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ANALYSIS OF REGIONAL RESILIENCE IN THE NORTH SUMATRA SPORTS CENTER AREA DEVELOPMENT PLAN BASED ON GIS AND SWOT

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Abstract

The development of the North Sumatra Sport Center in Batang Kuis Subdistrict, Deli Serdang Regency, is part of an effort to establish a new growth center that supports the enhancement of the region's physical, social, economic, and environmental resilience. The objective of this study is to analyze the region's resilience potential based on the development plan for the North Sumatra Sports Center, using a spatial approach based on Geographic Information Systems (GIS) and a SWOT analysis, with the aim of formulating sustainable and resilient regional development strategies. The research method used is a mixed-methods approach combining qualitative and quantitative analysis. Research data were obtained from spatial satellite imagery, area planning documents, observations, and literature reviews. GIS analysis was used to identify spatial structure, accessibility, land use, as well as the area's potential and vulnerabilities, while SWOT analysis was used to determine development strategies based on the region's internal and external factors. The research findings indicate that the North Sumatra Sport Center area holds strategic potential as a new economic growth hub through the integration of sports, business, education, and transportation functions based on the Transit-Oriented Development (TOD) concept. The area's key strengths lie in its regional accessibility, multimodal connectivity, and the presence of integrated supporting facilities. However, the area's development also faces challenges in the form of flood risks due to land-use changes, the potential for gentrification, and pressures on environmental quality. Based on the SWOT analysis results, the recommended priority strategy is to optimize the integration of the railway station with the business center and commercial areas to enhance the region's competitiveness, accompanied by strengthened spatial planning management, sustainable drainage systems, and the provision of green open spaces as a form of environmental mitigation. This study is expected to serve as a reference for the planning of integrated sports areas oriented toward the principles of sustainability and regional resilience.

Keywords : Regional resilience, Sport Center, GIS, SWOT, area development, TOD, North Sumatra.

BACKGROUND

The development of integrated sports areas has become one of the most widely used methods in urban development in recent years. Sports areas go beyond simply providing sports facilities; instead, they have evolved into centers of economic, social, and public service activity that can stimulate growth in their surrounding areas. From a regional and urban planning perspective, the development of sports complexes can serve as new growth centers, promoting equitable development and reducing the concentration of activity in major urban centers. In the context of regional development, the integration of spatial planning and transportation systems is a key factor in determining the success of a region's development. Zhang's (2025) study explains that the concept of transportation-oriented development (TOD) continues to evolve as an approach that focuses not only on mobility but also on sustainability, regional resilience,

and adaptation to future urban challenges. Furthermore, research conducted by Hasibuan and Mulyani (2022) in the Jakarta metropolitan area shows that the implementation of TOD helps change land use patterns and encourages more sustainable urban development.

The concept of sustainable development supports the development of sports areas integrated with commercial, educational, and transportation facilities. This concept emphasizes the importance of achieving a balance between economic growth, environmental sustainability, and the social well-being of the community. Because large-scale development often results in changes in land use, increased mobility, and pressure on surrounding communities and the environment, regional resilience is a key consideration in this context. Regional resilience encompasses a region's ability to support development processes and also its ability to cope with the changes, damage, and risks generated by these processes. Regional development must be carried out in an integrated manner, taking into account spatial, economic, social, and environmental planning. Milanie (2023) explains that to promote sustainable regional development, biophysical, economic, social, institutional, and environmental factors interact with each other. Furthermore, Milanie et al. (2024) emphasize the importance of spatial-based planning when changing land use in peri-urban areas. This is done to ensure that the changes comply with spatial planning guidelines and do not cause land use conflicts. Additional research by Milanie et al. (2025) found that regional resilience analysis based on a SWOT analysis can be used to identify regional vulnerabilities and create development strategies that are more appropriate to environmental risks and changes. These results emphasize that development in these areas requires more than just infrastructure projects; planning that considers sustainable development and regional resilience is also necessary.

While much previous research has addressed regional development, land-use change, and regional resilience, most research remains sector-specific. Research on land-use change typically focuses on the adequacy of land-use planning, while research on regional resilience often addresses only specific aspects related to disasters or the environment. To assess regional resilience in the development of an integrated sports complex, research combining GIS-based spatial analysis with SWOT analysis is still rare. To date, only a few studies have examined regional resilience in the development of the North Sumatra Sports Center in Batang Kuis District, Deli Serdang Regency. This area is strategically located along a regional development corridor connecting the Railink network, educational areas, the buffer zone of Medan City, and Kualanamu International Airport. Current conditions indicate that the North Sumatra Sports Center has the potential to become a new sports hub and growth center in North Sumatra. Therefore, this study was conducted to address this gap by using a methodology that incorporates spatial elements, regional resilience, and regional development strategies into a comprehensive analytical framework.

The development of this area is also supported by transportation integration through the Railink line and plans to build a train station within the area. This concept aligns with the Transit Oriented Development (TOD) approach, which prioritizes connectivity between land use and public transportation to facilitate and streamline community mobility. With this integration, the North Sumatra Sport Center area is expected to have better accessibility and become a new hub of activity in North Sumatra. Conversely, large-scale development without adequate urban planning can cause many problems. If open spaces become urban, surface runoff increases, increasing the risk of flooding in the surrounding area. The expansion of commercial areas and rising land prices can also impact the surrounding social community. This demonstrates that regional development requires more than just physical planning; it also needs to be supported by a regional resilience plan that can balance economic growth, environmental conditions, and community social life.

As an environmental mitigation measure, the North Sumatra Sports Center area is planned to be equipped with a rainwater retention pond and green open space that will function as a water catchment area and help maintain the area's ecological balance. The creation of green open space not only has aesthetic value but also plays a crucial role in maintaining environmental quality and mitigating the long-term impacts of urbanization in the region. Based on the above, this study was conducted to analyze regional resilience in the development of a sports complex in North Sumatra using a Geographic Information System (GIS) and a SWOT analysis. It is hoped that this research will provide an overview of the potential, vulnerabilities, and most sustainable development strategies in the region, thus providing a basis for planning an integrated sports complex in North Sumatra.

LITERATURE REVIEW

2.1 Regional Resilience Theory

The ability of a region to withstand, adapt to, and recover from various stresses or shocks caused by economic, social, environmental, or spatial changes is referred to as regional resilience. The ability of a region to recover after

experiencing disruption and the ability to change for the better are also components of regional resilience, according to Martin and Sunley (2015). The ability to manage economic growth, maintain environmental conditions, improve transportation facilities, and increase the social capacity of the surrounding community is a picture of a form of regional resilience in the development process of the North Sumatra Sport Center area. Therefore, the development of this area does not only focus on physical development, but also on increasing the ability of the area to adapt to various changes that may occur in the future.

2.2 Smart Growth

The urban development approach known as "smart growth" emphasizes efficient land use, integrated transportation systems, reducing uncontrolled urban sprawl, and creating more pedestrian- and transit-friendly environments. The United States Environmental Protection Agency (EPA) states that smart growth aims to create sustainable communities through development that integrates environmental, economic, and social functions. The "Smart Growth" concept in the North Sumatra Sports Center area is demonstrated by the development of a multi-purpose complex, integration with the Railink network, and the provision of easily accessible public facilities. This approach is expected to improve space utilization and reduce reliance on private vehicles.

2.3 Sustainable Urban Development

The concept of sustainable urban development emphasizes a balance between economic growth, social welfare, and environmental sustainability, and aims to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. The implementation of sustainable development principles in the North Sumatra Sports Area is demonstrated through the development of green open spaces, a sustainable drainage system, improved public transportation, and the integration of economic and social functions within the area. These methods are crucial for maintaining a balance between environmental carrying capacity and physical development.

2.4 Transit-Oriented Development (TOD)

Transit-Oriented Development (TOD) is a spatial planning concept centered on public transportation systems, with the goal of creating accessible, dense, and integrated environments. According to Calthorpe (1993), TOD prioritizes the integration of spatial planning, public transportation networks, and pedestrian mobility within a certain radius around transportation hubs. The Railink station development project demonstrates the application of the "Transit-Oriented Development" (TOD) model in the North Sumatra Sports Center area. The station is integrated with a sports complex, business center, educational center, and commercial space. This integration is expected to improve accessibility in the area and encourage more sustainable and efficient mobility for the local community.

2.5 Spatial Resilience

The ability of a regional system to maintain its core functions and structures despite environmental pressures and changes is known as spatial resilience. This term emphasizes the importance of regional planning that is able to adapt to development pressures, disasters, and climate change.

Using Geographic Information Systems (GIS), this study analyzes spatial resilience to identify land use patterns, accessibility, regional connectivity, and potential environmental vulnerabilities. This method can assist in the development of more robust and sustainable regional development plans.

RESEARCH METHODOLOGY

3.1 Research Approach

This study uses a mixed-approach, combining qualitative and quantitative methods, supported by spatial analysis using GIS. This approach was chosen because the study not only examines the physical and spatial conditions of the North Sumatra Sports Center but also examines internal and external strategic factors that influence the region's growth resilience. This study used scoring and weighting techniques for several regional resilience indicators based on physical, social, economic, and environmental aspects. This technique was used to measure the potential and weaknesses of the North Sumatra Sports Center area. This spatial quantitative analysis was also conducted by overlaying maps of land use, accessibility, and transportation networks using a Geographic Information System (GIS).

3.2 Research location

This research location is located in the North Sumatra Sport Center area , which serves as the center for sports development and public activities in North Sumatra Province. This area was chosen because of its strategic function as a regional sports activity center, an urban public space, and part of regional infrastructure development. Administratively, the research area is located in North Sumatra Province, encompassing the sports development area and its surrounding buffer zone. The location was determined using a sampling technique, taking into account the following considerations:

1. The area has strategic value in regional development.
2. There is potential for economic and social development of the community.
3. It has challenges related to regional resilience such as accessibility, land use, and environmental sustainability.
4. Availability of spatial and non-spatial data that supports research.
5.

3.3 Data Sources

This study uses primary and secondary data. Primary data were obtained through field observations in the North Sumatra Sport Center area and its surrounding areas to identify existing land use, accessibility, transportation networks, and environmental conditions. Secondary data were obtained from the North Sumatra Sport Center Master Plan, the Deli Serdang Regency Spatial Plan (RTRW), high-resolution satellite imagery, scientific literature, and relevant planning documents. Secondary data was used to identify the direction of regional development, while field observations were used to verify the area's actual conditions. The combination of these two data types served as the basis for a Geographic Information System (GIS)-based spatial analysis and a SWOT analysis to assess the potential for regional resilience in the development of the North Sumatra Sports Center.

3.4 Data Analysis Techniques

The data analysis techniques used in this study were descriptive, spatial, and quantitative approaches to determine the level of regional resilience in the development of the North Sumatra Sports Center area. The analysis was conducted using a combination of a Geographic Information System (GIS) and a scoring and weighting-based SWOT analysis.

3.4.1 GIS Spatial Analysis

Spatial analysis was conducted using Geographic Information System (GIS) to identify the physical conditions of the area, land use patterns, regional accessibility, transportation networks, and environmental potential and vulnerability in the North Sumatra Sport Center area.

3.4.2 Quantitative Analysis with Scoring and Weighting Methods

The quantitative analysis in this study used a scoring and weighting method for regional resilience indicators, which consist of three aspects: physical aspects, such as area accessibility, transportation connectivity, and the availability of basic infrastructure; environmental aspects, such as the presence of green open space and potential flood risks; and finally, socioeconomic aspects, such as the potential for economic growth and the availability of public facilities. These are shown in the following table:

Variables	Indicator	Assessment Parameters	Score
Physique	Area accessibility	Proximity to main roads and stations	1-5
Physique	Transportation Connectivity	Availability of transportation	1-5
Physique	Infrastructure	Availability of area utilities	1-5
Environment	Flood risk	Drainage and runoff conditions	1-5
Environment	Green open space	Area of infiltration area	1-5

Socio-economic	Economic activity	Business and investment potential	1-5
Socio-economic	Public facilities	Education and health	1-5

Table 3.1 Regional Resilience Indicators

Each indicator is given a score of 1-5 with the following categories;

score 1 = very low
score 2 = low
score 3 = moderate
score 4 = high
score 5 = very high.

Each indicator is then weighted based on its level of influence on regional resilience. The final score is obtained by calculating:

Regional Resilience Value = Σ (Weight × Score)

The calculation results are then used to determine the level of resilience of the North Sumatra Sport Center area.

3.4.3. Quantitative SWOT Analysis

The SWOT analysis in this study was conducted quantitatively through the preparation of IFAS (Internal Factor Analysis Summary) and EFAS (External Factor Analysis Summary) matrices. Each internal and external factor was given a weight and rating to determine its level of influence on the development of the North Sumatra Sports Center area. The weights indicate the level of importance of each factor to regional resilience, with a value range of 0.00–1.00, with the total weights equaling 1.00. Weights are determined based on analysis of planning documents, literature reviews, field observations, and the factors' relevance to regional development objectives.

Ratings indicate the condition or level of influence of each factor on the region. For the strengths and opportunities factor, a rating of 4 indicates very strong or very supportive conditions, while a rating of 1 indicates less supportive conditions. For the weaknesses and threats factor, a rating of 1 indicates a very strong influence on the region, while a rating of 4 indicates a relatively small influence. The score is obtained by multiplying the weights and ratings. The total IFAS and EFAS scores are then used to determine the position of the region's development strategy in the SWOT matrix.

RESULTS AND DISCUSSION

4.1. Area Profile

The North Sumatra Sports Center Area Profile, the area subject to this planning, is a strategic development area located within the administrative area of North Sumatra Province. Specifically, this area is located in Batang Kuis District, Deli Serdang Regency. Geographically, this location occupies coordinates between 3°59' – 3°66' North Latitude and 98°69' – 98°82' East Longitude. Some of the main characteristics of this area profile include:

1. Proximity to Educational Institutions: This area is directly adjacent to or very close to the UINSU Batangkuis campus, making it a center of activity for students and academics.
2. Regional Accessibility: This location is flanked by two main sub-districts, namely Batang Kuis Sub-district and Beringin Sub-district, which shows its position as a connecting node between regions.
3. Transportation Integration: This area is planned to become a modern transportation hub with the RailLink line and plans to build a Railink Station right in the heart of the area.
4. Physical Characteristics: Based on satellite imagery, this area was originally dominated by open land and vegetation which is now starting to be transformed into an integrated (mixed-use) area with a main focus on sports, commercial and social functions.
5. Area Boundaries: The planning area is bounded by residential areas on several sides as well as a network of main roads connecting regional activity centers.

4.1.1. Analysis of the Strategic Position of the Region

Based on spatial analysis of satellite imagery and the North Sumatra Sports Center Master Plan, the study area lies within the strategic Medan-Kualanamu corridor, one of the main transportation corridors in North Sumatra Province.

This location offers easy access to Medan city center, Kualanamu International Airport, and new growth areas in Deli Serdang Regency.

The area is located along regional transportation routes, including the Primary Arterial Road and the Kualanamu Airport railway line. It is possible to build a new activity center focused on sports, trade, and services based on the high connectivity conditions in the area. The research area is located in the strategic Medan-Kualanamu corridor, one of the main movement centers in North Sumatra Province, according to spatial interpretation of satellite imagery and the North Sumatra Sport Center Master Plan document. This position offers many advantages, including easy access to Medan City Center, Kualanamu International Airport, and new growth areas in Deli Serdang Regency.

The area's location is on a route served by regional transportation networks such as the Primary Arterial Road and the Kualanamu Airport railway line, indicating that the area has a high level of connectivity, which can help develop new activity centers focused on sports, trade, and services.

4.2. Spatial Structure

The spatial structure analysis in this planning uses a modified Central Place Theory approach , dividing the area's functionality into several integrated zones to create spatial efficiency. The following are details of the Spatial Structure based on the plan map:

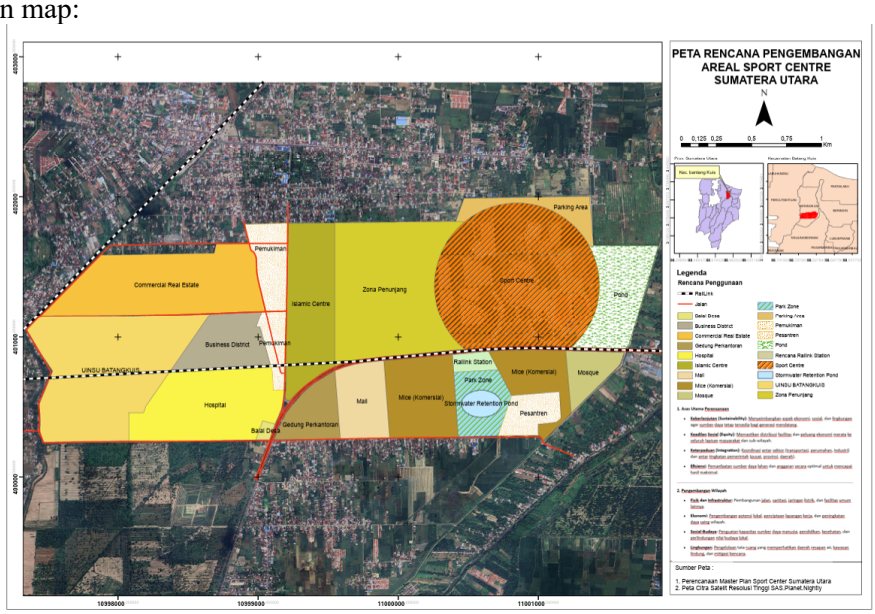

Figure 1.1. Map of the Sports Center Area Development Plan
Source: Spatial data processing

1. Sports Center as the Core.
   In the spatial hierarchy, the Sports Center is positioned as the main orientation (core) of the entire development of this area. Strategically located in the center of the area with a significant area, it functions as the main magnet to attract the crowd. The main function is as a center for regional-scale sports activities supported by a large parking area on the north side to accommodate visitors. Spatial Hierarchy: Being a meeting point between the education zone on the west side and the green/infiltration zone on the east side.

2. Integrated Commercial and Service Support Zone.
   To ensure the economic sustainability of the area, the activity center is surrounded by various supporting zones, including the Business District, Commercial Real Estate, and Office Buildings located on the west and central sides as formal economic drivers. Retail & Meetings, Incentives, Conferences, and Exhibitions (MICE). The existence of Malls and MICE (Commercial) facilities is positioned along the main corridor to maximize accessibility for visitors from outside the area. Social & Religious Functions, this zone is also strengthened by the presence of an

Islamic Center, Mosque, Islamic Boarding School, and Hospital that provide social services for residents in the Residential area.

3. Transportation Infrastructure.
   Multimodal Connectivity The resilience of mobility in this spatial structure is achieved through the planning of massive transportation infrastructure integration. Rail Integration (RailLink) trains divide the area horizontally, providing fast public transportation access to other regional centers with the planned station (Railink Station) positioned right in the center of the supporting zone, creating a TOD (Transit Oriented Development) node that facilitates access to the Sport Center and commercial areas. Main Road Network, the road network pattern is designed to connect functional blocks efficiently, ensuring the smooth flow of logistics and mobility of local residents.

4.3. Regional Resilience based on Environment & Disaster Mitigation.

Environmental Resilience & Disaster Mitigation in the development of the North Sumatra Sport Center area, the environmental resilience aspect is a priority to mitigate the risk of disasters that arise due to the transformation of land from open areas to built-up areas (impermeable surfaces).

4.3.1. Analysis of the Role of Stormwater Retention Ponds and Ponds

Land use changes from natural vegetation to buildings such as Malls, Sport Centers, and Commercial Real Estate will significantly increase the runoff coefficient. To anticipate the risk of flooding in the Batang Kuis area, this planning integrates a sustainable drainage system. The Stormwater Retention Pond function is located near the Mice (Commercial) zone, this retention pond functions as a temporary reservoir for rainwater to reduce the peak discharge of runoff. This is crucial to prevent excessive load on the macro drainage channels around the settlement. The existence of the Pond. In addition to the retention pond, there is a Pond area on the east side of the area that functions as a water absorption reserve and regulates the hydrological balance of the area. Disaster Mitigation, This step is in line with the principles of spatial management that pay attention to water absorption areas to mitigate flood disasters, as stated in the environmental development plan points.

4.3.2. Evaluation of Park Zones as Green Open Spaces (RTH)

Environmental resilience is also strengthened through the provision of functional green open space in the form of Park Zones. The provision of green open space, Park Zone is strategically positioned near Railink Station, providing ecological balance amidst the high intensity of commercial buildings. The Ecosystem Function, in addition to being an aesthetic area, Park Zone plays a role in reducing the Urban Heat Island effect that may arise due to massive road paving and office buildings. Sustainability as an Evaluation of Park Zones demonstrates a commitment to the principle of sustainability, ensuring that environmental resources are maintained for future generations even as economic development continues.

3.4. Regional resilience based on socio-economics:

A region's socio-economic resilience is measured by its ability to provide stable livelihoods and access to basic services that strengthen community structures. In the planning of the North Sumatra Sports Center, these aspects are integrated through commercial zoning and public service facilities.

4.4.1 The Role of Business Districts and MICE in Job Creation.

The planned commercial zone has an economic multiplier effect for the community in Batang Kuis District and its surroundings as a center for Local Economic Growth. The existence of the Business District and MICE (Commercial) is designed to attract investment and become a new engine of economic growth in the Deli Serdang region. Diversification of Employment with the presence of MICE Facilities creates a need for labor in the service, tourism, and event management sectors, while the Business District provides space for the formal sector and offices. Economic Justice (Equity), this development aims to ensure the distribution of economic opportunities evenly to all levels of society and sub-regions, thereby reducing regional economic disparities. Increasing Competitiveness by creating a conducive business climate, this area increases regional competitiveness independently through the development of local potential.

4.4.2 Strengthening Social Capital through Health and Education Facilities.

Social resilience depends not only on the economy, but also on "social capital" formed through access to education and health. The presence of a hospital within the area ensures a health safety net for local residents and visitors, which is a vital component of physical and social resilience. Educational Synergy (UINSU & Pesantren) with the Integration of educational institutions such as UINSU Batangkuis and Pesantren creates an academic and spiritual environment that strengthens the capacity of human resources (HR). Protection of Cultural Values, through religious facilities such as the Islamic Center, Mosque, and Pesantren, this plan also seeks to maintain and protect cultural values and local identity amidst the modernization of the area. Strengthening human resource capacity through education and health is a form of long-term investment so that the community is able to adapt to changes in regional functions in a sustainable manner.

3.5. Planning Principles Analysis

Sustainability and Equity in evaluating the success of a city development plan, the use of the Main Principles of Planning parameters is crucial to ensure that the project is not only economically profitable, but also fair and sustainable.

3.5.1. Sustainability Principle Analysis.

This principle emphasizes the balancing of economic, social, and environmental aspects so that resources remain available for future generations. Environmental Aspect: This plan shows efforts to mitigate environmental impacts through the provision of Stormwater Retention Ponds and Ponds to maintain water catchment areas. However, criticism needs to be given to the massive built-up area (Mall, Sport Center, Commercial Real Estate) which has the potential to reduce the basic green coefficient if not strictly monitored. In the Economic Aspect, the existence of the Business District and MICE guarantees the long-term economic sustainability of the region by creating a new, independent growth center. The Social Aspect of social sustainability is supported by the integration of educational facilities (UINSU, Islamic Boarding School) which guarantees the continuous development of human resource capacity.

3.5.2. Analysis of the Principles of Social Justice (Equity)

This principle demands an even distribution of facilities and economic opportunities to all levels of society and sub-regions. Facility Accessibility, the placement of public facilities such as Hospitals and Mosques in the center of the area facilitates access for residents of residential areas and outside visitors. Economic Opportunities, this plan seeks to provide economic opportunities for local communities through commercial zones. However, there is an Equity challenge if this development actually triggers Gentrification, where native residents in old residential areas are marginalized by rising land values due to Commercial Real Estate. Integration. The presence of Village Halls and government office buildings within the area demonstrates an effort to maintain the function of inclusive public services for all residents, not just for commercialization alone.

4.5.3 Critical Summary Overall,

plan has attempted to integrate these two principles through integrated coordination between sectors such as transportation (RailLink) and housing. Efficient land use and budget utilization are optimized to achieve maximum results in physical area and infrastructure development.

4.6. Regional Resilience Analysis

Regional resilience assessments were conducted using a scoring method for several variables considered to influence the region's ability to support regional development. Scoring was based on the region's spatial conditions, planning documents, infrastructure availability, accessibility, economic potential, and environmental aspects within the North Sumatra Sport Center development area. Each variable was assigned a score between 1 and 5, with higher scores indicating greater regional resilience potential, as explained in Subsection 3.4.2.

Indicator	Weight	Score	Mark
Area accessibility	0.20	5	1.00
Transportation connectivity	0.15	5	0.75
Basic infrastructure	0.15	4	0.60
Drainage conditions	0.15	3	0.45
Green open space	0.10	4	0.40
Economic potential	0.15	5	0.75
Public facilities	0.10	4	0.40
Total	**1.00**		**4.35**

Table 3.1 Regional Resilience Scoring Results

Based on the scoring results for the North Sumatra Sports Center development plan, a score of 4.35 was obtained, indicating high regional resilience potential if all planning components can be implemented in accordance with the regional development plan. The highest score was for accessibility and transportation connectivity, supported by the Railink line and the planned integrated station development. Meanwhile, environmental aspects, particularly drainage conditions, still require improvement to reduce the risk of flooding due to the increase in built-up areas.

4.6.1. Urban Resilience in the Development of the North Sumatra Sports Center Area

The concept of urban resilience emphasizes the ability of urban areas to withstand, adapt to, and recover from various stresses and disruptions, whether caused by economic, social, or environmental changes, or by natural disasters. Urban resilience refers not only to physical infrastructure but also encompasses institutional, social, and economic capacity to cope with change. The analysis shows that the development plan for the North Sumatra Sports Center area demonstrates the potential for establishing an urban system characterized by strong urban resilience, as demonstrated by the integration of functions in the areas of sports, education, health, commerce, and public transportation. The diversity of planned functions has the potential to make the urban system more adaptable. Furthermore, there is evidence of efforts to improve the region's ability to cope with flooding, traffic congestion, and environmental pressures caused by urbanization, demonstrated by the presence of water reservoirs, public transportation networks, and extensive green spaces. Consequently, the development of the North Sumatra Sports Center can be seen as an effort to increase urban resilience using an integrated spatial planning approach.

4.6.2. Sustainable City in the Development of the North Sumatra Sports Center Area

The concept of a sustainable city emphasizes urban development that maintains a balance between economic growth, environmental quality, and the social well-being of its residents. A sustainable city focuses not only on physical development; it also prioritizes resource efficiency, emission reduction, and improving the quality of life for its residents. However, expanding urban areas without strict land-use regulations can be detrimental to the environment. Therefore, preserving green spaces, monitoring water resources, and improving public transportation are essential components of sustainable development.

4.6.3. TOD Resilience in the Development of the North Sumatra Sports Center Area

Transportation-driven development (TOD) aims not only to improve a region's accessibility but also to enhance regional resilience through the integration of transportation systems, land use, and urban activities. From a regional resilience perspective, TOD resilience refers to a region's ability to maintain its mobility functions, economic activity, and social interaction despite the pressures arising from inefficient land use. Spatial analysis shows that the area around the North Sumatra Sports Center lies within a strategic corridor connecting the Railink network to Medan City and Kualanamu International Airport. The planned Railink station development has the potential to strengthen the area's position as a regional mobility hub, connecting various urban functions, such as sports facilities and healthcare centers.

Environmentally, combining public transportation is a better way to travel than using a private car. This aspect is especially important given the likelihood that the Sports Center area will receive significant numbers of visitors during regional or national sporting events. Public transportation reduces the burden on the road network, thereby reducing the risk of traffic congestion and reducing the quality of transportation services. The application of the TOD concept in regional planning has the potential to increase the resilience of mobility systems and enhance regional economic stability. When transportation and spatial planning are combined, ease of access can boost regional economies, attract new investment, and encourage business and service growth. The presence of business districts,

commercial areas, meeting, conference, and trade exhibition (MICE) venues, and other supporting facilities planned to be integrated with transportation hubs demonstrates this phenomenon. The implementation of TOD in the North Sumatra Sports Center not only functions as a transportation strategy, but also as a regional development tool that is able to simultaneously increase energy efficiency, air pollution, and road load by reducing people's dependence on private transportation.

4.6.4. Sport City Development in the Development of the North Sumatra Sport Center Area

The current focus of sports area planning extends beyond simply providing sports facilities to embracing the concept of sports city development. Within this concept, sports are seen as a catalyst for development, with the potential to improve the quality of life for residents, strengthen city identity, and create new, more competitive growth centers. Based on the spatial and SWOT analysis, the development of the North Sumatra Sport Center area demonstrates characteristics that lead to the formation of a sports city. This area is not only designed as a center for sports activities but also integrates commercial, educational, health, religious, and transportation functions within a single integrated area system. This integration reflects the mixed-use development approach, a key characteristic of modern sports city development. The presence of large-scale sports facilities in a particular area can have a multiplier effect on the retail, service, hospitality, transportation, and tourism industries. Various sporting events can attract visitors from outside the region, driving local economic growth. The business district and MICE facilities in the area enhance its position as a new economic hub in Deli Serdang Regency. The Sports Center area is planned to function as a public space that can increase social interaction and encourage a healthy lifestyle. The presence of easily accessible sports facilities can increase community participation in physical activity, while strengthening social cohesion through various community and recreational activities.

Furthermore, the development of the North Sumatra Sports Center has the potential to become a new growth tool that can reduce the development gap between Medan's city center and its suburbs. Due to its location in a regional development corridor, there is an opportunity to build a new, more balanced spatial structure and promote equitable regional development. The existence of this large-scale sports center also has the potential to become a new hallmark of North Sumatra. In the long term, this complex has the potential to become a regional icon, serving not only as a center for sports but also as a hub for social, economic, and cultural activities. Consequently, the development of the North Sumatra Sports Center can be considered the beginning of a sports city that will continuously enhance the region's competitiveness.

4.6.5. Climate Change Adaptation

One of the major challenges facing urban and regional development is climate change. Development plans can improve a region's ability to adapt to various environmental risks caused by increased rainfall, the frequency of extreme weather events, and rising temperatures in urban areas. In the development of the North Sumatra Sports Center, climate change adaptation is crucial because a large portion of open land has been converted into urban areas with high land use. The results of the spatial analysis indicate that increased surface runoff caused by decreased soil absorption capacity is one of the main risks. This condition can increase the risk of waterlogging and flooding, especially during the heavy rainy season. Therefore, one way to implement adaptation strategies aimed at maintaining the hydrological balance of the region is to incorporate ponds, green open spaces, and rainwater reservoirs into regional development plans. In addition to controlling flooding, adaptation to climate change must also focus on reducing the urban heat island effect, which generally occurs in areas dominated by buildings and paved surfaces. Ecological infrastructure such as the establishment of green spaces, green corridors, shade trees, and green open spaces serves to lower environmental temperatures, improve air quality, and enhance thermal comfort in the area.

Planting native vegetation, preserving catchment areas, optimizing rainwater collection systems, and using permeable materials in sidewalks and parking areas are all ways to support climate change adaptation. These methods allow areas to develop without compromising the environment's ability to provide ecosystem services. A region's ability to adapt to climate change is one of the main indicators determining the sustainability of long-term development from a regional resilience perspective. The greater a region's ability to adapt, the greater its ability to maintain its economic, social, and environmental functions when faced with the pressures arising from climate change. Therefore, integrating climate adaptation principles into regional development is a crucial step.

4.6.6. Relationship of Analysis Results with Regional Resilience Theory and Spatial Resilience

Regional Resilience Theory explains that regional resilience is the ability of a region to survive, adapt, and thrive amidst various pressures and changes stemming from economic, social, environmental, and infrastructure factors. In

the context of the North Sumatra Sports Center development, regional resilience is measured not only by the region's ability to support sports activities but also by its ability to manage spatial changes resulting from large-scale construction projects. Based on the evaluation of the regional development plan, the North Sumatra Sports Center demonstrated high regional resilience potential with a score of 4.35. This score indicates the region has the potential to have sufficient capacity to support development while maintaining existing regional functions. The key factors supporting the region's ability to adapt to increased mobility and economic activity in the future are high levels of accessibility and transportation connectivity. The Railink network, the development of mixed-use areas, and the planned construction of integrated railway stations demonstrate a strong regional adaptive capacity, from the perspective of Regional Resilience Theory. Planned diversification of functions, including the integration of sports, commerce, education, health, and transportation, can enhance a region's ability to cope with economic and social change. This is important because regions dependent on a single sector tend to be more vulnerable than those with a more diverse range of activities and economic structures.

The presence of business districts, MICE facilities, and commercial areas, as well as the potential for developing service industries and sports tourism, demonstrates the region's potential economic resilience. These diverse economic activities create investment and employment opportunities, which can enhance the region's economic capacity. A region's ability to generate new sources of economic growth is a key indicator in regional resilience theory, demonstrating its excellent ability to adapt to changing regional economic conditions. The presence of schools, hospitals, Islamic centers, and residential areas in the social sector demonstrates that development in the region is not solely focused on economic growth. This integration of social infrastructure also helps improve the quality of human resources, enhance access to public services, and develop community social capital. This aligns with the concept of regional resilience, which views community capacity as a crucial component in building long-term regional resilience.

Furthermore, the spatial analysis results show that the area has integrated various essential components to build an adaptive area. To maintain a balance between physical development and environmental carrying capacity, green open spaces, water reservoirs, and functional area planning are included. Spatial resilience emphasizes that a sound regional system must be able to maintain its ecological function despite significant pressures from urban development.

Based on the results of this analysis, it can be concluded that the development of the North Sumatra Sports Center demonstrates the characteristics of a resilient region from an economic and social perspective, as well as from an infrastructure and environmental perspective. Regional resilience is based on the integration of regional functions, transportation connectivity based on transit-oriented development (TOD), the provision of green infrastructure, and strengthening economic activity. Therefore, the development of the North Sumatra Sports Center will enhance the region's ability to adapt and survive in the long term, in addition to serving as a regional sports hub.

4.7. SWOT Analysis

To establish strategic direction in the planning and development of the North Sumatra Sports Center area, a SWOT analysis is the process of identifying several aspects derived from internal and external sources, both spatially and non-spatially. Strengths and weaknesses are examples of internal elements, while opportunities and threats are examples of external factors. The following are the results of the SWOT analysis for the North Sumatra Sports Center area .

A. Internal Factors

Strengths:

- **Regional Accessibility & Multimodal Connectivity:** Strategic location at the inter-regional connecting node (Batang Kuis and Beringin Districts) which is integrated with the RailLink line to Medan city center and Kualanamu Airport.
- **Implementation of the TOD Concept:** The planned Railink Station right in the heart of the area supports efficient mass movement (especially during peak sporting event periods) and reduces dependence on private vehicles.
- **Complete Mixed-Use Ecosystem:** The area integrates core sports facilities with commercial zones (Business District , Mall, MICE), social (Hospital), religious (Islamic Center, Islamic Boarding School), and education (UINSU) in one functional unit.

- **Disaster Mitigation Infrastructure:** Planning has included a water management system through Stormwater Retention Pond and Pond to anticipate flood risks due to land use changes.

Weaknesses:

- **Massive Land Transformation:** Changes in land function from open areas/natural vegetation to very dense built-up areas (impermeable surfaces) automatically increase the run -off coefficient .
- **Potential for Social Disparity (Gentrification):** Risk of displacement of native residents in old residential areas due to the surge in land values from Commercial Real Estate development .
- **Peak Infrastructure Load:** As a regional sports hub, there are major challenges in managing mass surges (distribution flows) at certain times to avoid mobility paralysis.

B. External Factors

Opportunities:

- **New Growth Center:** Potential to shift the concentration of economic activity from the already crowded city center of Medan to the buffer zone in Deli Serdang.
- **Economic Multiplier Impact:** Extensive job creation in the service, tourism and event management sectors through MICE facilities and business districts.
- **Human Resource Capacity Building:** The existence of higher education institutions (UINSU) and Islamic boarding schools in the area creates synergy for long-term human resource development.
- **Public-Private Partnership (PPP):** Opportunity for private sector involvement in commercial zone management to reduce the burden of APBD/APBN maintenance.

Threats:

- **Hydrological & Flood Risks:** If the construction of built-up areas (concrete) is not strictly monitored and exceeds the Basic Building Coefficient (KDB) threshold, the area is at risk of becoming a source of flooding for the surrounding areas.
- **Noise and Air Pollution:** The intensity of activity on the railway line (RailLink) and business areas can have a negative impact on the comfort of residential areas and academic environments if there is no adequate "Green Belt" .
- **Regulatory Misalignment:** Challenges in synchronizing coordination between central, provincial, and regional governments related to overlapping budgets or differences in development priorities.

4.8. Strategy based on SWOT Analysis

- **SO Strategy:** Optimizing the integration of railway stations with business centers to accelerate local economic growth and regional competitiveness independently.
- **WT Strategy:** Establish strict KDB zoning rules and require the use of porous materials (paving blocks) in large parking areas to maintain environmental carrying capacity against the threat of flooding.
- **ST Strategy:** Utilizing Park Zones not only for aesthetics, but as permanent local protected zones to reduce the Urban Heat Island effect and transportation activity pollution.

4.9. SWOT Matrix

Opportunities	**SO Strategy (Growth Strategy)**	**WO Strategy (Stability Strategy)**
1. Designation of the area as a New Growth Center .	• Optimizing the integration of train stations with Business Districts and MICE to attract investment .	• Utilize economic growth to finance social inclusion programs for residents in residential areas so that they are not marginalized .

2. The impact of the economic multiplier effect on local communities in Deli Serdang .	• Utilizing regional accessibility to make the area a logistics and services hub in North Sumatra .	• Directing local workers educated at UINSU/Pesantren to the formal sector in the regional business district .
3. Synergy with educational institutions (UINSU) for human resource development .	• Develop sports tourism packages supported by mall and MICE facilities .	• Tighten regulations on the use of remaining land for catchment areas before development becomes increasingly dense .
4. Government and private partnership (KPBU) scheme in management .		
Threats	**ST Strategy (Diversification Strategy)**	**WT Strategy (Defensive Strategy)**
1. Risk of flood disasters due to changes in land use .	• Functioning Park Zones and green corridors as Green Belts to reduce pollution and heat .	• Establish strict KDB (Basic Building Coefficient) rules and require the use of porous paving blocks .
2. Noise and air pollution from transportation and industrial activities .	• Using Railink Station as a density "relief valve" to prevent congestion on main roads .	• Synchronization of coordination between the Provincial Government and the Deli Serdang Regency Government in routine maintenance of the macro drainage system .
3. Lack of synchronization of regulations between levels of government .	• Strengthening social capital through health and religious facilities to maintain cultural resilience against modernization .	• Periodic audits of the Retention Pond capacity to ensure it remains capable of accommodating the water runoff load from massive buildings .
4. Long-term decline in environmental quality		

Based on the results of the analysis, the development of the North Sumatra Sports Center area has great growth potential by using the **SO (Strength-Opportunity) strategy.** Optimizing the integration of train stations with business centers to accelerate local economic growth and regional competitiveness independently .

In addition, the **WT strategy** Establish strict KDB zoning rules and require the use of porous materials (paving blocks) in large parking areas to maintain environmental carrying capacity against the threat of flooding and **ST.** Utilizing Park Zones not only for aesthetics, but as permanent local protected zones to reduce the Urban Heat Island effect and pollution from transportation activities.

This SWOT analysis demonstrates that collaboration between external policy support and local strengths is crucial to achieving the North Sumatra Sports Center Development. Effective management of these variables will make the North Sumatra Sports Center Development a socioeconomic tool that enhances community resilience.

4.10. Quantitative SWOT Analysis

A SWOT analysis is used to formulate a regional development strategy based on internal factors consisting of strengths and weaknesses and external factors consisting of opportunities and threats. This analysis is conducted by preparing the IFAS (Internal Factor Analysis Summary) and EFAS (External Factor Analysis Summary) matrices.

The weighting of the IFAS and EFAS matrices is based on the level of influence of each factor on the development of the North Sumatra Sports Center area. The weighting is based on spatial interpretation results, a literature review on regional resilience, and consideration of regional characteristics outlined in the Master Plan. The weighting ranges from 0.00 to 1.00, with a total weighting of all factors equal to 1.00.

Factors directly related to the area's primary function as a center for regional sports, economic, and transportation activities were given higher weight than other supporting factors. Therefore, accessibility, Transit-Oriented Development (TOD)-based transportation integration, and mixed-use development received relatively greater weight because they were considered to have a dominant influence on the potential for regional resilience and the success of regional development. These considerations were based on the area's position on the strategic Medan-Kualanamu corridor and its planned integrated sports activity center integrated with regional commercial, business, and transportation functions.

Internal Factors	**Weight**	**Rating**	**Score**
Regional accessibility (Strength)	0.20	4	0.80
TOD (Strength) Concept	0.15	4	0.60
Mixed-use (Strength)	0.15	4	0.60
Flood mitigation (Strength)	0.10	3	0.30
Land transformation (Weakness)	0.15	2	0.30
Gentrification (Weakness)	0.10	2	0.20
Infrastructure burden (Weakness)	0.15	2	0.30
Total	**1.00**		**3.10**

Table 3.2 IFAS Matrix (Internal Factor Analysis Summary).

External Factors	**Weight**	**Rating**	**Score**
New growth center (Opportunity)	0.20	4	0.80
Economic multiplier effect (Opportunity)	0.15	4	0.60
Human Resources Development (Opportunity)	0.15	3	0.45
KPBU)	0.10	3	0.30
Flood risk (Threat)	0.15	2	0.30
Pollution (Threat)	0.10	2	0.20
Regulation (Threat)	0.10	2	0.20
Environmental degradation (Threat)	0.05	2	0.10
Total	**1.00**		**2.95**

Table 3.3 EFAS Matrix (External Factor Analysis Summary).

Based on the results of the IFAS matrix calculation, the Strength value is 2.30 and Weakness is 0.80, resulting in an X-axis value of 1.50. Meanwhile, the EFAS matrix results show an Opportunity value of 2.15 and a Threat value of 0.80, resulting in a Y-axis value of 1.35. The coordinate position (1.50; 1.35) indicates that the evaluation results of the North Sumatra Sport Center area development plan are in Quadrant I (Growth Strategy), this position illustrates that the North Sumatra Sport Center area development plan has high internal strength and large external opportunities to be developed. The recommended development strategy is an aggressive strategy (SO Strategy) through optimizing regional potential to support economic growth and increase regional resilience.

The weighting results indicate that regional accessibility and transportation integration have the greatest influence on regional development. This is in line with the region's location along the strategic Medan-Kualanamu corridor, making connectivity a dominant factor in supporting regional resilience and future growth.

3.10. Development Strategy and Recommendations

To create a resilient North Sumatra Sports Center area, a strategy is needed that goes beyond just physical development. The following recommendations are prepared based on the results of spatial analysis and urban planning principles:

4.11. 1. Infrastructure Strengthening: Sustainable Physical Resilience

Infrastructure must be designed not only for current needs, but also to be resilient to future climate change pressures.

- **Integrated Drainage System:** Ensure that drainage channels around the Sport Centre and Commercial Real Estate are technically directly connected to the Stormwater Retention Pond to avoid peak surface water loads.
- **Climate-Resilient Power and Sanitation Networks:** Construction of underground utility networks to minimize the risk of damage from extreme weather. Use of centralized wastewater treatment plants (WWTPs) to maintain groundwater quality in residential areas.
- **High Road Standards:** The main road materials must use specifications that are resistant to flooding and heavy vehicle loads, considering that this area will become a logistics and mass transportation hub (Railink).

4.11.2. Spatial Planning Management: Protection of Environmental Carrying Capacity

The map shows high building intensity, so that protection of ecological functions is a non-negotiable price.

- **Optimization of Infiltration Areas:** Recommend that Ponds and Park Zones should not only be aesthetic elements, but be designated as local protected zones in the Deli Serdang Regency RTRW to prevent future land conversion.
- **Strict KDB (Basic Building Coefficient) Determination:** For areas around water catchment areas, zoning regulations are needed that limit the area of cement cover, encouraging the use of porous paving blocks in Parking Areas so that water can still seep into the ground.
- **Green Belt : Creating** a green corridor along the RailLink line to reduce noise and air pollution from train activities towards residential areas and UINSU .

4.11.3. Sectoral Integration: Efficiency and Governance

Regional resilience is impossible to achieve without synchronous coordination between stakeholders.

- **Central and Regional Synchronization:** The development of the Sports Center (national/provincial scale) must be aligned with the provision of basic infrastructure by the Deli Serdang Regency Government to avoid budget overlap.
- **Budget Utilization Efficiency:** Directing funding to priority projects that have a multiplier effect , such as the integration of Railink Station with business centers, so that infrastructure investment can trigger rapid local economic growth.
- **Public-Private Partnership (PPP):** Encouraging private sector involvement in the management of MICE and Mall zones so that the burden of maintaining the area does not rest entirely on the APBD, thus ensuring the sustainability of public service functions in the long term.

Conclusion and Suggestions

5.1 Conclusion

Based on the analysis of regional resilience to the development plan for the North Sumatra Sports Center in Batang Kuis, it can be concluded that:

1. **New Growth Potential:** This area has significant potential to transform into a new growth center in Deli Serdang. The integration of sports facilities, commercial zones (Business District and MICE), and educational institutions (UINSU and Islamic Boarding School) creates a self-sufficient and competitive regional ecosystem.
2. **Mobility Resilience: The implementation of** the Transit-Oriented Development (TOD) concept through the integration of Railink Station and RailLink lines is a strategic step to ensure smooth mass movement and reduce dependence on private vehicles, which supports energy and time efficiency.
3. **Hydrological Challenges:** Despite its massive economic potential, this development faces significant environmental risks. The land-use change into a highly dense built-up area requires **rigorous hydrological risk management** . The effectiveness of the stormwater retention pond and ponds is key to preventing this area from becoming a source of flooding for surrounding settlements.
4. **Balance of Principles:** Theoretically, this plan has attempted to accommodate the principles of Sustainability and Equity . However, its success on the ground will depend heavily on consistent enforcement of spatial planning regulations and protection of the social capital of local communities.

5.2 Suggestions

Regular monitoring of drainage coefficients and routine maintenance of water catchment zones are required. Furthermore, synchronization between the central, provincial, and regional governments must be maintained to maximize budget efficiency in supporting infrastructure development.

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