Development of Regional Utility Infrastructure in the Teluk Haru Area, Langkat Regency

Donni Febriansyah Saragih[1], Cut Nuraini[2]

Abstract

This study aims to analyze the needs, priorities, and development strategies of utility infrastructure in the Teluk Haru area, Langkat Regency, to support the region's readiness for sustainable autonomy. The research employed a descriptive qualitative approach, with data collected through in-depth interviews, field observations, and a review of regional planning documents. The findings reveal that infrastructure and utility conditions in Teluk Haru remain limited and unevenly distributed, particularly in road networks, clean water supply, sanitation, electricity, and telecommunications. The main challenges include budget constraints, coastal geographical conditions, limited institutional capacity, and low community participation in maintenance efforts. Development priorities focus on the equitable distribution of basic infrastructure, improved access to energy and telecommunications, and planning that considers both regional potential and risk factors. The recommended optimization strategies encompass potential-based spatial planning, gradual and equitable infrastructure development, institutional strengthening, enhanced community participation, environmentally conscious development principles, and diversification of funding sources. Through these strategies, Teluk Haru has the potential to evolve into an autonomous region that is self-reliant, productive, and sustainable ultimately improving community welfare and regional competitiveness.

Keywords: Teluk Haru, Utility Infrastructure, Sustainable Development, Regional Autonomy, Development Strategy

Donni Febriansyah Saragih[1]
[1]Master of Regional and Urban Planning, Universitas Pembangunan Panca Budi, Indonesia
e-mail: febriansyah212donni@gmail.com[1]

Cut Nuraini[2]
[2]Master of Regional and Urban Planning, Universitas Pembangunan Panca Budi, Indonesia
e-mail: cutnuraini@dosen.pancabudi.ac.id[2]
2nd International Conference on Islamic Community Studies (ICICS)
Theme: History of Malay Civilisation and Islamic Human Capacity and Halal Hub in the Globalization Era
https://proceeding.pancabudi.ac.id/index.php/ICIE/index

Introduction

Regional development represents a strategic effort to stimulate economic growth, improve community welfare, and promote equitable development across regions. One of the essential aspects of regional development is the availability of adequate infrastructure and public utilities, including clean water networks, electricity, sanitation, drainage, local roads, and telecommunication systems. These utilities serve as the backbone of social and economic activities and act as key indicators in assessing the level of regional development [1].

The Teluk Haru region in Langkat Regency possesses significant potential in fisheries, agriculture, and coastal tourism. However, this potential has not yet been fully optimized due to the limited and uneven development of basic infrastructure and public utilities. Several areas in Teluk Haru still face issues such as restricted access to clean water, inadequate road infrastructure, poor drainage systems that cause flooding, and insufficient electricity and communication networks that fail to reach all settlements. These conditions directly impact the community's quality of life and slow down the pace of economic activities in the region [2].

Moreover, the increasing population activities and the planned development of the coastal area as a new economic hub demand a stronger and more integrated utility infrastructure system. Without adequate infrastructure support, local economic growth, investment opportunities, and public services will be significantly constrained. Therefore, the development of utility infrastructure has become an urgent necessity to enhance regional connectivity, improve accessibility, and support the sustainable utilization of Teluk Haru's natural resource potential.

Figure 1. Map of Teluk Aru (Aru Bay) in Pangkalan Susu District, Langkat Regency, North Sumatra

Teluk Aru (Aru Bay) is the name of a bay located in the Pangkalan Susu District, Langkat Regency, North Sumatra Province, with its central coordinates at 4°9'25.60″ North Latitude and 98°12'30.24″ East Longitude. The bay extends approximately 6.14 km from north to south (180.07°) and 8.32 km from east to west (269.34°), or 9.79 km from northeast to southwest (228.78°). Aru Bay has been recognized internationally since the era of the Langkat Sultanate.

Meanwhile, Teluk Haru refers to one of the three development regions within Langkat Regency, namely: Langkat Hulu (Upland Langkat), Langkat Hilir (Lowland Langkat), and Teluk Haru (Haru Bay). These administrative divisions have existed since the Langkat Sultanate era, although their names have changed over time. During the early post-independence period, the regions were known as Kewedanaan Langkat Hulu (centered in Binjai), Kewedanaan Langkat Hilir (centered in Tanjung Pura), and Kewedanaan Teluk Haru (centered in Pangkalan Berandan). Initially, Development Region III (Teluk Haru) consisted of four subdistricts: Besitang, Pangkalan Susu, Babalan, and Gebang. However, in response to the growing discourse on establishing Teluk Haru Regency as a new autonomous region, additional subdistricts were created Sei Lepan, Brandan Barat, and Pematang Jaya to meet the administrative requirements for new regency formation in North Sumatra Province.

The Teluk Haru region in Langkat Regency has a long historical background and occupies a strategic position in the development of North Sumatra's eastern coastal area. Geographically, the region includes several subdistricts Pangkalan Susu, Babalan, Besitang, Gebang, Sei Lepan, Brandan Barat, and Pematang Jaya with Aru Bay serving as the central hub of economic and social activity. Aru Bay itself, stretching nearly ten kilometers from northeast to southwest, has been recognized since the Langkat Sultanate period as a vital port and trading hub connecting coastal economic activities with the hinterland.

However, despite its rich historical and geographical potential, the development of basic infrastructure and public utilities in the region remains limited. Teluk Haru currently faces challenges in providing essential infrastructure such as inter-district road networks, clean water systems, sanitation, drainage management, and electricity distribution. Many villages along the coast from Pangkalan Susu to Pematang Jaya still lack access to clean water and proper sanitation facilities. In several areas, local road networks are poorly connected, hindering community mobility and the transport of local products. These constraints have directly affected the quality of life of coastal communities and reduced the region's economic competitiveness.

In fact, Teluk Haru holds tremendous potential in marine fisheries, wetland agriculture, and marine tourism around Aru Bay. Yet, without adequate infrastructure and utility systems, these resources cannot be transformed into a sustainable economic base.

This issue becomes increasingly significant in light of the ongoing plan to establish Teluk Haru as a new autonomous regency (Daerah Otonomi Baru – DOB). The formation of a new regency requires readiness in basic infrastructure, particularly public utilities, to ensure the region's capacity for self-governance and efficient public service delivery. However, much of Teluk Haru remains less developed compared to Langkat Hulu and Langkat Hilir in terms of infrastructure equity and public service distribution.

In addition to infrastructure disparities, there exists spatial inequality among Teluk Haru's subdistricts. Areas close to industrial and port zones, such as Pangkalan Berandan and Babalan, are relatively more developed than areas like Pematang Jaya or Brandan Barat. This imbalance underscores the need for a planned and proportionate infrastructure development strategy across the region. The observed disparity highlights a gap between Teluk Haru's enormous potential and the limited realization of its infrastructure development. Adequate utility infrastructure is, in fact, a key prerequisite for accelerating development, attracting investment, and improving the living standards of communities along North Langkat's coastline.

Therefore, research on the development of utility infrastructure in the Teluk Haru region of Langkat Regency is essential to understand existing conditions, identify constraining factors, and formulate strategic policy directions that strengthen Teluk Haru's role as a new strategic region in North Sumatra.

From a spatial planning perspective, infrastructure development must also consider environmental sustainability. Since much of Teluk Haru consists of coastal and wetland areas, it is vulnerable to climate change, tidal flooding, and seawater intrusion. Hence, a sustainable

development approach is required to ensure that built infrastructure is not only technically functional but also adaptive to environmental conditions and long-term community needs.

Accordingly, this study on the development of regional utility infrastructure in Teluk Haru, Langkat Regency is both relevant and timely. It is expected to provide an overview of existing infrastructure conditions, identify urgent needs and problems, and propose integrated and sustainable development strategies. Through well-planned utility infrastructure development, Teluk Haru can grow into a productive, livable, and competitive region at both regional and national levels.

Problem Identification

Based on the background and current phenomena in the Teluk Haru region of Langkat Regency, several key issues have been identified:

1. Uneven availability of basic infrastructure across Teluk Haru's subdistricts, particularly in coastal and inland areas such as Pematang Jaya and Brandan Barat.
2. Limited access to clean water and sanitation systems, resulting in decreased public health and welfare.
3. Suboptimal road and land transportation networks, which hinder inter-regional connectivity and product distribution.
4. Inadequate drainage and waste management systems in several subdistricts, causing flooding and potential environmental pollution.
5. Insufficient electricity and telecommunication networks, especially in settlements located far from district centers.
6. Development disparities among subdistricts, where industrial areas such as Babalan and Pangkalan Berandan are more developed than others.
7. Absence of a comprehensive and sustainable utility infrastructure development plan to support the establishment of Teluk Haru as a new autonomous region.
8. Lack of integration between regional development policies and local coastal potentials, such as fisheries, marine tourism, and coastal agriculture.

These issues emphasize the urgent need for a targeted, comprehensive, and regionally grounded utility infrastructure development strategy, enabling Teluk Haru to emerge as a strategic and competitive area within Langkat Regency.

Research Questions

Based on the identified problems, the research questions are formulated as follows:

1. What is the current condition of **infrastructure and utilities** in the Teluk Haru region of Langkat Regency?
2. What are the **key factors** constraining the development of utility infrastructure in Teluk Haru?
3. What are the **needs and priorities** for utility infrastructure development to support Teluk Haru's sustainable regional development?
4. What **strategies** can be implemented to optimize the development of utility infrastructure in preparation for Teluk Haru's transition toward a **new autonomous region**?

Literature Review

2.1 Infrastructure Development and Regional Development Theory

The theory of infrastructure development emphasizes that the provision of physical facilities such as transportation, water, sanitation, electricity, and telecommunications is a prerequisite for local economic growth, poverty reduction, and equitable regional development. Infrastructure investment affects market connectivity, transaction costs, and access to essential services, thereby accelerating the accumulation of social and economic capital in underdeveloped regions [3].

In the context of regional autonomy and the establishment of new administrative regions, infrastructure readiness becomes a critical factor to ensure adequate public service delivery and to attract investment [4]. This theoretical perspective underpins the argument that disparities in public utility infrastructure across subdistricts in Teluk Haru hinder the optimal utilization of its fisheries, wetland agriculture, and coastal tourism potential while also presenting challenges in the discourse on forming a new regency. (Local development planning documents further reinforce the need to improve public service utilities in the Teluk Aru area.)

2.2 Theories of Water, Sanitation, and Hygiene (WASH) and Service Sustainability

Recent literature indicates that clean water provision models in coastal and rural areas must adopt decentralized approaches, community-based management, and climate risk adaptation (e.g., droughts, saltwater intrusion). The sustainability of WASH services depends on three dimensions: technical (sources and networks), institutional (operational management), and economic (maintenance and cost recovery).

In the Indonesian context, national review studies recommend continuous investment to achieve safe and sustainable access to water and sanitation. The challenges of clean water and sanitation access in several subdistricts of Teluk Haru therefore require technical solutions (e.g., decentralized distribution systems), strengthened local management capacity, and sustainable financing policies so that WASH services can endure under climate change and coastal intrusion pressures.

2.3 Coastal Resilience and Nature-Based Solutions

Research since 2019 has increasingly emphasized the importance of nature-based solutions including mangrove restoration, the development of coastal green spaces, and wetland rehabilitation as essential strategies to mitigate the risks of flooding, coastal erosion, and seawater intrusion. Moreover, integrating climate adaptation measures into infrastructure planning (such as adaptive drainage and elevated critical infrastructure) has been widely recommended in international studies as a dual strategy: protecting the environment while maintaining the economic functionality of coastal zones.

Given that the Teluk Aru and Teluk Haru regions are prone to tidal flooding and climate-related hazards, the development of utility infrastructure must incorporate sustainable, nature-based approaches (such as mangrove conservation and natural drainage systems) to enhance regional resilience and sustain the productivity of the fisheries sector.

2.4 Urban–Regional Planning, Spatial Equity, and Green Infrastructure

Contemporary urban planning literature underscores the importance of equitable access to infrastructure arguing that spatial planning must explicitly address inequalities between core and peripheral areas. Urban Green Infrastructure (UGI) and integrated spatial planning approaches can enhance environmental quality, reduce urban flooding, and improve quality of life when embedded in regional masterplans.

Recent studies recommend planning practices that link infrastructure services, public spaces, and ecosystems. In this context, spatial inequalities between subdistricts such as the contrast between Babalan and Pematang Jaya demand an integrated planning approach that prioritizes disadvantaged subdistricts through equitable infrastructure interventions and inclusive access programs.

2.5 Drainage Management and Flood Risk in Coastal Areas

Recent studies on drainage management reveal that traditional drainage designs often fail to withstand the combined effects of extreme rainfall and sea-level rise. Therefore, integrating hydrological modeling, infrastructure elevation, and hybrid solutions (combining gray and green infrastructure) is increasingly essential.

Case analyses show that without adequate risk modeling, infrastructure investments are vulnerable to damage or underperformance. Consequently, the drainage systems in several subdistricts of Teluk Haru need to be reassessed using a risk-based and sea-level rise projection approach to ensure that future infrastructure remains resilient to extreme weather events.

2.6 Governance, Regional Policy, and the Formation of New Autonomous Regions (DOB)

Public policy literature and regional expansion (DOB) evaluations show that the establishment of new administrative regions succeeds only when supported by institutional, fiscal, and infrastructure readiness. Assessments of regional autonomy implementation reveal varied outcomes some regions experience improved public services, while others face fiscal strain and institutional challenges due to the initial infrastructure burden.

Accordingly, utility infrastructure readiness is a key component in feasibility studies for regional expansion. In the case of the proposed Teluk Haru Regency, this study must assess the readiness of public service utilities (PSU), the capacity of local government institutions, and funding scenarios to ensure sustainable public service delivery post-establishment. Local development planning documents in Langkat (RPD/RENJA) also identify the preparation of a PSU database as a policy priority, aligning with the analytical framework of infrastructure readiness evaluation.

2.7 Theoretical Synthesis and Conceptual Framework

Drawing from the theories above, this research integrates four analytical dimensions:

a. Technical infrastructure availability and physical condition of public service utilities (PSU);
b. Environmental resilience coastal adaptation and nature-based solutions;
c. Institutional and policy dimension governance capacity and regional autonomy preparedness; and
d. Socio-economic dimension access disparities and development priorities.

The recommended analytical approach is a mixed-method study combining physical condition surveys and service accessibility assessments, spatial mapping of disparities, stakeholder interviews, and policy and investment prioritization analyses. (Supporting references are cited in the preceding sections.)

2.8 Research Gaps

Based on the literature reviewed from 2019 to the present, several gaps relevant to the Teluk Haru study are identified:

1. Limited local case studies integrating coastal resilience, PSU infrastructure readiness, and regional expansion analysis in the context of regencies within North Sumatra (most existing studies remain national or global in scope).
2. Lack of applied approaches that combine adaptive drainage modeling with utility development planning for flat coastal regions such as Teluk Aru.
3. Need for policy-oriented research evaluating funding mechanisms and institutional frameworks to ensure the sustainability of WASH operations in potential new administrative regions.

Research Methodology

3.1 Research Approach

This study employs a qualitative approach with an exploratory case study design, focusing on the Teluk Haru region (particularly the Teluk Aru coastal area). The case study approach enables the researcher to explore the complex phenomena of public utility infrastructure development within its real-life context, integrating multiple stakeholder

perspectives including local government officials, related agencies, community leaders, fisheries and agriculture actors, and local residents.

The selection of an exploratory case study is grounded in methodological literature emphasizing the strength of qualitative inquiry in uncovering processes, meanings, and contextual nuances deeply embedded in local realities [5].

3.2 Research Location and Duration

The research was conducted in the Teluk Haru region, with a field focus on subdistricts surrounding the Teluk Aru coastal zone (central coordinates: 4°9’25.60″ N – 98°12’30.24″ E), encompassing Pangkalan Susu, Besitang, Babalan, Gebang, Sei Lepan, Brandan Barat, and Pematang Jaya.The fieldwork was planned for **8 to 12 weeks**, covering infrastructure inventory surveys, in-depth interviews, focus group discussions (FGDs), and direct field observations.

3.3 Units and Research Participants (Informants)

The unit of analysis comprises regional public utility infrastructure specifically clean water, sanitation, drainage, roads, electricity, and telecommunication facilities and the institutional actors related to their planning, provision, and management. Key informants include:

1. Officials from technical departments (Public Works, Housing and Settlements, Fisheries);
2. Subdistrict heads and village or urban ward leaders;
3. Community leaders, local fishermen, and wetland farmers;
4. Local business actors (small port operators, fish-processing entrepreneurs);
5. Experts and planners (consultants and local academics).

3.4 Sampling Techniques

A purposive and snowball sampling strategy was applied to identify key informants possessing in-depth insights into the conditions of public utilities (PSU), planning processes, and local dynamics. The number of informants remained flexible, adjusted until thematic saturation was achieved.

Following recent methodological recommendations [6]; [7] meaning saturation the point at which no new conceptual insights emerge served as the main criterion, while code saturation (the point of issue identification) might occur earlier.

FGDs were organized to capture the diversity of community perspectives.

The initial sampling plan included document reviews, in-depth interviews, and on-site infrastructure observations. However, the final sample size was determined by the level of saturation achieved during data collection.

3.5 Data Collection Techniques and Procedures

A data triangulation method was applied to enhance the depth, consistency, and validity of the findings. The main data collection techniques were as follows:

1. Semi-Structured In-Depth Interviews
   - Targets: government officials, technical stakeholders, community representatives, and business actors.
   - Interview Guide Topics: existing infrastructure conditions, operational and financial constraints, perceptions of regional division (DOB) plans, priority needs, and environmental or climate-related impacts.
   - Interviews were audio-recorded with consent and transcribed verbatim for analysis.
2. Field Observation and Infrastructure Inventory Survey
   - Observations focused on the physical condition of infrastructure (roads, water networks, drainage, solar micro-grids where applicable, and telecommunication lines).

- Technical details, photographic documentation, and GPS-based mapping were recorded.
- The inventory data served as a basis for subsequent GIS mapping.

3. Document and Policy Analysis
   - Reviewed materials included Regional Development Plans (RPD/RENJA), Medium-Term Development Plans (RPJMD), infrastructure masterplans, departmental technical reports, administrative maps, and historical archives of subregional formation (Luhak/Kewedanaan).
   - These documents were used to contextualize policy direction, budget allocation, and infrastructure planning history.

All research instruments including interview guides, FGD protocols, and infrastructure inventory checklists were pilot-tested with 2–3 informants to ensure clarity and comprehensibility of the questions.

3.6 Data Analysis Techniques

Data analysis followed a qualitative thematic analysis framework as formulated by Braun & Clarke (2021–2022). The analytical process consisted of six recursive phases:

1. Familiarization with the data;
2. Generating initial codes;
3. Searching for potential themes;
4. Reviewing themes;
5. Defining and naming themes;
6. Producing an analytical report.

The actual coding process employed first-cycle and second-cycle coding techniques (Saldaña, 2021/2022), complemented by data display strategies such as matrices and flowcharts from [5] to clarify inter-category relationships and present empirical evidence visually through tables and thematic maps.

A combined inductive–deductive approach was used: several themes were guided by the theoretical framework (e.g., coastal resilience, WASH service sustainability, and spatial equity), while others were allowed to emerge organically from the field data. Analytical steps included:

1. Transcription of interview recordings accuracy check and anonymization;
2. Line-by-line coding (first-cycle coding) axial coding theme formation;
3. Triangulation across data sources (interviews, FGDs, observations, documents);
4. Visualization of findings through inequality maps, priority-need tables, and strategic development models for PSU.

Results

Existing Conditions of Infrastructure and Public Utilities in the Teluk Haru Area, Langkat Regency

The current condition of infrastructure and public utilities in the Teluk Haru area presents a heterogeneous situation. In certain zones particularly those located near industrial sites or local administrative centers infrastructure facilities tend to be relatively adequate. However, in many coastal and inland villages, the availability and quality of basic infrastructure remain limited or deteriorated. According to the Regional Development Plan (RPD) and the Work Plan (RENJA) of the Housing and Settlement Office of Langkat Regency, the provision of public infrastructure, facilities, and utilities (PSU) is still uneven and has been identified as a top priority for improvement during the 2025–2026 planning period.

1. Clean Water and Sanitation

Access to clean water remains a persistent challenge in several coastal and low-lying swamp areas around Teluk Aru. In many locations, communities rely on shallow wells or

surface water sources that are highly vulnerable to seawater intrusion and contamination, particularly during dry seasons or periods of sea-level rise. The RENJA document emphasizes the need to strengthen water supply systems and improve uninhabitable housing conditions indicating a significant gap between current service capacity and the actual needs for WASH (Water, Sanitation, and Hygiene) services [8].

2. Roads, Accessibility, and Transportation

Road connectivity between villages and subdistricts in the Teluk Haru region varies considerably in quality. Several district and village roads are severely damaged, disrupting community mobility and the distribution of agricultural and fishery products. Local reports have highlighted cases of serious road damage, such as in Pelawi Selatan Village (Babalan Subdistrict), which have caused traffic accidents and logistical difficulties. Poor road conditions also increase transportation costs, reducing the region's overall economic competitiveness [9].

3. Drainage, Flooding, and Coastal Risk

The coastal zones of Teluk Aru are highly prone to flooding, tidal inundation, and the impacts of climate change, including sea-level rise. Existing drainage systems in several subdistricts are inadequate to cope with the combination of extreme rainfall and rising tides, resulting in frequent flooding and infrastructure damage. Both the RPD/RENJA and risk-mapping studies have identified the enhancement of drainage capacity and the implementation of adaptive solutions as priority interventions [10]

4. Electricity and Energy

Electricity supply is relatively available in subdistrict centers and near power generation sites (such as around the Pangkalan Susu power plant). However, several settlements still experience unstable electricity access or remain disconnected from the main grid. The establishment of large-scale energy projects like the Pangkalan Susu Power Plant demonstrates efforts to expand energy access, yet issues of distribution and service reliability persist particularly in supporting basic public services and local economic activities [11].

5. Telecommunications and Digital Connectivity

Telecommunication coverage (mobile signal and internet access) remains uneven. Areas close to district centers and main roads are generally well-served, while remote coastal villages continue to experience poor connectivity. This digital divide hampers access to education, telemedicine, and digital economic opportunities. The regional expansion proposal documents highlight the need to improve digital access to ensure more effective governance and public service delivery [12].

6. Institutional Capacity, Planning, and Administrative Readiness

Institutionally, regional planning documents have identified the Teluk Aru/Teluk Haru area as a strategic intervention zone for infrastructure improvement, and discussions on administrative expansion (the establishment of Teluk Aru Regency) have further emphasized the need for infrastructure readiness. However, disparities between subdistricts, limited infrastructure data, and weak inter-agency coordination continue to hinder effective program implementation and investment planning. Although infrastructure development projects have been listed as county-level priorities for 2025, successful execution will require stronger governance, adequate financing, and enhanced technical capacity [13].

In summary, infrastructure and utility conditions in Teluk Haru are spatially uneven. While basic services such as clean water, sanitation, roads, drainage, electricity, and telecommunications are available in some central areas, many coastal and rural zones remain

underserved. These disparities constrain local economic potential (fisheries, wetland agriculture, tourism), exacerbate environmental vulnerability, and complicate regional expansion readiness. Therefore, an integrated approach featuring accurate infrastructure inventory, investment prioritization, coastal risk–based adaptive solutions, and institutional capacity strengthening is required for sustainable development [14]

Constraints in Infrastructure and Utility Development in the Teluk Haru Area

Several key constraints hinder the development of infrastructure and utilities in Teluk Haru and its surrounding subdistricts. These constraints can be grouped into several thematic categories to facilitate problem mapping and policy response.

1. Limited Funding and Budget Allocation

   A major constraint is the insufficiency of funding for construction and maintenance across all districts. Although infrastructure is recognized as a priority in regional plans, budget allocation often faces competition from other sectors. As a result, small-scale or dispersed projects (e.g., village water networks, local drainage systems) struggle to secure consistent financing.
2. Geographical and Environmental Challenges

   The coastal and lowland topography of Teluk Haru presents significant technical challenges. High flood risks, seawater intrusion, and waterlogging during rainy seasons increase infrastructure costs and complexity. Climate-related factors (e.g., prolonged droughts, fluctuating water levels) also affect water supply reliability. Hence, infrastructure designs must adopt adaptive approaches (elevated structures, decentralized systems) rather than replicating standard technical templates.
3. Poor Road Networks and Accessibility

   Severely damaged inter-village and inter-district roads impede material transport, service delivery, and local economic mobility. Poor logistics access increases project costs and delays construction timelines, making maintenance sustainability difficult.
4. Institutional and Governance Capacity Gaps

   The ongoing discourse on administrative expansion highlights institutional weaknesses, including poor coordination among agencies, fragmented cross-sectoral planning, and limited technical capacity at local levels. Without stronger institutional governance and budgeting capacity, infrastructure programs risk fragmentation and inefficiency.
5. Data and Planning Deficiencies

   The absence of updated infrastructure inventories hampers evidence-based planning. Incomplete data on networks, conditions, and maintenance needs lead to weak prioritization and poor project monitoring. Regional plans have emphasized the need for an integrated PSU database, yet inter-agency implementation remains limited.
6. Technical and Human Resource Limitations

   Advanced infrastructure solutions such as decentralized WASH systems or adaptive drainage require specialized technical expertise, which is unevenly distributed at the district level. Limited availability of skilled contractors and supervisors often results in substandard construction quality.
7. Socioeconomic and Behavioral Factors

   Poverty, land-use patterns, and community practices affect infrastructure sustainability. In many coastal areas, low-income households struggle to contribute to maintenance costs, resulting in rapid degradation of facilities unless supplemented by subsidies or community-based financing.
8. Weak Operation and Maintenance (O&M) Systems

   Infrastructure deterioration is often caused by poor maintenance regimes rather than design flaws. Lack of dedicated O&M budgets and asset management systems causes rapid functional decline soon after project completion.

9. Land Use and Regulatory Constraints

   Land acquisition, licensing delays, and land-use conflicts particularly in transitioning agricultural or coastal zones frequently disrupt project implementation and increase costs.

In summary, Teluk Haru's infrastructure development barriers are multidimensional spanning financial, technical, institutional, social, and environmental domains. Addressing them requires integrated solutions: strengthening infrastructure databases, adopting risk-based planning, enhancing institutional capacity, expanding blended financing (public–private partnerships), and implementing sustainable maintenance mechanisms.

Infrastructure Development Needs and Priorities for Sustainable Growth in Teluk Haru

Teluk Haru holds a strategic position as a coastal corridor linking the Malacca Strait with inland economic centers in North Sumatra. However, field observations and interviews with local officials reveal that existing infrastructure remains disproportionate to the region's potential. Key priorities include improving inter-district road connectivity, expanding clean water access, strengthening drainage systems, and upgrading sanitation, electricity, and telecommunications.

The primary priority is the rehabilitation and development of road networks connecting Pematang Jaya, Brandan Barat, and Sei Lepan, where many segments remain unpaved or severely damaged. Improved road infrastructure will facilitate mobility, accelerate the distribution of agricultural and fishery products, and attract investment.

The second priority concerns clean water and sanitation systems. Most coastal residents rely on rainwater or shallow wells, which are often unsuitable for consumption, especially during dry seasons. Establishing area-based Water Supply Systems (SPAM) and integrated sanitation networks is therefore essential for improving public health and environmental quality.

The third priority involves energy and telecommunication enhancement. Several inland areas still face limited electricity and internet access. Expanding power grids and digital connectivity is crucial for supporting local industries, small enterprises, and digital-based livelihoods.

Spatially, each subdistrict requires context-sensitive utility planning. Coastal areas such as Pangkalan Susu and Babalan need enhanced port facilities and wastewater management, while hinterland areas like Brandan Barat and Pematang Jaya demand improved road access and essential services. Sustainable utility planning also requires inter-agency policy coordination and active community participation. A balanced development model must combine physical infrastructure with governance reform, environmental stewardship, and social equity.

Strategic Directions for Optimizing Infrastructure Development toward Teluk Haru's Regional Autonomy Readiness

Optimizing infrastructure development in Teluk Haru requires strategies that go beyond physical construction to include institutional strengthening and community empowerment. As part of its preparation for potential regional autonomy, Teluk Haru's infrastructure planning must be comprehensive, inclusive, and sustainable [15].

1. Spatial and Potential-Based Planning

   Infrastructure strategies should align with local resource profiles e.g., fisheries and port facilities in Pangkalan Susu and Babalan, and wetland agriculture in Gebang and Pematang Jaya. A Master Plan for Infrastructure Development in Teluk Haru should be formulated, integrated with Langkat Regency's spatial plan and the North Sumatra regional master plan.

2. Phased and Equitable Development

Road connectivity and port access must be prioritized to ensure efficient logistics and service delivery. Simultaneously, rural subdistricts like Sei Lepan and Brandan Barat need enhanced water, sanitation, energy, and communication infrastructure. The underlying principle is "infrastructure for equity," ensuring all subdistricts possess comparable service capacity when the new regency is formed.

3. Institutional Coordination and Governance Reform

   A Teluk Haru Infrastructure Management Forum should be established to coordinate planning, monitoring, and evaluation among subdistricts, technical agencies, and communities improving transparency and efficiency in resource utilization.

4. Community-Based Infrastructure Development (CBID)

   Community participation is crucial to ensure ownership and sustainability of infrastructure. The CBID model encourages local involvement in planning, implementation, and maintenance particularly for water, sanitation, and rural road systems.

5. Environmentally Sustainable Infrastructure

   Given the area's vulnerability to tidal floods and coastal erosion, infrastructure design must integrate environmental mitigation and climate adaptation. The use of green technology and eco-friendly infrastructure (e.g., mangrove-based drainage protection) should be prioritized.

6. Innovative Financing and Public–Private Partnerships (PPP)

   Langkat Regency should promote collaboration between government, private investors, and local communities through PPP schemes and CSR programs to diversify funding sources beyond public budgets.

In conclusion, the optimal strategy for Teluk Haru's infrastructure development must be integrative, adaptive, and participatory. Strengthened spatial planning, equitable infrastructure distribution, improved institutional capacity, and environmental sustainability will form the foundation for Teluk Haru's transition into a capable and self-reliant autonomous region serving as a model for balanced coastal development in North Sumatra.

Conclusion

Based on the findings of the study on the development of public infrastructure and utilities in the Teluk Haru area of Langkat Regency, several key conclusions can be drawn as follows:

1. The existing condition of infrastructure and utilities in Teluk Haru remains suboptimal. Road networks, clean water supply, sanitation systems, electricity, and telecommunications are unevenly distributed across sub-districts. This inequality hinders residents' mobility, disrupts the distribution of agricultural and fishery products, and limits access to essential public services.
2. The main constraints in infrastructure and utility development include limited funding and budget allocation, challenging geographical and coastal climate conditions, damage and inadequacy of transportation networks, weak institutional capacity and governance, incomplete data and infrastructure inventories, shortages of technical human resources, as well as socio-economic factors and poor maintenance practices.
3. Development needs and priorities are centered on fulfilling basic infrastructure requirements such as roads, clean water, and sanitation while improving electricity and telecommunication networks. Spatial planning should be grounded in local potential, with an emphasis on sustainable, risk-based, and equitable development across regions.
4. Optimization strategies for infrastructure and utility development include strengthening spatial planning based on regional potential, implementing phased and equitable infrastructure development, enhancing institutional capacity and inter-agency coordination, promoting community participation in planning and maintenance, adopting environmentally conscious development principles, and diversifying financing

sources through collaborative schemes such as Public–Private Partnerships (PPP), Corporate Social Responsibility (CSR), and government funding.

5. Through the implementation of these strategies, Teluk Haru can position itself as a self-reliant, productive, and sustainable autonomous region. This transformation will not only improve the quality of life for its residents but also contribute significantly to regional economic growth and long-term development resilience.

References

[1] Grabowski ZJ, et al. Transforming urban green infrastructure planning to address equity and justice. Landsc Urban Plan. 2023;240:104813.
[2] Guest G, Namey E, Mitchell M. A simple method to assess and report thematic saturation in qualitative research. PLoS One. 2020;15(5):e0232076.
[3] Hanna E, et al. Urban green infrastructure and sustainable development: A literature review. Sustainability. 2021;13(20):11498.
[4] Kuwae T, et al. Linking climate change mitigation and adaptation through nature-based solutions in coastal areas. J Environ Plan Manag. 2021;64(12):2091–111.
[5] Miles MB, Huberman AM, Saldaña J. Qualitative data analysis: A methods sourcebook. Updated ed. Thousand Oaks (CA): SAGE Publications; 2019.
[6] Braun V, Clarke V. Thematic analysis: A practical guide. London: SAGE Publications; 2022.
[7] Hennink M, Kaiser B. Sample sizes for saturation in qualitative research: A systematic review of empirical tests. Soc Sci Med. 2022;292:114523.
[8] Dinas Perumahan dan Kawasan Permukiman Kabupaten Langkat. RENJA 2025 Penyusunan Data Base PSU untuk wilayah Langkat Hilir, Langkat Hulu, dan Teluk Aru. Langkat: Pemerintah Kabupaten Langkat; 2025. Available from: https://perkim.langkatkab.go.id
[9] Obara C, et al. Drainage failure and associated urban impacts under present and projected sea-level rise. Sci Rep. 2025;15(1):2134.
[10] Busetto L, Wick W, Gumbinger C. How to use and assess qualitative research methods. Neurol Res Pract. 2020;2:14.
[11] Grabowski ZJ, et al. Transforming urban green infrastructure planning to address equity and justice. Landsc Urban Plan. 2023;240:104813.
[12] Guest G, Namey E, Mitchell M. A simple method to assess and report thematic saturation in qualitative research. PLoS One. 2020;15(5):e0232076
[13] Maulana A. The progress of regional autonomy policy and development attainments: Indonesia's experience 1999–2021. ResGate Papers. 2022. Available from: https://www.researchgate.net
[14] Ocean Panel. Resilience, restoration and infrastructure requirements: Coastal development full paper. The High Level Panel for a Sustainable Ocean Economy; 2022.
[15] Saldaña J. The coding manual for qualitative researchers. 4th ed. London: SAGE Publications; 2021.