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Environmental and Natural Resources Impact of Road Infrastructure Development in Sidenreng Rappang District, Indonesia: Dynamic Consideration and Policies

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ABSTRACT

Sidenreng Rappang Regency's road infrastructure development offers a fantastic chance to enhance community welfare by promoting accessibility and mobility and bolstering regional economic development. To reduce adverse effects on the environment and guarantee the sustainability of natural resources for future generations, this study must, nevertheless, give prudent management top priority. This study reviews policies and dynamic factors to investigate how the development of road infrastructure in Sidenreng Rappang Regency affects the environment and natural resources. In this study, documentation, interviews, and observation were the methods employed for gathering data. The data used in this study are separated into primary and secondary categories. The study is descriptive and uses a survey method. The study's conclusions indicate that adverse effects on the environment and natural resources need to be properly managed. Long-Term Impacts: According to research, road infrastructure has a long-term positive impact on people's economic well-being, especially when it is supported by good maintenance and management policies. These studies highlight the necessity of investing in road infrastructure as a way to improve people's economic well-being, alleviate poverty, and achieve long-term economic growth. They also emphasize the importance of taking a comprehensive approach to road development that takes into account the environmental and social implications.

1. INTRODUCTION

Developing a nation's infrastructure is essential to boosting its economic growth. Public welfare and the rate of economic growth are closely correlated with the availability of road infrastructure. The length and spatial expanse of roads are growing at a rate never seen before in the history of the world [1, 2]. Since 2000, the global length of officially approved roads has grown by 12 million km [3], and by 2050, an additional 25 million km of paved roads are anticipated [4]. The G20 industrialized nations have stated that by 2030, they will require US$70 trillion in spending for new roads and other infrastructure, more than doubling the amount of money invested in infrastructure globally to date [5].

Reducing poverty and promoting shared prosperity in low- and middle-income nations requires sustainable economic growth, which is partly reliant on secure and dependable transportation infrastructure. A good quality of life is created and maintained in large part by road and highway systems. For the effective movement and distribution of manufactured goods and services, employee mobility to and from work, and the movement and availability of energy and raw materials, local businesses rely on stable road infrastructure. Access to health care, education, food and clothing, farm animal movement, and personal mobility are all dependent on transportation in local communities. For towns, regions, and nations to function, highway and road networks must be carefully planned, designed, built, operated, and maintained [6, 7].

Given the limited availability of natural resources, delicate environmental conditions, and constrained financial resources, a growing number of transportation planners, engineers, and environmental scientists across the globe are realizing the need for more sustainable roadway systems. In addition to the environmental benefits of energy conservation and the production of alternative energy, sustainability also refers to the successful and efficient project-level management of environmental, social, and economic factors [8].

This could include things like average vehicle occupancy, productivity of the transit system, affordability, accessibility, and safety for different income groups. In order to successfully manage potential negative environmental and social consequences and hazards, we must plan, develop, build, and maintain transportation networks while also working to promote both directly and indirectly connected good impacts or benefits [9].

Although they are vital to any society's economic growth, roadway pavements need a lot of resources to build and

maintain. Achieving sustainable economic growth and providing social benefits require well-maintained pavement networks, which are becoming more and more necessary due to rising urbanization and population expansion. However, creating, maintaining, and renovating pavements are costly procedures that require the use of energy, the extraction of resources, and the generation of garbage. As a result, road pavements have a significant environmental impact in addition to their beneficial socioeconomic effects [10-12].

The transportation sector's carbon footprint is mostly caused by vehicle emissions, but the infrastructure itself also has a big impact. Roughly 23% of the world's carbon dioxide (CO_2) emissions come from the transportation sector, and up to 10% of these emissions may be attributed to road building, according to some research estimates. For this reason, pavement infrastructure is essential to reducing greenhouse gas (GHG) emissions. Enhancing the environmental results of the road infrastructure sector is possible through the use of eco-friendly pavement development techniques [13, 14].

Infrastructure development has two sides: development objectives and development impacts. According to the Ministry of Public Works Strategic Plan 2010-2014, the development of road and bridge infrastructure aims to support the distribution of goods and human traffic and form a regional spatial structure. Without a doubt, every development project has an influence on the environment, both positively and negatively. It is important to think about how development should be carried out to maximize benefits and outcomes while reducing adverse effects on the environment.

The building of ecologically friendly roads and bridges is governed by a number of laws and directives from the government. When these rules and regulations are put into practice, they form a part of the terms and conditions of the contract, obliging contractors—who are operating as service providers—to abide by these articles. In accordance with the GBHN, "the Indonesian nation desires a harmonious relationship between humans and God, as well as between humans and the surrounding natural environment." As a result, we need to work toward encouraging an increasingly peaceful coexistence of Indonesians and the environment. With natural resources serving as our fundamental capital, governments must constantly work to reduce environmental harm.

According to the Republic of Indonesia Road Infrastructure Law No. 38 of 2004, roads are essential to the realization of the advancement of national life. This is because highways play a crucial and vital role in facilitating population movement and the distribution of goods and services. Highways that satisfy specific specifications are necessary because they serve as infrastructure for the safe, comfortable, rapid, and inexpensive transportation of people and commodities. The availability of roads is an absolute necessity for the entry of investment into a region.

Roads are land transportation infrastructure that includes all components of the road, including auxiliary structures and equipment meant for traffic, located on the surface of the ground, above the surface of the ground, below the surface of the ground and/or water, and above the surface of the water. Railroads, lorry roads, and cable roads are not considered to be part of the road network. Creating room for vehicles and overcoming different geographic constraints are the main tasks involved in road construction. The earth's surface must be moved, bridges and tunnels must be constructed, and even flora that permits deforestation must be moved. For this procedure, a variety of road building equipment will be used [15-17].

An alternative to boost tourism, economic growth, and transportation is to build new roads. The distance between cities can be shortened by the existence of road infrastructure. The government anticipates that the Pitu Riase sub-district's road infrastructure development will have a favourable effect on the regional economies of South Sulawesi. Building new roads requires a large amount of money and land. Land from the neighbouring community must be acquired in order to create road infrastructure. Undoubtedly, acquiring land for a road brings with it new difficulties. Many plantation areas are impacted by land acquisition. The loss of work land may result in job role modifications or even the end of employment.

The South Sulawesi Provincial Government has made improving the road network in Pitu Riase District a top priority, along with boosting the area's economy and competitiveness. In addition, the road development project aims to give connectivity to unconnected village communities so they can sell agricultural products that were previously only delivered once a week to the city. By improving road access, companies want to save operating expenses and transit times.

Taking into account dynamic policy concerns, this study aims to investigate the effects of environmental and natural resource issues on road development in Sidrap Regency, Indonesia. According to local knowledge from the study region in Sidrap Regency, Indonesia, environmental and natural resource elements have a large and intriguing impact. This research is notable since it examines these factors in detail. Through firsthand observation, this study seeks to understand how the expansion of road infrastructure affects the environment and natural resources. Interviews were undertaken with community groups, including users, economic actors, and regulators, who are involved in the usage of road infrastructure. Regulators uphold established regulations on behalf of the government. People who use the roadways in the community are called users.

2. LITERATURE REVIEW

2.1 Sustainable road development

The social sciences categorize development theory into two basic paradigms: modernization and dependency [18-20]. Parung et al. [21] divide development theory into three categories: Modernization, underdevelopment, and dependency. Different variations of the concept of development arose as a result of these paradigm shifts.

Maulana et al. [22] define development as an intentional strategy and execution of growth and transformation by a nation, state, or government toward modernity within the context of nation-building. Amiruddin et al. [23] provide a clearer definition, describing development as a deliberate process of change in a positive direction.

Experts define the concept of development in numerous ways, including planning. Different people, regions, and countries may understand the term "development" differently. However, there is widespread agreement that development is a process of transformation [24, 25]. Development is a transition process that affects all aspects of society, including politics, the economics, infrastructure, military, education and technology, institutions, and culture [26]. Tumpu and Lapian [27] describes development as a transition of the economy, society, and culture. Development is a process of deliberate

change aimed at improving many areas of people's lives.

Public amenities and infrastructure are both considered types of infrastructure. People typically associate facilities with public amenities such as roads, hospitals, bridges, water, telephones, electricity, and so on. Infrastructure is a type of public capital in economics that results from government investments [28]. The World Bank divides infrastructure into three categories: economic, social, and administrative infrastructure. Dawood et al. [29] categorize infrastructure into two types: Basic and complementary infrastructure. 1. Basic infrastructure consists of sectors that have public features and essential interests in other economic sectors, are non-tradeable, and cannot be separated technically or physically. Basic infrastructure includes highways, trains, canals, ports, seas, drainage systems, dams, and so on. 2. Supplementary infrastructure, such as gas, power, telephone, and potable water delivery.

2.2 Environmental impacts of road infrastructure

As defined by Mora-Rivera and García-Mora [30], infrastructure comprises "those services derived from the set of public works traditionally supported by the public sector to enhance private sector production and allow for household consumption". Batool and Goldmann [22] describe infrastructure as not just economic, but also defensive and government-sustainable. Furthermore, Pasra et al. [9] defined infrastructure as roads, bridges, water and sewage systems, airports, ports, and public buildings, as well as schools, health facilities, jails, recreation, power plants, security, fire, waste disposal, and telecommunication. Because of a lack of infrastructure, many people are forced to live in remote places where poverty is extreme. Poverty, infectious disease epidemics, starvation, illiteracy, and backwardness are among the issues that people face in their daily lives. The solution for curing these numerous ailments is to create fundamental infrastructure such as roadways, irrigation, clean water, education, and health care. The problem stems from the fact that the development of basic infrastructure requires enormous financial resources, which usually fail to result in a meaningful increase in value added. People frequently overlook isolated locations with less economic and socio-cultural potential.

Road infrastructure is a locomotive for economic development, not only in urban areas but also in rural or remote areas. Infrastructure development can create jobs that require a lot of labour. This scenario will enable a reduction in the cost of goods and services, making them affordable for the majority of Indonesians, many of whom still have modest incomes. Therefore, the movement of goods, services, people, money, and information also influences price movements in the markets; in other words, the road infrastructure balances the prices of goods and services between different regions, such as cities and villages.

2.3 Road network

Roads are defined as land transportation infrastructure in Law Number 38 of 2004, which includes all sections of the road, as well as traffic-related buildings and equipment. With the exception of railroads, lorry roads, and cable roads, these parts can be on the land's surface, above the land's surface, below the land and/or water, or above the water's surface. The unified road network is made up of two network systems: primary and secondary, which are interconnected in a hierarchical connection. According to Article 6 of Government Regulation No. 34 of 2006, the road network system is divided into two parts: A primary road network system and a secondary road network system, which are interconnected in a hierarchical manner. 2. The regional spatial plan directs the layout of the road network system, taking into account connectivity between different regions, both urban and rural.

The Road Network System categorizes roadways based on their roles. 1. The primary road network system. The principal road network system provides a distribution service for the growth of all regions on a national scale, with distribution service nodes assuming the shape of cities. Spatial planning and national-level regional development structures organize the principal road network system, connecting the distribution service nodes in the following way: a. Within the development area. The system continuously connects the first-level, second-level, third-level, and lower-level cities to the plot within each development area unit. It also develops linkages between the first-level cities within each development area unit. system the secondary road network system provides a distribution service to the communities within the city. Spatial planning organizes the secondary road network to connect functional regions.

2.4 Natural resources

Natural resources can be used by humans for a variety of purposes and requirements, allowing them to live more prosperously in the surrounding natural environment. Natural resources are present in all of the elements—soil, water, land surface, air, and more. The characteristics of natural resources, whether they be inanimate or living creatures, are crucial to humanity.

Natural resources encompass all of the biotic and abiotic gifts found on Earth. Systems and natural resources that benefit humanity in terms of technology, the economy, and certain social circumstances are included in the definition of natural resources. Next, we employ natural resources for a range of uses, including direct consumption and as a source for additional management. Natural resources might be seen as a flow of products or services produced by these resources, or as a fixed supply.

2.5 Mitigation strategies

Stocks or reserves represent what is always known to be available, whereas products and services demonstrate that they are in use. Natural resource availability is influenced by social restraints, cost structures, and technological advancements. Natural resources need to be seen as a component of the larger system. Prevent other forms of resources from being harmed by resource management. Resources include natural resources, which are dynamic and changeable, as well as the number of pre-existing materials that need to be processed and utilized. Natural resource values are contingent upon temporal and spatial factors, technological advancements and novel discoveries, human perspectives toward these resources, and shifts in domestic and international consumer preferences.

Solar and air energy. The third kind of natural resources are those that, by their very nature, are boundless or perpetual in the natural world. This happens as a result of the ongoing cycle that this specific kind of natural resource experiences over time. There are also small-scale natural resources in daily life. Resources that are considered renewable include lakes, rivers,

land, forests, and wildlife. These resources have the capacity to restock, regenerate, and endure. Because of their inherent qualities, renewable natural resources are the first class of natural resources. Natural resources that are renewable can be restored rather easily, and the process of doing so doesn't take too long. This natural resource can be replenished in the near future through rejuvenation. Non-renewable natural resources (irreplaceable/stock natural resources) include metals and petroleum.

3. METHODS

3.1 Research location

This study was carried out in three villages in the Wajo, Luwu, and Enrekang regencies' border area—Pitu Riase sub-district in Sidenreng Rappang District. The five village sections that correspond to theThe five village locations in Sidenreng Rappang Regency that are the subject of this research are Bila Riase, Bola Bulu, Batu, Compong, and Lombo Village, economic activity in the surrounding regencies and Sidrap Regency. Figure 1 shows the research location.

3.2 Conceptual framework of research

Roads and other natural resources in Pitu Riase District's infrastructure have a direct and indirect effect on the region's economic productivity by raising output levels, creating job possibilities, and fostering the growth of various economic sectors. This study's main goal is to investigate how road infrastructure development, directly affects the environment and natural resources. The concept of this investigation is outlined in Figure 2 of the research model. The research concept framework guides the development of the study variables in Table 1. The variables employed in this study will be analysed to produce fresh results.

This study intends to make a significant contribution by investigating how road infrastructure development affects the community's economic well-being at the micro level, specifically in the everyday lives of households, as well as how it influences the community's social life. It also looks into how road infrastructure development affects the local ecology and natural resources.

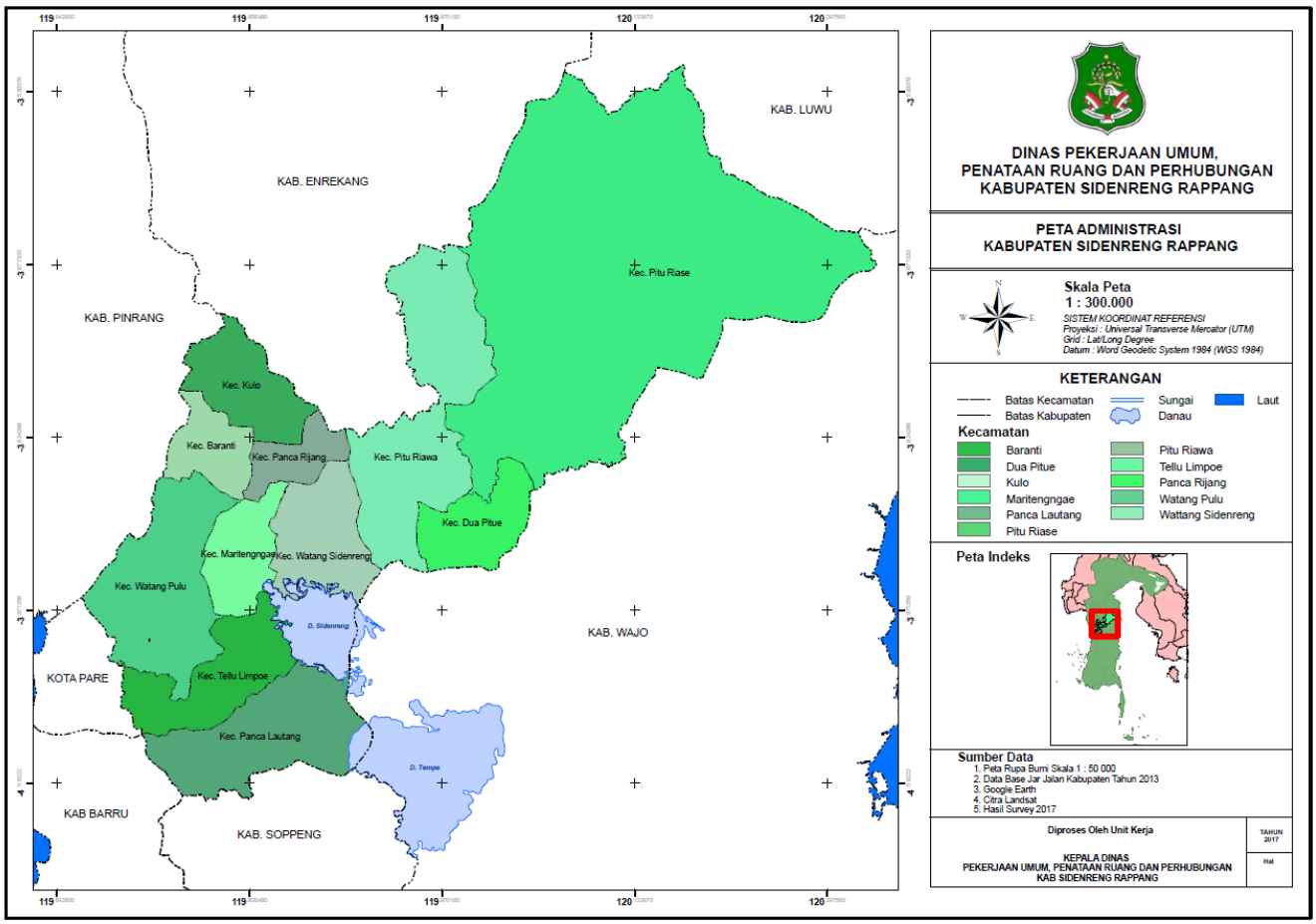

Figure 1. Research location

3.3 Data needs and data collection techniques

The data needed to see the economic conditions of the studied area are:

a. Land Data
b. Protected Forest Area
c. Natural Disaster Data (Landslides and Floods)
d. Alternative Roads

In this study, documentation, interviews, and observation were the methods employed for gathering data. The primary goal of this research is to use firsthand observation to determine how road infrastructure expansion affects the environment and natural resources. Interviews were undertaken with community groups, including users,

economic actors, and regulators, who are involved in the usage of road infrastructure. Regulators uphold established regulations on behalf of the government. People who use the roadways in the community are called users.

The documentation methodology, which involves getting data through supporting documents connected to the data under study, is one way to acquire research data indirectly. Data can be obtained through the review of written documents in the form of images, tables, diagrams, or data, as in a documentation study. In order to chronicle the economic circumstances of the community in the research area, we gathered written materials and photos for this study. Researchers looked at the subdistrict area's key commodities and demographic conditions.

In this study, we use the following data collection strategies to get the necessary information to account for the writing. This study's data collection techniques included interviews, observations, and questionnaires delivered to relevant parties. We detail all data collection methods and data processing steps in order to achieve the study's objectives.

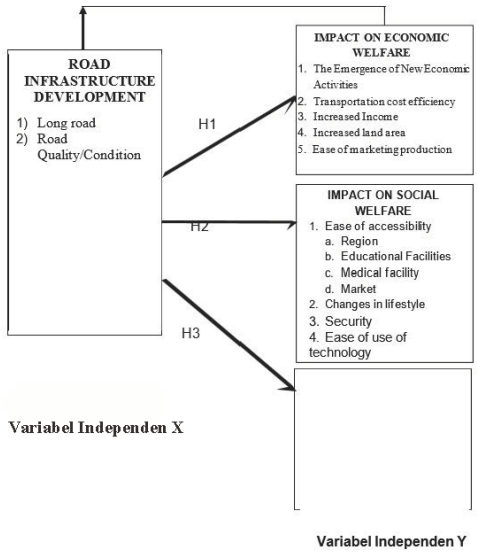

Figure 2. Conceptual framework of research

Table 1. Research variable

No.	Variable	Dimension	Indicator	Scale
1	Road infrastructure	Length of the road	1. National road 2. Provincial road District road	Interval
		Road quality/Condition	1. Good 2. Currently 3. Minor damage 4. Mayor damage	Interval
2	Community economic welfare	The emergence of new economic activities	1. Number of trading units 2. Types of trading units Trading unit conditions	Interval
		Transportation cost efficiency	1. Transportation services 2. Transportation rates 3. Mode of transportation	Intrerval
		Increased income	1. Main income 2. Side income 3. Number of working members in the family	Interval
		Increased land area	1. Land ready to be cultivated 2. Productive land 3. Residential land	Interval
		Ease of product marketing	1. Traveling time 2. Mileage 3. Accessibility transport node	Travelling time
3	Social welfare of the community	Ease of accessibility	1. Educational facilities 2. Health facilities 3. Market	Interval
		Changes in lifestyle	1. Level of education 2. Healthy living 3. Community participation	Interval
		Security	1. Crimes that occur 2. The accident that happened	Interval
		Ease of use of technology	1. Internet access 2. Agricultural tools 3. Health services	Interval
4	Environment/Natural resources	Environmental damage	1. Illegal logging 2. Landslide 3. Flood	Interval
		Opening of agricultural land (food crops/plantations)	1. Clove fields 2. Cocoa land 3. Durian land	Interval
		Reduction of agricultural land	1. Rice fields 2. Land acquisition 3. Alternative route	Interval

3.4 Data analysis technique

Here, we're employing study data that has been divided into primary and secondary data types. In the descriptive study, a survey methodology is used. Primary data is collected directly from the field using techniques like calculation, measurement, and observation. In order to gather primary data, we used a number of quantitative characteristics, including stand data, land cover conditions, physical field conditions, and the Pitu Riase District, Sidenreng Rappang Regency, strategic road improvement plan area, which indicates the area's inclusion in the protected forest area. Administrative maps, land cover, land conditions, location accessibility, and other relevant data are examples of secondary data. Usually obtain secondary data from affiliated organizations.

In order to assess the community's preparedness for road maintenance management, we performed a quantitative descriptive analysis on the replies given by respondents. We looked at participation based on role types like ideas, costs, and manpower as well as management elements like planning, financing, institutions, and control. The influence of road infrastructure development on community welfare and natural resources was determined through quantitative descriptive analysis using a frequency distribution table to identify the answer criteria with the highest frequency of occurrence as the dominant criteria over other criteria.

3.4.1 Descriptive analysis

In this case, we use research data divided into two categories: primary and secondary data. We conduct a descriptive study utilizing a survey. We obtain primary data directly from the field through techniques such as measurement and observation. We collected primary data using a variety of quantitative factors, including stand data, land cover conditions, physical field conditions, and the scope of the strategic road improvement plan in Pitu Riase District, Sidenreng Rappang Regency, which encompasses the protected forest region. Secondary data includes administrative maps, land cover, land conditions, site accessibility, and other relevant information. We obtain secondary data from relevant agencies.

3.4.2 Quantitative analysis

We conducted a quantitative descriptive analysis of respondents' responses regarding the community's readiness to engage in road maintenance management, looking at participation based on role types such as ideas, costs, and manpower, as well as participation based on management aspects such as planning, financing, institutions, and control. To better understand the influence of road infrastructure development on community welfare and natural resources, we performed a quantitative descriptive analysis using a frequency distribution table, selecting the answer criteria with the highest frequency of occurrence over other criteria.

3.5 Population and sample

A population, according to Maulana et al. [22], is a generalization region that comprises persons or items with particular attributes and traits that researchers examine before drawing conclusions. All of Pitu Riase District's villages and households made up the study's population. A sample is a portion of the population. 50 farmers and gardeners from three (three) villages in Pitu Riase District—Compong Village, Lombo Village, and Leppangeng Village—made up the study's sample.

Based on land cover conditions, landscape conditions, and location accessibility, we identified the sample points using the non-probability sampling technique at three locations: Compong Village, Pitu Riase District, for points 1 and 2, Lombo Village, Pitu Riase District, for points 3 to 9, and Leppangeng Village and Tana Toro Village, Pitu Riase District, for points 10 to 25. In order to ascertain how the strategic road improvement plan for Sidenreng Rappang Regency will affect these places, researchers looked at the land cover and current circumstances along the left and right sides of the road improvement plan, which is a protected forest area.

4. RESULTS AND DISCUSSION

Road infrastructure in Sidenreng Rappang Regency is critical to the community's economic well-being. We used a multiple linear regression analysis to examine how road condition, trip time, and transportation expenses affect community income. The findings of the analysis are discussed below: Good Road quality improves accessibility and comfort during travel, resulting in enhanced production and economic efficiency. People have easy access to workplaces, shops, and public services like education and healthcare. Improving road quality also saves car running expenses and travel time, allowing people to devote more time to productive economic pursuits.

Shorter trip times reflect greater transit efficiency. People have more time to work or pursue other economic pursuits when they spend less time on the road. Reduced commute time minimizes stress and weariness, increasing productivity and overall well-being. As a result, developing road infrastructure that reduces travel time is critical. High transportation expenses can be a financial burden on society. Transportation costs diminish the cash available for other requirements such as food, education, and health. As a result, lowering transportation expenses through road upgrades and public transit efficiency can boost people's purchasing power and economic well-being.

Improved Accessibility and Mobility: Good Road infrastructure makes it easier to reach a variety of amenities and services. This includes access to markets, health care facilities, and educational institutions. This greater accessibility allows for more active economic and social activities. Better roads not only save vehicle maintenance expenses and fuel consumption, but they also reduce the amount of time individuals spend driving. This allows people to better manage their resources and time. Increased Productivity: Better roads allow firms to run more efficiently. The distribution of goods and services increases faster, and logistical costs fall, resulting in higher economic productivity.

Road infrastructure has a harmful impact on the environment. Road development frequently necessitates considerable land removal, which can result in deforestation and damage of natural habitats. This may reduce biodiversity and alter local ecosystems. Increased Pollution: As road infrastructure improves, the number of motorized vehicles increases, potentially increasing greenhouse gas emissions and other air pollutants. This can have an adverse effect on air quality and public health. The results of the multiple linear regression analysis demonstrate that road infrastructure has a considerable impact on the economic well-being of the Sidenreng Rappang Regency community. Improving road

quality, reducing travel time, and lowering transportation expenses all increase community income.

4.1 SWOT analysis: Road infrastructure in Sidenreng Rappang Regency

The following effects of road infrastructure on the environment and natural resources in Sidenreng Rappang Regency are revealed by the SWOT analysis.

4.1.1 Strength

1. Enhancing Accessibility: An efficient road system makes it easier to access different parts of Sidenreng Rappang Regency, which promotes population mobility and transportation. The outcomes make this point very evident. The composite dependability value of the build is shown in the above table. Road infrastructure, community welfare, and natural resources had composite reliability scores of 0.916, 0.883, and 0.90, respectively. Because the three constructs' composite reliability values are more than 0.70, we regard them as trustworthy indicators.
2. Regional Economic Growth: Building new roads can stimulate trade and tourism, two local economic activities that can have a major positive impact on the local economy.
3. Efficiency of Transportation: A more effective distribution of goods and services is made possible by decent roads, which also cut down on travel times and expenses.

4.1.2 Weakness

1. Environmental Damage: Deforestation, soil erosion, and the degradation of natural habitats are all consequences of road development that endanger biodiversity.
2. Better road infrastructure can lead to a rise in motor vehicle traffic, which can worsen air pollution and greenhouse gas emissions, which will exacerbate climate change.

4.1.3 Opportunities

1. Enhanced control over the surroundings. This offers a chance to integrate ecologically friendly and sustainable construction methods into projects involving road infrastructure.
2. Development of tourism that is sustainable. Access to tourist locations can be improved by using a sustainable tourism strategy that takes environmental preservation into account.
3. Education and awareness of the environment. Road building projects can be accompanied by environmental education initiatives to increase community knowledge of the value of protecting natural resources.

4.1.4 Threats

1. The degradation of ecosystems. Neglecting environmental considerations during road construction can lead to ecosystem degradation, which can have long-term effects on the natural equilibrium.
2. Conflicts involving land use. Development of infrastructure may lead to disputes with communities that rely on the area's natural resources, as well as with interests in conservation.
3. Natural Disasters. Building new roads in places vulnerable to natural catastrophes, such as those experiencing flooding or landslides, might make people more vulnerable to such events.
4. Economic progress and accessibility. The development of road infrastructure in Sidenreng Rappang Regency promotes regional economic growth and increases accessibility. But in order to guarantee long-term gains, we need to strike a balance with environmental preservation initiatives. Impacts on the environment and natural resources. We cannot ignore the negative environmental effects of road building, even with its many economic benefits. Land use change, pollution, and habitat destruction are major issues that need for practical mitigation techniques.

4.2 Strategies for sustainable road development in Sidenreng Rappang Regency

Here are some suggestions to optimize positive effects and reduce negative ones:

1. Sustainable Development: Incorporate sustainable development ideas into the design and execution of road projects.
2. To avoid harming the environment or natural resources, road infrastructure projects in Sidenreng Rappang Regency might go through a thorough environmental impact assessment. By taking the following actions, Sidenreng Rappang Regency may guarantee that road infrastructure projects do not harm the environment or natural resources by conducting an extensive environmental impact assessment.

a. Planning and sizing up. Let's start by outlining the project's purpose, locating its stakeholders, and establishing its parameters.

b. Researchers are gathering baseline data on the following topics: biodiversity, soil and geology, water and air quality, and social and economic elements. Determination and evaluation of possible effects.

c. Plans for specific mitigation include using low-emission fuels, flushing construction roads on a regular basis, and covering material transport trucks. Before runoff reaches aquatic bodies, we are filtering it with biofilters and building sedimentation ponds. In order to guarantee habitat connection, we are also doing reforestation projects and building green corridors. We are planting erosion-resistant vegetation and terracing areas as conservation measures. We offer impacted communities skill training and compensation programs. By taking these actions, we can ensure that road infrastructure projects in Sidenreng Rappang Regency have no negative effects on the environment or natural resources.

3. Rehabilitation and Reclamation: Post-development land rehabilitation and reclamation initiatives should be put in place in order to restore disrupted ecosystems.
4. Supervision and Monitoring: Keep a constant eye on how road infrastructure projects are affecting the environment.
5. Education and understanding: Through public campaigns and educational initiatives, raise public understanding of the value of environmental protection.

4.3 Balancing economic development and environmental impact of road infrastructure

In order to promote both community welfare and economic development, road infrastructure is essential. But typically, a big worry is how it may affect the environment and natural resources [23]. In the context of Sidenreng Rappang Regency, road infrastructure can have a positive impact on the environment and natural resources, but it can also pose serious risks. The benefits of road infrastructure include the following:

1. Enhancement of Accessibility Sidenreng Rappang

Regency's accessibility to different places is improved by well-maintained roads. Residents may now more easily access public services like markets, healthcare, and education. This enhanced accessibility can boost regional economic growth and raise standard of living in the neighbourhood.

2. Development of Local Economy. Trade and tourism are two economic activities that can be stimulated by road construction. Improved access makes tourist areas more accessible to visitors and allows local items to be sold in larger markets. This could lead to a rise in local revenue and the creation of new jobs.

4.3.1 Negative impact on the environment

1. Destroying habitats and biodiversity road construction projects frequently require extensive land clearing, which results in deforestation and the degradation of natural habitats. This poses a threat to biodiversity, particularly if building occurs in or close to protected forests or the habitats of endangered animals.

2. Pollution of the air and water Improved Road infrastructure can result in a rise in motorized vehicles, which can raise air pollution and greenhouse gas emissions like CO_2. Furthermore, road runoff and building operations can contaminate nearby water sources, lowering the quality of water that is available to locals and ecosystems.

3. Flooding and Soil Erosion Soil erosion and changes in natural water flows might result from road building. This can harm agricultural land, disturb freshwater ecosystems, and raise the risk of floods in the surrounding communities if it is not handled appropriately.

4.3.2 The impact on natural resources

1. Use of Land Large tracts of land are needed for road development, which frequently means removing land from profitable forests or farms. This land use may diminish forest resources, lower the amount of land accessible for agriculture, and jeopardize local food security.

2. Land use disputes development and conservation concerns may clash over land usage for road infrastructure [24]. Communities that rely on the land for their subsistence may lose both land and essential resources.

4.3.3 Environmental impact mitigation strategies [25]

1. Assessment of Environmental Impact. Conducting a thorough environmental impact assessment is crucial prior to beginning any road development project. Potential negative effects can be found and efficient mitigation strategies can be created with the aid of an EIA.

2. Enduring Progress Incorporate the concepts of sustainable development into the planning and execution of your projects. This includes the use of eco-friendly technologies, safeguarding protected areas, and rehabilitating land after construction.

3. Management of erosion and flooding Use flood and erosion control strategies, such as terracing, creating efficient drainage channels, and planting vegetation that retains erosion. This may lessen detrimental effects on the land and water.

4. Recuperation and Restoration Reclamation and land restoration should be done when building is finished in order to repair damaged ecosystems. To maintain biodiversity, restore natural ecosystems and replant native plants.

5. Monitoring and oversight Keep an eye on and oversee the effects that road infrastructure initiatives are having on the environment. This makes it possible to identify issues early and take corrective action quickly.

Implement environmental mitigation strategies during and after road building. This includes replacing trees and protecting designated places. Regular maintenance programs are critical for preventing further deterioration of roads and ensuring their constant good state. Good road infrastructure in Sidenreng Rappang Regency has a substantial positive impact on the local economy. Improved road quality, shorter travel times, and cheaper transportation costs all help to boost community revenue and economic well-being. However, we must also consider environmental consequences and employ appropriate mitigation techniques during road building. Thus, we may get the economic benefits of road infrastructure without jeopardizing environmental health or the sustainability of natural resources.

While developing the road infrastructure in Sidenreng Rappang Regency can have a positive economic impact, it can also have detrimental effects on the environment and natural resources. To guarantee that infrastructure development does not negatively impact significant ecosystems and natural resources, it is crucial to put into practice suitable mitigation techniques and sustainable practices. With proper planning and management, Sidenreng Rappang Regency may reap the economic benefits of road development without sacrificing the sustainability of natural resources or the health of the environment.

The Asian Development Bank (ADB) performed a study titled Impact of Road Infrastructure on Economic Growth and Poverty Reduction in Southeast Asia, which provides an overview of the relationship between road infrastructure and societal economic welfare. This study examines the influence of road development in many Southeast Asian nations, including Indonesia, on economic growth and poverty reduction. The study's findings suggest that investing in road infrastructure improves accessibility, lowers transportation costs, and promotes regional economic growth. Using data from India, the economic impact of rural road upgrades on poverty reduction and employment in the country is analyzed. Key findings indicate that road upgrades improve access to markets and jobs, resulting in higher household incomes and lower poverty. The paper "Infrastructure and Economic Growth in Developing Countries: Recent Advances and Research Challenges" by Esfahani, H. S., and Ramrez, M. T., investigates the relationship between infrastructure, particularly roads, and economic growth in developing nations. The study emphasizes that proper infrastructure is critical to facilitating economic activity and enhancing output.

To investigate the impacts of road infrastructure, we bring together fields such as ecology, economics, sociology, and civil engineering. This method makes it possible to evaluate the impacts of road development in great detail. Participatory surveys and focus group discussions (FGDs) are effective methods for involving nearby communities in the process of gathering data and evaluating the impact. This ensures that traditional knowledge and local viewpoints will be taken into account. In order to assess long-term environmental risks such as soil erosion, habitat loss, and flood threat, we are developing forecasting models. Climate projections and historical data can serve as the foundation for these models. We are creating and evaluating novel strategies to lessen the effects on the environment, like buffer zones to save important habitats, green drainage systems, and bioengineering methods for erosion management. We are creating models to predict the long-term costs and benefits of road building that incorporate environmental and economic impact analysis. Making more

sustainable and informed decisions is aided by this.

Accessibility and mobility: Good Road infrastructure improves people's accessibility and mobility, making it easier to reach markets, jobs, and public services. This boosts production, income, and poverty alleviation. Improved roads lower transportation costs and travel time, which boosts economic efficiency. This lowers transport costs for businesses while increasing people's purchasing power. Regional Development: Investment in road infrastructure can boost regional growth by attracting capital and creating new job opportunities. It can also help to alleviate regional inequities by connecting outlying areas with economic hubs.

Long-term impacts: According to research [18], road infrastructure has a long-term positive impact on people's economic well-being, especially when it is supported by good maintenance and management policies. These studies highlight the necessity of investing in road infrastructure as a way to improve people's economic well-being, alleviate poverty, and achieve long-term economic growth. They also emphasize the importance of taking a comprehensive approach to road development that takes into account the environmental and social implications.

There are several versions in use, especially in Sidenreng Rappang Regency.

1. Economic Modelling

a. Cost analysis

Capital Expenditure (CapEx): Initial costs for road construction.

Operational Expenditure (OpEx): Annual operating and maintenance costs.

b. Benefit Analysis

Transportation Efficiency Improvement: Reduced travel time and costs.

Local Economic Development: Increased economic activity and property values.

Tax Revenue: Increased revenue from vehicle and property taxes.

2. Environmental Impact Modelling

a. Environmental Impact Assessment (EIA): Using baseline data to model the impacts of road construction on the environment.

b. Spatial Modelling: Using GIS to map environmental impacts around the project site.

c. Risk Assessment: Using risk analysis to assess potential environmental damage and required mitigation.

3. Integration of Economic and Environmental Models

a. Cost-Benefit Analysis: Combining economic costs and benefits with environmental impacts to assess the net benefit of a project.

b. Use of Environmental Economic Valuation Methods: Assessing environmental impacts in monetary terms, such as health costs from air pollution, costs of ecosystem restoration, and the economic value of biodiversity.

4. Simulation and Prediction

a. Dynamic Models: Create dynamic models that can simulate a variety of road construction scenarios, such as route changes, improvements in construction technology, and variations in environmental policies.

b. Sensitivity Analysis: Evaluate how changes in underlying assumptions (such as traffic growth, climate change) affect model results.

A loading factor value for indicator $X_{1.1}$ of 0.623, $X_{1.2}$ of 0.609, $X_{1.3}$ of 0.766, $X_{1.4}$ of 0.780, $X_{1.5}$ of 0.735, $X_{1.6}$ of 0.547, $X_{1.8}$ of 0.808, $X_{1.9}$ of 826, and $X_{1.10}$ of 0.652 was obtained from the road infrastructure construct (X), as measured by 10 indicators. Based on eight indicators, the Community Welfare Construct (Y_1) had a loading factor value of 0.716 for indicator $Y_{1.1}$. The values of $Y_{1.2}$, $Y_{1.3}$, $Y_{1.4}$, $Y_{1.6}$, $Y_{1.7}$, $Y_{1.8}$, and $Y_{1.6}$ are 0.722, 0.666, 0.693, 0.711, 0.749, and 0.752, respectively. Ten indicators produce loading factor values: $Y_{2.1}$ at 0.193, $Y_{2.2}$ at 0.192, $Y_{2.3}$ at 0.657, $Y_{2.4}$ at 0.513, $Y_{2.5}$ at 0.751, $Y_{2.6}$ at 0.794, $Y_{2.8}$ at 0.742, $Y_{2.9}$ at 0.785, and $Y_{2.10}$ at 0.784. These indicators measure the Natural Resources Construct (Y2).

5. CONCLUSION

Investments in road infrastructure should mainly support the densification of overpopulated areas, the growth of underdeveloped areas lacking in development possibilities, and the expansion of labour mobility.

It would appear plausible to assume that the transportation infrastructure influences the development of the Sidenreng Rappang Region by promoting economic and social growth based on the literature analysis and research undertaken. At the same time, the research suggests that unduly slow regional development may cause a sizable number of residents to leave the study area. Given the initiatives taken by local government to enhance the region's appeal, employers are rather hopeful about the socioeconomic development of the area. In addition to their promotional efforts, they make it abundantly evident that funding for the development of transportation infrastructure and tourism is necessary.

The economic well-being and standard of living of the people of Sidenreng Rappang Regency are greatly impacted by the state of the road system. However, to reduce adverse effects on the environment and natural resources, cautious management is required. The usage of recycled asphalt in Sidenreng Rappang Regency is one example of environmentally friendly infrastructure that tries to lessen carbon emissions by using asphalt that is manufactured from recycled materials. Moreover, the Green Drainage System. Farmer markets and skill development programs support regional economic empowerment. Community Engagement regularly hosts forums for conversation with nearby communities to hear about the status of projects and get input. innovation and technology. routine assessment and modification of strategy.

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REFERENCES

[1] Rosmariani, A., Tumpu, M., Savitri Reskiana, A., Rifan, F. (2022). Study of measuring the application of construction safety management systems (CSMS) in Indonesia using the analytic hierarchy process. International Journal of Engineering Trends and

Technology, 71(3): 354-361. https://doi.org/10.14445/22315381/IJETT-V71I3P237
[2] Li, J., Ji, S. (2020). Empirical analysis on the relationship between institutional pressure, environmental strategy and corporate environmental performance. International Journal of Sustainable Development and Planning, 15(2): 173-184. https://doi.org/10.18280/ijsdp.150207
[3] Alakkas, A.A., Shabir, S., Alhumoudi, H., Boukhris, M., Baig, A., Khan, I.A. (2023). The impact of sustainability accounting on environmental performance and productivity: A panel data analysis. International Journal of Sustainable Development and Planning, 18(8): 2431-2441. https://doi.org/10.18280/ijsdp.180814
[4] Latief, R.U., Anditiaman, N.M., Rahim, I.R., Arifuddin, R., Tumpu, M. (2023). Labor productivity in construction projects viewed from influence factors. Civil Engineering Journal, 9(3): 583-595. https://doi.org/10.28991/CEJ-2023-09-03-07
[5] Okafor, S.O., Igwe, J.N., Izueke, E.M.C., Okoye, O.E., Okechukwu, A.B., Obiozor, E.E. (2022). Environmental knowledge and policy sustainability: A study of pro environmental policy support among the southeast Nigerian rural communities. International Journal of Sustainable Development and Planning, 17(1): 341-350. https://doi.org/10.18280/ijsdp.170135
[6] Huang, H., Hsin, C.T. (2023). Environmental literacy education and sustainable development in schools based on teaching effectiveness. International Journal of Sustainable Development and Planning, 18(5): 1639-1648. https://doi.org/10.18280/ijsdp.180535
[7] Wolny, A., Ogryzek, M., Zróbek, R. (2019). Towards sustainable development and preventing exclusions—Determining road accessibility at the sub-regional and local level in rural areas of Poland. Sustainability, 11(18): 4880. https://doi.org/10.3390/su11184880
[8] Springer, A., Walkowiak, K., Bernaciak, A. (2020). Leadership styles of rural leaders in the context of sustainable development requirements: A case study of Commune Mayors in the Greater Poland Province, Poland. Sustainability, 12(7): 2676. https://doi.org/10.3390/su12072676.
[9] Pasra, M., Tjaronge, M.W., Caronge, M.A., Djamaluddin, A.R., Lapian, F.E.P., Tumpu, M. (2022). Influence of tensile load on bonding strength of asphalt concrete containing modified Buton asphalt and polyethylene terephthalate waste: A case study of Indonesian roads. International Journal of Engineering, Transactions C: Aspects, 35(9): 1779-1786. https://doi.org/10.5829/IJE.2022.35.09C.14
[10] Surówka, M., Popławski, Ł., Fidlerová, H. (2021). Technical infrastructure as an element of sustainable development of rural regions in Małopolskie Voivodeship in Poland and Trnava Region in Slovakia. Agriculture, 11(2): 141. https://doi.org/10.3390/agriculture11020141
[11] Badassa, B.B., Sun, B., Qiao, L. (2020). Sustainable transport infrastructure and economic returns: A bibliometric and visualization analysis. Sustainability, 12(5): 2033. https://doi.org/10.3390/su12052033
[12] Mabui, D., Tumpu, M., Widodo, S., Rusmin, M., Rangan, P.R. (2024). Optimization of asphalt content through Marshall characteristics using modified asbuton. Geomate Journal, 26(117): 116-123. https://doi.org/10.21660/2024.117.4133
[13] Ferrari, C., Bottasso, A., Conti, M., Tei, A. (2019). Chapter 7—The economic effects of transport infrastructures: A critical review of the empirical evidence. Economic Role of Transport Infrastructure, 181-240. https://doi.org/10.1016/B978-0-12-813096-4.00007-X
[14] Li, B., Gao, S., Liang, Y., Kang, Y., Prestby, T., Gao, Y., Xiao, R. (2020). Estimation of regional economic development indicator from transportation network analytics. Scientific Reports, 10(1): 2647. https://doi.org/10.1038/s41598-020-59505-2 1
[15] Prus, P., Sikora, M. (2021). The impact of transport infrastructure on the sustainable development of the region—Case study. Agriculture, 11(4): 279. https://doi.org/10.3390/ agriculture11040279
[16] Urbanyi-Popiołek, I. (2019). Cruise industry in the Baltic Sea Region, the challenges for ports in the context of sustainable logistics and ecological aspects. Transportation Research Procedia, 39: 544-553. https://doi.org/10.1016/j.trpro.2019.06.056
[17] Polyzos, S., Tsiotas, D. (2020). The contribution of transport infrastructures to the economic and regional development. Theoretical and Empirical Researches in Urban Management, 15(1): 5-23. https://doi.org/10.2307/26868292
[18] Makan, A., Fadili, A. (2020). Sustainability assessment of large-scale composting technologies using PROMETHEE method. Journal of Cleaner Production, 261: 121244. https://doi.org/10.1016/j.jclepro.2020.121244
[19] Mudronja, G., Jugović, A., Škalamera-Alilović, D. (2020). Seaports and economic growth: Panel data analysis of EU port regions. Journal of Marine Science and Engineering, 8(12): 1017. https://doi.org/10.3390/jmse8121017
[20] Saretta, E., Caputo, P., Frontini, F. (2019). A review study about energy renovation of building facades with BIPV in urban environment. Sustainable Cities and Society, 44: 343-355. https://doi.org/10.1016/j.scs.2018.10.002
[21] Onokala, P.C., Olajide, C.J. (2020). Problems and challenges facing the Nigerian transportation system which affect their contribution to the economic development of the country in the 21st century. Transportation Research Procedia, 48: 2945-2962. https://doi.org/10.1016/j.trpro.2020.08.189
[22] Batool, I., Goldmann, K. (2021). The role of public and private transport infrastructure capital in economic growth. Evidence from Pakistan. Research in Transportation Economics, 88: 100886. https://doi.org/10.1016/j.retrec.2020.100886
[23] Dewi, T.M.K., Herdiansyah, H., Soesilo, T.E.B., Venus, A. (2024). Identifying and addressing the right to burn for indigenous-led fire stewardship practices. International Journal of Environmental Impacts, 7(2): 159-168. https://doi.org/10.18280/ijei.070201
[24] Li, Z.B., Ding, C., Jiao, J.F. (2020). Introduction to special issue: Innovations for transport planning in China. Journal of Transport and Land Use, 13(1): 409-412. https://www.jstor.org/stable/10.2307/26967251.
[25] Ananta, M.I., Limantara, L.M., Soetopo, W. (2024). The impact of climate change on air temperature in the rainy and dry seasons in East Java, Indonesia: A case study of climate change in the Wlingi Dam area. International

Journal of Environmental Impacts, 7(2): 169-180. https://doi.org/10.18280/ijei.070202
[26] Wardhana, A., Kharisma, B., Lisdiyanti, T. (2020). Technology information communication and economic growth in the western and eastern regions of Indonesia for the 2014-2018 period. Journal of Economics and Business, 9(11): 1103-1116. https://doi.org/10.24843/EEB.2020.v09.i11.p05
[27] Solomon, E.M., Van Klyton, A. (2020). The impact of digital technology usage on economic growth in Africa. Utilities Policy, 67: 101104. https://doi.org/10.1016/j.jup.2020.101104
[28] Fajar, I. (2021). The third level digital divide among rural youth in Cianjur Regency, Indonesia. Jurnal Komunika: Journal of Communication, Media and Informatics, 10(1): 44-54. https://doi.org/10.31504/komunika.v9i1.4260
[29] Dawood, S.R.S., Ghazali, S., Samat, N. (2019). Digital divide and poverty eradication in the rural region of the northern Peninsular Malaysia. The Indonesian Journal of Geography, 51(2) 67-77. https://doi.org/10.22146/ijg.37758
[30] Mora-Rivera, J., García-Mora, F. (2021). Internet access and poverty reduction: Evidence from rural and urban Mexico. Telecommunications Policy, 45(2): 102076. https://doi.org/10.1016/j.telpol.2020.102076