THE DEVELOPMENT OF MALAYSIA'S THREE-DIMENSIONAL MARINE CADASTRE DATA MODEL BASED ON LAND ADMINISTRATION DOMAIN MODEL

NOR AINN ALFATIHAH BINTI ZAMZURI

UNIVERSITI TEKNOLOGI MALAYSIA

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NOR AINN ALFATIHAH BINTI ZAMZURI

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy

Faculty of Built Environment and Surveying
Universiti Teknologi Malaysia

APRIL 2022

DEDICATION

This thesis is dedicated to:

My Mother & Father
For their endless love, support, and encouragement in accomplishing this research.
(Nor Azila Talib & Zamzuri Husain)

My Supervisor
For all this guidance and taught me that the best kind of knowledge
(Dr. Muhammad Imzan Hassan)

Prof. Dr. Alias Abdul Rahman
For assisting this research work and providing the great ideas.

3D GIS Research Lab Members
For all their words of inspiration and consultation throughout this study process.

Yayasan Terengganu
For supporting my financial throughout this research development.

My Family & Friends
For all of their words of encouragement and support, I am grateful.

THANK YOU

ACKNOWLEDGEMENT

I spoke with many people while writing this thesis, including researchers, academics, and practitioners. They are aided my comprehension and thought processes. I'd want to convey my heartfelt gratitude to my thesis supervisor, Dr. Muhammad Imzan bin Hassan, for his support, guidance, counsel, and friendship. He taught me that even the most significant task could be accomplished if done one step at a time.

Then, I would like to express my gratitude to Prof. Dr. Alias Abdul Rahman for assisting my research progress. A lot of ideas and suggestions have been shared throughout this study process.

In addition, I would like to point out my gratefulness to Yayasan Terengganu for supporting my financial throughout my study journey. It is an honour to have this golden opportunity to be sponsored by your side and I really appreciate it. Thank you.

Next, I would like to express my appreciation to all the lecturers, 3D GIS Research Lab members, and friends for all their encouragement and helps in completing my research study. To those who are directly and indirectly played a part in the contribution of this study, your contribution means a lot to me.

Lastly, I am deeply indebted to my lovely parents, Zamzuri Husain and Nor Azila Talib for their moral support throughout the completion of this research.

ABSTRACT

Marine space and properties are contributors to the economy in many countries. Multiple usages of coastal and maritime areas often lead to conflict in overlapping Rights, Restrictions, and Responsibilities (RRRs) in the water surface, water column, and seabed as well as technical, legal, and stakeholder management issues. Marine spaces and properties in Malaysia are controlled by multiple jurisdictions, which has caused conflicts and overlapping ownership over the properties involved. A lease or license, known as a Temporary Occupation License (TOL), is normally applied to give a temporary right to occupy the marine properties. Since some of the land concepts can be adopted and applicable to the marine environment, this research proposed a 3D marine cadastre data model based on land standards, Land Administration Domain Model (LADM), and Malaysia as a case study. This research attempted to develop a data model by investigating the elements needed in Malaysia's marine environment and 3D cadastre practices. Unified Modelling Language (UML) application was used to develop the conceptual and the technical model. The data model was developed by considering Malaysia's marine concept to suit the international standard of LADM. The developed marine cadastre data model consists of three packages: party, administrative, and spatial unit package. This 3D marine cadastre data model illustrates the components of marine resources within the coastal zone, the integration of data between legal spaces and spatial unit features through external classes. The model was validated by running a prototype. The experiment on the data model also included database implementation and simple queries. A 3D visualization was generated to represent the stored datasets. The structure of the marine cadastral data model, which complies with international standards, LADM, provides a common language, data interoperability, and procedural simplification for all parties involved. Relevant parties could utilize the described approach as a reference in modelling and managing a variety of RRRs of marine spaces and properties.

ABSTRAK

Ruang dan hartanah laut adalah penyumbang utama kepada ekonomi di kebanyakan negara. Penggunaan kawasan pesisir pantai dan maritim sering membawa kepada perselisihan antara individu dalam Hak, Sekatan dan Tanggungjawab (RRRs) yang bertindih di permukaan air, dalam dan dasar laut serta isu dalam pengurusan pelaksanaan, perundangan dan pengurusan pihak yang berkepentingan. Ruang dan hartanah laut di Malaysia dikendalikan oleh pelbagai bidang kuasa, sehingga menyebabkan perselisihan antara individu dan pemilikan bertindih ke atas hartanah terbabit. Pajakan atau lesen, yang dikenali sebagai Lesen Pendudukan Sementara (TOL), biasanya digunakan untuk memberi hak sementara kepada pemaju untuk mentadbir hartanah laut. Memandangkan beberapa konsep daratan boleh diguna pakai dan dibangunkan untuk persekitaran laut, kajian ini mencadangkan pembangunan 3D data model bagi kadaster laut berdasarkan piawaian darat, Model Domain Pentadbiran Tanah (LADM), dan Malaysia sebagai kajian kes. Penyelidikan ini membangunkan data model dengan mengkaji unsur-unsur yang diperlukan dalam persekitaran laut dan konsep 3D kadaster di Malaysia. Aplikasi *Unified Modelling Language (UML)* digunakan untuk membangunkan model konseptual dan teknikal. Data model ini dibangunkan dengan mempertimbangkan konsep laut di Malaysia agar sesuai dengan piawaian antarabangsa LADM. Data model bagi kadaster laut yang dibangunkan terdiri daripada tiga pakej iaitu pakej parti, pentadbiran dan unit ruang. 3D data model bagi kadaster laut ini menggambarkan komponen sumber laut dalam zon pantai, penyepaduan antara data ruang, perundangan dan ciri unit ruang melalui pengkelasan antara entiti. Model telah disahkan dengan menjalankan prototaip. Percubaan pada data model juga termasuk pelaksanaan pangkalan data dan pertanyaan mudah. Gambaran secara 3D telah dijana untuk menggambarkan set data yang disimpan. Struktur data model kadaster laut, yang mematuhi piawaian antarabangsa, LADM, menyediakan bahasa yang sama, keupayaan data dan kemudahan prosedur untuk semua pihak yang terlibat. Pihak yang berkaitan boleh menggunakan pendekatan yang dijelaskan sebagai rujukan dalam memodelkan dan mengurus pelbagai RRRs ruang dan hartanah laut.

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LIST OF ABBREVIATIONS

LADM	-	Land Administration Domain Model
TOL	-	Temporary Occupation License
RRRs	-	Right, Restriction, Responsibility
3D	-	Three-Dimensional
UML	-	Unified Modelling Language
EU	-	European Union
NSDI	-	National Spatial Data Infrastructure
ICZM	-	Integrated Coastal Zone Management
MSP	-	Marine Spatial Planning
OGC	-	Open Geospatial Consortium
DBMS	-	Database Management System
MAS	-	Marine Administration System
TSB	-	Territorial Sea Baseline
LAT	-	Lowest Astronomical Tide
EEZ	-	Exclusive Economic Zone
URA	-	User Requirement Analysis
MGDI	-	Marine Geospatial Data Infrastructure
NOP	-	National Ocean Policy
NOAA	-	National Oceanic & Atmospheric Administration
LWM	-	Low Water Mark
IHO	-	International Hydrographic Organization
MLB	-	Maritime Limits and Boundaries
NMCA	-	National Mapping and Cadastre Agencies

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Approximately 70% of the earth's surface covered by marine space. Over 80% of the ocean is never been surveyed, explored, or even seen by humans (National Geographic Society, 2019). Whereas there is much more to discover, marine space contributes to the global economy by serving as the hub for socio-economic activities such as urbanization, fishing, aquaculture, tourism, and recreation. This marine space separated by a land-sea boundary known as the coastline, defined as the line between the highest and lowest tides, as Dietriech G. (2010) noted. The shoreline is defined in Section 5 Baseline of the Maritime Zone Act 2006 as the low-water line along the coast as depicted on large-scale charts. The demand for coastal development is expanding due to population growth and industrialization, contributing to coastal city growth. Figure 1.1 and Figure 1.2 illustrate the instances of socio-economic activities in the coastal environment.

Figure 1.1 Aquaculture (https://theleaders-online.com)

Figure 1.2 Coastal Development (https://www.lexishibiscuspd.com)

Tourism and agriculture are now significant contributors to the economic sector's employment. Marine wealth includes marine properties (tourism, resorts, petroleum platforms), marine natural resources (fishing, oil, natural gas), and marine properties that run through the seabed (cables and pipelines). These situations triggered many researchers to develop proper marine spatial planning to manage all the activities involved within the area. Some countries integrated their navigational data in National Spatial Data Infrastructure (NSDI). Some countries, such as the Republic of Croatia (Roić, 2016) and Malaysia (Albotoush and Tan Shau-Hwai, 2019), also have introduced Integrated Coastal Zone Management (ICZM). However, these approaches caused some integration issues. There are no special regulations regarding coastal zone management. Still, there are regulations concerning particular coastal zone issues, which are not fully aligned.

Meanwhile, some scholars, Ng'ang'a (2006); Vaez (2014); Gazzola et al. (2015), agreed that extending the competencies of onshore (land) institutions to offshore (marine) areas would result in a more extensive and uniform structure. However, this extension need to be managed appropriately because of differences in legal status, professional institutions, and border conceptions. This kind of approach is also been acknowledged as a marine cadastre. To manage marine resources, several coastal countries, including Canada, as Sutherland et al. (2016) and Greece, as Athanasiou et al. (2017) noted, have implemented the marine cadastre concept, including Malaysia as mentioned by Abdullah et al. (2014). Malaysia is alienated into

two regions by the South China Sea, with 11 states in Peninsular Malaysia and two states on the island of Borneo (Sabah and Sarawak), as shown in Figure 1.3.

Figure 1.3 Malaysia Map (Anim et al., 2009)

Malaysia's coastline totals 4675 kilometers (Peninsular Malaysia, 2068 km and East Malaysia, 2607 km), making the coasts one of the country's most critical natural resources (Central Intelligence Agency, 2021). To manage coastal zone, several researchers within the country, namely Anim et al. (2009); Amsyar et al. (2011); Abdullah et al. (2012) Abdullah N. et al. (2012); Abdullah A. et al. (2014); Rahibulsadri et al. (2014); Abdullah N. et al. (2016); Omar et al. (2017) and Yatim et al. (2018) have discussed the marine space management by considering land administration concept. All the 11 states in the Peninsular Malaysia area use a similar land system, Torrens System, as mentioned in National Land Code, 1965. The Torrens System is a land title registration system. The government keeps all land and title records. A land title serves as a guarantee of completion, invulnerability, and legal control. The register is everything in the Torrens System. It would be inappropriate to authorize an investigation into a person's rights. Some countries like Greece use the other system, namely the Deed System. Table 1.1 shows the differences.

Table 1.1 Differences between Torrens System and Deed System

Details	Torrens System	Deed System
Passing of Title	Passed upon registration	Passed upon execution, signing, sealing, and delivery
Accuracy	Simple, easy, and secured	Uncertainty-filled, complex, expensive, and complicated
Security	Registration is critical and mandatory	Registration is not compulsory
Guarantee by the State	Guaranteed by the state – if any loss occurs due to registration errors, the state will be responsible	The state did not guarantee it because transactions are made between individuals.

Considering the components needed for proper marine space management, such as stakeholder involvement, ownerships, marine properties situation, and land-sea coordination, the evaluation of land cadastre towards marine environment become an initiative to govern the maritime space effectively. Fortunately, some of the land concepts are equivalent to the marine area. The applied three-dimensional (3D) cadastre concept onshore can be used offshore since the marine environment needs to be handled in 3D practice. The 3D cadastral objects such as buildings and pipelines need to be represented geometrically with their legal spaces. Property inland which deals with dimensions below the earth's surface, is been managed within stratum context as addressed by Zulkifli et al. (2017). The same concept can be applied to properties in the marine area. The idea of 3D cadastre can be employed to utilize 3D parcels both above and below the surface.

A standard is been applied on the land area to ensure spatial data uniformity, known as the Land Administration Domain Model (LADM). ISO (2012) stated that this standard had found justified and accepted applications in the international construction and implementation of 3D cadastres for non-submerged lands and built environments. It applies to the marine environment, as cited by Sutherland et al. (2016). In previous studies, mentioned in several publications, Athanasiou K. et al. (2016); Athanasiou A. et al. (2017); Lemmen et al. (2019), cadastral components (e.g., adjudication), survey elements (e.g., boundaries and datum considerations), and ownership rights are been said applicable to marine spaces. Moreover, LADM also supports 3D spatial units associated with the correct rights, restrictions, responsibilities

(RRRs), as Lemmen et al. (2015) point out, which is needed for 3D representation of the marine properties. By definition, it is also supported by the upcoming version of LADM (LADM Edition II). The extended LADM's scope is suggested to be developed for the marine part.

To date, several publications are applied marine cadastre-based land practice concept in producing marine-land data models to prove the relevance of LADM to the marine environment. The same concept can be adapted for maritime spaces management in Malaysia. Stakeholders may assess the data model for the sufficiency of the multipurpose function. The data model is still at the academic level, and there is no practical approach. Of course, some criteria need to be considered to ensure it expedites the management of marine spatial information. Different countries need to have different data models based on their administration and management. Hence, this research attempts to develop a 3D marine cadastre data model within LADM to manage Malaysia's maritime spaces and properties. The data model will be developed based on the possibilities of implementing LADM together with the 3D cadastre practices in Malaysia. The 3D elements can be adopted by considering the Malaysian LADM Country Profile developed by Zulkifli et al. (2014). This approach might help sustain marine properties properly and clear up the conflicts between the economic activities since many agencies are involved.

1.2 Problem Statement

Marine cadastre is introduced in early 2000, and this concept is implemented in Malaysia during 2012 (Arvanitis and Giannakopoulou, 2016). It is a framework that contributes to the oceanic administration, such as allowing the maritime rights to be controlled and managing spatial information in the marine environment. The framework includes RRRs practiced by the legal authorities in the marine environment. It is an information system in which interest and spatial data (boundaries) and non-spatial data are recorded, managed, and visualized. Even though the marine cadastre conceptual idea is been implemented, a few details still need some improvements.

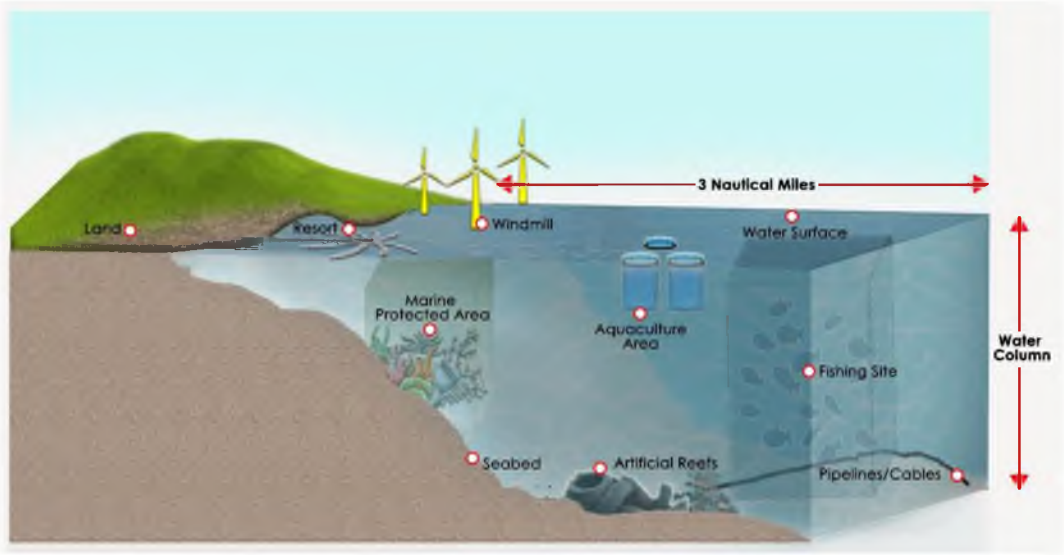

Figure 1.4 Situation of marine properties in 3D representation

Figure 1.4 illustrates the situation of marine properties in 3D representation. From the figure, there are multiple types of marine properties cases involved. Some of the marine properties capture the whole area (e.g., resort), some of the marine properties are located on the water surface and water column (e.g., aquaculture), and some of the marine properties lying underneath the seabed only (e.g., pipelines or cables). These situations need to be adequately addressed to avoid any conflicts. For example, multiple marine properties within the same area lead to ownership issues among the jurisdictions since numerous agencies are involved. Thus, it is crucial to know the exact location of the marine properties and their RRRs. By the definition, RRRs of a maritime property need to be clarified. By applying 3D representation, it can give an accurate picture to mirror the information of the marine properties, including the RRRs. Hence, 3D elements need to be considered in managing maritime space and properties.

As a coastal state, the economy is heavily reliant on the ability to manage marine resources. Thus, effective management of coastal zone and data integration between these three environments (land, coast, and marine) require proper management that incorporates them all. Aien et al. (2013a) suggested that application on marine cadastre can help manage the marine space properties by covering both spatial and administrative parts via the development of a data model. Several countries

(Canada, Greece, Croatia, and Turkey) are applied LADM's concept in developing a marine data model.

In Canada, Sutherland et al. (2016) highlighted that the same cadastral components, survey features, and ownership rights descriptions apply to marine spaces. The conceptual scheme of the LADM-based marine cadastre for Canada is shown in Figure 1.5. The classes developed are shaded. The new classes added in the LADM are MC_MaritimeZone, MC_MarineResource, and MC_MarineLayer. However, the marine data development still in academic level. Currently, Eger et al. (2021) mentioned that the country experimenting various governance arrangement where due to the fact that activities are managed by different government departments, each with its own authority, resources and priorities, which difficult for one department to have a single responsibility and ability. Canada has proposed Integrated Coastal and Marine Management (ICM) where the approach can be founded through policy instruments in developing a holistic strategy for coasts and oceans management. Yet, it remains a work in progress.

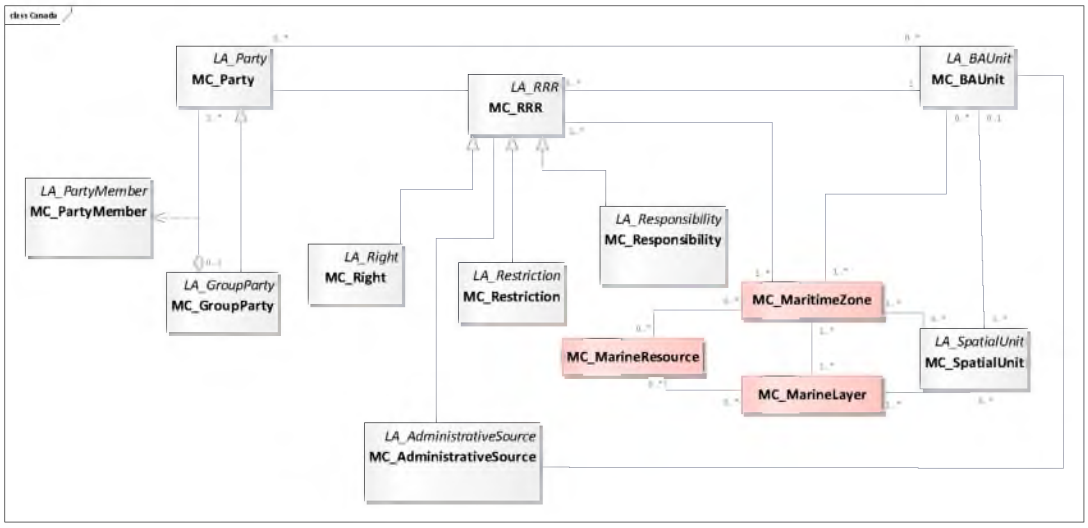

Figure 1.5 Land Administration Domain Model-Based Marine Cadastre Conceptual Schema for Canada (Sutherland et al., 2016)

In Greece, the Special Secretariat of Waters within the same Ministry of Environment and Energy, develops and implements all program for the water resource protection and management including coordinates all competent authorities dealing with marine environment as referred to European TSP Platform (2021). There is no

legally binding national Marine Spatial (MS) plan but Marine Spatial Planning (MSP) issues are addressed in Specific Frameworks for Spatial Planning. In addition, maritime space planning at the regional planning level are introduced, but there is no regional MSP authority in detail. For now, multiple ministries dealing with specific MSP related topics where Ministry of Tourism responsible for the licensing process and private works related to coastal and marine space.

In the past 2017, Athanasiou A. et al. (2017) have linked 3D marine administration within LADM, as shown in Figure 1.6 as an approach to handle marine space properly. They focused on how the RRRs relate to marine space may be organized. Overlapping of ownership on a gas pipeline and aquaculture area became their case studies. This model is capable of displaying legal entities in aquatic environments and can store 3D data records. It is likely to refer to this research work because it contains elements for the attributes required for each class involved; nevertheless, it would be ideal for including integration on physical and legal objects based on the international model, LADM as mentioned by the researcher. Same as Canada, this approach still in academic level.

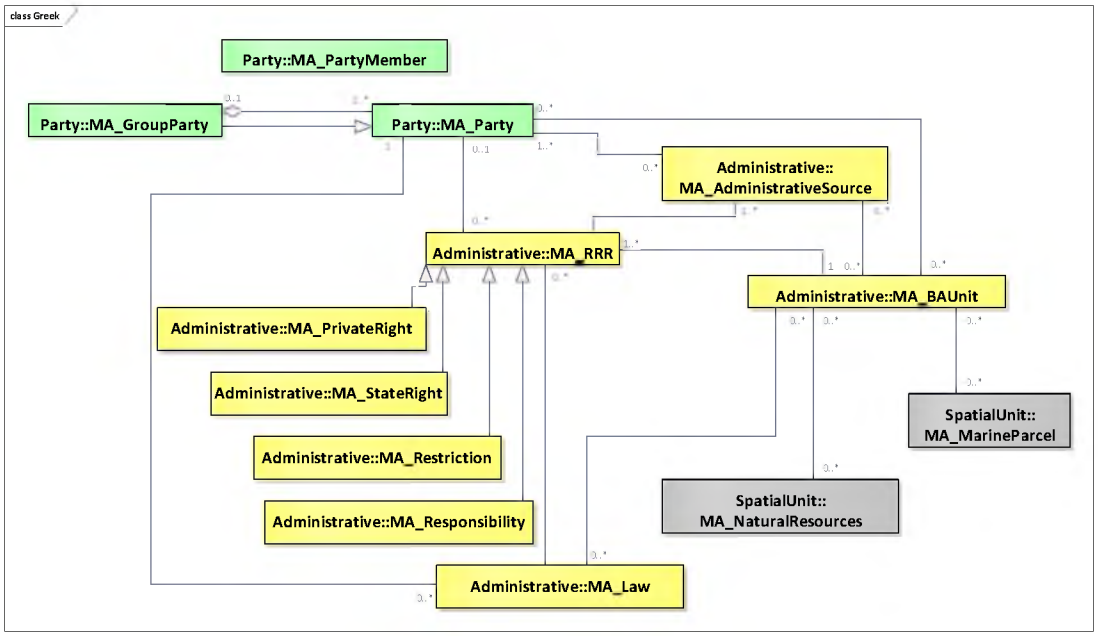

Figure 1.6 3D Marine Administration based LADM for Greece (Athanasiou A. et al., 2017)

Meanwhile, in Turkey, Baser and Biyik, (2019) discussed on the potential of managing coastal and marine zone within the land management's concept. They highlighted that problems mostly due to the population growth, housing, tourism, transportation, and industrial development felt in coastal areas where this region need to be administered properly in order to make sure the coastal area is protected and human activities are carried out in a rational way. More issues on marine region are discussed and some recommendations are suggested which is can be seen in the Table 1.2.

Table 1.2 Issues and suggestions for coastal and marine regions (*updated from* Baser and Biyik, 2016)

	Issues	Suggestions
Legal	• Issues on presence of private properties in coastal and marine zone. • Lack of legislation related to marine zones.	• Usage restrictions must be accurately recorded in national and international law. • Comprehensive legislation for coastal and marine areas needs to be developed.
Technical	• Lack of information systems. • Lack of national database and data sharing.	• Information systems need to be set up to establish appropriate decision-making and support agencies.
Institutional	• Lack of coordination among the institutions. • Involvement of many different institutions in coastal and marine zones.	• Inconsistency and disagreements between institutions should be resolved.

In Malaysia, state authorities manage some part of the marine region, which is started at the shoreline up to three (3) nautical miles offshore. Currently, there are multiple departments handle different marine activities which caused issues on RRRs. Aziz et al. (2019) point out the possibilities in adopting and implementing MSP for Malaysia. This approach might be able to reduce conflict in coastal and ocean's use. Conflicts between users and activities have a direct impact on health of the marine environment. Limited space and marine resource issues, coupled with tremendous economic expansion, create several marine threats such as overfishing, pollution, and habitat destruction. Moreover, as the coastal and marine tourism industry grows, the

development of such activities, including eco-based activities, needs to be accompanied by environmental and planning practices.

Since coastal zone is considered as land part, the activities around the area can be managed like onshore administration. For instance, the state authorities granted marine activities or parcels through leasing or a Temporary Occupation License (TOL). By definition, TOL allows the licensee to occupy certain areas given by the state authorities for a limited period. It needs to be renewed annually. These stakeholders are not the permanent owners of the marine properties; however, they are part of the beneficiaries through leasing or licensing contracts. Besides, the state has the right to exploit or dispose of the resources for specific purposes because the license holder is not the permanent owner, which is unbeneficial to the stakeholders or the individuals.

From the findings, LADM concept has the possibilities to be linked to the marine cadastre in maintaining maritime management from economic, environmental, and social perspectives. It might be quite different to other countries because of varying administration. Greece, for example, uses the Deed System as its land registration, while Malaysia uses the Torrens System. The differences between the systems can be seen in Table 1.1. Hence, it is essential to determine which part of the existing data model resembles Malaysia's marine administration.

Current initiatives of marine's administration for Malaysia lack of providing real schemes for handling the degree of 3D marine cadastre issues and challenges. Besides, research in the field of 3D marine cadastre is mainly focus on different (legal and technical) issues and challenges in terms of data model integration, 3D registration, 3D cadastral, queries, and 3D visualization without a clear discussion of the marine spatial data issues. A 3D marine cadastre data model based land administration would become as one of the approaches in administrating coastal and marine development where it can be as reference to the related agencies. Considering the previous finding's suggestion on integrating legal and physical, the data model is designed to be ready for spatial and non-spatial components assimilation. RRRs issues in marine environment could be resolved according to Malaysia's administration.

1.3 Research Aim

The research aim for this study is to develop Marine Cadastre Data Model towards 3-Dimensional based on Land Administration Domain Model (LADM) using Malaysia as a case study. This development is designed to analyse the current scenario of 3D marine cadastre in Malaysia. It is also designed to discuss several issues (RRRs) and challenges (marine spatial information) by relating them to 3D marine cadastre data model implementation.

1.4 Research Objectives

The needed objectives to achieve the aim as follow;

1. To investigate the existing practice on marine cadastre administration in international and local context.
2. To design a conceptual model for a 3D marine cadastre based on the international standard model, LADM.
3. To develop a technical model (database schema) for 3D marine cadastral registration based on LADM.

1.5 Research Questions

The main research question for this study is mentioned earlier in section 1.2. To answer the main research question, the aim in section 1.3 is proposed. The research aim seeks the following objectives (see section 1.4). Table 1.3 shows the specific questions to fulfil all the research objectives.

Table 1.3 Research Questions

Main Research Question How to handle marine properties and space registration?		
The Aim Developing a 3D Marine Cadastre Data Model based on Land Administration Domain Model (LADM) using Malaysia as a case study		
Objective 1 To investigate the existing practice on marine cadastre administration.	**Objective 2** To design a conceptual model for a 3D marine cadastre based on the international standard model, LADM.	**Objective 3** To develop a technical model (database schema) for 3D marine cadastral registration based on LADM.
Sub-Research Question(s) • What is the current status on marine cadastre practice within international and local context? • What are the approaches that have been taken to manage the marine spaces? • What is marine cadastre? • Who is familiar with marine cadastre stakeholders or responsible parties? • What is the previous data model regarding marine cadastre? • How was the implementation wise on marine cadastre?	**Sub-Research Question(s)** • What are the needed components to become a 3D marine cadastre data model? • How the data model will be developed? • Which elements in marine cadastre and LADM can be embedded? • How to embed between the marine cadastre and LADM models? • How modelling tools such as Unified Modelling Language (UML) and Enterprise Architect work with LADM and marine cadastre?	**Sub-Research Question(s)** • How to organize the data? • How to describe the relationships of data? • How database schema can describe the data model? • How to validate the data model? • How to make use of GIS software for representing the stored data?

1.6 Scope of Study

This study focused on developing a conceptual model for 2D and 3D marine registration based on international standard, LADM. The 3D marine cadastre data model is developed by applying Malaysia as a case study. The development based on Malaysia's administration where Torrens System is being applied. UML diagram is constructed as a starter in conceptual model development. This 3D marine cadastre data model covered a case study area for three nautical miles (5.6 km from the shoreline to the sea).

It focused on administrative and spatial units, including data management. The type of data used are administrative data (e.g., ownership information of the marine parcel) and spatial data (e.g., database for the marine objects). Since the real marine dataset is unavailable, simulation data are created based on the cadastre basis concept to validate the data model. Anything about the legal issue is outside the scope of this research. This study is not focused on taxation or valuation.

1.7 Methodology

The workflow depicted in the flow chart can be used to accomplish the objectives.

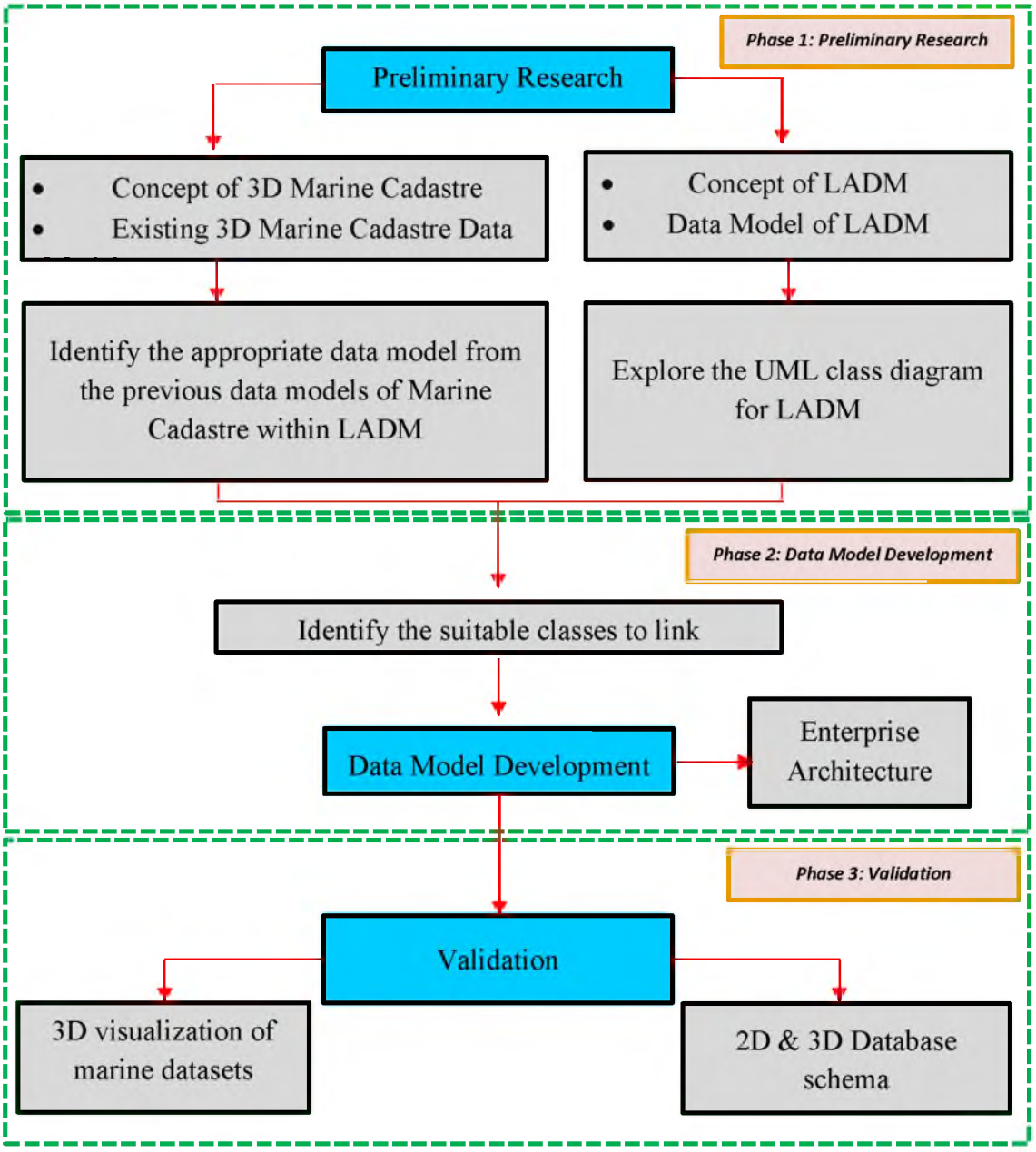

Figure 1.7 Research Flow Chart

The workflow for this research consists of three phases: preliminary research, data model development, and validation phases. The workflow begins with the initial investigation. Figure 1.7 illustrates the workflow of this study to achieve all the objectives mentioned.

Phase 1: Preliminary Research

This phase focused on the concept of marine cadastre and LADM based on their standards. The UML class diagram for LADM is being explored. Existing data models of 3D Marine Cadastre within LADM from other countries are identified. Then, the related classes are been finalized, and appropriate data models are been improvised.

Phase 2: Model Development

This phase defined the overall scope and content of the 3D Marine Cadastre within the LADM. Conceptual model designed by using Enterprise Architecture. This software is been chosen for efficient operation with lower costs, more shared capabilities, a flexible workforce, less duplication, and redundancies.

Phase 3: Database Schema

Phase 3 is the final phase. The technical model represents identifiers and types of keys (e.g., Primary and Secondary Keys) used in this phase. The variety of attributes is being explained by presenting a database schema in 2D and 3D based LADM.

1.8 Significance of Study

The extension of this standard is to support marine data by embedding it within LADM. A conceptual model needs to be developed to implement marine cadastre particularly. It is a need for a marine cadastre to be part of the spatial data infrastructure

and to handle complex and possibly overlapping rights in 3D space. Through this research, stakeholders will obtain better documentation regarding the marine objects' information and their ownerships. Developing a data model is a good start for data mining in the marine environment. The proposed model enhanced spatial and non-spatial aspects of maritime information sharing, such as oceanic layers, marine properties, natural resources, and related attributes. This 3D marine cadastre data model depicts the classes of marine resources in the coastal zone and data integration between legal spaces and spatial unit characteristics via external types and administrative sources. This marine cadastre data model may soon enable the country's coastal areas for 2D and 3D applications and management purposes.

1.9 Thesis Structure

This research consisted of six chapters as follow;

Chapter 1 spelled out the research background, problem statement, objectives, research questions, scopes, research area, and significances. This chapter discussed the purpose of the research, and several goals are developed to accomplish the study's objectives.

Chapter 2 discussed the marine cadastre issues in conjunction with LADM. This chapter went into detail about marine cadastres and LADM. It goes into detail about the issues raised by this study.

Chapter 3 discussed on status of the marine cadastre in Malaysia. It elaborates on the marine cadastre concept that is been studied by several researchers and how the marine space properties are been managed in the country.

Chapter 4 illustrated the development of the data model. It focused on the tools needed to develop the conceptual model. The classes, attributes, and other components involved in creating a data model are discussed. This chapter also defined the methods to generate the data model.

Chapter 5 elaborated the finding of this research. The result of this research is an embedded 3D Marine Cadastre within LADM. The output is based on the combination between the conceptual model in LADM and marine cadastre. To describe the components of the data model, a technical model is developed. A simple prototype is built to evaluate the 3D marine cadastre data model. The experiment included a few queries and the visualization of stored datasets in 3D.

Chapter 6 summarized the results obtained, objectives achievement, and recommendations to produce a better outcome for future research.

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