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A Review on Green Road Development as an Effective Strategy for Plastic Waste Reduction in Bhutan

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Abstract - *The idea of green road development provides a method to lessen the effects of plastic waste, which has emerged as a global environmental concern. Bhutan, a developing country that places a strong emphasis on Gross National Happiness, confronts difficulties because of its difficult geography and few resources. Nevertheless, the nation has taken aggressive steps to minimize plastic waste, such as outlawing plastic bags and encouraging garbage sorting and recycling. Bhutan takes an active involvement in regional and international forums to learn about and put sustainable practices into practice. Sustainable materials, stormwater management, landscaping, energy efficiency, and active mobility are all included in "green" road development. It enhances road safety, safeguards wildlife habitats, and lowers carbon emissions. Case studies from the Netherlands, Singapore, and India show how green road Programmes have been successfully implemented. In order to achieve green road development in Bhutan, it is necessary to solve technical, budgetary, and policy-related issues while involving stakeholders and the general public. To increase the sustainability of green road systems, future directions include integrating renewable energy, creating self-healing materials, and using smart technologies.*

Keywords: Green Road, Plastic Waste, Gross National Happiness, Sustainable practices

I. Introduction

Plastic waste has become a global environmental challenge, posing significant threats to ecosystems and human health [1]. Rapid urbanization, changing lifestyles, and inadequate waste management infrastructure have contributed to the proliferation of plastic waste leading to the concept of Green Road Development. When designing, building, and maintaining roads, green road development focuses on environmentally friendly road infrastructure that takes into account resource conservation and the reduction of plastic waste. This strategy is in line with Bhutan's distinctive Gross National Happiness (GNH) development ideology, which places an emphasis on sustainable socio-economic growth and environmental preservation.

Bhutan, a tiny developing nation between China and India, has a population of over 780,000 people and is experiencing economic expansion and urbanization. The challenging mountainous terrain poses difficulties for transportation and commercial activities due to road degradation. To address this issue, Green Road, a construction company, has developed an innovative and environmentally friendly solution by utilizing plastic waste for road paving [2]. Bhutan, with its rugged terrain and challenging topography, heavily relies on road transportation for economic activities and connectivity within the country. However, non-recyclable materials like bitumen, asphalt, and single-use plastic goods are frequently used in the building and upkeep of traditional roadways. These resources add to the buildup of plastic garbage and worsen the environmental

problems the nation already faces [3].

Green Road Development offers a holistic approach to road infrastructure planning and management by incorporating principles of sustainability and waste reduction. The idea covers a range of topics, such as the use of recycled materials, the use of cutting-edge waste management strategies, and the promotion of environmentally friendly transportation methods [4]. Plastic waste reduction may be considerably helped by using recycled resources like plastic trash in road building. Road performance and durability may be improved while the need for virgin materials can be decreased by mixing plastic waste into the pavement. This method has been successfully used in a number of nations, including India and the Netherlands, with good results in terms of waste reduction and road condition[5]. The encouragement of environmentally friendly transportation methods is another important component of green road development. The total need for road building and the resulting production of plastic garbage can be decreased by promoting the use of public transit, carpooling, and non-motorized forms of transportation. Bhutan may lessen its reliance on private automobiles and, as a result, the requirement for developing road infrastructure by investing in effective public transit systems and encouraging active mobility.

Implementing Green Road Development in Bhutan, however, is not without its challenges. The challenging geography, scarce resources, and technical limitations of the nation may make it challenging to implement some components of this plan. A few of the issues that must be resolved to guarantee the effective implementation of Green Road Development include the provision of suitable recycling facilities, the creation of legislation and policies, and the capacity-building of stakeholders. Despite the challenges, the benefits of implementing Green Road Development as a strategy for plastic waste reduction in Bhutan are manifold.

I.I. Objectives

- Assessing the current situation of plastic waste management in Bhutan, including the sources, quantities, and disposal methods of plastic waste
- Identifying the challenges and barriers that may hinder the successful implementation of green road development, including technical, financial, and policy-related aspects.
- Analyzing the policy frameworks, regulations, and initiatives related to plastic waste management in Bhutan and evaluating their effectiveness in addressing the issue.

II. Methodology

Various published research articles and review articles published before March 2023 are the major source of data for this study. We search through Google Scholar and Research Gate to collect more published information in the various disciplines in the greed road and green development.

III. Plastic Waste Management in Bhutan

The prohibition on plastic bags is one of Bhutan's main priorities. One of the first countries in the world to do so, the nation outlawed the import and use of plastic bags entirely in 1999. [6]. This proactive move paved the way for a more all-encompassing strategy for managing plastic trash and drastically decreased the usage of single-use plastic bags. The government set harsh rules and fines for people and businesses found to

be in violation of the prohibition in order to enforce it and assure compliance. Public awareness campaigns were launched to educate the population about the environmental hazards of plastic waste and promote the use of alternative, eco-friendly materials [7]. This collective effort has led to a significant reduction in plastic bag usage and a change in public behavior towards more sustainable practices.

Bhutan prioritizes waste segregation and recycling, establishing advanced centers for plastic waste collection, sorting, and recycling, reducing landfill waste and promoting environmental sustainability [8]. Bhutan promotes biodegradable and compostable alternatives to single-use plastics, supporting local entrepreneurs in developing sustainable packaging solutions [9]. This not only reduces the dependence on plastic but also creates income-generating opportunities for local communities.

In order to share experiences and learn from other countries, Bhutan actively participates in regional and worldwide forums as part of its commitment to sustainable development. The nation works with groups like the United Nations Environment Programme (UNEP) to embrace cutting-edge techniques and regulations that support its conservation objectives [10]. Bhutan faces challenges in managing plastic waste due to limited resources, infrastructure constraints, and awareness campaigns. To mitigate environmental impact, Bhutan must focus on capacity building, waste management infrastructure, and public awareness campaigns. However, evaluating the effectiveness of these measures requires a comprehensive assessment of waste generation, recycling rates, and overall reduction in plastic waste. Continuous monitoring and periodic reviews are crucial for long-term success in tackling the issue.

IV. Green Road Development as a Sustainable Solution

In an era marked by rapid urbanization and increasing environmental concerns, the need for sustainable infrastructure has become paramount. Green road development is emerging as a promising solution that aims to balance the growing demand for transportation with the imperative to protect the environment. By integrating environmentally-friendly features, such as renewable energy sources, efficient drainage systems, and biodiversity conservation, green roads have the potential to revolutionize transportation networks while minimizing their ecological footprint [11]. The green road development is a crucial step towards achieving long-term sustainability and must be embraced by governments, policymakers, and communities alike.

A green road is a sustainable and environmentally friendly transportation infrastructure that aims to minimize its ecological footprint and promote ecological balance. It encompasses various design principles and technologies to ensure minimal impact on natural resources, ecosystems, and communities. Green roads prioritize the use of renewable energy sources, such as solar or wind power, for lighting and other infrastructure needs [12].

One of the primary advantages of green road development is its potential to significantly reduce carbon emissions. Traditional road infrastructure heavily relies on fossil fuel-powered vehicles, contributing to air pollution and climate change [13]. Green roads, on the other hand, promote the adoption of electric vehicles

and public transportation systems, reducing greenhouse gas emissions and improving air quality. Moreover, green roads can incorporate solar panels and other renewable energy sources to power electric charging stations, further reducing dependence on non-renewable energy [14].

Green road development puts the environment first by including wildlife crossing, green spaces and corridors to protect biodiversity. Permeable pavement & green infrastructure control stormwater runoff and prevent water pollution. Green roads are designed to co-exist with nature, unlike traditional roads that disturb habitats and threaten wildlife. Green road development benefits the environment while also providing economic and social benefits. It stimulates innovation, provides jobs in renewable industries, e-mobility, and creates sustainable infrastructure. Road safety is improved by adding cycling lanes, walking paths, and intelligent traffic management systems. Active lifestyles and public health are promoted by green roads. Revitalize urban areas and attract tourism and improve residents' quality of life [15].

By focusing on environmentally-friendly practices, Bhutan strives to minimize the ecological impact of road construction and maintenance. The integration of renewable energy sources, such as solar-powered streetlights, reduces carbon emissions. Additionally, green road development prioritizes the protection of wildlife habitats and ensures minimal disruption to the surrounding ecosystems. Bhutan's commitment to sustainability extends beyond infrastructure, promoting eco-friendly transportation options like cycling and electric vehicles. Through this holistic approach, Bhutan showcases its dedication to preserving the environment, fostering community connectivity, and paving the way for a greener future.

V. Key features and principles of green road development

Green road development refers to the concept of designing and constructing roads in a manner that minimizes their environmental impact and promotes sustainability. It involves incorporating various key features and principles to ensure that roads are built with the utmost consideration for the natural environment [16]. The following are some key features and principles of green road development:

1. Sustainable Materials: Green roads use sustainable materials like recycled aggregates, reclaimed asphalt, and low-carbon concrete to reduce resource demands.
2. Stormwater Management: Stormwater management is essential for green road development, reducing erosion and pollution.
3. Vegetation and Landscaping: Green roads enhance ecological value by incorporating vegetation, providing habitat for wildlife, and absorbing carbon dioxide.
4. Energy Efficiency: Green roads minimize energy consumption through efficient lighting, intelligent traffic management, and renewable energy sources.
5. Active Transportation and Multi-modal Connectivity: Green roads prioritize pedestrians, cyclists, and public transportation users with bike lanes, sidewalks, and safe crossings, promoting active transportation and sustainable alternatives.

By adopting these key features and principles, green road development contributes to the overall sustainability of transportation infrastructure. It helps protect natural resources, reduce greenhouse gas

emissions, enhance biodiversity, and improve the quality of life for both humans and the environment.

VI. Case Studies of Green Road Development Initiatives

The Netherlands is renowned for its innovative approach to green road development. Plastic road structures are one among many to provide three times the service life of a road based on a plastic element, with only a few days of construction work required and minimal maintenance. The company KWS recycles plastic waste into lightweight pre-fabricated hollow elements, which facilitates transport and construction, with less heavy equipment required to deliver and build plastic roads, resulting in significantly lower greenhouse gas emissions compared to traditional methods.

Figure 1. Plastic road structure adopted in Netherland [17].

The element concept offers easier and sustainable repair works, as the damaged element can be easily replaced and refurbished or recycled into a new element, which prolonged life expectancy contributes to a circular economy. the first Plastic Road in the world was opened on September 11th, 2018 in Zwolle (the Netherlands) as a 30-meter-long bike path [32]. Plastic Road applications include residential, provincial, highways, and airports, but concerns include stiffness, vibration, noise pollution, and potential power generation within plastic hollows.

Green Road, also known as Plastic Road, is a sustainable infrastructure solution in Singapore. It combines

recycled plastic and asphalt, reducing demand for traditional materials and minimizing plastic waste. Since 2018, over 50 kilometres of Green Roads have been built, diverting 2.5 million kilograms from landfills. The Singaporean government supports the initiative, collaborating with private sector partners and research institutions. Green Roads have exceeded expectations, with durability and reduced maintenance costs. They serve as a successful model for other countries to follow [18].

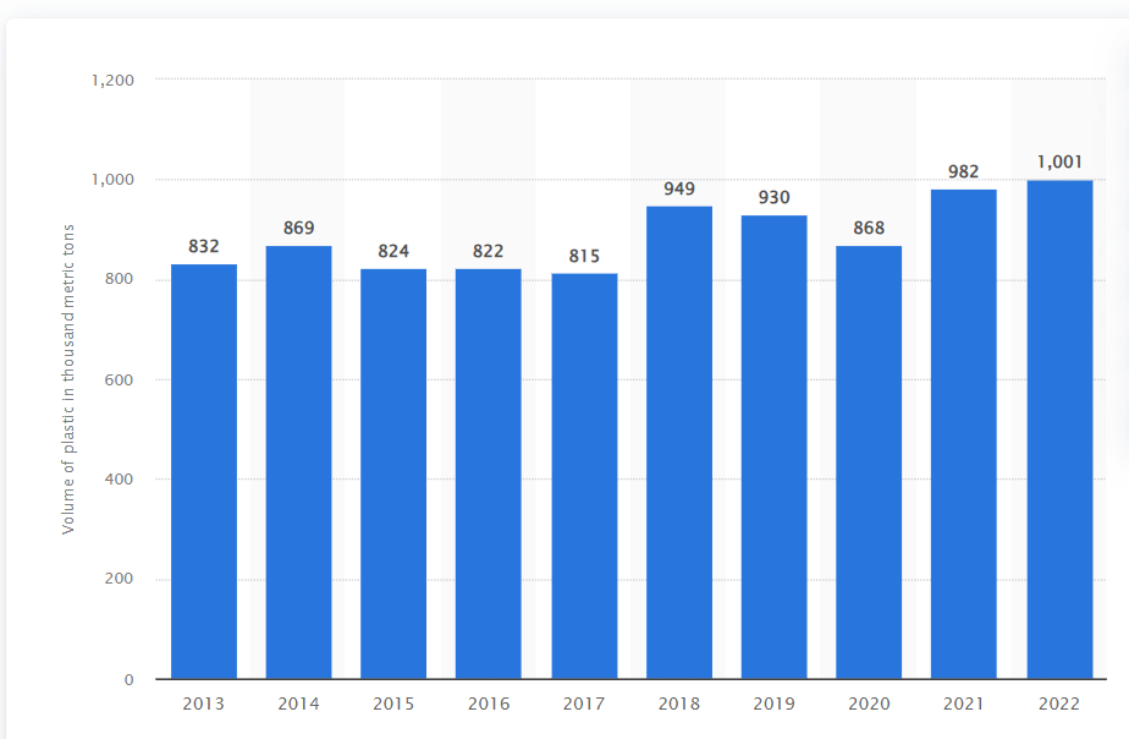

Figure 2. Average plastics waste generated annually in Singapore [19]

Singapore promotes sustainable solutions to address plastic waste, including green roads, which incorporate waste into construction materials. The initiative has gained traction, with several projects underway. Singapore's government and stakeholders prioritize sustainability and innovative methods for managing plastic waste effectively [20].

India is one of the highest producers of plastic waste in the world. In 2020, a group of researchers explores the use of plastic waste in flexible pavement construction to promote sustainable and environmentally friendly highway infrastructure. The study addresses the environmental impacts of plastic waste, including pollution, resource depletion, and waste management challenges. The researchers propose using plastic waste as an alternative material, focusing on its high durability, resistance to moisture, and potential to enhance pavement performance. Techniques include shredded plastic waste as an aggregate replacement, bitumen blending, and geosynthetic form. The study also discusses the environmental benefits, such as

reduced landfill waste accumulation, conservation of natural resources, and energy savings. However, the researchers also address potential challenges, such as long-term durability, leaching harmful substances, and potential effects on pavement recycling processes. Further research and monitoring are needed to effectively address these issues[21].

VII. Green Road Development Challenges in Bhutan

Bhutan faces challenges in developing green roads due to its rugged terrain, requiring extensive engineering efforts and disrupting the natural ecosystem. The country's rich biodiversity and fragile ecosystems also pose risks. Balancing connectivity and accessibility while preserving Bhutan's natural beauty and ecological balance requires careful planning and sustainable approaches. Like in any other nation, Bhutan faces obstacles and problems in implementing green road construction successfully. To achieve a seamless transition to environmentally friendly road infrastructure, these obstacles must all be addressed. They may be divided into three categories: technical, financial, and policy-related.

Technically speaking, building and maintaining green roads presents one of the biggest problems. It takes specialised knowledge and skills to implement sustainable design ideas, such as using recycled materials and adding features that minimise environmental effect. Bhutan may not have many people with the necessary skills to create green roads, thus programmes to increase capacity and fill the gap are required.

Financial barriers pose another significant challenge. Research, development, and implementation costs for green road development are frequently upfront. Construction materials that are environmentally benign, such recycled aggregates or low-carbon cement, might cost more than traditional resources. It might be difficult to get sufficient support for these efforts, especially in a nation with limited resources like Bhutan. Financial obstacles may be solved by cooperation with international organisations, public-private partnerships, and investigation of novel finance techniques.

A significant factor impeding the effective implementation of green road development is policy-related difficulties. To build an enabling environment, supportive policies, rules, and standards must be developed and put into effect. Bhutan has to create detailed regulations that support environmentally friendly road construction, including procurement procedures that give sustainability considerations first priority. Additionally, it could be necessary to remove administrative barriers, simplify approval procedures, and guarantee effective cooperation between pertinent government departments.

Initiatives to promote green roads must engage stakeholders and the general public. It is crucial to inform the public about the value of sustainable transportation and win the backing of local communities, companies, and transportation organisations. Overcoming social and cultural opposition to change can be difficult, especially in rural locations where old practises are ingrained.

VIII. Future Directions and Research Gaps

In spite of the fact that green roads have showed promise in reducing the environmental effects of transport infrastructure, more study and development are required to meet the future orientations and knowledge gaps.

The performance and sustainability of green road systems may be significantly improved by integrating renewable energy sources, developing self-healing and adapting materials, customizing designs for specific locales, and utilizing smart technology. We can lay the foundation for a cleaner and more sustainable transport future by making investments in these sectors.

IX. Conclusion

Green Road Development is a sustainable solution for reducing plastic waste and promoting environmentally friendly road infrastructure. Bhutan can benefit from implementing Green Road Development to address road degradation issues and minimize ecological impact. Bhutan has taken proactive steps in plastic waste management, such as banning plastic bags and promoting waste segregation and recycling. However, challenges like geography, limited resources, and technical limitations can be overcome through recycling facilities, supportive legislation, and stakeholder capacity-building. Key principles of green road development include sustainable materials, stormwater management, vegetation integration, energy efficiency, and active transportation. To advance green road development, Bhutan should focus on technical capacity-building, innovative finance mechanisms, and supportive policies. Future research gaps include integrating renewable energy sources, self-healing materials, customizing designs, and smart technology, contributing to a cleaner and more sustainable transport future.

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