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

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Introduction:
The Marine Cadastre

- Marine cadastre entends cadastral principles to marine environments.
- It defines rights, boundaries, and ownership in the ocean and sea spaces.
- Includes surface, subsurface, and airspace aspects of marine zones.
- External **infrastructure projects** (e.g., subways, tunnels) affecting subsurface boundaries.

3D Cadastral Property Situations

- 3D cadastre involves property ownership and rights extending to vertical and subterranean spaces, high-rise buildings, underground structures, and airspace rights.
- The **cadastral situation** of a property refers to its official status and details as recorded in the cadastral registers including marine cadastre.
- Includes boundaries, ownership, parcel identification, property size, legal description, land use designation, and value.

3D Cadastre Situation & Impact

- An Affected 3D cadastral situation indicates changes in ownership(New ownership), boundaries(reconfiguration due to construction or demolition), or legal uses in any vertical layer (above, below, or on the surface).
- Changes in subsurface rights (e.g., oil, gas, or mineral extraction). Impact on infrastructure like offshore wind farms, pipelines, or telecommunications cables.
- Changes in navigation zones or environmental or Govt. regulations affecting marine space.

Related Works

- 3D land and marine cadastral representations are advanced land registration systems that provide detailed spatial property boundaries, aiding urban development, legal clarity, asset and real estate management, and valuation planning. (N. A. A. Zamzuri & Hassan, 2021); Ehler, (2021); (Karabin et al., 2020); (Gkeli et al., 2020b); (Gkeli et al., 2020a); (Pouliot et al., 2018); Levin et al. (2018); (Drobež et al., 2017; Longhorn, 2016).; (Semlali et al., 2015). Abdul Rahman et al., 2012; and Binns et al., 2004.
- The complexities of modern property and resource management and overcoming technical, legal, and administrative challenges (Gürsoy Sürmeneli, Koeva, et al., 2022); (Paasch & Paulsson, 2021); (Polat & Alkan, 2018); and (Aien et al., 2017).
- The integration of temporal data, temporal transactions, and current efforts integrating 3D cadastral object registration with time attributes using the ADE 4D cadastral data model to address knowledge deficits in land-based cadastres (Atulukwu & Rahman, 2023; Gursoy Sürmeneli, Alkan, et al., 2022; Gursoy Sürmeneli, Koeva, et al., 2022); (Rakuša et al., 2021); Ho & Hong, (2021); (Polat et al., 2020); (Alkan & Gursoy Surmeneli, 2020;. (Alberdi & Erba, 2020); Döner et al., 2010.
- Shortcomings of existing models and historical documentation of past, present, and future records were examined (Atulukwu et al., 2024; Oosterom et al., 2019). (Kvet & Matiaško, 2013)
- The following reports by Gürsoy Sürmeneli, Koeva, et al. (2022), Gürsoy Sürmeneli, Alkan, et al., 2022a; A. Zamzuri 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.
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The Case Study: – Panji Baku Rakit Terengganu

- **Terengganu** is one of the states in **Malaysia**, located on the eastern coast of the Malay Peninsula and bounded by the **South China Sea**
- The coastal region of **Panji Batu Rakit in Terengganu** is under significant threat from sea level and erosion with direct implications for coastal properties
- The cadastral situations of 3D properties Presentation on the Terengganu shoreline, **highlights the challenges associated with temporal changes, modeling, presentation, and updating the documentation** of cadastral properties in marine environments (Fig 1 & 2), and is characterized of

A. Land status change **(Land loss, Property loss, Unusable land)**

B. Structural Damage**:** the sea erosion (**Damages; Building foundations, Road foundations, Structural failure)**

C. Risk & Decline Values on Properties by insurers and buyers on properties in the study area

D. **D**. No Unclos free zone of 5.6 km to the shoreline

E. Washed off Coastal Setback (International standard of 60m – 100m and Malaysia 30m – 100m), the current setback to the property is **22.632m** or 0.012 nautical mile.

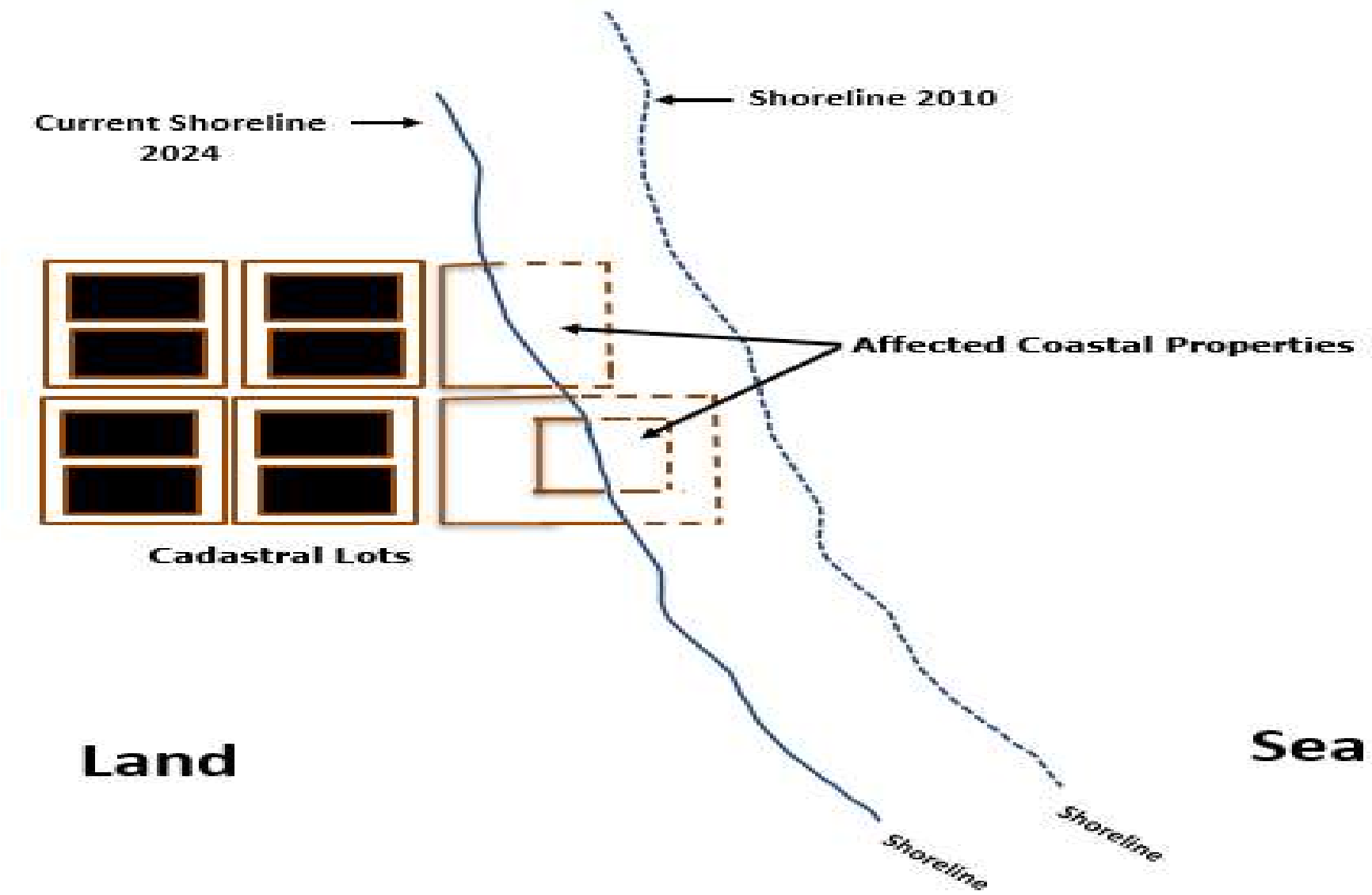
Fig 1: Study Area - Batu Rakit, Kuala Nerus Vie Google Earth

Fig 2: Cadastral Situations of 3D Properties at Panji Batu Rakit, Terengganu Shoreline Kuala Nerus

Fig 3: Some Affected Cadastral Properties at Study Area by Drone, August 2024

Setback distance of Property to Shoreline = 22.632m (0.012 Nautical mile

Fig 4: 3D Situation of Cadastral Property Representation due to Shifting Shoreline at Panji Batu Rakit, Terengganu, Kuala Nerus

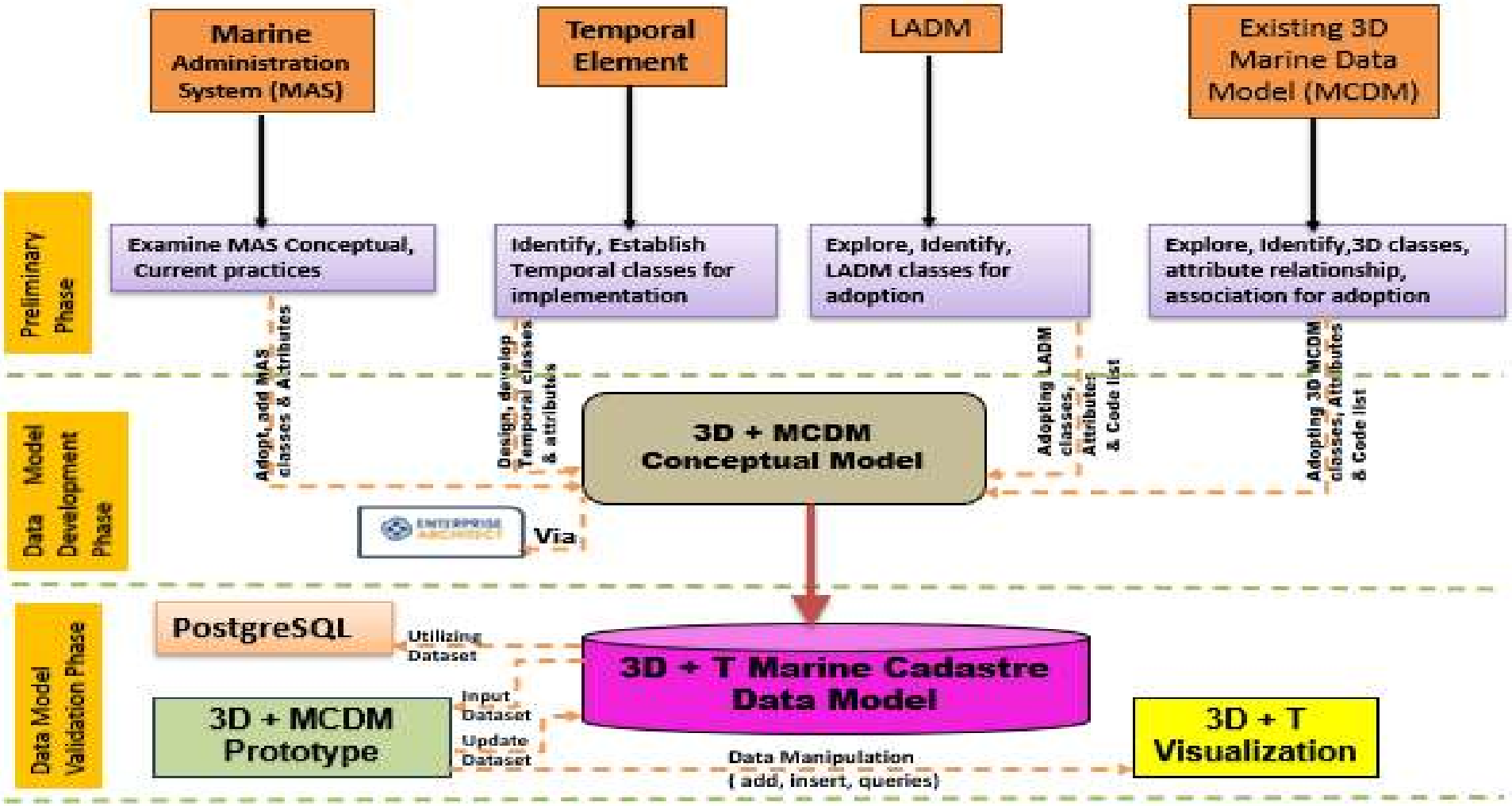


Kg. Panji Batu Rakit Area

Why 3D + T(4D) Modeling

- **The current** Malaysia 3D Cadastre data model **lacks the time component** to handle temporal changes over time
- A multi-facet approach, **combining engineering solutions with natural defense, strict regulatory frameworks, and community** involvement is required, and
- **Urgent Need to Investigate** the **relationship** between **cadastral lots (with 3D properties) and time** (temporal) concerning the eroded shoreline at **Panji Batu Rakit Terengganu** using **LADM [fig 2,3]**
- **Develop a 3D + Time (4D)** marine **cadastre data model.**
- Introduces **two new classes, bitemporal transaction class and archived historical record class into LADM [fig 7]**
- The bitemporal transaction Class 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.

Figure 5: 4D (3D + T) Model Development Framework



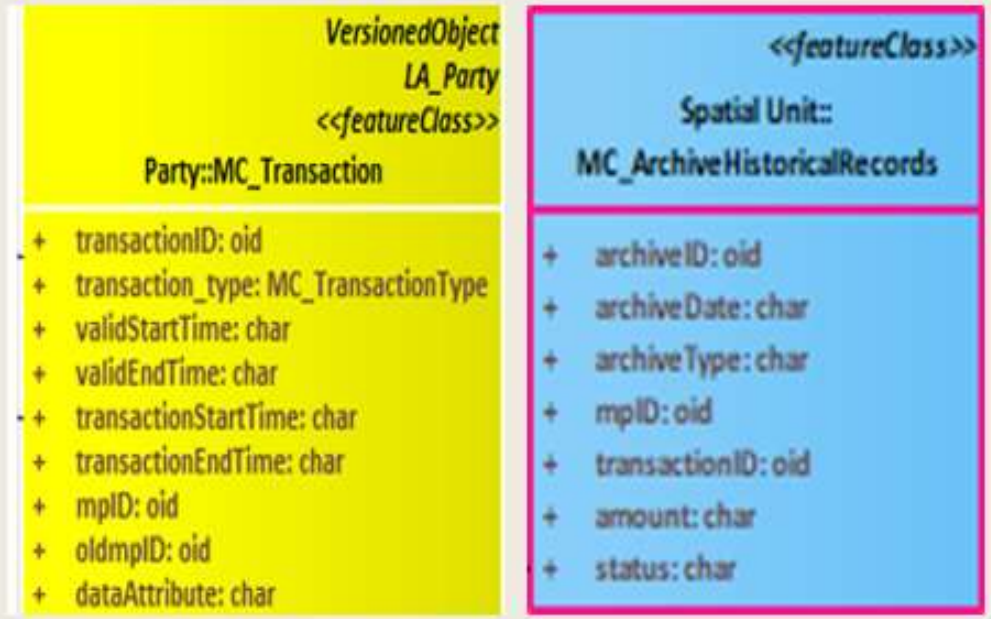
Note: LDAM:- Land administration domain model, MCDM:- Marine cadastre data model

The Modeling task is elaborated in Figure 3 (Preliminary, Data model and Validation Phases)

Fig 6: Possible Classes & Data type

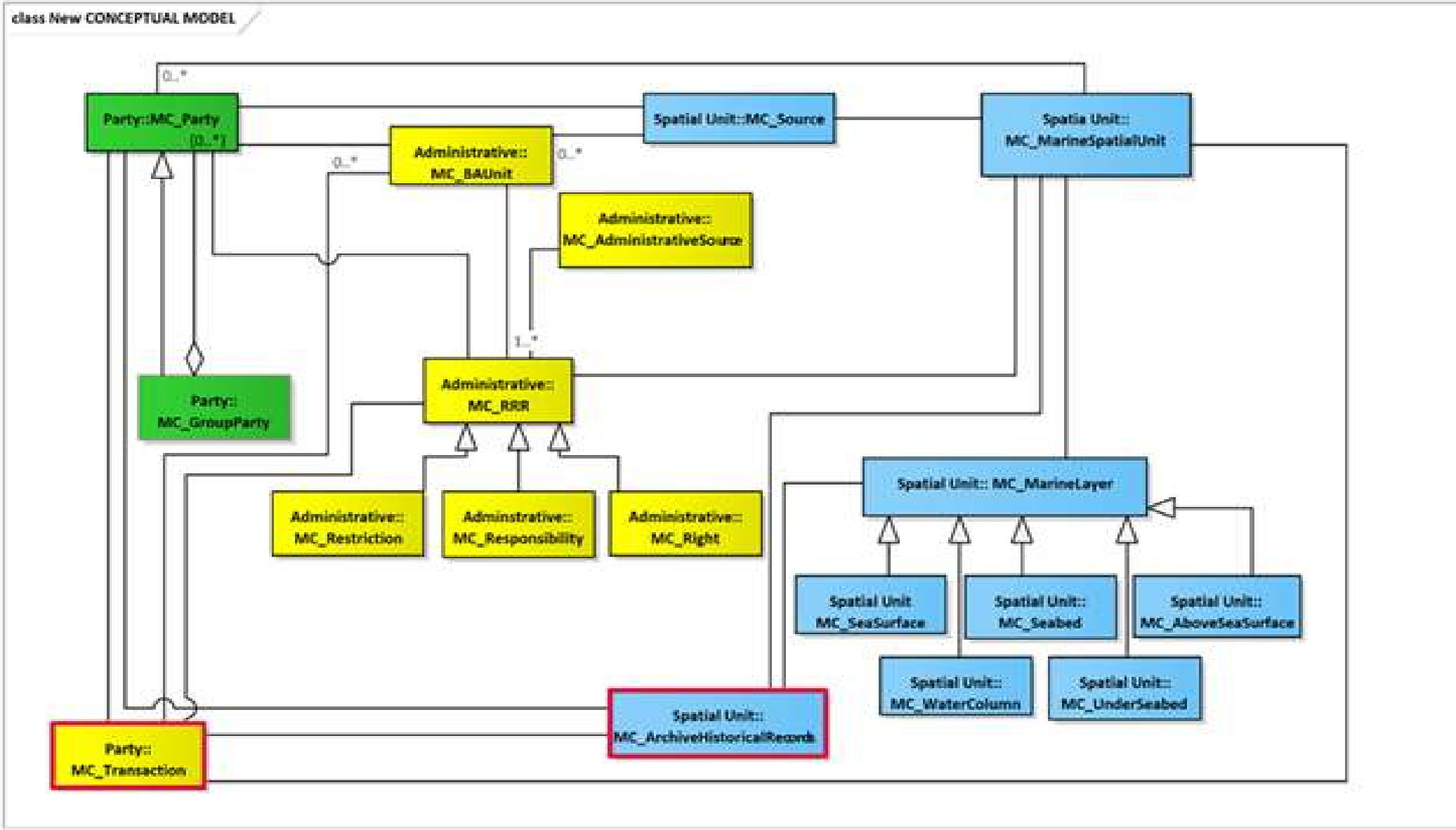
Group/Package	Subclasses
Party	MC_Party MC_PartyMember
Administrative	MC_RRR MC_Right MC_Responsibility MC_Restriction MC_BAUnit MC_AdministrativeSource MC_Transaction
Spatial Unit	MC_MarineSpatialUnit MC_MarineLayer MC_Source MC_SeaSurface MC_AboveSeaSurface MC_WaterColum MC_Seabed MC_UnderSeabed MC_ArchiveHistoricalRecord

Possible classes



Data Type for New classes

Fig. 7: The LADM Conceptual Model



Discussion: Conceptual Data Model

- The developed 4D marine cadastre conceptual data model 4D (3D+T) (MCDM) with the introduced classes comprised of party, administration, and spatial unit packages based on LADM, the 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.
- In this research work, the prefix 'MC_' designates the Marine Cadastre and is utilized.
- The MC_Party is organized in GREEN color and subdivided into MC_Party and MC_GroupParty. As the administrative Unit, the MC_Party package in this work acquires the MC_Transaction class, which specifies who has superior jurisdiction over maritime operations.
- The MC_Administrative in YELLOW, 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.
- The MC_ArchiveHistoricalRecords class is introduced to the spatial unit, enhancing record update of changes, and relates by association to MC_Party, MC_RRR, MC_BAUnit, and MC_SpatialUnit.
- The MC_AchiveHistoricalRecords relate by association to MC_Transaction, MC_Party, MC_Spatial Unit, and MC_MarineLayer, respectively.

Conclusion

- 4D cadastre is a **powerful tool** for **managing properties over time** in **both land and marine environments** & **ensures accurate tracking of temporary changes, legal rights,** and **environmental impact**.
- It is crucial for infrastructure projects, resource management, and urban planning.
- This study **introduces the 4D (3D + Time) Marine Cadastre Conceptual Data Model (MCDM)** for marine property management,
- **Integrate temporal elements to the current 3D Malaysian marine Cadastre data Model**, particularly for the Terengganu shoreline modeling.
- The model is expected to **track both valid and transaction time**, ensuring accurate data changes over time.
- Future work would focus on data model development, visualization, and validation.

Future Works:- Model Development & Validation,

Data Collected

- Study Area Orthophoto, (Fig. 8) Via Drone Technology
- Study Area Digital Elevation Model (Fig. 9) Via Drone Technology
- Cadastral lots to be collected

Fig. 8 Orthophoto, August 2024

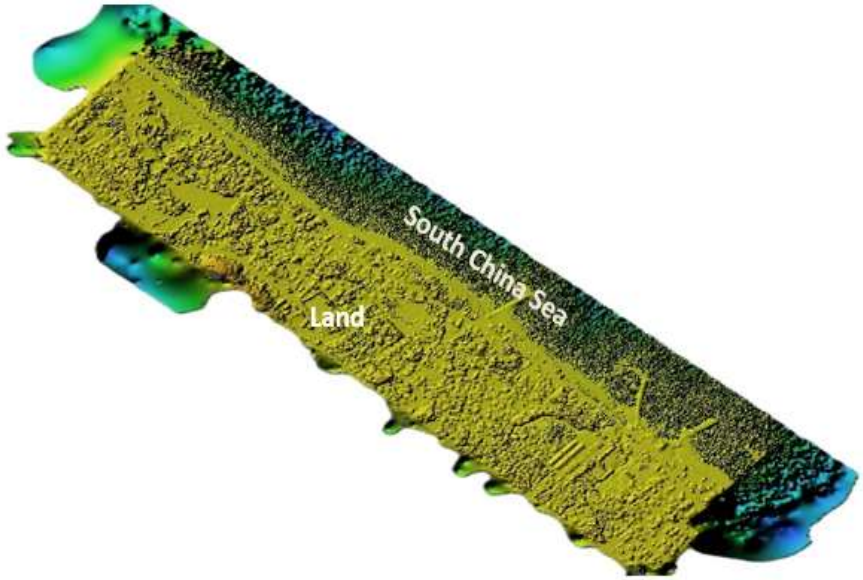
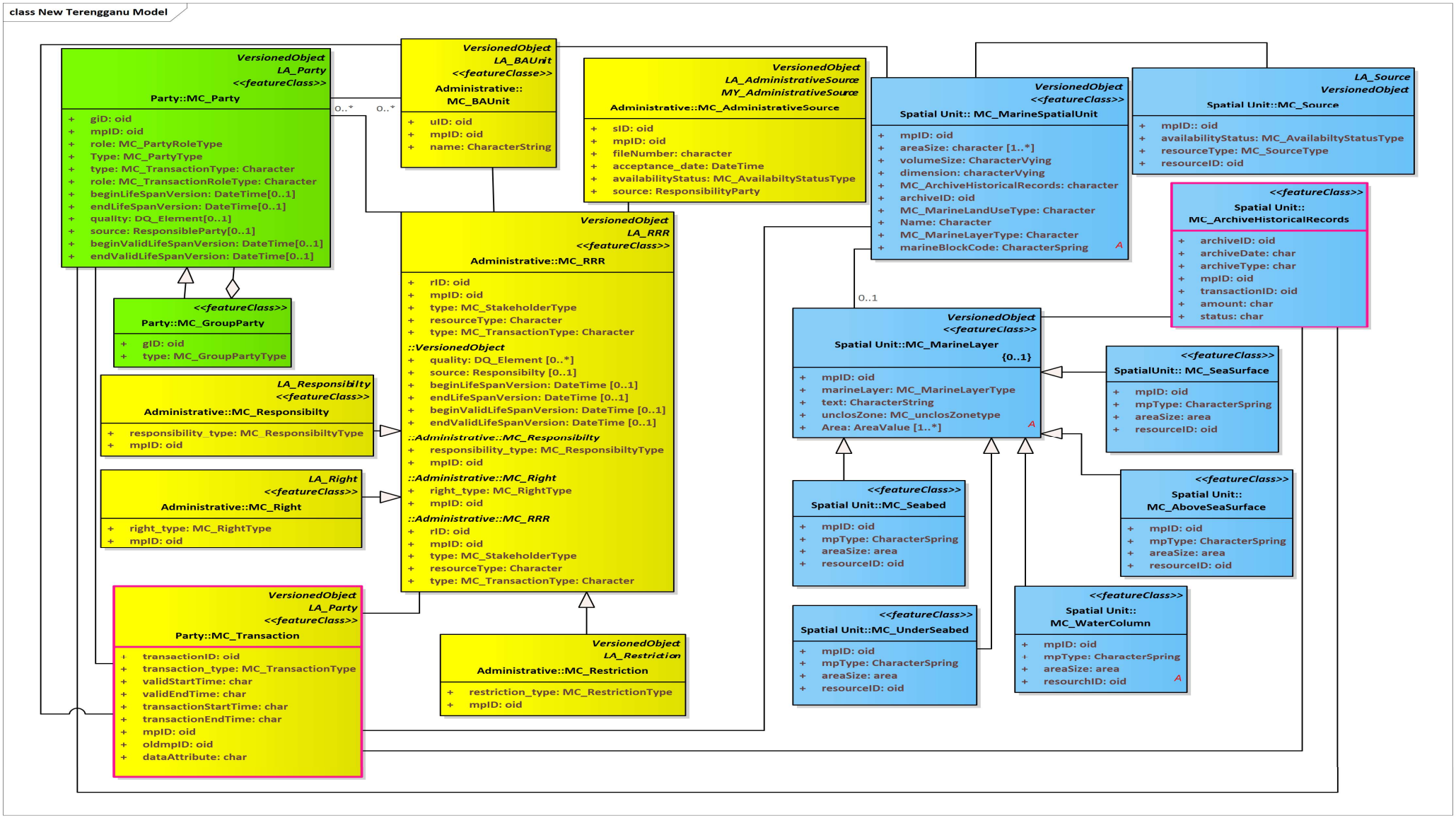


Fig. 9: Digital Elevation Model (DEM), August 2024

The Logical Data Model



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Thank you