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Study on the Implementation of the Eco-Road Concept: A Case Study of Duri

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Study on the Implementation of the Eco-Road Concept: A Case Study of Duri West Ring Road"

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Abstract: *The construction of roads traversing forest areas has the potential to cause habitat fragmentation, disrupt wildlife movement, and reduce ecosystem quality. The West Duri Ring Road, which passes through the Talang Forest—most of which lies within the Balairaja Wildlife Reserve—was developed to alleviate traffic congestion, reduce road accidents, and improve regional accessibility. This context forms the basis for conducting a study on the application of environmentally friendly road (eco-road) concepts to ensure the sustainability of road functions while preserving environmental integrity. The objective of this research is to analyze the degree of conformity in implementing the eco-road concept on the segment of the West Duri Ring Road that crosses the Talang Forest area. This study employs a descriptive qualitative method with a comparative approach by comparing eco-road parameters, as stipulated in the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.23/MENLHK/SETJEN/KUM.1/5/2019, with the initial road planning documents and existing field conditions. This approach is intended to assess the conformity level of eco-road implementation on the road segment passing through the Talang Forest. The findings indicate that out of 20 eco-road parameters, 15 parameters (75%) were in accordance with the initial planning documents and the provisions of the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.23 of 2019, while 5 parameters (25%) were not yet available or implemented due to budget constraints and are planned to be realized in subsequent development phases. At the time of the study, fieldwork was still ongoing or nearing completion. Nevertheless, since the construction of the West Duri Ring Road is still in progress, there remain opportunities to address the outstanding parameters with sufficient technical, institutional, and financial support.*

Keywords: *Eco-Road, Environmentally Friendly Road, Talang Forest, West Ring Road–Duri, Wildlife Mitigation.*

Introduction

In Duri City, Bengkalis Regency, the main transportation route is on Jalan Jenderal Sudirman which is part of the Sumatra Cross Road and connects Pekanbaru, Dumai, to Medan. This road section serves not only community mobility, but also the distribution of various main commodities, such as *Crude Palm Oil* (CPO), Fuel Oil (BBM), and other logistics. The high intensity of vehicles, especially large-tonnage vehicles, has raised various transportation problems in the Duri urban area. Traffic congestion, increasing the potential for accidents, and accelerating damage to road bodies due to overload are real problems faced by the community. To overcome this, the Bengkalis Regency Government built the Duri West Ring Road as an alternative route that functions to divert the flow of heavy vehicles from the city center. The construction of this ring road is expected to be able to break down congestion, improve traffic safety, and support the smooth running of community socio-economic activities. Geographically, the Duri West Ring Road stretches for 32,225 kilometers, starting from KM 11 of Air Kulim Village in the District Bathin

Solapan to the Sumatra Cross Road in Balai Raja Village, Pinggir District. The existence of this road is believed to improve the quality of transportation services in line with the development of the city. However, a big challenge arose because of the road route crossing the Talang Forest area, which is part of the Balai Raja Wildlife Sanctuary. This forest area serves as an important habitat for Sumatran elephants and other wildlife, while having high ecological value in storing carbon, producing oxygen, and supporting the biodiversity of flora and fauna (Wiyono, 2023). Infrastructure development in the area has the potential to cause habitat fragmentation, disrupt animal movement, and trigger animal-human conflicts. In this context, *eco-road* planning becomes very relevant. Hamilton et al. (1989) explained that *eco-road* is a road concept designed to minimize negative impacts on ecosystems through the management of interactions between road infrastructure and wildlife. The main principles of *the eco-road* include habitat conservation, regulation of animal movement, and prevention of ecosystem fragmentation. The Ministry of Public Works and Public Housing (2017) also emphasized that environmentally friendly roads need to apply ecological principles to maintain habitat connectivity, so that animals can move safely without the risk of accidents or human disturbances. Regulations through the Regulation of the Minister of Environment and Forestry Number P.23/MENLHK/SETJEN/KUM.1/5/2019 have provided technical guidelines for the construction of strategic roads in forest areas, including *eco-road* parameters that must be met.

In line with these regulations, the initial planning document for the Duri West Ring Road prepared by Professor Sugeng Wiyono, Professor of Civil Engineering at the Islamic University of Riau (2023), adopts *an eco-road* concept. This planning is specifically designed to minimize the ecological impact in the Talang Forest area through habitat conservation, maintenance of animal connectivity, and control of potential conflicts between animals and humans. Thus, this planning document serves as an initial reference that describes the application of the concept of environmentally friendly roads in the context of infrastructure development in forest areas. The initial planning document emphasizes the application of *the eco-road concept* through the arrangement of road tracks that protect natural habitats, the provision of mitigation facilities to maintain animal connectivity such as vegetation on the left and right of the road as *a buffer zone*, canopy bridges, elephant tracks and elephant ditches, the use of used tires as a mixture in flexible pavement (*crumb rubber*)) and control of potential human-animal conflicts through the use of safety fences, warning signs, and surveillance posts and monitoring towers.

In line with the *eco-road concept* applied in the initial planning document of the Duri West Ring Road, a number of previous studies have also examined the application of environmentally friendly roads in different contexts. Martinusa et al. (2017) focused on the implementation of *eco-roads* in the National Park area, while Damayanti (2023) focused on the planning and conservation of animals as an effort to mitigate the impact of the construction of the Aceh toll road that crosses protected forest areas, by referring to the

Regulation of the Minister of Environment and Forestry Number P.23/MENLHK/SETJEN/KUM.1/5/2019. Surbakti et al. (2021) assessed the application of *the Green Road Construction* concept in the Parapat-Ajibata National Road Cantilever construction project, including contractor constraints and the solution strategies implemented. These studies show that the concept of *eco-roads* has been extensively studied, but it highlights more technical aspects of construction and general mitigation without particular emphasis on the ecological context of conservation areas.

However, this study has a main difference from previous research, namely a more specific focus on ecological aspects, paying attention to the sustainability of ecosystems and habitats around the road construction area which is a conservation forest area. As the first study to raise the concept of *eco-roads* in Riau Province, especially on the Duri West Ring Road in Bengkalis Regency, this research is expected to make a new contribution because the road section has never been used as an object of study before. Thus, this study aims to analyze the suitability of the application of *the eco-road* concept on the Duri West Ring Road that crosses the Talang Forest, as well as to examine the estimated impact that occurs if the concept is not implemented. Through this study, it is hoped that policy and technical recommendations can be produced that not only support smooth transportation, but also ensure the sustainability of the ecological function of the Talang Forest as an important habitat for wildlife.

Metodhology

This study uses a qualitative descriptive method with a comparative approach that aims to analyze the application of the concept of *eco-roads* on the Duri West Ring Road, especially on the trase that crosses the Talang Forest area in Bengkalis Regency. The selection of qualitative descriptive methods was based on the objectives of the research that wanted to describe the existing conditions in depth, while the comparative approach was chosen to compare the suitability of the existing conditions and initial planning documents with *the eco-road parameters* regulated in the Regulation of the Minister of Environment and Forestry Number P.23/MENLHK/SETJEN/KUM.1/5/2019 concerning Strategic Roads in Forest Areas**.** With this combination of approaches, the research can provide a comprehensive picture of the extent to which *the eco-road concept* has been implemented, as well as examine the estimated impact that will occur if the concept is not implemented.

Data collection in this study was carried out through field observation and literature study. Primary data was obtained from direct observation on the track of the Duri West Ring Road that crosses the Talang Forest, including measurements of road geometry (lane width, road shoulder, median, and slope), stop visibility, corner radius, and longitudinal and transverse slope. In addition, the environmental conditions around the track were also noted, including the presence of fences, drainage, *box culverts*, vegetation, and other supporting elements. All observations were documented in the form of photographs to strengthen the visual evidence. Meanwhile, secondary data was obtained from various

relevant written sources, including the initial development planning document of the Duri West Ring Road, Regulation of the Minister of Environment and Forestry Number P.23/MENLHK/SETJEN/KUM.1/5/2019 as the main reference, and the book *Green Infrastructure Design for Transport Projects: A Road Map to Protecting Asia's Wildlife Biodiversity* (ADB, 2019) as an additional reference. The research process is carried out systematically through several stages. The first stage is preparation, which includes the identification of research sites and the review of the literature to understand the concept *of eco-roads*. The second stage is the collection of primary and secondary data as described. The third stage is data analysis. This analysis was carried out to assess the suitability and incompatibility of the application *of the eco-road concept* in the field. The fourth stage is the preparation of results and discussion, namely presenting the results of the analysis of the existing condition of the Duri West Ring Road and its level of conformity with the initial planning documents and *eco-road parameters*. The description is focused on parameters that have been met and those that have not. In addition, the estimated impact arising from the *unfulfilled eco-road* parameters was also discussed, as well as possible improvement steps that can be taken to increase the implementation of the eco-road concept in the Talang Forest area. The final stage of the research is to formulate conclusions to answer the formulation of problems related to the application *of the eco-road concept* on the Duri West Ring Road and its estimated impact, then to prepare applicable suggestions for local governments and Talang Forest managers to support the sustainable implementation of *eco-roads*.

Results and Discussion

The environmental identification of the Duri West Ring Road was carried out based on initial planning documents and observation of existing conditions. The results of the environmental identification of the Duri West Ring Road were analyzed for their suitability with *the eco-road parameters* in accordance with the Regulation of the Minister of Environment and Forestry No. P.23/MENLHK/SETJEN/KUM.1/5/2019, and the estimated impact that would occur if *the eco-road* concept was not implemented.

Results of the Analysis of the Application of the Eco-Road Concept on the Duri West Ring Road

The analysis of the application *of the eco-road concept* on the Duri West Ring Road was carried out by comparing the initial planning documents and the existing condition of the road against the parameters stipulated in the Regulation of the Minister of Environment and Forestry Number P.23/MENLHK/SETJEN/KUM.1/5/2019. The results of the analysis are presented systematically in Table 3.1.

Table 1. Results Analysis of the Suitability of *Eco-Road* Parameters on the Duri West Ring Road

No.	Parameter *eco-road*	Planning	Existing West Ring Road of Duri	Analysis (Minister of Environment and Forestry Regulation Number P.23 of 2019	explanation
A	Geometri Jalan				
1.	Maximum street space	15.00	15.00	17.00	Appropriate
2.	Road benefit space (m)	9	9	15.00	Appropriate
3.	Road way (m)	9.00	9.00	9.00	Appropriate
4.	Traffic lane width (m)	2 x 3.50	2 x 3.50	2 x 3.50	Appropriate
5.	Road shoulder width (m)	1.00	1.00	1.00	Appropriate
6.	Median width (m)	No Median	No Median	No Median	Appropriate
7.	Maximum road pavement slope (%)	2	3	3	Appropriate
8.	Maximum road shoulder slope(%)	4	6	6	Appropriate
9.	Edge Channel Width (m)	1.00	1.00	0.5	suitable because it is for drainage and safety functions.
10.	Safety Threshold Width (m)	1.00	1.00	1.00	Appropriate
B	Wildlife Mitigation Building				
1.	Canopy Bridge	Height ≥5.2 m; Width ≥0.3 m; Length adjusts the path	-	Height ≥5.2 m; Width ≥ 0.3 m; Length adjusts the path	None
2.	Underpass	Height ≥5 m; Width ≥6 m; Length ≥10; OI = 3	Height ≥5 m; Width ≥10 m; Length≥12; OI=4.16	Height ≥4 m; Width ≥4 m; OI Value ≥2.25 (ADB, 2019)	Appropriate
3.	*Box Culvert*	Height ≥3 m;	Height ≥3 m;	Height ≥3 m;	Appropriate

No.	Parameter *eco-road*	Planning	Existing West Ring Road of Duri	Analysis (Minister of Environment and Forestry Regulation Number P.23 of 2019	explanation
		Panjang ≥2,5 m; Lebar 1 m	Length ≥2.5 m; Width 1 m	Length ≥2.5 m;	

Table 2. Results of Analysis of the suitability of *eco-road* parameters on the Duri West Ring Road (continued)

No.	Parameter *eco-road*	Planning	Existing West Ring Road of Duri	Analysis (Minister of Environment and Forestry Regulation Number P.23 of 2019	explanation
4.	Animal Signs	Height ≥1.75 -2.65 m; ≥0.6 m distance measured from the outermost leaf signs to the outermost edge of the road shoulder; visibility 50–100 m; Types of Traffic Signs	-	Height ≥1.75 - 2.65 m; ≥0.6 m distance measured from the outermost leaf signs to the outermost edge of the road shoulder; visibility 50–100 m; Types of walking signs; (Permenhub RI No. PM. 13/2014 concerning Traffic Signs).	None
C	Land Occupancy Mitigation Building				
1.	Pay squatter	Height ≥2.2 m; Harmonica Wire Material	Height ≥2.2 m; Harmonica Wire Material	Height ≥2.5 m; Concrete Materials/Other Combinations.	The determination of the 2.2 m height is based on an agreement between the land-owning

No.	Parameter *eco-road*	Planning	Existing West Ring Road of Duri	Analysis (Minister of Environment and Forestry Regulation Number P.23 of 2019	explanation
					authorities at that time, namely PT Caltex Pacific Indonesia, with the Bengkalis Regency Government
2.	Monitoring Tower	In accordance with the standards of the Minister of Environment and Forestry 23/2019	-	Minimum height of 5 m; Tiered Platform.	None
3.	Guard Pos	In accordance with the standards of the Minister of Environment and Forestry 23/2019	-	Wide & high according to the supervision function .	None
4.	Gate	-	-	Width according to the type of road; Permanent Buildings	None
D	Materials and Pavement				
1.	Types of Road Pavement	Bending pavement with modified asphalt Crumb Rubber	Bending pavement	porous asphalt/concrete; Eco-friendly materials	Appropriate

No.	Parameter *eco-road*	Planning	Existing West Ring Road of Duri	Analysis (Minister of Environment and Forestry Regulation Number P.23 of 2019	explanation
E	Operations / Traffic				
1.	Plan Speed/Vr (km/h)	40-60	40-60	30-80	Appropriate

Based on Table 3.1, of the 20 *eco-road parameters* analyzed, as many as 15 parameters (75%) have been in accordance with the provisions listed in the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.23/MENLHK/SETJEN/KUM.1/5/2019, while 5 parameters (25%) have not been met, namely canopy bridges, animal signs, monitoring towers, guard posts, and gates. This condition shows that the application *of the eco-road* concept on the Duri West Ring Road still needs to be improved to comply with environmentally friendly road standards. However, this condition is not necessarily interpreted as a deficiency, but rather as a limitation at the initial implementation stage. The construction of the Duri West Ring Road itself is not yet final and is still in the process of completion, so it is natural that the implementation of the *eco-road* concept has not been fully accommodated. This is common considering that infrastructure projects are generally carried out in stages by adjusting the availability of resources, both from technical, managerial, institutional, and budget support aspects. Thus, *eco-road parameters* that have not been implemented still have the opportunity to be realized in the next stage of development.

Estimated Impact of Unfulfilled *Eco-Road* Parameters on the Duri West Ring Road

Although the construction of the Duri West Ring Road has initiated the implementation of *the eco-road concept*, the results of the analysis show that a number of parameters have not been met according to the Minister of Environment and Forestry Regulation Number P.23 of 2019. This condition indicates that the development is still in the early stages and is being implemented in stages, so it is necessary to identify the estimated impact as a basis for improving and optimizing the implementation of *eco-roads* in the next stage. The estimated impact is shown in Table 3.2.

Table 3. Estimated impact of unmet *eco-road parameters*

No	Unmet *Eco-road* Parameters	Function	Estimated Impact	explanation
1.	Canopy Bridge	Arboreal wildlife trajectory	Reduce animal connectivity; increases the risk of animal collisions with vehicles	Planned at the next stage of implementation
2.	Animal Signs	Provide information and warnings to motorists	The absence of signs also has implications for negligence in traffic safety aspects, both for motorists and animals; Drivers are not warned; increases the risk of animal accidents	Planned at the next stage of implementation
3.	Monitoring Tower	Supervise the movement of animals, detect illegal activities (hunting, illegal logging), and monitor the condition of the ecosystem around the road.	Supervision of road areas and animals is not optimal	Planned at the next stage of implementation
4.	Guard Pos	A center for direct control, guarding, and supervision of activities on the road	Traffic and animal regulation and monitoring are not optimal	Planned at the next stage of implementation
5.	Gate	A boundary marker for protected forest areas as well as an access control for entry and exit.	Vehicle access arrangements and forest area security are less effective	Planned at the next stage of implementation

Overall, Table 3.2 shows that *the eco-road* parameters have an important role in maintaining animal connectivity, improving traffic safety, and supporting the protection of forest areas around the Duri West Ring Road. The five *eco-road parameters* on this section have not been fulfilled and there are a number of impact estimates that need to be observed,

even though road construction is still in its early stages and is gradual. The absence of canopy bridges has the potential to reduce *arboreal* animal connectivity and increase interaction with vehicles, while the unavailability of animal signs reduces warning information for road users and can increase the risk of accidents. In addition, the absence of monitoring towers and guard posts hampered the supervision function, and the unavailability of gates as area boundary markers caused the regulation of vehicle access and the protection of forest areas to be suboptimal.

Thus, the results of the analysis confirm that the fulfillment of eco-road parameters plays an important role in maintaining ecosystem balance, protecting animals, and improving the safety of road users. Parameters that have not been realized can be seen as part of the next stage of implementation programs, so that the eco-road concept in the future can be applied more optimally and comprehensively. In anticipation of the various ***impact estimates*** outlined in Table 3.2, some further improvement directions are summarized in Table 3.3.

Table 4. Improvement recommendations

No	Parameter *Eco-road*	explanation	Recommendations for Improvement (Minister of Environment and Forestry Regulation Number P. 23 of 2019)
1.	Canopy Bridge	None	Building canopy bridges with dimensions and types according to the specifications of the provisions of the Minister of Environment and Forestry Regulation Number P.23 of 2019 to facilitate the movement of animals;
2.	Animal Signs	None	Installing animal warning signs at strategic points with height, distance, and visibility according to standards;
3.	Monitoring Tower	None	Build a monitoring tower with a height of at least 5 m with a multi-storey platform to facilitate the supervision of forest areas and roads;
4.	Guard Pos	None	Providing guard posts with a wide and high area according to the function of traffic and animal control;
5.	Gate	None	Build permanent gates according to the width of the road type for vehicle access arrangements and area security.

The improvement recommendations in Table 3.3 show that the implementation *of eco-roads* on the Duri West Ring Road still faces a number of limitations. As a follow-up, a design design was prepared for the five main *eco-road parameters* that need to be applied to the Duri West Ring Road to support the improvement of the implementation of *the eco-road*, namely the design of the canopy bridge can be seen in Figure 1, using a cable net with a diameter of at least 8 mm with an interval of 20–30 cm, installed transversely between large trees to maintain *arboreal animal connectivity*.

Figure 1. Canopy bridge design

The installation of animal signs is carried out at prone points of the track to increase motorists' vigilance, as shown in Figure 2.

Figure 2. Wildlife sign design

The monitoring towers are placed in strategic locations to extend the surveillance range, as shown in Figure 3.

Figure 3. Monitoring tower design

Guard posts that act as coordination centers in monitoring animal mobility and traffic flow. It can be seen in Figure 4.

Figure 4. Guard post design

Figure 5 presents a gate design that serves as an entry and exit access regulator as well as a reminder to road users that they are entering a sensitive area with special regulations. In addition, the gate also plays a role in preventing activities that are not in accordance with the designation along the road in the Talang forest area.

Figure 5. Gate design with portal

In addition to repairs to the 5 parameters above, it is also recommended to adjust the height of the guardrail along the Duri West Ring Road section which currently has a height of 2.2 meters. To increase the effectiveness of controlling access to wildlife and visitors, the height of the fence is proposed to be increased to 2.5 meters with the addition of 30 cm high wave-shaped threaded wire at the top of the fence, the design of which is as seen in Figure 6.

Figure 6. BRC panel fence design

The wavy design on the top of the fence as seen in Figure 6 not only ensures that the minimum height is achieved, but also increases the effectiveness of the fence as a guide for animals and a control of human activities, so that the conservation function of forest areas is more optimal. Apart from being a safety, the wire fence structure that has a cavity allows vines or natural vegetation from around the forest area to run through the fence. The

existence of these plants not only presents a natural impression but can also act as a microhabitat for small fauna that live on leaves, such as insects and other invertebrates. Thus, wire fences not only function technically as barriers, but also support the formation of vegetated *fences* that contribute to the increase in the ecological value of roads in accordance with *eco-road principles.*

In addition, occupational fences can also be made of concrete as stated in the Minister of Environment and Forestry Regulation Number P. 23 of 2013. Figure 7 is one type of occupational fence design that uses concrete.

Figure 7. Concrete occupancy fence design

The design of the occupation fence in Figure 7 is planned using a precast concrete system with a kali stone foundation. Reinforced concrete columns of 20/20 cm are installed 2.5 m apart, with precast wall panels 5 cm thick between them. The river stone foundation functions as a load distributor and stability support. The application of this fence is not only a structural element, but also part of *the eco-road* concept to limit access to the forest, so that the ecosystem is maintained and disturbance to animal habitats can be minimized. Thus, the occupation fence has a dual function, namely to protect the forest area as well as to guide animals.

This repair effort is expected to make the Duri West Ring Road function optimally, be animal-friendly, maintain ecosystem sustainability, and have the potential to be developed as an environmental education tourism. With the comprehensive application **of the eco-road** concept, the Duri West Ring Road in the future will not only become a means of transportation, but also function as an **eco-road-based environmental education road**, which is a pilot infrastructure that provides learning to the community about the application of environmentally friendly road principles.

Conclusion

Based on the results of field observations, analysis of initial planning technical documents, and guidelines used, the application of the concept of an *eco-road* on the Duri West Ring Road has not been fully optimal. Of the 20 parameters studied, as many as 15 parameters (75%) have been in accordance with the provisions of the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.23/MENLHK/SETJEN/KUM.1/5/2019, while 5 parameters (25%) have not been fulfilled

and will be implemented in the next stage of development. The parameters that have not been met include the provision of canopy bridges, animal warning signs, monitoring towers, guard posts, and gates. This condition is expected to cause environmental and safety impacts, such as habitat fragmentation, increased risk of vehicle-to-animal interaction, low awareness of motorists due to the absence of animal signs, and limited monitoring and control functions in the area. In addition, the construction of the Duri West Ring Road itself is not fully final, it is still in the completion and development stage, so the application of *the eco-road concept* has the opportunity to continue to be refined to better support the ecological function as well as road safety. This research provides a scientific contribution as an initial study of the application of *eco-roads* in the Riau region, which has never been researched before, thus enriching the literature on the relationship between transportation infrastructure and ecosystem conservation. The results of this research can be the basis for the preparation of policies and technical guidelines for road construction in forest areas, especially in ensuring that the function of roads runs in tandem with environmental conservation. In the future, further research needs to be focused on the detailed technical design of mitigation infrastructure, such as animal tunnels, canopy bridges, and elephant ditches, so that *the eco-road* concept can be implemented more comprehensively.

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