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Assessment of the Suitability of Basic Infrastructure Design to Spatial Land Use Patterns in Slum Settlements: A Case Study of Sepaso, East Kutai

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Abstract: Basic infrastructure plans that are misaligned with an area's spatial needs are among the causes of the low quality of slum settlements in Indonesia. This study aims to evaluate the correspondence between basic infrastructure design and spatial land-use patterns in the Sepaso slum area, East Kutai, based on the 2024 Detail Engineering Design (DED) document. The study adopts a descriptive-quantitative and spatial approach, analyzing the ratio of road network length and drainage channel length to the area of residential, public facilities, buffer/green open space, and access road zones. The results show that the access road zone has the highest infrastructure ratios, namely 30 m of roads and 11 m of drainage channels per 100 m². In contrast, the residential zone, which is the largest zone (4,600 m²), has no internal road network and a relatively low drainage ratio (2.61 m/100 m²). This disparity indicates that the planning has not fully accounted for the intensity of space utilization in each zone. A graphical visualization reinforces these findings, showing that infrastructure distribution tends to be sectoral and not yet spatially equitable. The study concludes that micro-scale design adjustments are needed such as adding local access roads and tertiary drainage channels in the residential zone so that infrastructure can reach the entire area in an equitable and functional manner. These findings have important implications for the planning of other slum areas with similarly dense and spatially fragmented characteristics.

Keywords: Basic Infrastructure; Slum Settlements; Spatial Zoning

1. Introduction

Basic infrastructure planning in slum settlement areas plays a vital role in ensuring the quality of life for marginalized urban communities (Barimani & Karsami, 2018; Trindade et al., 2021). Infrastructure such as local roads, drainage channels, and green open spaces are fundamental elements supporting the social, economic, and health aspects of life in these areas (UN-Habitat, 2020; Hutagalung, 2023). The Indonesian government, through policies like Presidential Regulation No. 2 of 2015 on the National Medium-Term Development Plan (RPJMN) and the Ministry of Public Works and Housing Regulation No. 14 of 2018, has targeted the reduction of slum areas via spatial-based approaches that address the actual needs of communities (Kementerian PUPR, 2018). However, various studies indicate that infrastructure planning is often not adjusted to actual on-site spatial utilization patterns (Susanti & Nugraha, 2021; Priyanto et al., 2022).

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In this context, spatial zoning is a key variable that determines how infrastructure should be designed and allocated. Zoning not only influences the function of space, but also dictates the efficiency of technical services such as the distribution of drainage networks, road networks, and sanitation systems (Setiawan, 2019; Abubakar & Widiatmaka, 2020). Proper alignment between infrastructure provision and spatial zoning enables the creation of areas that are efficient, disaster-adaptive, and supportive of sustainable development (Firman, 2020; Nawir et al., 2023). Conversely, mismatches between zoning and infrastructure networks often lead to technical inefficiencies, isolation of certain areas, and increased flood risk (Rizki et al., 2021; Anggraini & Febrina, 2022).

This research aims to evaluate the extent to which basic infrastructure planning aligns with the actual spatial needs of the Sepaso slum area in East Kutai, based on the available DED documents. By analyzing the relationship between zoning and infrastructure network ratios, this study contributes to strengthening a micro-planning approach based on area function. The study expands the scope of the technical discourse from merely physical development to an adaptive spatial planning process that is responsive to the socio-environmental context (Surya et al., 2020; Handayani & Pradono, 2023).

2. Materials and Methods

2.1. Study Location

This research was conducted in Kelurahan Sepaso, Bengalon District, East Kutai Regency—one of the densely populated areas categorized as an uninhabitable settlement (slum) according to KOTAKU indicators (the national "City Without Slums" program). The study area was analyzed using the Detail Engineering Design (DED) document of 2024. Figure 1 shows the map of the planning area.

Figure 1. Map of the Planning Area

2.2. Research Methodology

This study employs both a qualitative descriptive approach based on technical document analysis and a quantitative-descriptive, spatial-interpretative approach. This mixed approach was chosen because the study aims to:

1. Evaluate the suitability of basic infrastructure plans (roads, drainage, green open space) with the spatial structure of the area.
2. Measure the ratio of infrastructure capacity to the area and function of each zone based on DED technical data.
3. Interpret spatial imbalances, both in terms of network distribution and inter-zone accessibility.

With the following research stages and table Ratio of Infrastructure Length to Zone Area in the Sepaso Area:

1. Document Study: Review the Sepaso Slum Area DED (site plan, technical drawings, zoning, and bill of quantities), and define the zone classifications (residential, public facilities, buffer/green open space, and access road).
2. Quantitative Data Collection: Calculate each zone's area (m²), road length (m), and drainage length (m) from the planning documents, and compile the primary and secondary data into spatial tables.
3. Spatial Suitability Analysis: Use the infrastructure-to-area ratio for each zone to assess the adequacy of technical services, and compare the actual distribution with the ideal needs of each zone.
4. Visualization: Create bar charts and summary tables showing the distribution of infrastructure per zone, illustrating the relationship between the amount of infrastructure and the area's size and function.
5. Interpretation and Conclusion: Identify zones that should be prioritized for infrastructure improvements, and provide recommendations for micro-design enhancements in zones with low infrastructure ratios.

Table 1. Ratio of Infrastructure Length to Zone Area in the Sepaso Area

Zone	Area (m²)	Road Length (m)	Drainage Length (m)	Road/100 m²	Drainage/100 m²
Residential	4,600	0	120	0.00	2.61
Public Facilities	800	25	40	3.13	5.00
Buffer/Green Open Space	1,200	30	60	2.50	5.00
Access Road	1,000	300	110	30.00	11.00

The comparison between infrastructure length and zone area can be expressed quantitatively. For example, the total area of the region $\boldsymbol{L_t}$ is the sum of all zone areas (Equation 1). Meanwhile, the ratio of infrastructure of type j in zone i ($\boldsymbol{R_j}$) is defined as the length of infrastructure type j ($\boldsymbol{P_j}$) divided by the area of zone i ($\boldsymbol{A_i}$), which can be normalized per 100 m² for comparison. This calculation of total area and infrastructure ratios was used to derive the proportional contribution of each zone (in percentage) and was visualized in a zoning composition pie chart.

$$\boldsymbol{Rij = \frac{Iij}{Ai}} \qquad (1)$$

Where:
$\boldsymbol{Rij}$ = ratio of infrastructure type j
$\boldsymbol{Iij}$ = length of infrastructure type j
Ai = area of zone i.

3. Results

The analysis of the Sepaso slum DED document indicates that the basic infrastructure plan was designed with consideration of the area's zoning. The site is divided into a residential zone (4,600 m²), a public facilities zone (800 m²), a buffer/green open space zone (1,200 m²), and an access road zone (1,000 m²). The planned basic infrastructure comprises 355 meters of local roads and 330 meters of drainage channels, which are not evenly distributed across all zones. To gauge the suitability between infrastructure provision and zone area, we used the ratio of road length and drainage length per zone area (normalized per 100 m²). To illustrate the imbalance in infrastructure distribution among zones, a bar chart of road and drainage length per 100 m² for each zone is presented (Figure 2).

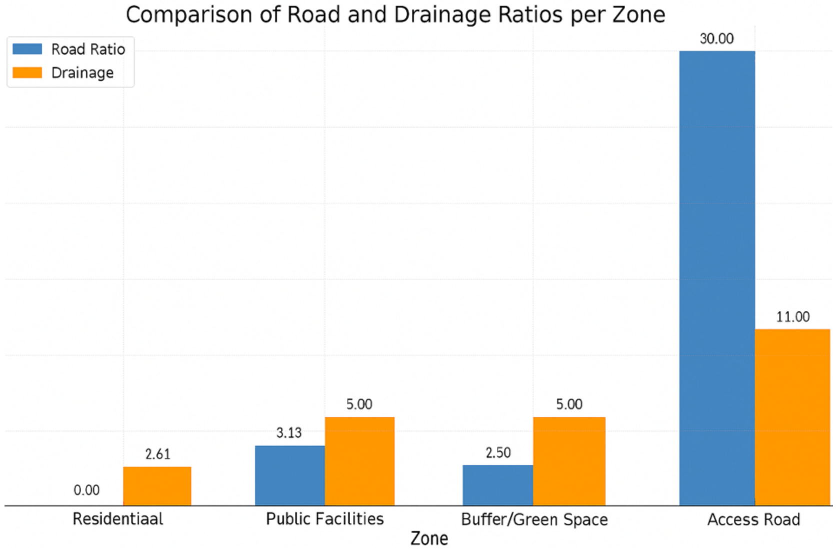

Figure 2. Bar chart of road and drainage lengths per 100 m² in each zone

The bar chart shows that the access road zone has the highest ratios for both road network (30 m/100 m²) and drainage (11 m/100 m²), reflecting its dominant role as the backbone of connectivity in the area. Meanwhile, the residential zone despite being the largest zone and the center of residents' activities has no internal road network recorded in the DED (road ratio 0.0). The public facilities and buffer/green open space zones have a relatively balanced drainage provision (5 m/100 m² each), but their road network density is still far lower compared to the access road zone. These data form the basis for an assessment that although, in general, infrastructure planning follows the spatial function of each area, not all zones have received network allocations proportional to their needs. The residential zone in particular requires attention in the micro-design so that the quality of access and technical services can be evenly distributed and inclusive.

4. Discussion

The suitability of basic infrastructure planning to an area's spatial structure is an important indicator in efforts to improve the quality of slum settlements in a planned and adaptive manner. Based on the infrastructure ratio calculations, the distribution of road and drainage networks still shows an imbalanced pattern between zones. The access road zone demonstrates a very high infrastructure capacity, reflecting its function as the backbone of the area's connectivity system. On the other hand, the residential zone which is the largest area with a high intensity of social activities was found to have no internal road network recorded in the DED.

This imbalance can lead to various technical and social issues, such as limited access to basic services (solid waste management, clean water supply, emergency response) and the isolation of densely populated residential spaces. In fact, according to the principles of sustainable settlement planning, infrastructure networks should be proportional to the area size and population density of a given zone (UN-Habitat, 2020). The absence of internal roads in the residential zone can also reduce the effectiveness of the existing drainage channels, because surface runoff is not integrated with the technical pathways that should carry rainwater.

In addition, the drainage ratio in the buffer and public facility zones (5 m/100 m²) indicates that the technical planning for those zones is quite responsive to the needs of water absorption and flow control. However, compared to the residential zone, the intensity of space use and flood risk are higher in the residential area, so the distribution of drainage infrastructure should be more focused there. This shows that the planning has not been fully based on actual spatial needs, but instead remains somewhat sectoral and generalized.

Considering the graphical and ratio analysis results, it can be concluded that the macro-level area planning has been fairly well executed, but there is a need to strengthen spatial-functional design at the micro level. Zones with high social function, such as residential and public facility areas, require revisions to their technical layouts, the addition of internal access roads, and the redistribution of tertiary drainage networks so that infrastructure services become truly inclusive and sustainable. This approach will improve the effectiveness of infrastructure and accelerate the transformation of the area toward a settlement that is healthier, more responsive, and adaptive to environmental pressures.

5. Conclusions

This study shows that the basic infrastructure planning in the Sepaso slum area has generally considered the area's spatial structure through a clear division of zones between residential, public facilities, buffer/green open space, and access roads. However, the analysis of infrastructure length ratios to zone area revealed a distributional imbalance. The access road zone has a high density of infrastructure networks, appropriate to its function as a main corridor, whereas the residential zone being the largest and most densely populated zone has no internal road network recorded and its drainage ratio remains limited. This indicates that the plan has not been fully responsive to actual spatial needs on the ground.

Thus, the alignment between technical planning and spatial needs has not been completely achieved, especially in zones with high social activity and population density. Micro-scale design adjustments are necessary, in the form of adding local roads and tertiary drainage channels in the residential zone, as well as redistributing technical elements based on the intensity of space use. These steps are important to ensure that basic infrastructure is not only available at a macro scale, but is also integrated in a fair and effective way across all zones of the area. The implications of these findings can serve as a basis for revising technical designs and as a reference for developing spatial planning guidelines in the upgrading of slum areas at other locations with similar characteristics.

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