Development of 4D Marine Cadastre Data Model – A Case Study of Terengganu Shoreline

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Key words: Temporal Dimension, 4D (3D + T) Cadastral system, Marine Cadastre, LADM.

SUMMARY

In this paper, a 4D (3D + time) marine cadastral data model (MCDM) based on LADM is presented to improve the management of 3D marine properties considering the temporal elements, especially on the coast of Terengganu, Kuala Nerus. The model integrates temporal components and introduces a new bitemporal transaction class, the archived historical record class, which is structured to document two types of time-related information: valid time and transaction time. This dual-time perspective is critical for accurately recording data changes over time. Suffice it to say that the LADM version object in its current form may need to be included or redesigned to accommodate bitemporal data. This paper will first examine current practices in marine management, identify and establish temporal elements for implementation, identify LADM and existing 3D classes for adoption along with their attributes, relationships, associations, and code lists, and develop a conceptual data model that describes the modeling technique and requirements for coastal data, leading to a 4D MCDM. The output result is expected to provide visualization of the position and boundaries for each component of the marine and land cadastre in the area and, by extension, present a practical country utilization of 3D LADM provisions in the marine and land cadastre context, which can serve as a model for many aspects of modern urban planning.

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1. INTRODUCTION

Human activities and natural occurrences such as erosion have led to geometrical alterations in spatial and non-spatial property attributes (Celliers, 2016; Morar et al., 2022). Land status changes have great consequences for both the government and the people, particularly property ownership, which affects the entire land allocation, possession, and ownership process. Changes in questions could be when the land cover changes take place from land to marine (as noticed along most Malaysian beaches and coastal areas, especially in Terengganu, and others), marine to land (reclamation like in the case of Forest City in Johor Malaysia), and marine to marine situations. Other Malaysian beaches affected include, Kuala Maras near Batu Rakit, and Kuala Besut.

Changes in the physical characteristics of spatial objects both terrestrial and marine with their geometries and locations will continue to occur if the Earth's surface temperature is trending toward record highs, which will raise sea levels and generally degrade land surface area (Abdul Rahman et al., 2024). These changes are critically on the increase despite government mitigation and intervention plans saw owners of properties continuously losing them which invariably affects cadastral documentation (Rashidi et al., 2021). Furthermore, these changes are monumental and affect the entire cadastre situation in both the land and marine cadastres including but not limited to the destruction of coastal properties submerging and complete loss of properties affecting cadastral property ownerships. The affected land and property become marine and now government property while the original owner is still in the custody of the legal instrument (RRR) of ownership which is valid for historical and legal purposes. Cadastral changes are equally recorded over time from the initial cadastral model or platform used in the allocation has undergone transitions from 2D, 2.5D, or 3D to the present LADM 1 to LADM II. Changes in jurisdictions from land cadastre jurisdictions to marine cadastre jurisdictions require necessary compliance, and regulations, based on the new development (Trice et al., 2021). Equally, equipment and software used in the initial data collection, processing, and analysis methods employed in cadastres have changed over time from analog to digital, and software changes have occurred over time with the use of AutoCAD, Ilwis, and now Enterprise Architect, PostgreSQL. Database creation and archiving, from manual data archiving to digital archiving, be it conventional or blockchain databases, are part of the transitional temporal changes. Seamless transition or transfer of the record to the appropriate cadastre from land to marine cadastres or marine to land cadastres for appropriate jurisdiction and documentation. For a credible cadastre devoid of litigation, settlement, and resettlement plans, compensations to avoid litigation as witnessed in Terengganu, Malaysia, as reported by

V Anbalagan of FMT Media Sdn on February 12, 2022, faced a conflict with landowners who claimed RM5.5 million in damages for breach of contract and statutory duties. If we must address these issues particularly property loss and others and avoid any form of litigation, the time (t) element must be incorporated to account for the shifting shoreline border over time for a real 3D situation, and presentation of attributes and properties. Moreover, the historical data of transactions over time must be obtained, analyzed, and processed using the 4th dimension capability (documenting the temporal changes), particularly for marine environments as presentation and visualization of properties in 3D land cadastre is static visualization, so cadastral property presentation and visualization in marine cadastre environment requires temporal integration for proper visualization which can be achievable only in 4D (3D + Time). This paper attempts to develop a 4D marine cadastral data model for land administration. It involves the integration of temporal elements of shoreline changes and property ownership loss, accounting for these temporal truncations, documenting, and archiving based on LADM.

This paper will cover several sections. Section 2 discusses the Related works, Section 3, the Conceptual Model Development, Section 4, the Conclusion, and future works.

2. RELATED WORKS

The utilization of 3D land and marine cadastral representations of properties showcases their application in various fields (Abdul Rahman et al., 2012). A 3D land cadastre are advanced land registration systems that provide a comprehensive volumetric delimitation of property rights, enabling a more detailed spatial representation of property boundaries compared to conventional 2D cadastres (Drobež et al., 2017); (Semlali et al., 2015). 3D land cadastre is critical for urban development since it requires precise property rights delineation for efficient use of urban space, especially in high-rise buildings and subsurface infrastructures. The three-dimensional land cadastre promotes legal and administrative clarity, eliminating conflicts over land and property rights by providing precise boundaries in three dimensions (Levin et al., 2018). It is used to develop and manage complicated property arrangements, such as multilevel commercial complexes. Equally, the technology improves asset and real estate management by providing a comprehensive geographical context, enriching transactions with detailed 3D property descriptions, and assisting with valuation and development planning (Gkeli et al., 2020a). A 3D marine cadastre, maps and manages marine boundaries and property rights in three dimensions, covering the surface water, water column, and seabed (Kurniawan et al., 2023) (N. A. A. Zamzuri & Hassan, 2021), (Gkeli et al., 2020b),(Pouliot et al., 2018) &(Binns et al., 2004). It aids in maritime spatial planning, facilitating the management and planning of marine resources and activities like fishing, shipping lanes, and offshore energy production (Ehler, 2021), (Longhorn, 2016). Also, it helps in conflict resolution among competing users of marine spaces by providing clear boundaries. It ensures environmental protection and facilitates the conservation of Marine ecosystems by delineating protected areas in three dimensions. Also, it accounts for different habitats and species at various depths, assisting in monitoring and enforcing environmental regulations on infrastructure development, critical for the planning and management of underwater infrastructure like cables, pipelines, and tunnels (Karabin et al., 2020). The system ensures the safe and efficient placement of offshore installations like wind farms and oil rigs by accurately mapping the seafloor and water column.

In spatial representation, both 3D lands and marine cadastres represent significant advancements in the field of spatial information management, addressing the complexities of modern property and resource management (Polat & Alkan, 2018);(Aien et al., 2017). While they offer substantial benefits in terms of detailed and precise spatial data, their implementation requires overcoming significant technical, legal, and administrative challenges (Gürsoy Sürmeneli, Koeva, et al., 2022); (Paasch & Paulsson, 2021). The development of robust 3D cadastral systems is essential for sustainable development, efficient resource management, and effective governance in both terrestrial and marine environments.

The geometric aspects of 3D land and marine cadastres differ significantly due to the nature of their environments. The 3D land cadastre deals with relatively static, well-defined boundaries and complex urban structures, relying on precise volumetric representations. In contrast, the 3D marine cadastre must handle dynamic, multi-layered environments with fluid boundaries, requiring constant updates and integration of temporal data (Karki et al., 2010)(Griffith-charles et al., 2014). Both systems employ advanced technologies and tools to capture, integrate, and visualize their respective geometries, but they face unique challenges due to the inherent differences in their physical contexts (Rosdi, 2016)(Fraser et al., 2003).

The integration of temporal data in 3D land and marine cadastres varies significantly due to the different nature and dynamics of their environments (Atulukwu & Rahman, 2023); (Rakuša et al., 2021)(Polat et al., 2020). The dynamic boundaries of ownership transactions and legal instruments like RRR require a comprehensive consideration of time components. Failure to do so may lead to embarrassment for the government and stakeholders. The current effort to resolve this issue includes the integration of 3D cadastral object registration with time attributes (3D + t) within the Turkish LADM framework, focusing on land cadastres and no representation in marine cadastral environments (Gürsoy Sürmeneli, Alkan, et al., 2022). Also, the application of the ADE 4D cadastral data model for 3D cadastral item registration in Turkey demonstrates the legal and physical boundaries of multi-story addressing knowledge deficits in land-based cadastres but deficient in marine environments ((Alkan & Gursoy Surmeneli, 2020); (Gürsoy Sürmeneli, Koeva, et al., 2022). Efforts to increase cadastral capacity were witnessed to effectively manage the temporal dimension of modern land use in Turkey, the Netherlands, and Queensland, Australia. Still, this initiative was only for Land cadastre and not deployed to the dynamic marine environment ((Döner et al., 2010); (Ho & Hong, 2021) focused on temporal modeling in cadastral systems, specifically valid time, and the semantics of temporal information for Taiwan's cadastral data system. However, the temporal integration here was limited to land cadastre and was not extended to the dynamic marine environment. In Argentina, a conceptual model for water bodies, like LLO, with dynamic limits based on Argentine law's riparian boundaries (Riparian water rights is a system for allocating water among those who possess land along its path) was proposed, but they did not consider temporal transactions and property representation but limited to water right (Alberdi & Erba, 2020). Turkey developed a Temporal Cadastral Information System for land use, focusing on easement rights and national cadastral data management standards, but the focus of the study was limited to land cadastre and not extended to cover marine cadastre and its environments (Polat et al., 2020).

According to (Oosterom et al., 2019), existing models often overlook the spatial representation of property boundaries, morphology, and temporal dynamics and lack valid transaction time forms, limiting validity in uni-temporal and bitemporal models, and overlook property boundaries, causing inaccurate appraisals and financial losses. According to (Atulukwu et al., 2024), the absence of effective procedures for monitoring and documenting changes in property ownership over time can result in disputes, conflicts, and legal ambiguities in land management and legal actions. (Oosterom et al., 2019); (Kvet & Matiaško, 2013) argue that temporal truncation events in property ownership, including subdivisions at different transaction times, pose challenges in marine and land cadastres. Historical documentation is crucial for understanding past, present, and future records and tracing subdivision and land use patterns. (Kara et al., 2024); (Lemmen et al., 2021); (Thompson & van Oosterom, 2021), the Land Administration Domain Model (LADM-ISO 19152) offers bi-temporal support but lacks a valid time interval or life span, affecting spatial unit and party relationships.

Land title and cadastral data are dynamic and crucial for property applications like taxation, valuation, and mortgage. This paper discusses the modeling of Rights, Restrictions, and Responsibilities (RRR) in Turkey, focusing on easement rights. A prototype model was built using the Land Administration Domain Model (LADM) RRR classes and national cadastral data management standards. The model includes temporal cadastral attributes related to easements, providing significant advantages to land administrators, governments, and users in Turkey (Polat et al., 2020). This paper explores the conversion of 2D analog cadastral boundary plans into 3D digital information, focusing on a research project in Stockholm. The study highlights legal issues and the need for detailed interpretation of existing legislation to incorporate 3D models into cadastral decisions. It also analyzes the current cadastral process and suggests further development, highlighting the need for further investigation and interpretation of 2D cadastral data (Larsson et al., 2020). Turkey's land register and cadastre (LRC) data is widely used by both public and private organizations. However, traditional LRC systems have manual archiving, making it difficult for users to perform temporal analyses quickly and reliably. This research aimed to design and developed a Temporal Geographic Information System (TGIS) for Turkey, evaluating agencies' needs and testing the system (Polat et al., 2020).

Atulukwu et al. (2024). positioned the development of a 4D Malaysian marine cadastre data model based on the Land Administration Domain Model (LADM) to address the challenges of effective land management in coastal and marine settings, integrating temporal dimensions with existing 3D marine models which will enhance land administration methodologies in dynamic marine settings and promote sustainable marine development. Siejka et al., (2014) discusses the introduction of a 3D+time system transition from a 2D cadastre to a 3D+time system using official spatial data registers in Poland aiming to enhance property rights, database efficiency, data quality, planning, and land management with advanced technologies like CAD, GIS, and DBMS enable 3D visualization and reconstruction of real estate state.

The 3D cadastre, a key component of the Land Administration System, provides a 3D view of legal and physical boundaries in multi-story properties. Also, that most 3D integrated data models are conceptual, leading to a knowledge gap in logical data model relationships was the canvassed in the study proposing an innovative ADE 4D Cadastral Data Model for 3D cadastral object registration with time attributes using LADM and CityGML, managed in an open-source database for the Turkish cadastral system (Gürsoy Sürmeneli, Koeva, et al., 2022). According to (Aien et al., 2017) the authors repoerted the theories and concepts of the common existing cadastral data models and their management of 3D legal and physical data as none of the existing models can fully support the requirements of 3D cadastres or develop new models.

Temporal integration of marine properties ensures accurate records, addresses issues in dynamic ecosystems, and improves monitoring, sustainability evaluations, human impact assessments, dispute settlement, and legal representation by considering temporal dynamics like jurisdictional control and resource availability. The inability to integrate legal and physical data leads to inconsistent descriptions, complicating enforcement and increasing the likelihood of legal disputes (Flego et al., 2021), (Radjai & Rassoul, 2016) and (Van Oosterom & Stoter, 2010), and. Cadastral integration can be achieved by adding legal data to physical information models or combining both. Combining Enterprise Architect (EA) or CityGML and LADM ideas involves designing a profile of LADM for a country and creating an ADE for the EA or CityGML standard (Gürsoy Sürmeneli, Koeva, et al., 2022), (Rajabifard et al., 2021), (Spijkerboer, 2021), and (Sun et al., 2019). The study explores the integration of marine cadastral units with land administration, aiming to improve marine resource management opportunities within existing land administration frameworks (N. A. A. Zamzuri & Hassan, 2021). The paper highlights how the integration of marine cadastre with land administration can enhance the coordination of marine and terrestrial spatial data, as studied in projects like the Dutch North Sea Dialogues and Agreement (Spijkerboer, 2021). The integration of maritime settings is crucial for sustainable marine resource management and decision-making, as studies show temporal and local impacts on coastal areas and the scalability of water property measurements ((Nylén et al., 2021). Marine spatial planning integration practice is viewed from multiple perspectives and addresses challenges and problems in diverse settings, highlighting its importance for efficiency, participation, and sustainability (Saunders et al., 2019). Also, temporal truncation events in property ownership, including subdivisions at different transaction times, pose significant challenges in marine and land cadastres. Historical documentation of these events in spatial models is crucial for understanding past, present, and future records, which are not currently implemented (Oosterom et al., 2019) (Kvet & Matiaško, 2013). The transaction time in cadastre records is crucial for tracing subdivision and land use patterns, planning future activities, and maintaining the database's knowledge. Existing models lack the "valid time" and "transaction time" forms of time stamping (Oosterom et al., 2019). The temporal and transaction models are crucial for data processing, storing both current and future data. Uni-temporal models limit data validity, while bitemporal models consider both validity and transaction time, allowing for updates without user input (Kvet & Matiaško, 2013). The Land Administration Domain Model (LADM-ISO 19152; ISO-TC211, 2012) partially provides bi-temporal support (beginLifespanVersion and endLifespanVersion) but lacks a valid time interval or life span. The LADM VersionedObject only covers TransactionTime concepts, not focusing on recording interval events or recurring patterns, thereby affecting the relationship between spatial units and parties, which is one of our focus areas in this current research work (Kara et al., 2024); (Lemmen et al., 2021); (Thompson & van Oosterom, 2021).

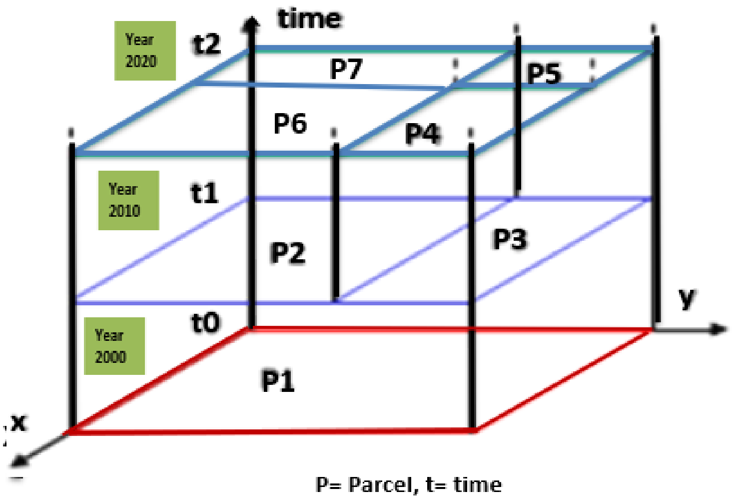


Figure 1. Land cadastral property representation, modified after (Pouliot et al., 2018)

Figure 1 illustrate 3D land cadastres record changes in land records based on schedule updates. Regulated modifications such as division, subdivision, alteration, and amalgamation are manifested here. The boundary here is static, and there is no change in geometric attributes or spatial units as the boundary remains static, showing that cadastral property representations here can be declared true in 3D representations of properties. Also, the diagram shows that the initial one parcel (P1) in year 2000 and time (t0) was then subdivided into two parcels (P2 and P3) at time (t1) in year 2010 after ten years, and at another ten-year interval, parcel P2 and parcel P3 at time (t2) were further subdivided into parcels P4, P5, P6, and P7, respectively, and can be amalgamated into a larger parcel with new land use depending on needs. The emphasis here is that the spatial unit remains unchanged and does not affect the geometric attributes except for the unit changes in the subdivisions.

The followiing reports by Gürsoy Sürmeneli, Koeva, et al. (2022), Thompson & van Oosterom (2021), Ho & Hong (2021), Pribadi et al. (2021), and Cole & Wilson (2016) summarized the need to consider the time aspect of land ownership and transactions, highlighting the drawbacks of current models.

The overall aim of this research is to attempts to develop a 4D marine cadastral data model for land administration. It involves the integration of temporal elements of shoreline changes and property ownership loss, accounting for these temporal truncations, documenting, and archiving based on LADM and to improve the 3D situation, and presentation of attributes considering the temporal elements, particularly in the Terengganu shoreline. The model would integrate temporal components and introduces a new bitemporal transaction class, the archive Historical Record class, which is structured to track two types of time-related information: valid time and transaction time. This dual-time perspective is crucial for maintaining a comprehensive and accurate record of changes in data over time. This research work would follow a workflow divided into preliminary research phase, conceptual and data model development phase, and data model validation phase respectively. This work took cognizance of past research efforts in Malaysia, Turkey, and some other nations but their outcome were limited to land cadastral administration; however, Malaysia has developed a marine cadastral data model based on LADM at a 3D level, which is short by lack of integration of the temporal component, thereby necessitating the current integration of the temporal component for the 4D (3D + T) Marine cadastral data model to ensure sustainable marine cadastral administration. The expected model will on the LA_SpatialUnit receive an additional object class, bringing to a total of six (6) classes, while the LA_Party Unit and the LA_BAUnit inherit the transaction class, respectively and is expected to provide visualization of features and boundaries for each component for the marine cadastre in the area, and, by extension, present a practical country utilization of 3D LADM provisions in the marine context, which can serve as a model for many aspects of modern urban planning. However, this paper focuses on the development of the 4D marine cadastre conceptual data model for the integration of temporal elements of changes for the management of 3D situation of cadastre properties in Terengganu shoreline based on LADM (Gürsoy Sürmeneli, Alkan, et al., 2022; Gürsoy Sürmeneli, Koeva, et al., 2022; A. Zamzuri et al., 2022; Drobež et al., 2017; Ashraf Abdullah et al., 2014).

3. THE CONCEPTUAL MODEL DEVELOPMENT

Marine boundaries are dynamic due to natural processes, tides, currents, and human activity, causing changing shoreline, overlapping claims and disagreements. This makes it difficult to establish stable legal boundaries and maintain consistent legal descriptions in the marine cadastre. The lack of integration between legal and physical data also complicates matters. Malaysia's 3D marine cadastre model and current data models have limitations in representing temporal dynamics of maritime environments, necessitating the development of a 4D marine cadastre model. A 4D marine cadastre model is needed to improve resource management and address these limitations. The cadastral situations of 3D properties on the Terengganu shoreline (Figures 2, 3, 4, and 5) illustrate property presentations, highlighting the challenges associated with temporal changes, modeling, presentation, and updating the documentation of cadastral properties in marine environments. The situations illustrated in the following figures 2, 3, 4 and 5 serve as a research gap in this paper; thus, all the related modeling processes or tasks will be elaborated on in sections 3.1–3.3, respectively.

Figure 2. Coastal situation of Kuala Besut coast north of Terengganu as of 2024

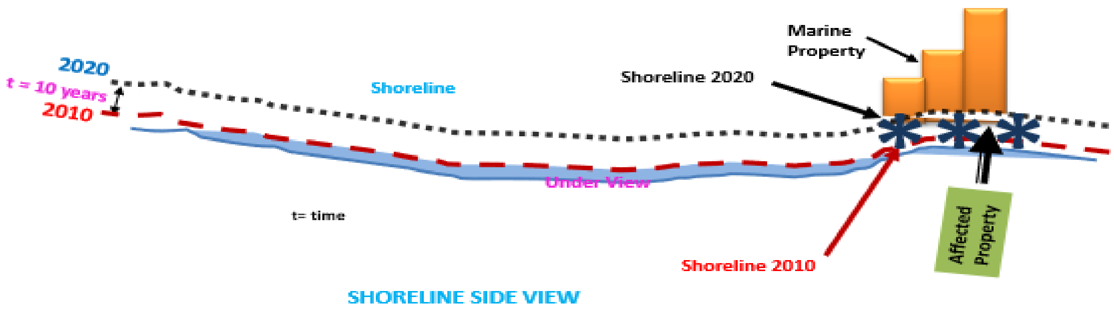


Figure 3. 3D Situation of marine cadastral property representation

Figure 3 illustrates a 3D Situation of marine cadastre presentation of attributes and properties showing natural changes. 3D marine cadastres need constant updates to manage the dynamic maritime environment with constantly shifting boundaries over time. The representation here is by 3D + T to account for the temporal (t) change over time. In the transactional process, time is of the essence, and the intricate integration of temporal (t) for marine cadastral 3D property representation is a necessity.

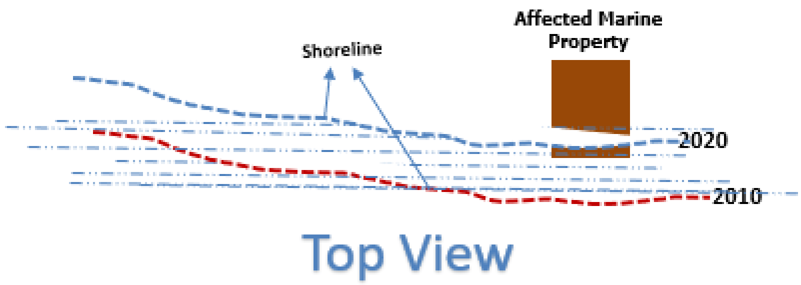


Figure 4. 3D Situation of shoreline changes and property loss (Land-Marine)

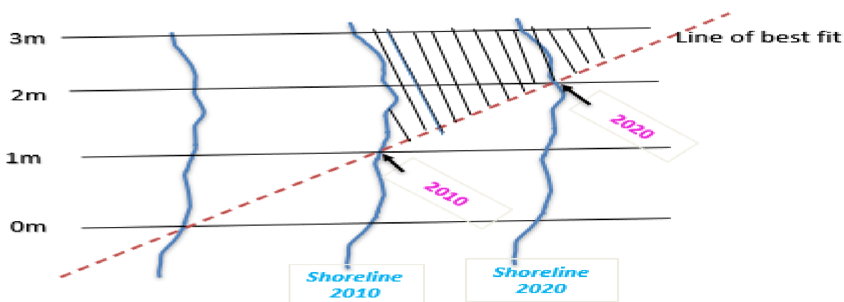


Figure 5. Cross-section of shoreline changes (Land-Marine)

Figure 5 illustrates the cross-sectional view of shoreline changes with time, particularly for status changes from land to marine of affected property area in a pattern using 1meter interval.

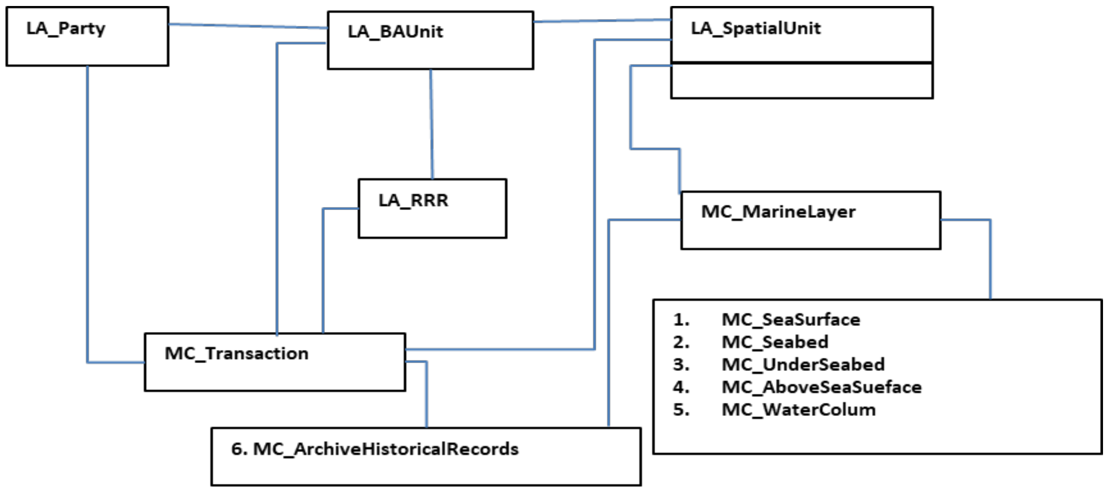
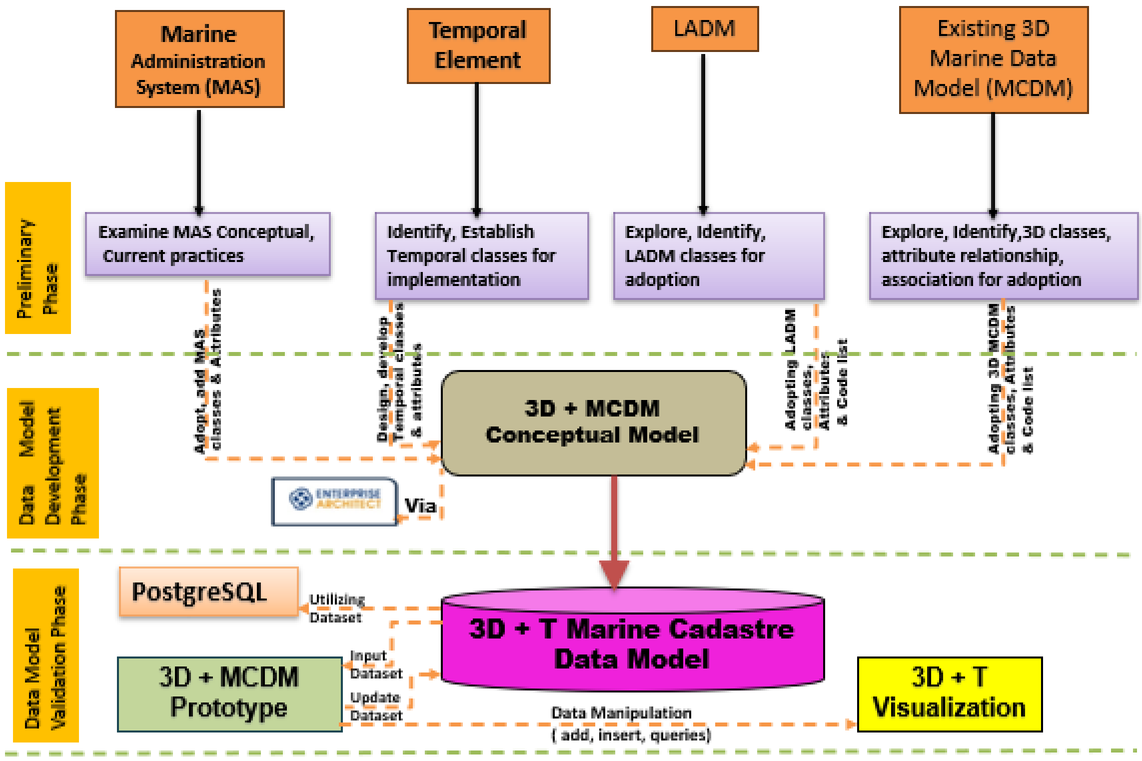


Figure 6. Object modeling process based on LADM classes

Figure 6 illustrates the modeling process of marine property object classes and their relationships based on LADM classes and standards.



Note: LDAM:- Land administration domain model, MCDM:- Marine cadastre data model

Figure 7. Research framework for 4D marine cadastre data model development

Figure 7 describes the research framework for the development of the 4D MCDM based on LADM and consists of the preliminary, data modeling, and data validation phases.

3.1 Preliminary Research Phase

The preliminary research phase discusses the 4D marine data model developmental phase, which examines current practices in marine management, identifies and establishes temporal elements for implementation, identifies LADM and existing 3D classes for adoption along with their attributes, relationships, associations, and code lists, and develops a conceptual data model that describes the modeling technique and requirements for coastal data, leading to a 4D MCDM.

The next phase is the data model validation phase, which is the translation of the developed conceptual model into a logical database, converting the classes into schemas, prototype model development, and finally developing the 4D marine cadastre data model, followed by validation, respectively.

3.2 Data Model Development Phase

Data modeling consists of developing a conceptual representation of object classes and their relationships, which incorporates implementing constraints, code list classes, object identity, association cardinality, inheritance, and an appropriate data format. As a result, the UML diagram tool of Enterprise Architect will be used to define classes and attributes, establish relationships between the classes, and create a model that better represents the data in a way that organizations, database administrators, and other stakeholders can understand. The data model creation phase specifies how the information retrieved and adopted from preliminary

3.3 Potential Classes

The potential classes in Table 1 for the development of the conceptual model based on the LADM standard were identified and classified along the LADM structure of the party unit, the administrative unit, and the spatial unit, respectively. The newly proposed classes are covered with red boxes, and their grouping was generated based on Malaysia's LADM country profile. The generated possible classes were expanded and translated into the 4D marine conceptual model (Figure 8).

Table 1. Potential classes

Group/Package	Subclasses
Party	MC_Party MC_PartyMember
Administrative	MC_RRR MC_Right MC_Responsibility MC_Restriction MC_BAUnit MC_AdministrativeSource MC Transaction
Spatial Unit	MC_MarineSpatialUnit MC_MarineLayer MC_Source MC_SeaSurface MC_AboveSeaSurface MC_WaterColum MC_Seabed MC_UnderSeabed MC ArchiveHistoricalRecord

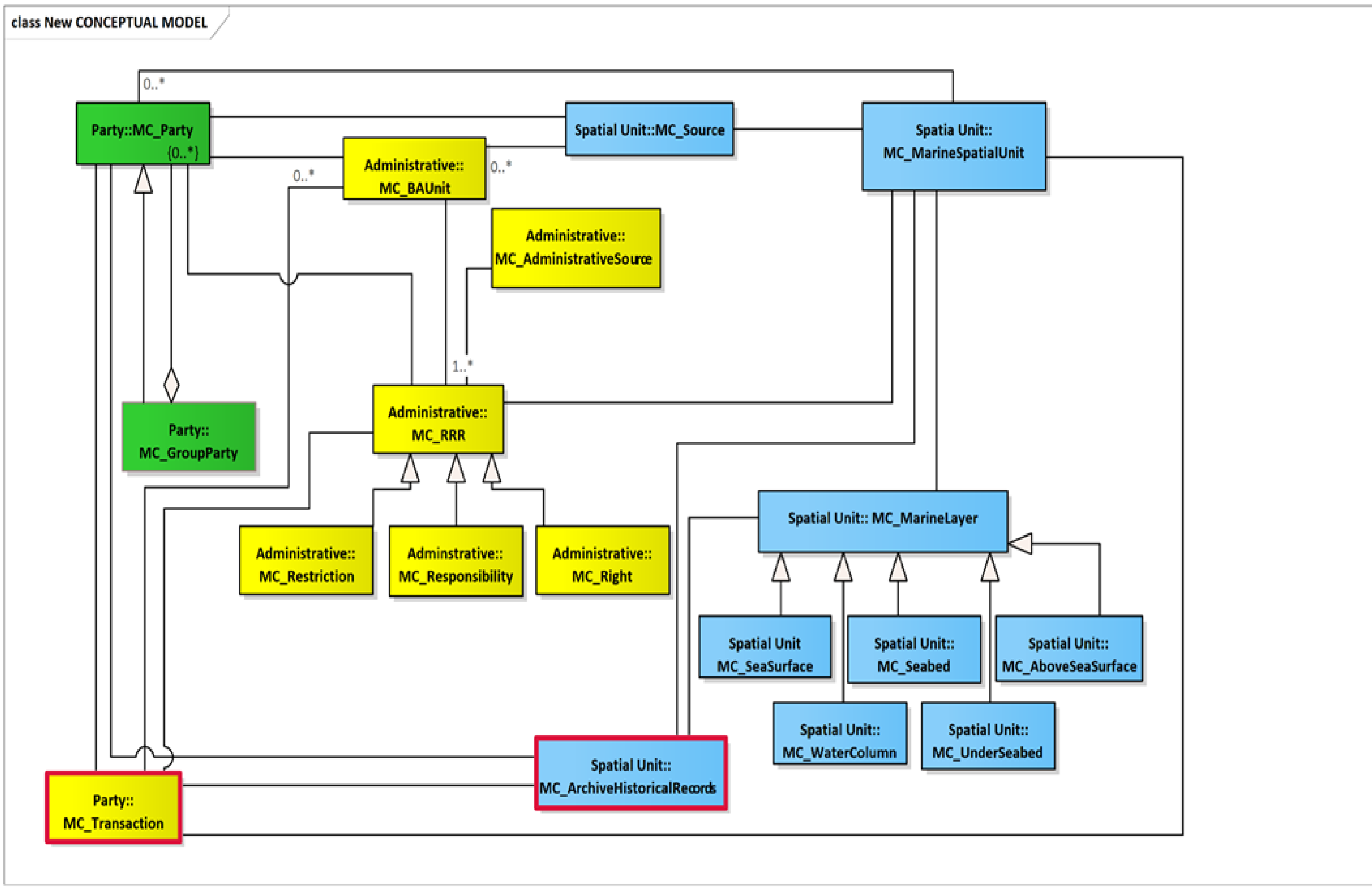


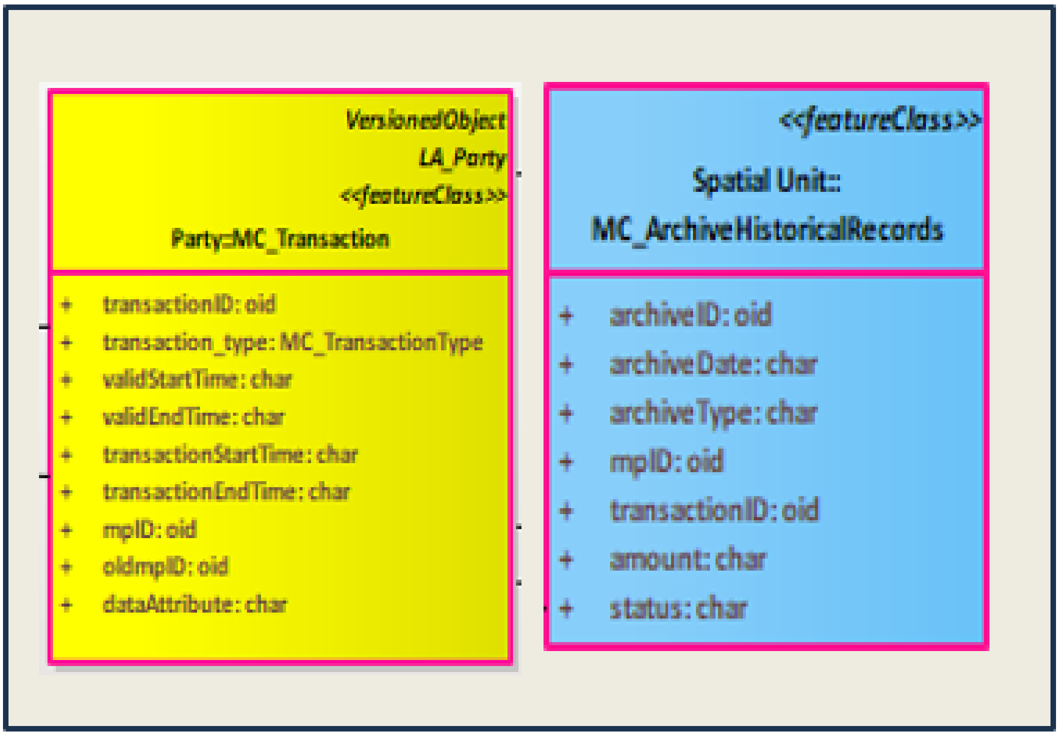
Figure 8. The 4D Marine cadastre conceptual data model

Figure 8 shows the developed 4D marine cadastre conceptual data model 4D (3D+T) (MCDM) with the introduced classes. The model comprises of party, administration, and spatial unit packages, but surveying and representation were excluded due to 'no-mark boundary quality' enabled by maritime space georegulation technology. The parties participating in a marine environment can include a state, a stakeholder, a company, or a group. Based on administrative interests, the party package in this work acquired the MC_Transaction class, which specifies who has superior jurisdiction over maritime operations or marine parcels and is introduced to the MC_Party unit. In this research work, the prefix 'MC_' designates the Marine Cadastre and is utilized. MC_Party is organized in green and subdivided into MC_Party and MC_GroupParty. MC_Administrative in yellow is expanded into MC_RRR, MC_Right, MC_Responsibility, MC_Restriction, MC_BAUnit, MC_AdministrativeSource, and MC_Transaction. The spatial unit in blue and enlarged to include MC_MarineSpatialUnit, MC_MarineLayer, MC_Source, MC_SeaSurface, AboveSeaSurface, MC_WaterColum, MC_Seabed, and MC_UnderSeabed is inherited from the current 3D Malaysian marine cadastre data model. At the same time, the MC_ArchiveHistoricalRecords class is introduced to the spatial unit, enhancing the marine administration. The transaction class is related by associations with MC_Party, MC_RRR, MC_BAUnit, MC_SpatialUnit, and MC_ArchiveHistoricalRecords, respectively. MC_AchiveHistoricalRecords is equally related by association to MC_Transaction, MC_Party, MC_Spatial Unit, and MC_MarineLayer, respectively. The proposed classes of transaction (bitemporal) and archive historical records have data structure and as in table 2.

MC_Transaction (Bitemporal)
+ transactionID: oid a unique identifier for the record.
+ Transaction_type: MC_TransactionType Relevant data attributes (e.g., owner name, land parcel ID).
+ validStartTime: char (The beginning of the valid time)
+ validEndTime: char (The end of the valid time)
+ transactionStartTime: char (The beginning of the transaction time).
+ transactionEndTime: char (The end of the transaction time)
+ mpID: oid
+ oldmpID: oid
+ dataAttribute: char

MC_ArchiveHistoricalRecords
+ archiveID: oid (a unique identifier for the record)
+ archiveDate: char
+ archiveType: char
+ mpID: oid (Marine property ID)
+ amount: char
+ status: char

Table 2. Proposed new classes and its data structure



4. CONCLUSION AND FUTURE WORK

In conclusion, this study presents a practical implementation of 3D LADM provisions within the marine and land context, offering a model for essential aspects of modern urban planning. The 4D (3D + Time) Marine Cadastre Conceptual Data Model (MCDM), based on LADM Edition II, aims to enhance marine property management by integrating temporal elements, particularly along the Terengganu shoreline. The model introduces a bitemporal transaction class, the archive historical record class, which tracks both valid time and transaction time. This dual-time perspective ensures a comprehensive and accurate record of data changes over time, preserving historical data and transaction records. To accommodate bitemporal data specific to marine environments, modifications to the current LADM version object may be necessary. Such adjustments are critical for thorough analysis and maintaining continuous data updates, which are essential for effective marine property management. Importantly, this research aligns with global and national priorities, contributing to the United Nations Sustainable Development Goals (SDGs) 11, 14, and 15, and supporting Malaysia's National Agendas 4 and 5. Despite its potential, this study has limitations, as it does not cover the provision of unique parcel identifiers for Malaysian maritime parcels, user training, or data auditing. Future work would be on the data model development, visualization, and validation to fully realize its potential and broader applicability.

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BIOGRAPHICAL NOTES

Yusuf Hussaini Atuklukwu obtained his MGIS in 2012 from the University of Ilorin, Nigeria. He has been a chief lecturer since 2015, teaching GIS and cartographic courses at the Federal Polytechnic in Bida, Niger State, Nigeria. He has been a PhD student since 2022 and has published in 2024: Developing a 4D Malaysian Marine Cadastre Data Model Based on LADM: Preliminary Works, Xlviii (January), 11–12. The International Archives of the Photogrammetry, Remote Sensing, and Spatial Information Sciences, Volume XLVIII-4/W9-2024, and in 2023, Marine Cadastre Data Models With Temporal Aspect: Review. International Archives of the Photogrammetry, Remote Sensing, and Spatial Information Sciences—ISPRS Archives, 48(4/W6-2022), 159–166. https://doi.org/10.5194/isprs-archives-XLVIII-4-W6-2022-159-2023 and have publications to his credit. He belongs to several professional bodies, including the Geoinformation Society of Nigeria, the Nigerian Cartographic Association, and the and the Nigerian Institution of Surveyors.

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