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Urban Fabric Investigation: A Review of Spatial Solid-Void of A District Center

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ABSTRACT

The construction of a new national capital city impacts the development of surrounding areas to provide public facilities and infrastructure in the context of urbanization. Such spatial impact on these locations must be controlled to prevent regional fragmentation. Penajam District, the capital of Penajam Paser Utara Region, is the closest district to the construction site of Indonesia's New National Capital City, which tends to become the new epicenter of urbanization. Not only does it connect the mainland with the other islands, but it also has the potential of its vast unbuilt area and the agriculture sector. Exploration of the spatial characteristics of the district center as a community node is carried out to detect certain patterns or forms of community economic activity and recommend the prospective expansion of the area. This research aims to discover the pattern of Penajam's District urban fabric in terms of built area and the linkage that connects part of the district to understand the pattern for future development. By employing the figure-ground and linkage map, the investigations are done by a qualitative description of 4 phases (from 2006 to 2022) of the site's growth to illustrate the development direction of the built-up area. Using the satellite data, the solid-void map area was drawn using arc GIS software to depict the tendency of the configuration of the solid and indicate the linkage of the unbuilt area. The results show that the general characteristics of solids are homogeneous, however, there are two typologies of solid, the scattered in the inland and the linear in the coastal area. The linkage in the center area is a mega form, while in the recent development, the linkage is a group form.

1. Introduction

The development of new urban centers, such as The New Capital City, invariably precipitates urbanization, driven by population influx, expanding urban boundaries, and the transformation of surrounding areas into buffer zones. While urbanization is an inevitable consequence of such development, its impact necessitates careful consideration and mitigation strategies. Previous

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spatiotemporal analyses have demonstrated that urbanization in central cities significantly influences spatial patterns, often leading to the fragmentation of open spaces (Li et al., 2019). For instance, a study conducted in Balikpapan City revealed that urbanization, propelled by industrial and economic factors, results in concentric urban forms characterized by interstitial spaces within the primary road network, ultimately driving infill development (Jordan et al., 2021). This phenomenon arises from the disparity between the pace of building construction and road network expansion, which serves as a critical link between urban centers.

Buffer areas, situated at the periphery of major cities, are particularly susceptible to urbanization pressures. These areas often function as access points and provide essential natural and human resources to the central city. Consequently, these areas become attractive destinations for population migration seeking economic opportunities generated by the main city's growth. This is particularly relevant in the context of IKN, which primarily serves administrative and office functions, thereby pushing residential and supporting infrastructure development towards its periphery. The interconnectedness of human activities and subsequent infrastructure development inevitably foster contact and integration between the main city and its buffer zones (Taufiq, 2020). However, buffer areas are crucial in regulating urbanization and require specific planning attention. Transition areas' presence is significant in fostering economic activity, and thus, societal well-being necessitates a balanced approach. As Pranadji suggests, effective buffer area planning should prioritize four key aspects: the integration of regional resources into the production chain, the development of robust economic systems, the establishment of supportive political frameworks, and the implementation of efficient financial management and organizational structures within these zones. Furthermore, from a land-use perspective, buffer area planning is essential for the conservation of land, water resources, and regional ecosystems (Maria et al., 2010; Pranadji, 2006).

Mitigating the potential for urban fragmentation, a common consequence of large-scale development and urbanization, is crucial. Urban fragmentation arises from spatial heterogeneity and landscape modifications inherent to urban growth (Liu et al., 2016). Of particular concern in the context of East Kalimantan is the conversion of green spaces and subsequent deforestation driven by development, leading to environmental degradation. This poses a significant threat and necessitates careful consideration to minimize adverse social and economic impacts on communities (Salsabila & Nurwati, 2020). A proactive approach to development, integrating the forest city concept into the IKN master plan alongside comprehensive spatial and physical development strategies, is recommended. This integrated approach aims to ensure the preservation and continuity of the forest ecosystem, recognizing the interconnectedness and mutual impacts between the urban environment and its surrounding areas (Mutaqin et al., 2021). However, a gap exists in current research regarding the identification of central points within sub-districts as reference points for predicting and managing potential urbanization areas. Further investigation into this aspect is critical for developing targeted and effective planning strategies.

To address the aforementioned challenges, this study proposes a planning approach that focuses on the spatial structure of a strategically located sub-district center within the IKN buffer zone, aiming for its eventual integration with the central IKN area. The initial phase of this approach involved mapping the sub-district identified as a potential support center for IKN to pinpoint areas susceptible to urbanization. Sepaku District, in North Penajam Paser Regency, designated as the IKN site, is slated to become a hub for trade, services, offices, and public amenities at the sub-district level, according to the 2012-2033 regional planning document. However, the district's administrative center currently resides in Penajam District, designated as a supporting area. This research focuses on identifying activity centers within Penajam District that exhibit the potential for urban growth. The long-term objective is to develop a planned infill spatial structure for these areas, mitigating the risk of fragmented urban development.

1.1 Figure-ground investigation

Figure-ground theory is frequently employed to analyze the interconnectedness of areas that develop horizontally. This theory is related to land use, focusing on the filled and utilized spaces to avoid voids, that in urban space's context often perceived negatively. Functionally, open spaces serve as transitional areas between public, semi-public, and private interests, forming a sequence and broader spatial structure relationships. Within an urban context, the resulting composition typically comprises a combination of grid, angular, curvilinear, radial concentric, axial, and organic forms, or modifications of these structures (Trancik, 1986). Understanding these particular patterns is not only beneficial for the user but also crucial for urban planners. Because of evolution, many decisions to develop the urban form create a diverse fabric that depicts the changes and characteristics of the land utilization. Although it is typically used to analyze and understand developed urban areas, planners also employ this approach to interpret the spatial identity and experiences necessary for planning the development of existing areas or designing infill development within historical districts. (Boeing, 2021; Eu & Jen, 2018; Sen, 2010).

1.1 Urban form for sustainability

In the context of regional sustainability, evaluation and categorization are integral processes of preservation and development acts. This involves understanding how small components, such as structure, function, and origin, are formed and identified to establish the basis for character and inform decisions on whether to preserve, update, or improve a particular urban space (Kropf, 2011). From a structural perspective, the arrangement of buildings and the connections within the street network can create identifiable patterns and systems within a city. Functionally, morphological patterns can enhance the understanding of the spatial logic behind the formation of the built environment, aligning with the planned architectural philosophy. For instance, the composition of spaces, interwoven between buildings and large patches of open space, often indicates low-density development. In contrast, linear development patterns illustrate the extension of infrastructure towards more inland areas. This serves as a foundation for concluding the specific characteristics of urban spaces, which can then be recognized as part of the city's identity (Farzaneh et al., 2017; Tallo et al., 2014). On the other hand, such urban form is closely related to the function of the area which shape the building arrangement due to the activities. Besides, urban morphology is closely related to the function of an area in accommodating user activities. Commercial areas typically have a linear characteristic that branches off to flank main thoroughfares, while residential areas tend to be more homogeneous and compact, designed for space efficiency to accommodate a higher density of housing. (Putri et al., 2016).

2. Methodology

This study adopts a qualitative research approach, employing a naturalistic setting and drawing upon empirical evidence to interpret the phenomenon under investigation. Recognizing the importance of rigorous data collection and analysis in qualitative inquiry (Merriam, 2009), the research leverages field observations and the researcher's analytical skills to enhance the trustworthiness of the findings (Groat & Wang, 2013). Specifically, the study utilizes figure-ground mapping techniques to visually represent built structures (black) concerning open spaces (white), highlighting the interplay between solid and void and enabling a nuanced understanding of spatial composition.

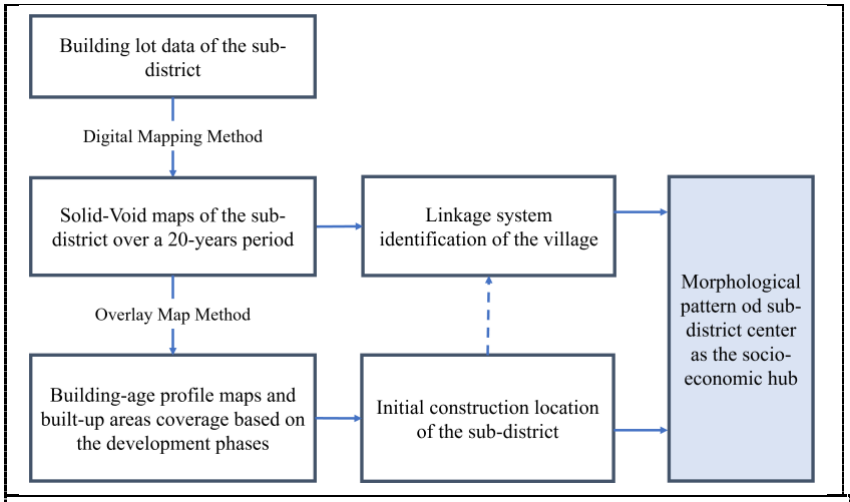

Fig. 1. The research's analytical process

The picture illustrates the general process of this research which includes the digital mapping method in the figure-ground mapping and overlay mapping to discover the building-age profile. To capture the evolution of spatial patterns, solid and void maps were generated for four distinct development phases: 2006, 2010, 2015, and 2022 (Phases 1-4), encompassing regional development trends both before and after the 2019 designation of East Kalimantan as Indonesia's new national capital. Analysis of each phase considers area size percentage, location, and the influence of environmental features, topography, and infrastructure on development patterns (Eu & Jen, 2018; Jordan et al., 2023).

An overlay analysis, spatially integrating the four-phase maps, was then conducted to discern variations in building age based on the presence of built structures. This approach, analyzing the evolving patterns of built and unbuilt spaces within the identified growth hub of Penajam Village, aimed to uncover trends in the direction and spatial distribution of new development. The resulting composite map visually represents building age through a gradient of shades, with each layer representing a distinct development phase and contributing to the cumulative solid composition. Data for this two-dimensional analytical observation, conducted within a macro-planning framework, were acquired through a comprehensive desktop survey incorporating shapefiles from Penajam District Statistics data, regional planning documents for North Penajam Paser Regency, and relevant scholarly literature.

3. Results

This research focuses on Penajam District, East Kalimantan Province, strategically situated in proximity to the designated site for Indonesia's new capital city. The district's robust agricultural and plantation sectors position it as a potential contributor to food security for the burgeoning IKN region. Beyond its proximity to the IKN site, the availability of undeveloped land within Penajam District further enhances its suitability as both a buffer zone and a target area for planned urban expansion. Accessibility to Penajam District from the IKN site is facilitated primarily through the Trans Kalimantan Highway, a major transportation artery connecting South Kalimantan and East Kalimantan Province. Additionally, the district benefits from its connection to Balikpapan City, the economic hub of East Kalimantan Province, via a strategically located port on the eastern coast, serving as a key gateway to the IKN.

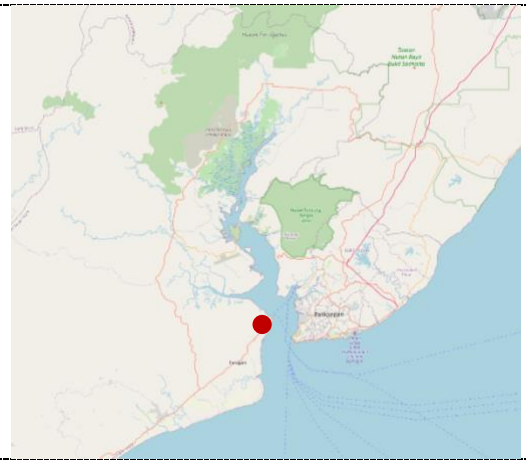

Fig. 2. Location of Penajam District

The investigation into Penajam District's development patterns, particularly as the regency's central hub, focused on analyzing land utilization trends in terms of built (building) and unbuilt (vacant land, streets, parks) areas. Initial observations from Phase 1 reveal a concentration of development (highlighted in yellow in Fig 3) along the coastal fringes and the district's periphery. Subsequent phases (Figs. 4, 5, and 6) exhibit a consistent pattern of construction activity centered around major roadways and extending along the northern and southern coastal stretches. This growth trajectory appears to be influenced by the historically significant economic activity located in the eastern part of the district. It is important to note that before the 2000s, the area under investigation constituted a portion of Balikpapan, characterized by a large landmass bisected by a bay.

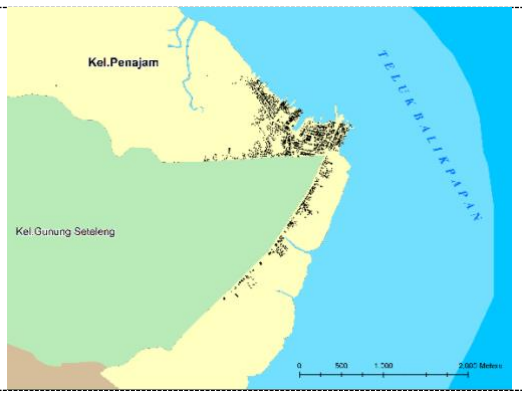

Fig. 3. Built-up area in phase 1

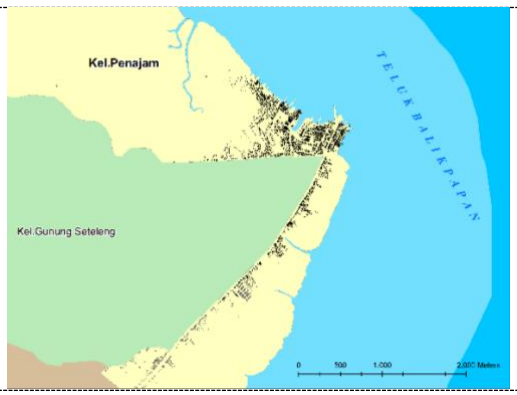

Fig. 4. Built-up area in phase 2

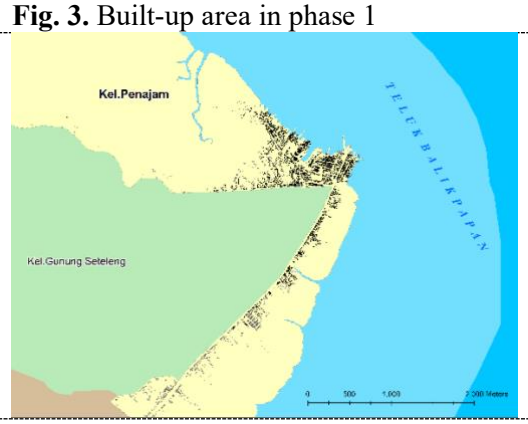

Fig. 5. Built-up area in phase 3

Fig. 6. Built-up area in phase 4

In the initial phase, built-up areas within Penajam District were observed primarily along waterways and major transportation corridors. Figure 7 illustrates this pattern, highlighting a dense concentration

of development in the eastern portion of the study area, while the western region exhibits a more dispersed development pattern. This suggests a trend of urban expansion from the coastal areas towards the inland regions. A closer examination of the spatial distribution of built-up areas reveals a distinct pattern: central areas exhibit a more compact form, while development in outlying areas appears more fragmented. Analysis of the solid configuration reveals a relatively irregular composition with variations in pattern. This irregularity is particularly evident in the road network, characterized by non-uniform patterns and interspersed with linear open spaces. The branching road structure contributes to the formation of development pockets with varying orientations and shapes. Despite the overall irregularity, a more granular analysis reveals identifiable patterns within the solid configuration. These include a grid-like pattern in densely developed areas, a linear pattern along road branches, and a spreading pattern characterizing areas experiencing westward expansion. Furthermore, the predominant solid sizes are small, with limited variation in larger sizes, suggesting a relatively homogeneous built environment (Trancik, 1986).

Contrasting spatial patterns emerge when comparing areas, A and B. Area B, as depicted in Figure 7, exhibits a compact solid structure extending inward from the coastline, characterized by a regular grid-like composition. The void spaces within this area are predominantly perpendicular in orientation, contributing to the formation of a distinct grid pattern interspersed with linear unbuilt areas. The high density of built structures is further emphasized by the narrow white spaces between buildings. In contrast, Area A presents a different pattern, with built-up areas concentrated along the main transportation artery connecting the port in Area B to the inland regions. Development in this area appears constrained by its proximity to the waterfront, resulting in a more scattered distribution of built structures and a less defined road network. The absence of significant road branches suggests a preference for linear development along the existing main road, likely influenced by land availability constraints.

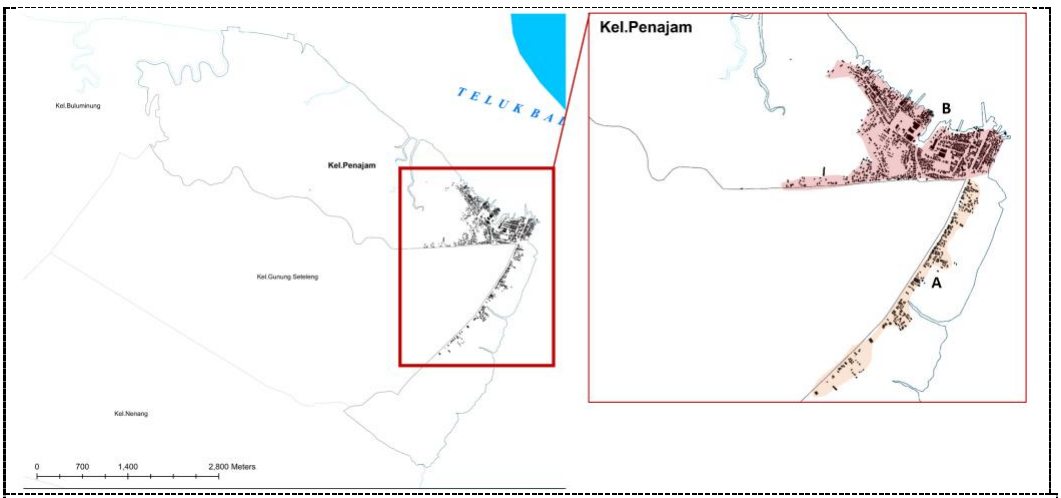

Fig. 7. Solid-void investigation on phase 1

Phase 2 is characterized by notable expansion in the northern and southern regions, as illustrated in Figure 8. This growth extends the existing street network established in the preceding phase. In Area A, new construction predominantly follows the main arterial road, resulting in the emergence of minor street intersections and built areas approaching the boundaries of Gunung Seteleng and Nenang sub-districts. While this phase witnesses an increase in built structures within previously developed areas, it does not translate into a significant expansion of the road network towards the waterfront. Instead, development in Area A during this phase exhibits a pattern of infill, filling in spaces along both sides of the main road in a somewhat fragmented and irregular manner.

Conversely, Area B experiences increased building density along the northern coastline, primarily through infill construction within the existing street grid and previously developed parcels. Along the

southern boundary of the district, development manifests as extensions of existing roads both within and adjacent to the main thoroughfare. Notably, Phase 2 is distinguished by a more heterogeneous development pattern in terms of parcel size and orientation. The fragmented nature of this growth is evident in the irregular spacing between built structures, lacking a discernible, organized pattern.

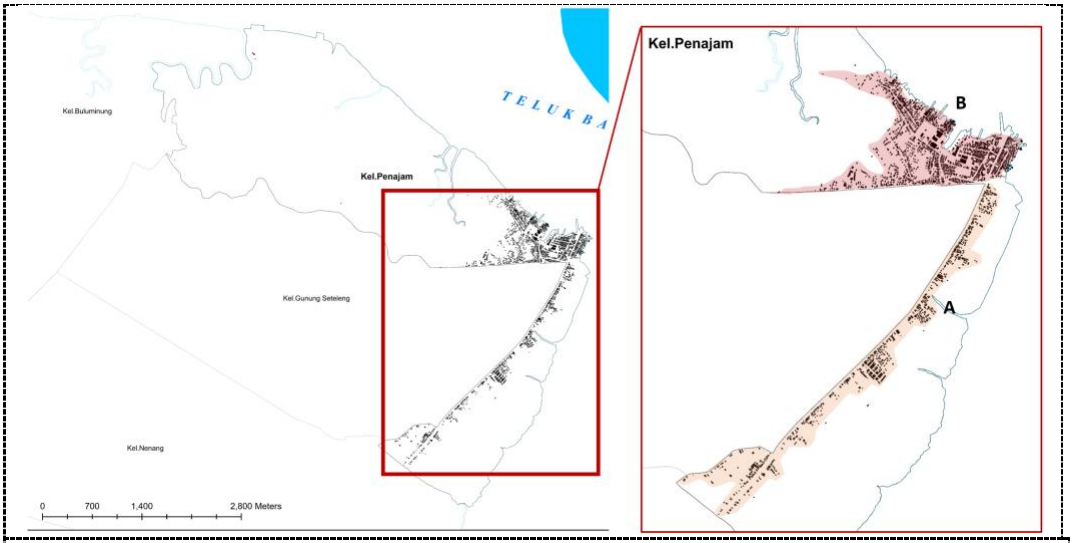

Fig. 8. Solid-void investigation on phase 2

Figure 9 reveals substantial growth during Phase 3, characterized by the emergence of new built-up areas on previously undeveloped land, distinct from earlier development patterns. In Area B, expansion is primarily concentrated in the northern region, manifesting as an extension of the coastal road network and development along the existing main arterial road. A fragmented development pattern is evident along the further reaches of the main road, while infill development contributes to increased density in more established areas.

Concurrently, Area A experiences heightened building density, exhibiting a more organized and regular arrangement in certain sections. However, development in this area remains largely concentrated along the main transportation corridor. A notable addition during Phase 3 is the emergence of a harbor area (denoted as Area C in Figure 9). This new development is directly linked to the main road, creating a circulatory traffic pattern connecting the main road to the northern coastal region. The harbor area distinguishes itself from the surrounding urban fabric with its distinct lot sizes and building scales, contrasting with the more homogenous lot sizes characteristic of the residential regions. Furthermore, the harbor development appears spatially isolated from the existing built environment, likely due to its specialized locational requirements.

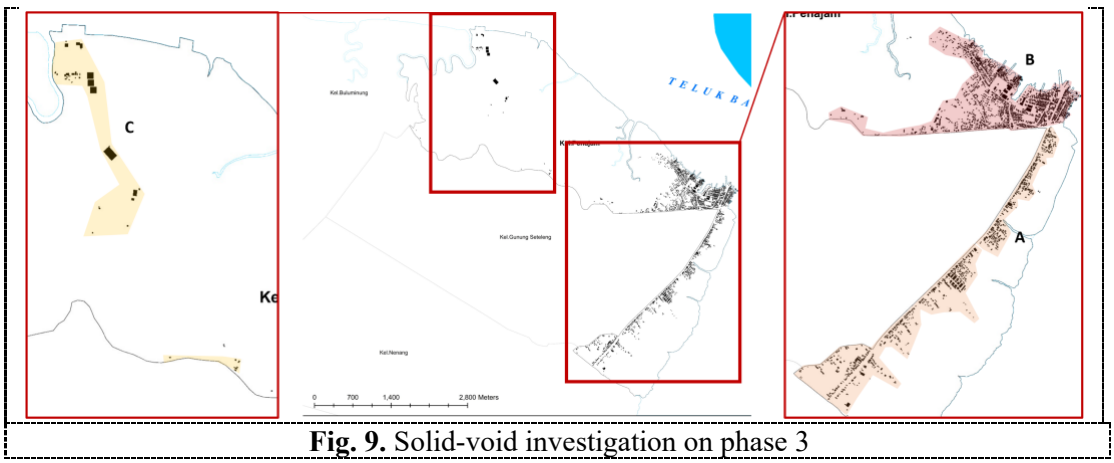

Fig. 9. Solid-void investigation on phase 3

The final phase of data collection, encompassing 2022, provides a snapshot of development patterns closely approximating the current conditions in Penajam Village. As depicted in Figure 10, this phase, while exhibiting continued growth, does not demonstrate the same level of expansive spatial expansion observed in previous phases. In Area A, building density remains significant, maintaining a comparable built space network to the previous phase. However, the distribution of built structures appears more dispersed, extending more prominently towards the coastal area. This growth takes on a more compact, linear form, oriented perpendicularly to the main arterial road. Area B, in contrast, experiences densification through infill development within the existing built footprint. This results in a more visually unified and contiguous built environment, particularly noticeable in the northern coastal region. Limited expansion of the road network is observed in the northern section, while scattered additions of individual structures occur along the main road. Within Area C, the harbor area, growth is concentrated around the port facilities, characterized by larger lot sizes compared to other areas. Additionally, development extends southward from the port in a more dispersed and fragmented pattern.

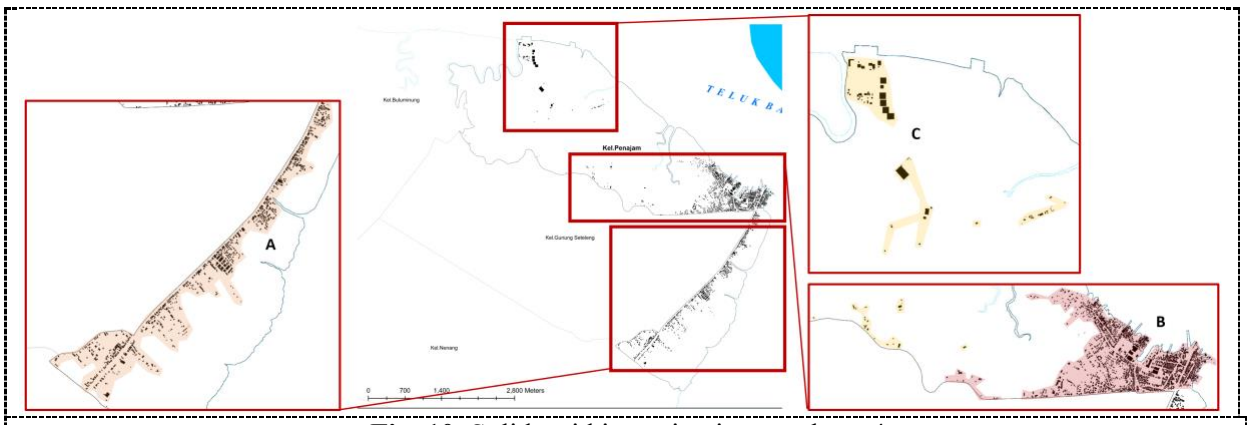

Fig. 10. Solid-void investigation on phase 4

Following the compilation of individual phase maps, an overlay analysis was conducted to identify the oldest areas within the study region, hypothesizing the potential role of the area as the epicenter of urban development. This methodology aligns with established building-age profile techniques, which utilize a chronological series of maps to discern and analyze patterns of urban growth across distinct developmental phases (Jordan et al., 2021; Rice, 2008). In this research, building-age data is derived from the presence of built-up areas as identified on the spatial maps generated from satellite imagery.

Figure 11 presents the compiled map data, illustrating the spatial distribution of building establishment periods within the study area. The overlay analysis reveals that the oldest built environment, represented by the darkest shade in Figure 11, is concentrated along the eastern coastal region. This area's presence across all four temporal datasets confirms its early development. Conversely, the northwestern portion of the district, depicted in the lightest shade, indicates the most recent construction activity. Quantitative analysis of the compiled data, as illustrated in Figure 12, reveals that by this final phase, built structures encompass approximately 70% of Penajam district's total land area. Furthermore, a notable trend of development concentrated along the main road network is observed, with significant expansion occurring in 2010 (15%), followed by continued, albeit slower, growth in 2015 (12%) and 2022 (below 5%). This suggests a period of rapid development centered around 2010. Interestingly, recent development in 2022 appears to shift northward, aligning with the designated location of the Indonesia's new capital city development. This is evidenced by the concentration of built-up areas along the northern main road. The spatial distribution of buildings in Figure 12 also highlights the historical development pattern oriented around the port, serving as a critical linkage to the adjacent urban center. Based on these spatial patterns, it can be posited that the

oldest section of the district, the eastern coastal region, represents the historical epicenter of urban development.

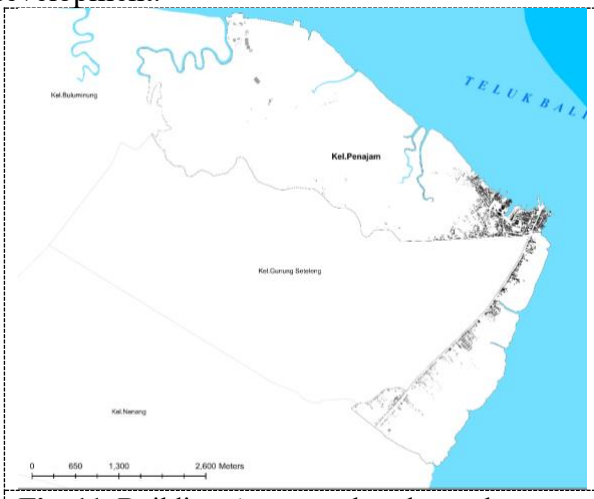

Fig. 11. Building-Age map that shows the different built-up areas from its presence

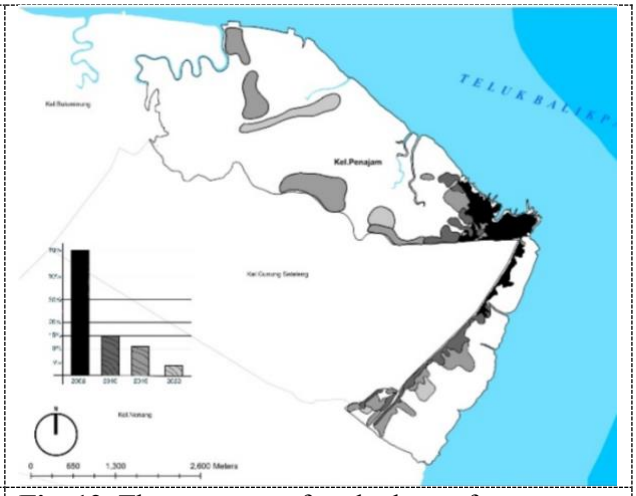

Fig. 12. The coverage of each phase of development

The following investigation focuses on the spatial linkage, the white area (void), and generally the street and vacant land. This analysis aimed to look at the tendency of connectivity and human movement on the morphological aspects. This analysis's observation area is the center of the area found in the previous study. While looking through a two-dimensional perspective, the land use and solid trends also contribute to understanding the formation of such composition.

In general, 3 forms of spatial linkage, in terms of vacant land, were found, which can be seen from the composition of voids to solids, namely a combination of mega form, group form, and compositional form, which fills the inside of the built area. Figure 13 depicts the general linkage composition that forms diverse open space typologies in 2022. It can be seen that the void type tends to follow the solid form, such as a relatively small and connected open space formed by the grid composition of the built area. Another example is the open space inside the enclosed arrangement of buildings formed by the composition of scattered construction along the street in a loop.

Meanwhile, the street-type void formed a linear-angular pattern with one continuous circulation axis, the main street between the port and deeper areas. This main circulation path connects Penajam with the Trans Kalimantan route, which lies between East Kalimantan and South Kalimantan. The linkage pattern on the main route is linear, with an angular direction in the intersection. It connects the smaller intersections, which are built in a regular pattern in the oldest area while growing irregularly in the developed area.

Fig. 13. Linkage investigation of the whole district circulation path

A detailed analysis of the void network reveals a hierarchical structure. Secondary streets branch out from the main arterial road, connecting interior areas to the coastline and creating a fine-grained network within the urban fabric. Interspersed within this network are clusters of open spaces exhibiting a *group form* configuration, as illustrated in Figure 15. These voids, often representing aggregations of open areas linked by pre-existing pathways, emerge organically within the built environment. Along the primary transportation corridors, a contrasting *megaform* pattern is observed. These larger expanses of void space, as depicted in Figure 134, punctuate the linear route, and have a visual prominence accentuated by the clearly defined boundaries delineated by buildings and roads, particularly in densely developed areas. This juxtaposition of built and unbuilt spaces highlights the dynamic interplay between *megaform* and the surrounding urban morphology. Conversely, *compositional forms*, characterized by smaller, enclosed open spaces, are distributed more sporadically throughout the study area. These interstitial voids, typically representing private yards or parking areas, occupy the gaps and setbacks between buildings, reflecting a more intimate scale of spatial organization within the urban fabric.

Fig. 14. The compositional form and mega form of void in the regular pattern of void

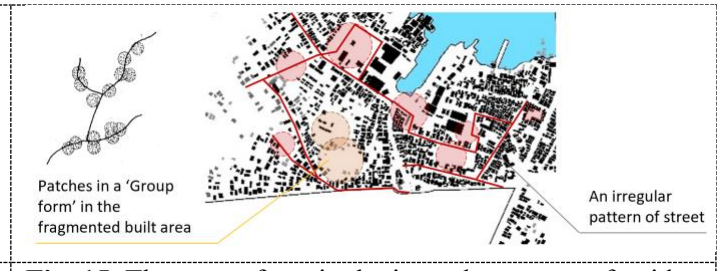

Fig. 15. The group form in the irregular pattern of void

Spatial analysis effectively reveals the overall structure of the district and the interconnections between its various zones. Using linear street patterns as a framework, the analysis identifies distinct urban form patterns, such as building strips along main roads and the spatial relationship between built

structures and open areas. A rhythmic pattern emerges, with buildings forming a continuous sequence along streets, interspersed by voids serving as public spaces, courtyards, or service areas.

Solid-void mapping reveals variations in lot sizes and building arrangements, providing insights into their spatial functions (commercial, residential, or mixed-use). For example, commercial corridors typically exhibit tightly packed solid forms with minimal voids, reflecting a high density of businesses. Conversely, residential areas within the same linear pattern may display a more regular arrangement of houses with larger voids representing yards or communal spaces. By correlating these observations with their functional roles, the analysis effectively categorizes urban forms based on use, offering a comprehensive understanding of the district's spatial dynamics. This understanding is essential for urban planners to guide future development while preserving or enhancing the existing character of the area.

The intricate interplay of streets, open spaces, and buildings reflects a dynamic process shaped by both planned interventions and spontaneous adaptations to functional needs and site constraints. While a repetitive regularity characterizes certain areas, likely indicative of planned development, the overarching spatial structure exhibits a predominantly organic nature, suggesting a significant influence of external factors and emergent patterns of growth. This inherent irregularity in the arrangement of roads and built spaces has become a defining characteristic of Penajam's urban morphology, influencing subsequent land use decisions and shaping future development patterns.

4. Conclusions

This morphological study, utilizing spatial structure mapping and morphological analysis, provides valuable insights into the evolving urban fabric and developmental trajectory of the Penajam area in the context of its proximity to Indonesia's new capital city. The detailed observations, grounded in spatial data and theoretical frameworks, offer a nuanced understanding of the existing urban composition. The implications of this study are multifaceted. For urban planners and policymakers, the findings underscore the importance of considering the historical and spatial context when making decisions about future developments in the buffer area around the new capital city. The observed patterns and trends can inform strategies aimed at balancing development with the preservation of existing urban character and ecological integrity while avoiding urban fragmentation. Moreover, the study highlights the potential challenges of managing urban growth in a way that is sustainable and aligned with the broader goals of regional development.

Looking forward, future research should focus on expanding the scope of analysis to include a broader range of factors influencing urban morphology, such as socio-economic conditions, environmental constraints, and community needs. Additionally, a more comprehensive understanding of the impacts of the new capital city relocation on the surrounding areas is needed a further research to track the evolution of the urban fabric over time.

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