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Application of Biomorphic Concepts in the Design and Development of the Banggai Port Terminal in Banggai Laut Regency

Yayu Marliani S[1], Nashrah Arsyad[2], Andi Muhammad Ikhsan[3]
[123] Muslim University of Indonesia
* Email correspondence; zubairyayu@gmail.com

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Abstract

Banggai Laut Regency is an archipelagic area, where the presence of ports plays a strategic role as the main hub for passenger mobility, logistics distribution, and inter-island connections. This terminal is classified as a collecting port, but the increase in operational activity intensity over the past few years has not been matched by adequate capacity and quality of facilities. This situation has led to several architectural problems, including limited waiting room capacity, circulation conflicts between passengers, vehicles, and goods, as well as suboptimal provision of supporting facilities that meet port service standards. The aim of this study is to analyze the application of biomorphic concepts in the design development of Banggai Port in Banggai Laut Regency. To achieve the research objectives, a descriptive method with qualitative and quantitative approaches was used. Data collection was carried out through field observations, interviews with relevant parties, as well as a literature review of regulations, technical standards, and relevant literature. The results of the analysis indicate that the design concept which adopts a biomorphic architectural approach through form transformations inspired by the morphology of the Banggai Dragonet (Pterapogon kauderni), an endemic species of Banggai Laut Regency is feasible. This approach is combined with a visual interpretation of ocean wave rhythms as a representation of the coastal area's character.

Keywords Banggai Port; Circulation; Development; Passenger Terminal; Biormofic Architecture

INTRODUCTION

Indonesia is the largest archipelagic country in the world that has more than 17,000 islands with a regional character that relies heavily on the sea transportation system as a link for social, economic, and logistics distribution activities. In the national transportation system, ports not only function as a place for passengers and cargo and cargo and unloading, but also serve as a transportation network node that determines the level of connectivity between regions. The existence of ports supported by adequate facilities and infrastructure

will improve mobility efficiency, strengthen trade networks, and encourage regional economic growth, especially in archipelagic areas that have a high dependence on sea transportation.

Banggai Laut Regency is one of the districts in Central Sulawesi Province which is geographically dominated by water areas and small island clusters. This condition makes sea transportation the main mode that connects population mobility, distribution of basic needs, and economic activities between islands. One of the infrastructures that has a strategic role is the Banggai Port Terminal which functions as a public port for passenger services, loading and unloading activities, as well as embarkation and debarkation of ships. Based on the Regional Regulation of Banggai Laut Regency Number 9 of 2015 concerning the Regional Spatial Plan of Banggai Laut Regency for 2015-2035, Banggai Port is designated as a collecting port that serves inter-district and inter-provincial shipping networks, so its existence is an important part in supporting the regional transportation system.

The increase in port service activities in recent years has not been matched by the improvement in the quality of available space and facilities. Existing conditions show that the passenger waiting room of about 300 m^2 with a capacity of 150 people often experiences excess capacity, especially when there is the arrival of several ships in close proximity or during the homecoming and long holiday periods. On the other hand, the circulation pattern in the terminal area still shows the crossover between passenger lanes and operational vehicle lanes and loading and unloading activities. This condition not only reduces user comfort, but also increases the potential for circulation conflicts and risks to the safety and security of activities in the port area.

This problem is strengthened by the suboptimal quality of supporting facilities, such as limited information systems, sanitation facilities that do not meet service standards, uncomfortable waiting areas, and lack of protection from sun heat and rain on the circulation route to the pier. If this condition continues, the quality of port services will decline further and it will be difficult to accommodate the increase in the number of users in the future. Therefore, terminal development is not enough to be carried out through the addition of building area alone, but also requires spatial planning, improvement of service quality, and the provision of facilities that refer to port implementation standards as stipulated in Government Regulation Number 61 of 2009 concerning Ports.

On the other hand, most port terminal development in Indonesia is still oriented towards fulfilling technical aspects, space capacity, and operational efficiency. This approach is indeed able to improve the service function, but it often does not provide an architectural identity that is able to represent the character of the area where the port is located. In fact, as the main entrance to a region, port terminals have the potential to build an image of the region through the expression of shapes, spaces, and visual characters of buildings that reflect geographical conditions and local wealth. Thus, the development of port terminals is not only seen as a provider of transportation infrastructure, but also as an element that forms regional identity (*sense of place*) that can strengthen the attractiveness of the region.

One of the approaches that is considered relevant to answer this need is Biomorphic Architecture. This approach develops architectural forms through the process of interpretation and transformation of biological characters found in nature into the composition of mass, space, structure, and façade elements of buildings without eliminating the principle of functionality. In the context of Banggai Laut Regency, the application of the biomorphic concept has strong relevance because this area has an endemic fauna that has been known internationally, namely the Banggai Dragonfly Fish (*Pterapogon kauderni*). The morphological characteristics of the fish, such as the proportional body shape, radially developed fins, and harmonious movement patterns in coastal ecosystems, provide conceptual inspiration for the formation of building masses. The inspiration is then combined with the character of sea waves as a representation of the dynamics of the maritime area, resulting in a terminal design that not only meets the demands of the transportation function, but also presents a distinctive visual identity.

Based on this description, this study aims to apply the concept of Biomorphic Architecture in the design of the development of the Banggai Port Terminal in Banggai Laut Regency as an approach that is able to integrate functional, aesthetic, and local identity aspects. Through the application of shape transformation sourced from the morphology of the Banggai Dragonfly Fish and the characteristics of the coastal environment, it is hoped that the terminal design can improve the quality of service, create a more effective spatial and circulation system, and present buildings that are adaptive to the tropical climate while strengthening the image of Banggai Laut Regency as an archipelago that has a rich ecological and maritime culture.

METHODS

The planning and design of the Banggai Port Terminal uses a descriptive method with a qualitative and quantitative approach. The qualitative approach is emphasized on descriptive and exploratory aspects through precedent studies or comparisons of similar buildings (Bau-Bau, Bakauheni, and Jayapura Ports). A quantitative approach is used to support analysis related to the calculation of projected passenger numbers up to the next 20 years and to determine the amount of space precisely. Primary data collection was carried out through direct observation at Banggai Port to map site conditions, identify circulation conflict points, and evaluate the capacity of existing facilities. Secondary data, such as general port service standards, were obtained from relevant government regulations and interviews with several parties of the Bangai class II Port Operator Unit (UPP). All of the data is then synthesized in the macro and micro analysis stages which include site processing, structure, utility, and architectural form transformation.

FINDINGS AND DISCUSSION

Development of the Integrated Banggai Port Terminal

The development of the Banggai Port Terminal is carried out to increase operational capacity and the quality of passenger services according to projected needs for the next 20 years. The terminal area, which was originally around 300 m² and often experienced excess capacity, was increased to 2,867.03 m². This development not only expands the building, but also rearranges the space and service system to meet port standards that are more effective and able to support the development of sea transportation in Banggai Regency. In site arrangement, existing conditions show an overlap between passenger circulation, operational vehicles, and loading and unloading activities, causing movement conflicts. To overcome this, the siteplan is designed with a clearer division of zones, including Passenger Zones, Vehicle Zones, Vital Areas, and Dock Zones. The division is able to separate each activity so that circulation becomes safer, organized, and more efficient.

The terminal building has also undergone a thorough change. The previous conditions that were uncomfortable, lacked weather protection, and did not reflect the identity of the region were developed into terminals with a modern tropical architectural approach combined with a biomorphic concept. This design optimizes natural ventilation, natural lighting, and the use of shading elements to improve thermal comfort while creating a more comfortable and functional waiting room and arrival area. In addition to the main building, supporting facilities were also developed through the rearrangement of sanitary rooms, waiting rooms, information systems, administrative areas, and commercial facilities. All of these facilities are integrated into supporting buildings so that they are able to improve service quality and support terminal operations more optimally. The arrangement of parking areas is also an important part of the development of the area. The parking area that was previously unarranged is now designed separately from the logistics line and integrated with the Vehicle Zone. This arrangement creates more orderly vehicle circulation, provides a safe drop-off area, and separates vehicle lanes from pedestrian movements so that the safety and comfort of terminal users can be more guaranteed.

Location

Site Location and Analysis

The design location is in Lompio Village, Banggai District, Banggai Laut Regency, Central Sulawesi with a footprint of about 1.9 hectares. The selection of this location is based on the existing position of Banggai Port which is very strategic as the capital of the district and the central point of sea connectivity in the area. The site faces north-northeast, directly towards the waters of the Banggai Sea, which provides an open view of the sea and ease of access for ships.

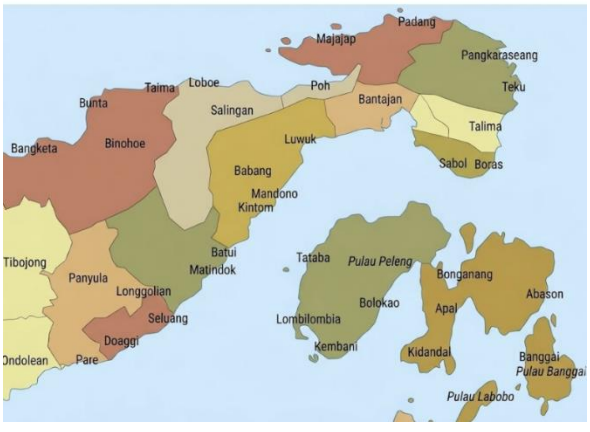

Figure 1. Administrative Map of Banggai District Image Source: Google Maps

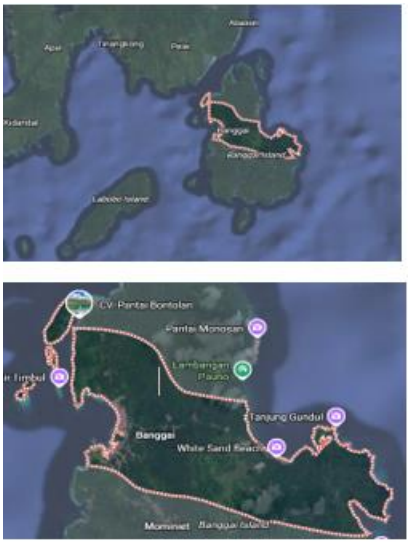

Figure 2. Site Location Image Source: Author, 2026

To avoid overlapping activities (conflict points), the port footprint is divided into four main zones:

1. People Zone: Placed in the middle and north of the site, making it easier for passengers to access without disturbing the logistics area.
2. Vehicle Zone: Located on the right side of the site to facilitate heavy equipment operations and cargo circulation from the dock to the stacking field.
3. Vital Areas: Placed in areas with a high level of security that can only be accessed by officers.
4. Pier Area: As a vital meeting point between the land and sea sides managed with a strict safety flow system

Definition of Biomorphic Architecture

The term biomorphic comes from the Greek, which *is bios* which means life and *morphe* which means form. Biomorphic architecture is a design approach that transforms the shapes, patterns, and structures of biological organisms into architectural forms (Senosiain, 2003). In contrast to organic architecture, which focuses more on site integration, biomorphic architecture explicitly extracts natural geometry both flora, fauna, and landscape elements as a solution to functional, structural, and aesthetic problems of buildings (Feuerstein, 2002). According to Aldersey-Williams (2003), the application of the biomorphic concept in modern architecture is not just mimesis (imitation) of natural forms literally (*literal translation*), but through the process of abstraction and technical rationalization. This is in line with the principles of bioclimatic design, where adapted natural forms must be able to provide adaptive responses to microclimate conditions, such as optimization of natural lighting, air circulation, and structural efficiency.

Building form before development

The initial shape of the Banggai Port Terminal building is dominated by a simple mass in the form of a rectangular prism designed based on the needs of operational

functions. The configuration of the building is rigid and only focuses on fulfilling terminal activities, so it has not considered aesthetic aspects, response to coastal climate, and regional character. The shape of the building can be seen in the picture below

Figure 3. Building Shape Before Development
Source : Author, 2026

The appearance of the building has not been able to reflect the local identity and maritime potential of Banggai Laut Regency. Therefore, it is necessary to develop a more dynamic building form, adaptive to the environment, and have a more representative architectural character as the face of the port terminal.

Shape Transformation

Step 1: Establishment of Basic Modular Geometry The design process begins with the arrangement of a very basic building mass, which is in the form of rectangular prism blocks. This rigid and modular geometric shape acts as an initial functional foundation, designed solely to accommodate the space efficiency and standard operational needs of a port terminal.

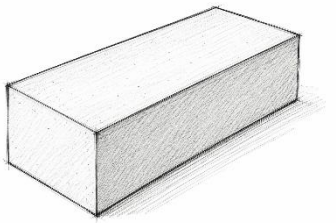

Figure 4. Building Base Shape, Square Beam
Source : Author, 2026

Step 2: Introduction of Dual Biomorphic Concepts (Fish & Waves) At this stage, the identity of the coastal nature is incorporated through a biomorphic approach that takes two metaphors at once.

- **First:** Extraction of specific morphology from the Banggai Dragonfly (*Banggai Cardinalfish*), by highlighting the proportions of the pelvic fin / ventral fin.

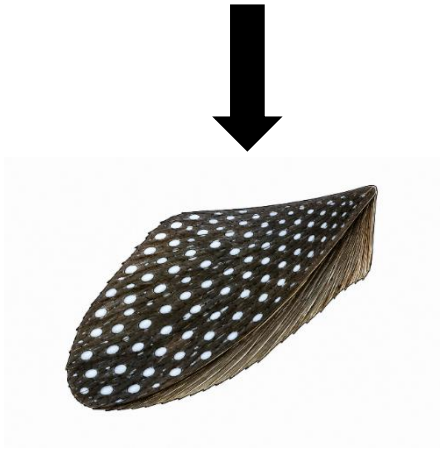

Figure 5. Basic Building Shape, Cardinalfish Fin
Source : Author, 2026

Second: Analysis of ocean wave patterns to capture the essence of rhythmic, dynamic, and fluid water movements.

Figure 6. Basic Shape of Building, Sea Waves
Source : Author, 2026

Step 3: Volumetric Transformation and Conceptual Fusion Entering the fusion phase, the mass of the originally static rectangular building begins to be manipulated. The base volume of the building is flexibly chiseled, retracted, and curved. The roof surface is transformed into a continuous wavy plane. This curvature is not just a random shape, but rather the

result of a visual marriage between the curved lines of a fish's fin and the rhythm of the tides of the ocean waves, creating a much more organic and lively volume structure.

Figure 7. Building Roof Shape, Combination of Cardinalfish Fins & Sea Waves
Source : Author, 2026

Step 4: Final Result of Architectural Integration The final stage shows a complete form of iconic architecture, where the function of the façade of the modern port has been perfectly integrated with the biomorphic beauty. The shape of the gold-colored roof now stands with a curved silhouette and sharply tapered edges. This final design straightforwardly and elegantly manifests the form of a cardinal fish fin and a wave roll simultaneously, creating a building landscape that is in harmony with the surrounding marine ecosystem and tropical topography.

Figure 8. Terminal Front View
Source : Author, 2026

Figure 9. Rear View of the Terminal
Source : Author, 2026

CONCLUSION

Based on the results of the research, the development of the Banggai Port Terminal in Banggai Laut Regency is carried out to meet the needs of port services and operations within the next 20 years. The terminal area which was previously around 300 m² was developed to 2,867.03 m² as a solution to the limited capacity in the existing conditions. In addition, the rearrangement of the siteplan through the division of passenger zones, vehicles, vital areas, and piers is able to reduce circulation conflicts, improve security, and support the smooth running of operational activities. The development also includes improving the quality of the main building, supporting facilities, and parking system so that terminal services become more organized and efficient. In terms of architecture, the design carries the concept of Biomorphic Architecture inspired by the shape of Fish.

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