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FRACTURED LANDSCAPES: STUDY ON LANDSCAPE FRAGMENTATION AND DEGRADATION DUE TO EXPRESSWAYS

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Abstract: Landscape fragmentation and degradation is an emerging issue in Sri Lanka, which is a result of the rapid development and inadequate concern on the visual and the environmental factors. Linear developments such as roads and power lines are mostly responsible for fragmentation. One such linear development, expressways, are an integral part of modern transportation as they facilitate links between commercial and industrial sectors and serves as an essential component for the development of the tourism industry, all of which ultimately contribute to the improvement of the country's economy. This paper presents the outcomes of a post construction landscape study pertaining to the visual aspects and physical connectivity of the landscape affected by the Southern Expressway, Sri Lanka. The Southern Expressway passes through urban, sub-urban and rural landscapes as well as plantations. In that context, the most preferable way to integrate engineering structures with the natural environment is imitating the natural forms to mitigate the adverse impact on human perception. These structures are responsive to mitigation of landscape fragmentation and degradation by improving the landscape permeability. Two main methods, mapping and photographic survey were used in this investigation. Further, GIS mapping was used to identify the landscape pattern. Landscape architectural solutions as a design approach will ultimately result in land form and drainage planning as well as facilitate ecological connectivity through landscape ecological applications and other appropriate landscape architectural proposals. Therefore it is vital that the landscape architects are included in the design team from the preliminary stages.

Keywords: Landscape Fragmentation; Landscape Degradation; Ecological connectivity; Landscape permeability;

1. Introduction

The natural tendency in humans for mobility has directed them to establish extensive transportation networks, which has brought about major changes to nearby towns and cityscapes. Growth of the road network, while stimulating economic and physical growth bringing about higher living standards for the cities has resulted in large scale fragmentation of landscapes.

Fragmentation can be defined as the breaking of a habitat, ecosystem or landscape into smaller pieces due to human activity [1].Natural landscape exists as a mosaic of inter-connected and interdependent habitats. However, human activities are increasingly fragmenting the natural landscapes isolating habitats and their linkages. Therefore, maintaining or restoring landscape connectivity is critical for conservation of global biodiversity [2].

In Sri Lanka, during the British colonial period, a network of thoroughfares was constructed to link the administrative capitals. However, the road network at present is deemed insufficient to support the growing traffic load. Therefore the latest trend in Sri Lanka is the construction of Expressways to facilitate fast land based transportation. This include, the Colombo-Katunayake Expressway (E 03), which is fully functional, the Southern Expressway (E 01) that operates up to Matara and planned to be extended up to Hambanthota, the Outer Circular Highway (OCH) that has been completed from Kadawatha to Kottawa and the Northern and Central

Expressways which are still at the final design stages.

Landscape fragmentation is one of the key negative impacts arising due to transportation corridors. Most developed countries therefore make use of a battery of mitigation measures in their latest road development projects. It is important to look evaluate these applications and determine whether they are replicable in the Sri Lankan context. It is also crucial to determine the origin of the issues, to find solutions and alleviate the problem.

Study of precedence and identification of the primitive landscape structure and the ecological pattern using landscape metrics is useful to mitigate the impacts of fragmentation and synthesize adequate parameters and precautions towards a sustainable transportation mechanism. This study provides appropriate suggestions to mitigate landscape fragmentation and degradation via landscape architectural practice. Further it will provide evidence for the need of the involvement of professional Landscape Architects to address the landscape issues during the design stage of the project. Finally, this study also examines the compatibility of engineered structures and human perception and whether road development results in visual fragmentation.

2. Landscape Fragmentation and Degradation

2.1 Landscape Fragmentation

Land modification to facilitate emergent development of Sri Lanka causes Landscape fragmentation. "Landscape fragmentation is mainly defined as the breaking of habitat, ecosystem or landscape into smaller pieces which is usually caused by human activity" [1]. "The main dimensions of landscape fragmentation are physical and perceptual. In the physical dimension, changes in landscape structures and functions are important. Functional changes include ecological and sociocultural dimensions." [1].

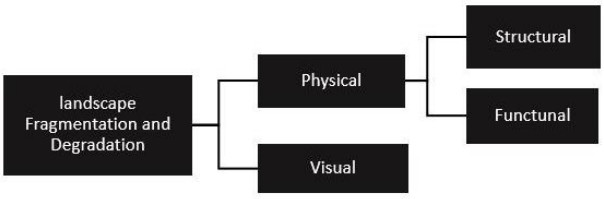

Figure 01. Dimensions of Landscape fragmentation and degradation studies

Source: [1]

2.2 Landscape Degradation

Degrading can be defined as the gradual reduction in biomass or structure [3]. Landscape degradation can be interpreted as the degradation of habitat, ecosystem or landscape. Habitat degradation is an emergent issue with the advancement of the transportation sector. "Habitat degradation can be brought on by pollution, generally caused by the movement and emission of vehicles along existing transportation corridors" [4].

3. Aspects of Landscape fragmentation and degradation

The affected group and the purpose should be considered when determining whether the landscape is fragmented or not. A place that is physically fragmented to people may not be physically fragmented for animals. Purpose refers to what is fragmented by development. Ex: circulation, social interaction, food productivity etc. Anyhow Expressway construction fragments and degrades adjacent land patches into small land parcels. According to this study, the above mentioned dimensions (shown in figure 01) are slightly changed.

3.1 Physical fragmentation and degradation

1. Structural

Fragmentation of the landscape structure, especially fractures in the land use pattern due to the relative rapid growth of the transportation infrastructure and urban agglomeration is considered here.

2. Functional

Socio-cultural, agricultural and commercial functions can be fragmented and degraded

by the growth of transportation infrastructure. Influence to the existing ecological functions of the landscape and alterations of the socio-cultural, agricultural and commercial circumstance of the affected areas are mentioned here.

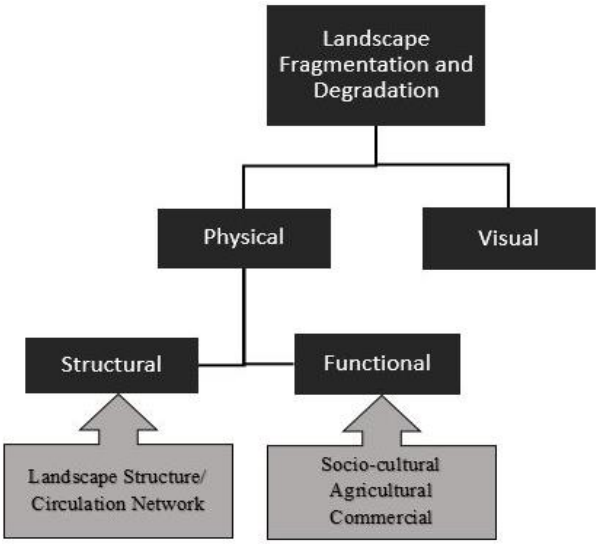

Figure 02. Dimensions of Landscape fragmentation and degradation studies

Source: author

3.2 Visual fragmentation and degradation

Human perception on the proposed structures, land modifications and their combination with the surrounding landscape of the expressways is considered here. Passengers and dwellers near the expressway are the affected parties in this instance.

4. Causes of Fragmentation and Degradation

There are many agents that cause landscape fragmentation and degradation, both physically and visually. Transportation Corridors, farm lands, transmission lines, oil pipeline corridors, industrial zones, and urban expansions are few agents that promote landscape fragmentation and degradation.

Transportation corridors have become major cause of landscape fragmentation and degradation. Among the various transportation modes, expressways are massive man-made features which causes considerable deviations to the topography and prevailing landscape. The whole development process leads to immense changes in macro and micro levels of the landscape.

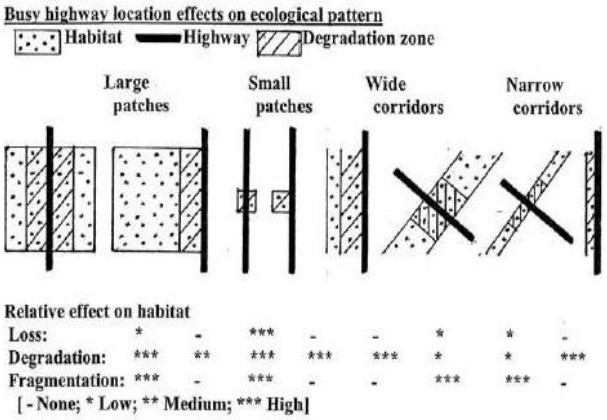

Figure 03. Busy highway location effects on ecological pattern

Source: [5]

Human and animals are the victims of the landscape fragmentation and degradation in a diverse manner, due to the obstructions of the physical links (physical structure), habitat flows and the visual intrusion by the expressways. Among these,

Wild animals are the main victims of habitat fragmentation during motorway construction. As the forest decreases in size and is divided by residential areas and traffic networks, their habitat gradually shrinks. These small habitats are not sufficient for the animal survive [6]. Further, transportation networks bisect natural landscapes and reduce the permeability. "The degree to which wildlife individuals are able to move across a landscape is known as landscape permeability" (Andreassen et al.1998, Frair et al. 2008, [4]).

"In scaling road and natural patterns, the busy highway produces a degradation zone on each side that extends an arbitrary 25 percent of the width of the large natural patch and 75 percent of the wide corridor." [3].This convinces the necessity for consideration of sensitive areas before road construction.

Road related habitats in both sides of the roads are extremely affected physically and biologically. "The edge climate may be warmer and drier, for example, and this can

lead to changes in species composition. Depending on the ecosystem type and species, these so-called edge effects can permeate hundreds of meters into adjacent habitat." (Reijnen et al. [7]). Human tendency on Technological advancements should be used as beneficial to reduce the negative effect on balance of natural flows in landscape.

4.1 Mitigation of landscape fragmentation in Expressways of Sri Lanka

Expressways are a crucial part of the advancement of transportation field in Sri Lanka. They should adhere to the international standards and also some cause that need further attention. During the project processing period of the Southern Expressway that started in 1996, environmental assessments were prepared by authorized institutions and authorities. "The expressway route is located, as much as possible, along the foot of the hill slopes to minimize the loss of farmland and the relocation of residential building." [8]. Committee of the Southern Expressway development project includes various monitoring teams and a cluster of responsible professionals to measure the effects on the existing mechanisms. The completion report presents the process and mitigation measures they have given for the success this project.

According to the Southern Expressway reports they were concerned about avoiding wetlands and existing flood plains, ensuring the aesthetic value of the area by tree plantation, minimize the tree removal during the construction and proposing over passes and under passes to increase permeability. They had considered mitigation measures for noise and visual intrusion caused by the expressway. According to the project reports, Outer Colombo Highway (OCH) had to have some specific structures to increase the physical permeability of both sides of the expressway including bridges, box culverts and viaducts.

4.2 Issues that need further attention

Deviation from the major wetlands during the construction of the Southern expressway project was a timely solution to abstain the destruction of flood retentions plains and other integrated mechanisms of the wetlands. It's must further concentration on the flood plains, existing irrigation before implementing new ground modulation, including land filling, cutting and earth embankment.

Elevated highways on viaducts in certain areas where the highways cross wetlands is a discerning solution to sustain the wetland community and the permeability of the landscape. But the recent records of the flood disaster compel us to rethink if the given solutions to restore the environment of the area affected by the expressway development, especially the wetlands bisecting areas, is enough. The objectives of the project report are appreciable, but no comprehensive solution for the crossings like overpasses and underpasses catered to wildlife as mentioned. It is essential to mitigate these issues by learned lessons from the implemented projects.

5. Precedence

Since the 1960s, many developed countries have begun to consider landscape design in motorway construction while attaching importance to the improvement of existing motorway landscapes, and these countries have also developed appropriate specifications and regulations. All these specifications and regulations focus on visually attractive highways with basic functions which aim to be harmonious with the surroundings. [6]. Road Ecology is a term, currently used in ecological practices in relation to the advancement of road infrastructure development. Except the massive engineering involvement, expressway construction is a collective endeavour of professionals across various disciplines that balance the processes behind the construction.

Wildlife crossings are creative engineering structures and these "Wildlife crossing structures are being designed and incorporated into road construction and

expansion projects to help restore or maintain animal movements across roads." (Spellerberg 2002, Forman et al.2003.) [7]).In addition to that, enriching the green belts in both sides of the expressways to restore the disturbed natural environment is essential to fulfil the ecological and visual aspects in motorway landscapes.

The Confluence Project- Vancouver, The Banff wildlife crossing project and Galleried tunnel – N2 motorway, Switzerland are some projects that reflect the influence on reduction of landscape fragmentation and degradation.

6. Data collection Methodology

Research Objectives

1. Study the evolution of the landscape patterns and character during the Southern expressway project
2. Identify the given solutions to mitigate landscape fragmentation and degradation.
3. Study the procedures on mitigation of landscape fragmentation and degradation in developed countries.

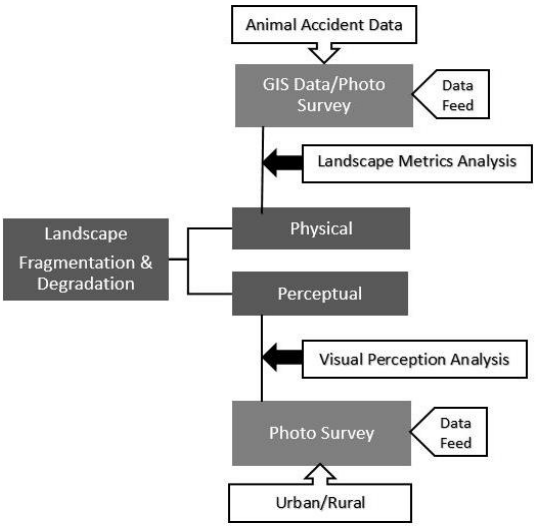

Figure 04. Data collection method

Source: Author

7. Case study selection criteria

Specific areas of the Southern Expressway (E01) were selected as case studies because E01 was the initially implemented expressway project in Sri Lanka.

Then specific plots of the Southern Expressway were selected. Case study selection criteria differs from each other according to the study dimensions.

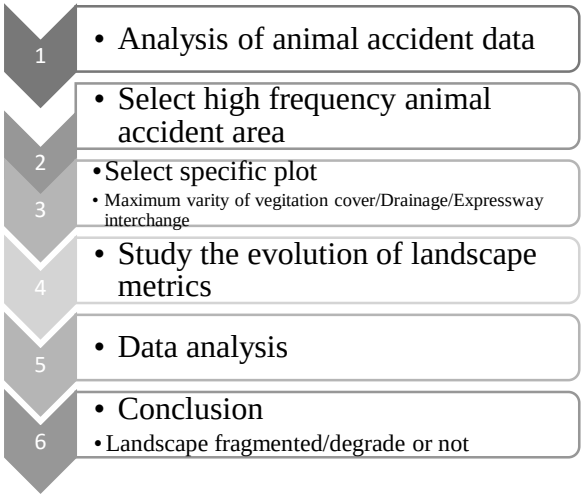

Figure 5: Data processing method, physical fragmentation Source: Author

7.1 Physical fragmentation and degradation study plot selection

This is focused to comprehend the landscape structure and land use pattern to identify how they affect ecological corridors, circulation pattern and continuity of that area. "Habitat fragmentation occurs when changes in habitat configuration occur as a result of the breaking apart of habitat, independent of habitat loss." (Fahrig 2003, [4]). Increased number of collisions between vehicles and animals become the main reason for habitat fragmentation.

Selected a specific plot consisting of a maximum variety of vegetation (including forest patches), an interchange environment, and drains to study the fragmentation and degradation of the landscape structure. This is a comparative study of the landscape transformation within the period of pre-construction, under-construction and post-construction stages of the Southern Expressway.

7.1.1 Case study

The frequent animal crossings and accidents were identified using the accident data records of the expressway. A five-year time frame from the opening year of the

Southern Expressway was selected to analyse the accident data. The collected numerical data demonstrates that 100-127 km range records frequent accidents due to animal crossings over the expressway.

To study the landscape structure with landscape metrics, a 50km^2 (10*5) area was selected from the 100-127 km range which included, forest patches, plantations (Rubber, Tea, Coconut and other), paddy fields, home gardens and, other (Scrubs/ Grass lands).

The selected area comprised of high dense forest reserves including Hiyare, Kottawa and Kudagala kanda reserves. Landscape pattern analysis indicated that these are located in the northern part of the expressway.

Three years were selected from the construction to completion of the project for comparative study and analysis of the landscape in the affected area of the Southern Expressway development.

7.2 Visual fragmentation and degradation study plot selection

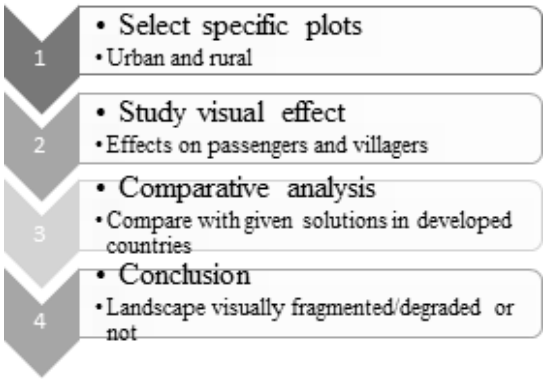

Figure 6: Data processing method: Visual fragmentation

8. Theoretical approach

Landscape ecology focuses structure, function and change of the landscape.

Structure: The spatial relationship among the distinctive ecosystems or elements.

Function: The interactions among the spatial features

Change: The alteration in the structure and function of the ecological mosaic over time [3].

8.1 Landscape structure

"Landscape structure expresses the spatial pattern of landscape elements and the connections between the different ecosystems or landscape elements. Landscape structure assesses relationship between ecosystems as measure, number, size and shape."(Forman and Godron1986; Gergel and Turner 2002, [9]).

8.2 Landscape metrics

"Landscape metrics help us to understand changes in landscape from different Perspective (Visual, ecological, cultural). Landscape metrics have greatly contributed to the landscape ecology studies."(Letiao and Ahern 2002; Miller et al. 2005, [9]).Landscape metrics could be calculated under Patch, Class and Landscape levels.

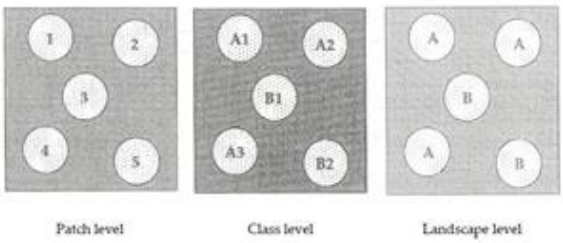

Figure 07. Calculation levels of landscape metrics (Farina, 2000)

Source: [9]

9. Data collection method

9.1 Land use maps/Geographic Information System (GIS) data

GIS data is used to identify the landscape metrics from patch level to landscape level. GIS is a very practical tool that can be effectively used for the analysis of spatial patterns and the geographical configuration of the expressway outskirts.

In this research, survey maps of three years were selected under the pre-construction, under- construction and post-construction stages to identify the land usage in this area.

By referring these, land use patterns and landscape metrics were identified. Then CA: Class Area, TLA: Total Landscape Area, NUMP: Patch Number and MPS: Mean Patch Size were calculated using GIS application.

These calculations initiated the analysis of landscape fragmentation and degradation levels of the selected area. Land use maps were used to identify the connectivity within the inner circulation network of the zone affected by the expressway.

9.2 Photographic survey

Photographs taken on site clarify two parameters of fragmentation, the visual and physical aspects. These contribute to, understanding the effect of engineering structures on human perception/ visual fragmentation and identify the effectiveness of the structural techniques used in the selected area.

1. Visual fragmentation and degradation

Photographs captured on selected urban and rural areas of the expressway were used to analyse the effect on the entire landscape and human perception of both passengers and dwellers by the built structures and land modulation strategies used in the expressway.

2. Physical fragmentation and degradation

Survey the structures implemented in the case study area to increase the mobility of both humans and animals and responsiveness to the circulation without disrupting existing conditions, to support restoration of mobility.

10. Data Analysis

According to the data analysis of the land use changes of landscape metrics, Patches of paddy lands and plantations have degraded after the construction of Southern expressway (E01).Land acquisition for the expressway construction must be a reason for the decrease of the patch number of plantation.

Table 1: Landscape fragmented and degraded percentages 2001-2015

Class level	CA(ha) %	NUMP %	MPS(ha)%
Forest	13.043	8.509	Not changed
Plantation	40.000	32.785	
Paddy land	154.406	59.619	
Home garden	14.630	2.863	
Others	62.628	6.084	
Landscape level	1.555		

CA: Class Area, NUMP: Patch Number, MPS: Mean Patch Size, ha: hectare, % percentage

Number increased
Number decreased

Paddy lands and home gardens have become fragmented because of the construction and further development of the expressway. Construction of the expressway has become the reason for the destruction of land patches of scrubs, grass lands and barren lands. Small patches in plantation and other vegetation category (scrub/grass/barren lands) have become devastated. Paddy lands and home gardens have degraded.

Recorded data of the selected plot in Southern expressway illustrate that the given response for the accessibility in some places are inadequate. Interior road network needs to be uplifted within the villages adjacent to the expressways and should have high concern to restore the mobility of human and animals, as it may result adversely in biological and sociological aspects. Should consider about the given distances between every underpass. Road crossing structures will be the most appropriate conception to reinstate the habitat movement in both sides. Without providing solutions for a selected area, the entire landscape must be considered when

giving the design solutions for an expressway development.

Confluence Project is one of the major projects that restore the lost connections between the historic Vancouver site to Colombia River over a highway by the Land Bridge in city of Vancouver.

"The Land Bridge concept draws upon nature's organic forms and the Native American significance of the circle, which symbolizes continuity of life and the cycles of nature."[10].

This shows how they considered the design concepts to amalgamate the existing socio cultural and ecological backgrounds of the existing context.

Highway A50 in Netherlands is another example that depicts how to respond to the wildlife mobility in both sides of the road, by using the appropriate structural applications.

Drainage structures which are the main engineering features that help to enhance the connectivity, essential to continue the ecological flows and the habitat connectivity. In some countries specify the drainage structures are specified by the category of the animals who are crossing the drain. TCH (Trans Canadian Highway) is an excellent example for preparing of habitat linkages through the highway.

Expressways are a major agent which contributes to noise pollution. Advanced concepts are used in developed countries to create noise barriers to reduce the negative effects on the adjacent community from the expressways. High perforated aluminium absorptive barrier in N2 motorway, Switzerland is a good example for a noise barrier which blend with the surrounding landscape.

Diverse ground modulation methods are used in the Southern expressway to remodel the landscape such as cutting off the hilly areas and modifying the natural geographical formations. In some areas modulation methods are successfully implemented and merged with the natural landscape. But in some areas it has become hazardous. Landslides has occured between Pinnaduwa to Godagama area, due to the disruption of the soil structure and lack of measures to reinforce the structure.

Structural fearures used in expressways at the urban areas are highly congested visually and physically. Various strategies are practiced in developed countries to reduce the visual effect on these huge manmade features by improving existing geomorphological features.

In the rural contexts of expressways, it is necessary to consider the scenic corridors and conceal the vistas through the transportation corridor. The profound sense on the spatial recognition must be used before arranging the landscape spaces of the expressways.

11. Conclusion

This research concentrates on the correlation between expressway construction and landscape fragmentation and degradation. Necessity of the fast transportation modes, speed up the diffusion of the expressways throughout the country. This research contributes to get an identification of the real impact to the landscape, alongside the expressways constructed in Sri Lanka with reference to the completed project and concentrates on the low attentive aspects in road construction field. Identification of the tendency for the landscape fragmentation and degradation helps to overcome the adverse effects.

Quantitative and qualitative data collected by GIS application and photographic surveys were used to identify landscape metrics and visually or physically fragmented and degraded landscapes with special reference to Southern expressway (E01).

Outcomes of the data analysis of the case study indicate that the construction of expressways has become one of the catalysts of fragmentation and degradation of the landscape. Numerical data analysis of landscape metrics helps understand the land use pattern of the study area and determine the variables of the land usage.

Photographic survey also reinforced the findings throughout the study process by providing the recorded evidences of the human and animal essentials on mobility and visual effect of the landscape fragmentation and degradation on people.

Identification of animal movement corridors and inter connectivity with the eco systems is crucial to uplift the permeability by animal crossings. Comprehension on the landscape mosaic is beneficial to minimum the obstructive effects to the natural flows by restore the habitat flows.

Some of the modulation techniques used in expressway construction has to be improved with the proper understanding of the context and by following the cases from developed countries. Expressways cause reduction in quality and quantity of the agricultural products and reduces the land quality because of land parcels. Insufficient linkages allocated to wildlife will be the key reason for the frequent vehicle collisions with wildlife crossings as a result of fragmentation of their movement corridors.

Locations with frequent animal crossings recorded have diversified vegetation corridors enriched with significant reserves. This signifies the importance of such mobility corridors for animals. Improvement and implementation of engineering structures to address these issues must be difficult because of the cost factors. Crossing structures are the best solution for the traversing of wildlife. It is realized that eco-system based solutions are enduring and sustainable.

In developed countries, they try to identify every factor that could affect the natural flow of the environment and give precautions. And also commence researches to identify the issues and search for solutions.

This research has to proceed with the post-construction surveys considering the identification and pattern creation of the bisected landscapes by the expressway construction. It is essential to survey the perception of people who were affected by the development project and their awareness on the landscape structure to make precautions for the planning and designing of upcoming projects.

Discussion on the social, ecological and economic effects with the relevant professionals to identify the errors behind the proposals is critical. It tries to convey the message of the importance of the involvement of experienced professionals at the beginning of the project.

This paper contributes to enhance the vision of the decision makers on the necessity of preparation of particular rules and regulations to decrease the negative effects to the landscape connectivity by the infrastructure development. This is the time to direct these transportation development strategies towards the creation of sustainable transportation system. Learned lessons from successfully implemented projects in developed countries is an opportunity to improve our future expressway projects in Sri Lanka.

Appreciable applications and given landscape solutions for the current infrastructure development projects cause to outsiders impression about the professional involvement on it. The active contribution of the landscape architects to these development projects is a must to enhance the standards of the existing road network. Synthesis of existing knowledge systems and learned lessons are essential to provide most preferable solutions. Involvement of Landscape Architects from the preliminary planning level of the transportation corridors is important to spatial recognition in addition to the social, ecological and economic processes. As a nascent profession of the country, Landscape Architects have to work on their key role and give their contribution to get maximum output for the development of the country.

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