packages were expanded for Malaysian LADM conceptual model with specialization on spatial unit package. It is included the customary areas, reserved lands, lots (2D and 3D) and legal spaces. Querying on 2D spatial objects based on – My_Lot2D, MY_LandParcel, MY_Customary and MY_ReservedLand. Meanwhile, 3D spatial units can be queried based on – MY_Lot3D, MY_ParcelUnit, MY_CommonPropertyUnit as well as MY_Utility. 'MY_' is the prefix for the Malaysian country profile, covering both spatial and administrative data modelling. The geometry can be obtained from MY_Point associated with SpatialSource. MY_Party as well as groups and subclasses of RRRs can be used to query descriptive data. UPI has been used to link between spatial and administrative data. Basically, the extended components in Malaysian LADM Country Profile are supporting the 3D elements and spatial units needed in marine environment. Implementation on Malaysian LADM country profile can lead to better marine administration in country as supported by the previous related to marine-

land data model works - (Athanasiou K. et al. 2017); (Athanasiou A. et al., 2017), (Baser & Biyik, 2018) and (Sutherland M. et al. 2016). The existing and previous marine data model in various countries motivated us to develop a data model for Malaysia marine administration. The marine cadastre data model was designed according to conceptual of marine cadastre in Malaysia as proposed by Abdullah A. et al. (2014), the appropriate components in Malaysian LADM country profile that can be expanded to marine part as well as suitable classes and subclasses for marine environment based on the previous researches in Canada by Sutherland M. et al. (2016), in Greece by Athanasiou A. et al. (2017), in Trinidad & Tobago by Athanasiou K. et al. (2017) and in Turkey by Bilgi C. et al. (2019). Figure 4 and 5 show the marine data model within land administration developed in Canada and Greece.

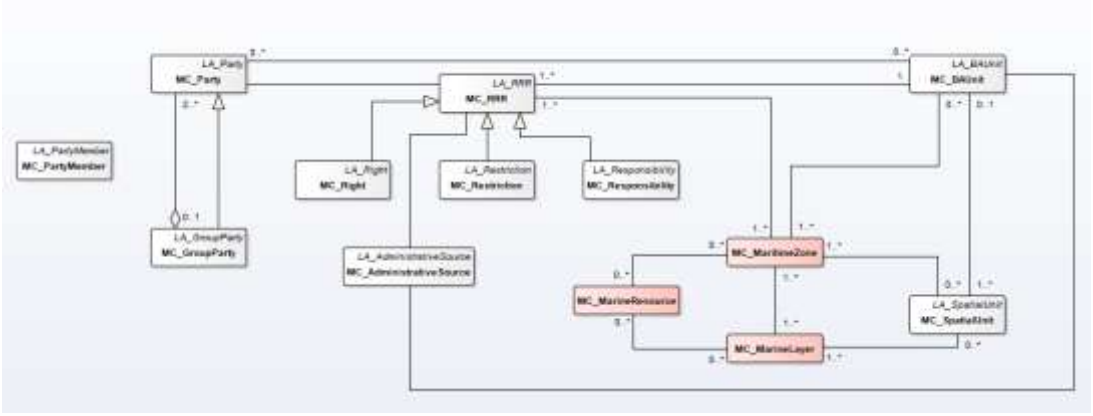

Figure 4. Land Administration Domain Model-based Marine Cadastre Conceptual Schema (Canada) (Sutherland M. et al. 2016)

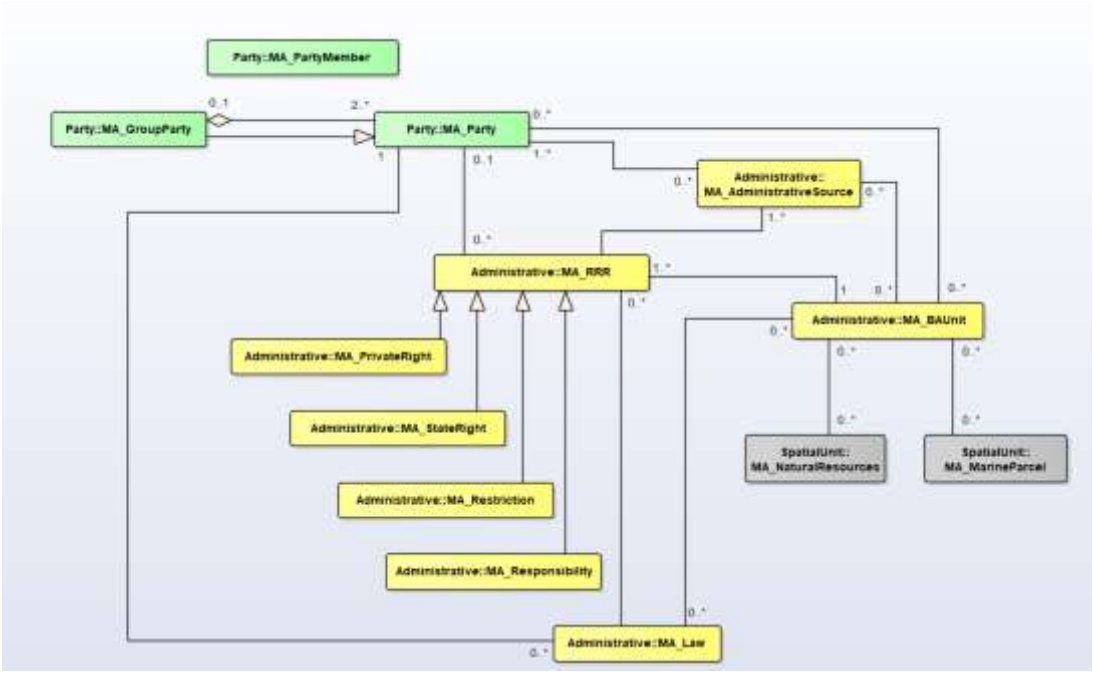

Figure 5. 3D Marine Administration based LADM (Greece) (Athanasiou A. et al. 2017)

The concept of LADM has the potential to be linked within marine cadastre to sustain marine management from any aspects such as economic, environmental, and social. However, both of these studies were using Canada and Greece as their case studies. In the previous study, Sutherland et al. (2016) highlighted 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. Figure 4 shows the conceptual schema of LADM based Marine Cadastre for Canada. The created classes are shaded. MC_MaritimeZone, MC_MarineResource and MC_MarineLayer are the new classes added in the LADM. This conceptual schema became as reference because of it involved marine layer which is included sea surface, water column and seabed. However, on the part MC_MaritimeZone, it involved all the sea zones which is too broad. In this particular research, the data model specifically focused on coastal zone (3nm from shoreline). Hence, the marine resources were limited around 3nm area. On the other hand, Athanasiou et al. (2017) has developed a linking 3D marine administration model within LADM. Figure 5 represents 3D Marine Administration Model based LADM for Greece. They were focused on how the rights, restrictions and responsibilities (RRRs) relating to marine space may be organized. Gas pipeline and aquaculture area became as their case studies on overlapping rights. This model presented for legal objects of the marine space management including possibility of 3D data record. It is good to refer to this research work because it consists on elements for the attributes needed for each classes involved, but, it will be great if has integration of physical and legal objects based on international model (LADM) as mentioned by the researcher. From these works, it found that the data models were lacking on physical and legal objects integration part. Furthermore, it might be quite different from other countries because of different administrations. For instance, Greece is applying Deed System as their land registration meanwhile Malaysia is applying Torrens System. Thus, the data model for Malaysia is developed by considering the factors and it is important to find out which parts of the existing data model resembles country's marine administration.

4.0 3D MARINE CADASTRE DATA MODEL – INITIAL RESULT

For the model development process, Unified Modelling Language (UML) class diagrams were used. It is a common language to describe, specify, design and structure a system. As starting point, concepts and their relationships of the real world were mapped to a conceptual model through UML and Entity-Relationship (ER) model. The ER model is a step to represent the logical relationships of entities (or objects) in order to create database graphically. The main components of ER model are entities followed by classes in order to create a database. The necessary classes were divided into groups and then the basic relationship between the classes were defined. The possible classes with their groups can be seen on Table 1. These possible classes were obtained by considering conceptual marine cadastre in Malaysia, the appropriate components in Malaysian LADM country profile that can be expanded to marine part as well as suitable classes and subclasses for marine environment based on the previous researches. In this work, 'MC_' is the prefix for marine cadastre covering both spatial and administrative parts.

Table 1. The possible classes and subclasses for marine properties

Group / Package	Main Class	Subclasses
Party	MC_Party	MC_GroupParty MC_PartyMember
Administrative	MC_RRR	MC_Right MC_Restriction MC_Responsibility MC_BAUnit MC_AdministrativeSource
Spatial Unit	MC_SpatialUnit	MC_MarineProperty MC_LegalSpaceUnit MC_Leasehold MC_Freehold MC_TemporaryOccupationLicense MC_LegalSpaceUtilityNetwork MC_MarineLayer MC_SeaSurface MC_WaterColumn MC_Seabed MC_NaturalSource MC_BoundaryFaceString MC_BoundaryFace MC_Point

The expanded version can be seen on Figure 6. Some of the components were retrieved from Malaysian LADM country profile and a few of the classes revived from the existing data model and several new classes introduced suits to Malaysia administration.

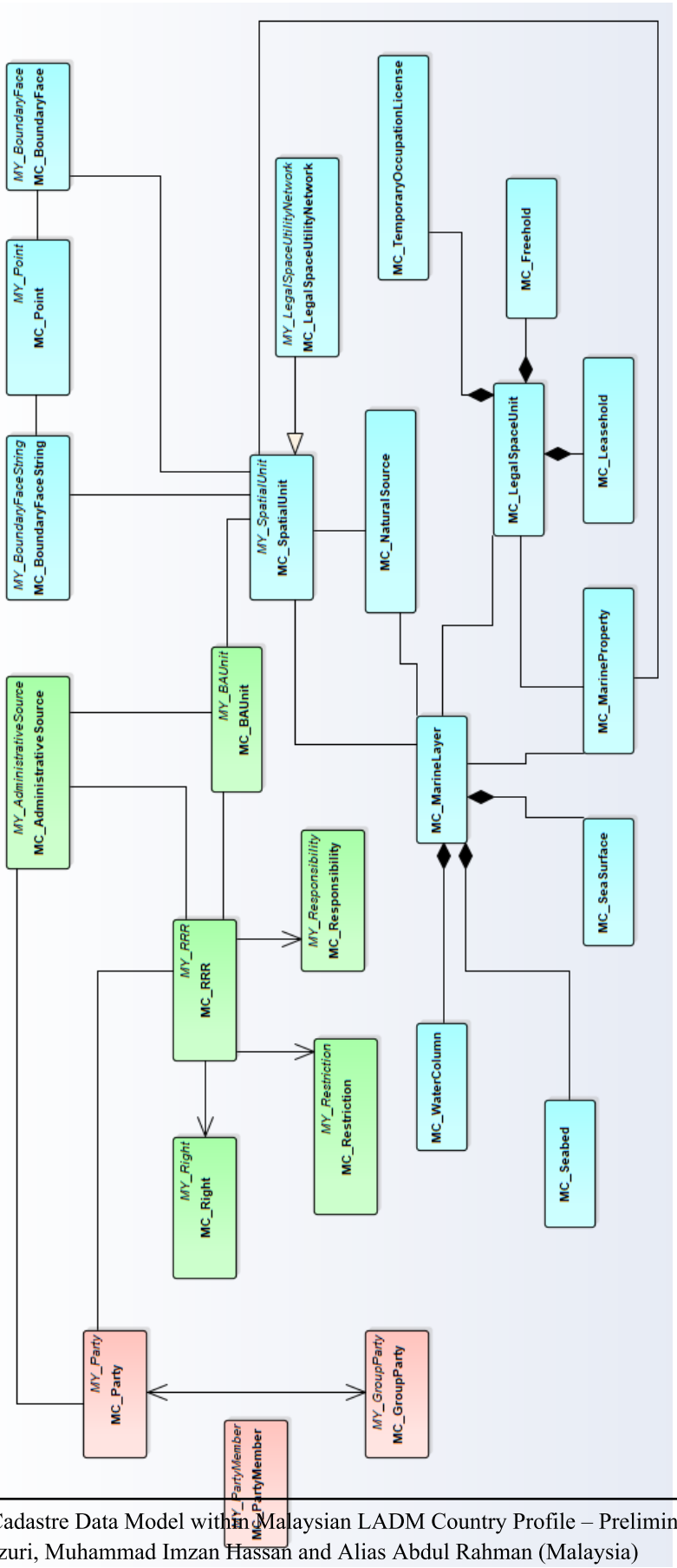

Figure 6. Conceptual model for 3D Malaysia marine cadastre with possible classes

This conceptual model encompasses three packages as following – Party, Administrative and Spatial Unit. MC_Party has been structured in coral color which is expanded into MC_GroupParty and MC_GroupParty meanwhile MC_RRR has been designed in green color with expansion of the following subclasses – MC_Right, MC_Restriction, MC_Responsibility, MC_AdministrativeSource and MC_BAUnit. Both of these packages were adopted from Malaysian LADM country profile. The other package, MC_SpatialUnit has been expanded according to Malaysia marine administration and suggested by Abdullah A. et al. (2014). The spatial part has been elaborated in blue color with the following components - MC_MarineProperty, MC_LegalSpaceUnit, MC_Leasehold, MC_Freehold, MC_TemporaryOccupationLicense, MC_LegalSpaceUtilityNetwork, MC_MarineLayer, MC_SeaSurface, MC_WaterColumn, MC_Seabed, MC_NaturalSource, MC_BoundaryFaceString, MC_BoundaryFace and MC_Point. The legal space component expanded into three subclasses – leasehold, freehold and license (TOL) to represent the status of the marine properties and marine layer expanded into three subclasses – sea surface, water column and seabed to represent the marine layer involved for a certain marine properties. All the new subclasses were created based on the recommendation for Malaysia marine cadastre by Abdullah A. et al. (2014). For the future work, every classes need to be composed with the possible attributes to represent the data structure needed and associated to each other. We attempt to develop the database for this 3D marine cadastre data model as illustrated in Figure 7 as part of our future work.

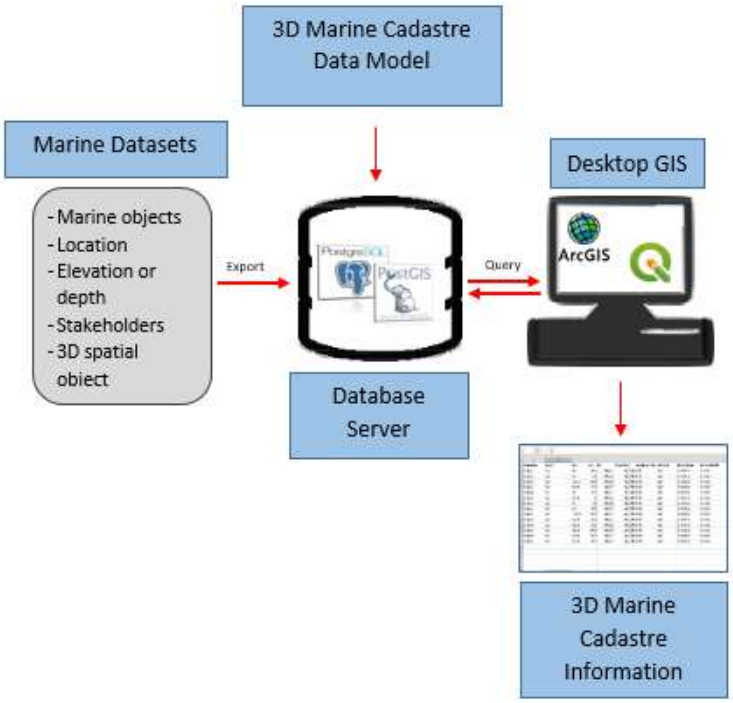

Figure 7. Schematic diagram of the 3D marine cadastre data flow

5.0 DISCUSSION

From the developed data model, several important classes have been introduced for marine aspects as illustrated in Table 1. We anticipate the marine classes should be able to represent the jurisdictions as well as rights of the objects, thus, a meaningful marine information from the developed data model. The model should be able to handle several marine cadastre objects such as water columns, aquaculture areas, cables and pipelines, water based bussiness entities e.g. resorts and windmills. It is flexible and adaptable. The extensions in LADM (LADM version II) have been discused where one of the components is to support the idea of embedding marine cadastre into LADM. In general, marine activities need to be handled and controlled properly for a sustainable management. In reality, marine cadastre will be the main platform for marine spatial information system. The next step (future work), the database will be developed where various queries on marine cadastral could be performed.

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