A METHODOLOGY TO ANALYZE ROAD LANDSCAPE IN ACCIDENT BLACK-SPOTS: THE CASE OF SOUTHERN EXPRESSWAY, SRI LANKA

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Road safety; black-spot; driving behavior; road landscape.

Abstract
The Road Landscape creates the character and the spatial quality for safe driving. It is evident that the spatial qualities of the road landscape have impacted on road accidents once the field data is analyzed. Identification of accident-prone areas (Black-Spots) is the vital factor for road safety management process. The study focused on to developing a methodology to visually analyze road landscape with using identified Black-Spots in Southern Expressway, Sri Lanka. Data is collected and analyzed as two phases; one is from recorded accidents data and other from a live recording of the expressway driving stretch. This study highlighted the possibilities of analyzing the identified ‘Black-spots’ by using Photo-Fixation method. In conclusion, the study emphasizes the possibility of using a qualitative methodology to analyze the road landscape through spatial characteristics; which can be developed up to a more advanced level to identifying driving behavior related accidents and to take migratory actions.
INTRODUCTION

Road accidents are the tenth-leading cause of all deaths globally, and as estimated 1.2 million people are killed in road crashes each year and as many as 50 million are injured. If the present trends continue, road traffic injuries are predicted to be the third-leading contributor to the global burden of deceases and injuries by 2020.

Also in Sri Lanka, there is a continuous increase of road accidents year after year. As mentioned by Somasundarawasan (2006), the road accidents are increasing as a result of two factors; increases in number of vehicles; and poor development of road infrastructure. Therefore, the annual death rate in the country due to accidents is 12.1 deaths per 100,000 and government spends about Rs.1100 million per year for the medical treatments. So, it is very much essential to mitigate road accidents and ensure road safety. The parent study of this paper was done to analyze the relationship of road landscape with the driving behavior, and this paper focused to discuss on its analytical methodology.

LITERATURE REVIEW - ROAD ACCIDENTS

The road accidents are influenced by three major categories - the human factors, the physical factors and the environmental factors.

![Figure 1: Factors determining Road Safety (Source: Author).](image)

Road accidents caused the deterioration of the safety on roads. It is found from road safety studies, 92% of road accidents happened due to the human factors. The study of Matijošaitytė & Navickaitė (2012) revealed that there is a direct relationship of road safety and the aesthetics of the Road Landscape, after analyzing the emotions and opinions of 486 respondents.

BLACK – SPOT - DRIVING BEHAVIOR

The term ‘Black-Spot’ is commonly defined as ‘a place where road traffic accidents have been concentrated' over time. Black spots are one of the indicators of road safety, and identification of Black Spots is much effective to design solutions for mitigate road accidents.

Driving is an activity, which is always attached with the outdoor environment. Drivers always make their driving decisions depending on what they have experienced visually on the
outside road environments. Mostly, the human eye perceives the results of anthropogenic activities happening in the surrounding landscape. The driving behavior is influenced by ‘endogenous factors’ and ‘exogenous factors’, whereas, the endogenous (internal) factors are identified at the basic preparation stage of the driver when performing the driving task, such as, sleep related factors. The exogenous (external) factors defined as the individual’s interactions with the road environment, such as characteristics of road geometry and road side environment. These major two factors define the driving task (Thiffault & Bergeron, 2002).

DRIVING BEHAVIOR AND VISUAL PERCEPTION

The term ‘visual perception’ is explained as, the ability of the user to gather the information provided to complete the communication exchange. The information should be collected at the proper time, so that the driving decisions can be implemented efficiently and safely. Therefore, visual perception of the driver creates a huge impact on the driver behavior. The safe use of any roadway is depending on visual perception.

The visual information collected by the brain creates sensible scenes that that can understood and negotiated. As visual information becomes more complex, driver may lose some of the sense of order and scenes become more difficult to understand. That difficulty may lead to confusion and sometimes hazardous situations (Schutt, Phillips, & Landphair, 2001). So, the driving behavior is depending on the level of perceiving information by the driver. The landscape along the roadside will contribute positively or negatively to the driving decisions made by the drivers. However, after studying 61 landscape improvement projects in roads, Mok et al. (2006) found that the landscape along the roadside is having a positive impact on driver behavior and perception, and it can be used as a tool to improve the road safety. According to the scenes of road landscape provided, the driver has to face many severe consequences, such as fatigue, vigilance, activation etc.

Fatigue

Fatigue, is a general incident, which emerges as a function of the driver and environment relationship in the particular driving environment. Fatigue reflects the decreased capacity to perform in safe driving, along the road environment. Fatigue is considered as a major factor in accidents, which is responsible for up to 20-30% of road accident fatalities.

Generally, fatigue can be interpreted as the transitory period between awake and sleep, if undisturbed can lead to sleep (Lal & Craig, 2001). Moreover, Nelson (1997) identified through his study, the highway design with lack of stimulation can induce fatigue-related accidents. So, the general causes of fatigue and drowsy driving can be generated by performing driving through monotonous driving environments. After an experiment with 56 drivers in driving simulator, Thiffault & Bergeron (2002) came to the conclusion that the roadside visual stimulation could be used to alter the fatigue and drowsiness on existing road infrastructure.

Vigilance

Vigilance is identified as the ability to maintain sustained attention within the road environment. The characteristics of both the driving task and road environment have an
influence on vigilance. Decrement of vigilance is considered as the dominant effect of fatigue and sleepiness.

The study of Thiffault & Bergeron (2002) highlights that driving requires sustained vigilance to perform at its best, and a lack of visual stimuli in road environments (monotonous road environments) can alter the ability to sustain vigilance.

**DRIVING BEHAVIOR AND ROAD ENVIRONMENT**

Always, drivers are interested in exposure to a broader visual field even for a brief moment. They also limit their visual experience mainly to the larger spaces and landforms. However, when the speed increases drivers automatically reduce their visual field (Antonson et al., 2009).

![Speed and field of vision](source: The Role of Road Engineering in Combatting Driver Distraction and Fatigue Road Safety Risks, 2015).

At about 65km/h speed the driver can observe about 1000 degrees and the focal point is near 400m; if it is increased to 80 km/h about 650 and the focal point is near 500m. When the speed is 100 km/h the field of vision becomes narrower to 400 degrees and the focal point goes beyond 600m. That clearly demonstrates that when the speed is increased the field of vision of the driver is narrowing, but the driver is focusing on to more distance views.

Road Landscape creates the visual field of the driver when they are travelling on a road. The roadside vegetation, road edges, boundary walls, soil embankments, sign boards and other natural and man-made introductions can be considered as the road landscape. According to the National Association of Australian State Road Authorities (NAASRA), the main goal of road landscaping is to produce roadways to high safety standards which will also aesthetically integrate with the environment. Many researches done in Germany on this, verified that 68% of all car accidents happened due to the wrong design of roads and its’ landscape; and insufficient information of roads and its’ landscape (Matijošaitiené & Navickaitė, 2012).

The experience of road landscape may affect drivers in many different ways. The findings from the Antonson et al.’s study (2009) revealed that the visual properties of different landscape settings affect the drivers. In addition, the study prove that after analyzing 18 drivers regardless of their gender and age, the drivers experience less stress and drive fast.
in open landscapes than in varying and forested landscapes. Moreover, Matijošaitienė & Navickaitė (2012) came to the conclusion in their study, the landscapes with ‘pleasant’, ‘beautiful’, ‘harmonious’, ‘natural elements matched with the surrounding environment’; recorded more car accidents and the landscapes which are ‘relaxing’, ‘visually safe’ and ‘sophisticated’ recorded the less car accidents.

The natural environments on road landscapes create an impact on driving behaviors. The research of Matijošaitienė (2011) on hedonomic road landscape, found that the hedonomics (pleasure) of roadscape depends on the natural elements. Furthermore, the ‘beautiful’ & ‘varied’ road landscapes formed with not less than 64% natural elements, ‘willing to drive’ and ‘left positive impression’ road landscapes formed with 78% and 70% of natural elements. The ‘safe’ landscapes formed with 60% of natural elements in the view and good visibility of road and its’ surrounding. Therefore, it is clearly proven that the road landscape has an impact on driving behavior. It is very important to develop a methodology to identify the driver fatigue with reference to the road landscape, but that has not been seriously thought of. Therefore, this paper tries to develop a methodology to analyze road landscape with reference to driver fatigue.

**METHODOLOGY - Identification of Black-Spot**

The Southern Expressway, the first ever introduced expressway to Sri Lanka, has the highest ‘Average Data Traffic (ADT)’ among current expressways in the country and it recorded the highest number of accidents than others. This paper focused to identify two Black-Spots in two directions of this expressway, and suggest a methodology to analyze the characteristics of road landscape through a visual analysis method.

In the study, the data collection and analysis has been done with two phases:

- Phase 01 - Recorded accident data collection & Analysis on Southern highway;
- Phase 02 - Field data collection & Analysis.

**Phase 01 - Recorded Accident Data**

Southern Expressway runs 126 km from Kottawa to Matara with 11 interchanges, connecting Western province, Southern province and in between townships.

From its' initiation (2011 November) to 2016 February, 2602 accidents were recorded, which have caused to eliminate valuable human lives and property damages to the country.

In the analysis of recorded accident data, these can be divided into major three categories: accidents caused by Human Factors, Physical Factors and Environmental Factors. The accident causes are recorded and categorized by the traffic engineers in the Southern expressway.
Table 1: Accidents by cause in southern highway (Source: Database EOM & M division- Southern Highway, compiled by the author, 2016).

<table>
<thead>
<tr>
<th>Human Factors</th>
<th>Physical Factors</th>
<th>Environmental Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol - 15</td>
<td>Vehicle defects - 293</td>
<td>Bad Weather - 527</td>
</tr>
<tr>
<td>Bad Driving - 396</td>
<td>Electrical Problems - 30</td>
<td>Animal crossing - 408</td>
</tr>
<tr>
<td>Fatigue - 316</td>
<td>Stone throw/hit - 127</td>
<td></td>
</tr>
<tr>
<td>Negligence - 146</td>
<td>Other objects - 7</td>
<td></td>
</tr>
<tr>
<td>Overtaking - 168</td>
<td>Road slippery - 14</td>
<td></td>
</tr>
<tr>
<td>Sudden Stopping - 29</td>
<td>Fire - 1</td>
<td></td>
</tr>
<tr>
<td>Speed - 113</td>
<td>Others - 9</td>
<td></td>
</tr>
<tr>
<td>Reverse - 3</td>
<td>Vehicle defects - 293</td>
<td></td>
</tr>
</tbody>
</table>

The accidents caused by Bad Driving, Fatigue and Negligence (totally 858 accidents, 32% of total accidents happened in Southern Highway between 2011 Nov. to 2016 Feb.) are considered as the causes for driving behavior related accidents. Then the driving behavior related accidents in Colombo – Matara direction are analyzed according to the interchanges by using the chart below.

Figure 3: Black-spot identification chart, most accidents in Colombo to Matara direction (Source: Author).
Table 2: Interchanges in southern highway (Source: Author).

<table>
<thead>
<tr>
<th>Distance</th>
<th>Interchange</th>
<th>Distance</th>
<th>Interchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0-6 km Kottawa-Kahathuduwa</td>
<td>F</td>
<td>68-80 km Kurungugahahetekma - Baddegama</td>
</tr>
<tr>
<td>B</td>
<td>6-14 km Kahathuduwa-Gelanigama</td>
<td>G</td>
<td>80-96 km Baddegama-Pinnaduwa</td>
</tr>
<tr>
<td>C</td>
<td>14-35 km Gelanigama-Dodangoda</td>
<td>H</td>
<td>96-108.4 km Pinnaduwa-Imaduwa</td>
</tr>
<tr>
<td>D</td>
<td>35-46 km Dodangoda-Welipenna</td>
<td>I</td>
<td>108.4-116.3 km Imaduwa-Kokmaduwa</td>
</tr>
<tr>
<td>E</td>
<td>46-68 km Welipenna-Kurundugahahetekma</td>
<td>J</td>
<td>116.3-126 km Kokmaduwa-Godagama</td>
</tr>
</tbody>
</table>

From figure 03, it can be identified that the most number of driving behavior related accidents are concentrated between ‘Kurungugahahetekma - Baddegama interchange’ and ‘Baddegama - Pinnaduwa interchange’. To identify the exact location of a Black-Spot, a ‘Dot-Density measure’ was used between those two identified interchanges. Dot density measure was done by placing a dot at the recorded accident locations in every kilometer distance.

According to the figure 04, 76th kilometer and 89th-90th kilometers were identified as the Accidents Black-Spots of driving behavior related accidents in Colombo to Matara direction.

Phase 02 – Field Data Collection and Analysis
It can be assumed that a driver experiences the road landscape as a movie, or a series of photographs changing in a very short time period. When the surrounding road landscape of the driver remains repetitive (without any stimuli), it is considered as monotonous road landscape. According to the literature review, the monotony of the road landscape leads the drivers to fatigue.
The field data collection has been done when travelling in a car starting from Kottawa interchange up to Godagama interchange (Matara). The entire driving environment has been recorded using a digital camera mounted in front of the driver’s seat. The vehicle speed always kept around the speed of 100 km/h.

The 'photo – fixation method' is employed as the methodology to analyze road landscape of the expressway. In the research of Matijošaitienė, (2011) on hedonomic road landscape, he used photo-fixation method in his field research and selected photos of road landscape were used for a qualitative survey. The video recording of the driving stretch was converted to a series of photographs and they were used to identify the characteristics of the road landscape. So, the identified Black-Spots above have been analyzed by using the photographs taken at approximately 500m intervals from the live video recording of the driving stretch.

![Figure 5: Sample photograph from the video recording (Source: Author).](image)

When the road landscape is not changing very much or keeps on repetitive, it creates same series of photographs for a while. That scenario reflects monotonous environment which leads drivers to fatigue or many other driving behavior related issues. So, when analyzing the impact of road landscape and driving behavior, series of photographs can be used for qualitative analysis with supportive spatial plans, sectional diagrams and road sections.

The figure 06 shows a part of an analysis of the parent research of this paper, done as a visual analysis of road landscape with relation to driving behavior. In this a series of photographs of road landscape with supportive sectional diagrams were used. As a part of the qualitative analysis of road landscape of the main research, the spatial characteristics of the road landscape have been identified and analyzed. A) Degree of enclosure B) Differentiate of forms are two identified spatial characteristics in road landscape, which are discussed in this paper.

**A) Degree of enclosure**

When a driver moves through a road he/she experiences different spatial enclosure effects in point to point. Variation of spatial enclosure creates a diversity of road landscape which
supports the driver to maintain a sustained attention or ‘vigilance’. Less variation of spatial enclosure creates monotonous driving environments.

The figure 06 analysis indicates the variation of enclosure effect of the road landscape along the identified Black-Spot in Colombo- Matara direction (Baddegama-Pinnaduwa interchange, 85km-92km stretch).

Figure 6: Sample of the application of photo-fixation analysis method in identified Black-Spot  (Source: Author).

Description of the qualitative analysis of photo-fixation

The area is mostly enclosed with the left side rocky surface. First 3km stretch creates a monotonous environment with left side rocky surface (fig. 4-9). Then, there is a sudden exposure to open low lands. Next, 3km stretch with enclosed soil slopes (fig. 11-14). Low composition of enclosed spaces & open spaces, directs to create uncomfortable, monotonous driving experience, which leads drivers to fatigue – vulnerable area to driving behavior related accidents.

B) Differentiate of forms

Humans always identify ‘forms’ first when they are exposed to a scenery, then identify the colors, textures and other details. So, the forms in the road landscape affect the legibility of the roadway. As discussed by Antonson et al. (2009), spatial form of a road or a street should give a clear visual guidance and signals to drivers regarding suitable speed and
driving behavior. Appleyard, Lynch, & Myer (1965) mentioned that the drivers limit their visual experience mainly to larger landforms and spaces, since they have limited their focus on to a narrow band with the speed.

The figure 07 shows, the analysis which indicates the differentiate of forms in the road landscape along the identified Black-Spot in Colombo- Matara direction (Baddegama-Pinnaduwa interchange, 85km-92km stretch)

Figure 7. Sample of the application of photograph analysis method in identified Black-Spot (Source: Author).

Description of the qualitative analysis of photo-fixation

In this area the variation of forms is very less. The area continues as the same form with less variation and that creates monotonous visual forms in the landscape. It causes fatigue & hypo-vigilance and a vulnerable area to driving behavior related accidents.

CONCLUSION

This study was carried out with a continuous speed of 100km/h, which is the highest permitted, since drivers experience is vital at the higher speeds. Somehow in lower speeds the experience may change since the human eye could identify more details and got a broader perspective. Therefore this Methodology can be used more effectively by identifying the speed of the vehicle, also by breaking down the intervals of visual field is considered. These intervals could also be linked with the frequency of the eye for identifying details and can improve more sophisticatedly even for vehicles to alarm on driver’s behavior.

REFERENCES


