Spatial Analysis of Topography Effect in Eco Driving Level on Corridor VI BRT Semarang

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Abstract. Public transportation is important facilities to service the mobilization of citizen in urban activity. Bus Rapid Transit (BRT) is one of the modes considered suitable for developing cities such as Semarang. To ensure the sustainability of the BRT, good planning and operation and maintenance are required. In the operation of BRT eco driving behavior is believed to save fuel up to 13% and keep the fleet condition safe and reliable. This research is intended to know the behavior of the driver in operating the BRT. From driver behavior and onboard survey can be classified the level of eco driving the operation of BRT in Semarang. An eco driving level assessment was conducted on a sample of the BRT fleet. The analysis is done by making the level of eco driving using spatial analysis GIS. It divided into several levels that is high, medium and low. In the other hand, the topography is believed caused of the driver behavior. Furthermore, spatial analysis is done to map the areas that have variance slope. From the mapping results can be concluded which areas have low levels of eco driving and the slope characteristic. From these conclusions, recommendations for BRT performance improvement can be formulated.

Keywords. *BRT, eco driving, topography, slope, sustainable transportation, spatial analysis*

1. Introduction

Researches about eco driving to reduce energy consumption and emission are important to make the sustainable development concept come true. The influence of urban transportation activity on the environment, among others, is the use of energy in transportation used. In the concept of energy sustainability is expected to be as efficient as possible. Inefficient energy use can have an effect on the environment. Environmental impacts can have an impact on climate change. The rise of automobile use has increased CO2 emissions resulting from motor vehicle burning. It was result in a greenhouse effect that impacts climate change from both local and global scale. Moreover, CO2 emissions have increased by 70.73% in the last 34 years [1]. The impact of CO2 emissions in this transport includes the greatest impact after urban industry [2].

There were some strategies to reduce the impact of inefficient energy use and CO2 emissions. The use of mass public transit can reduce the number of private vehicles on the streets and the impact of reduced energy and emissions [3]. There are various types of mass public transit such as Mass Rapid Transit (MRT), Light Rapid Transit (LRT) and Bus Rapid Transit (BRT). MRT and LRT are commonly used in big cities whereas for medium cities usually use BRT. Cities with medium-sized cities like the United States use BRT as a short-term strategy to reduce CO2 emissions [4].

Another strategy was introduced eco driving behavior in operating vehicle. Eco driving is a safe driving strategy for environmental sustainability and effective to reduce fuel consumption and emissions generated. Based on simulations and real-time experimental vehicle experiments in Southern California for 3 consecutive years from 2005, 2006 and 2007, eco driving has managed to conserve fuel consumption and reduce emissions by 10-20% [5]. Technical driving eco driving can also be said to drive by anticipating traffic such as not braking abruptly, not driving at high speed, avoiding acceleration

hard, moving gear to the highest rpm, always stable speed and limiting idling problems [6]. This driving technique can suppress excessive gas emissions or unnecessary gas emissions that can have an effect on environmental sustainability.

Semarang as a medium-sized city with an area of 373.8 km2 and a population of 1,648,279 people chose to use BRT as mass public transport. BRT is believed to have the advantage of performance and quality as well as cost-effective both operational and maintenance [7]. The use of BRT as a mass public transportation in Semarang City began in 2009. Previously Semarang city government has been using buses as a means of mass public transport but less successful, especially from the aspect of sustainability. This is because the use and maintenance of its vehicle is not planned carefully, monitored and evaluated its operation. To maintain the sustainability of the BRT, effective vehicle operation and maintenance is required. In this case, eco driving concept play te rule of effective maintenance. The behavior of each driver in BRT is not the same because the driver has its own habits and characteristics in driving. Not all BRT drivers have driving behavior with ecological behavior[8] or eco driving. BRT is considered to reduce gas emissions generated by motor vehicles but there is a driving behavior factor that is actually a factor that can increase gas emissions.

The influence of the driver does not behave in an eco driving manner when driving can be caused by the driver itself or even the effect of traffic conditions. BRT Corridor VI is the latest corridor located in Semarang City. Corridor VI also has characteristics quite different from other BRT corridors located in Semarang. Topographic and land use conditions in the study area may affect emissions levels and excess fuel use if the driver has not implemented an eco driving while driving. In BRT Corridor VI drivers who do not behave economically while driving can actually increase the emissions incurred and increase the use of excess fuel. To reduce the impact, it can be implemented by driving eco driving so that BRT Corridor VI can always be sustained and to support the concept of sustainable transportation in Semarang City. Therefore the research question arises, "Is the topographic of route affecting the eco driving level?"

The aim of this research is to give some brief description about the effect of topographic to the ecodriving level to improve the public transport service.

2. Data and Method

Bus Rapid Transit (BRT) is one example of integrated transportation mode. This is because BRT has a system that can be integrated with stations, roads, other public services [7]. One of the benefits of using BRT is that it is efficient to reduce the volume of road capacity. BRT is therefore appropriate if applied to a city that has high traffic problems. Research on BRT has been done before by some experts such as the corresponding BRT system on services provided for passengers [9]. In addition, research conducted by [10] discusses the impact of BRTs making transit centers in China, Beijing growing into new development and re-development. Research on the potential of BRT implementation can reduce the use of private vehicles associated with CO2 emissions also made by [4]. Research on eco driving related to sustainable transportation in Singapore has also been done by [11]. While the research of eco driving on BRT is still not much done for that this research needs to be done.

BRT is not independent of the environment as it can reduce emissions (CO, SOx, NOx, particulates, CO2) from pollutants that can affect human health. Environmental factors are a major and important factor in terms of transport sustainability as they can have a direct effect on the environment and living things [12]. Although BRT can reduce the problems that affect the environment but the driver behavior factor becomes the main factor that can cause an increase in emissions generated by motor vehicles. Individual actions to take a role in climate change are considered highly significant. For that driver BRT needs to change the behavior or driving style to pay more attention to the environment [13]. For that driver needs to change driving behavior by applying eco driving because based on simulation and experiment vehicle conducted in Southern California for 3 consecutive years from 2005, 2006 and 2007, eco driving successfully reduce fuel consumption and reduce emissions by 10- 20% [5].

In order for eco driving successfully done then it is necessary to apply eco driving indicators in driving. There are a variety of eco driving indicators that are applied to save fuel consumption and reduce emissions. According to Killian R [14] eco driving successfully done if applying the following indicators:
a. Do not step on gas and brakes suddenly / quickly (can increase fuel usage by 40%)
b. Maintain a constant / steady speed (constant and steady speed reduces emissions of gas)
c. Turn off the engine when it stops for a long time (the engine that burns for 10 seconds consumes more fuel than when turning on the engine)
d. Checking the tire pressure every time when it will travel (lack of tire pressure affects the speed increase when driving)
e. Note the speed limit, fuel use increases 5% or more if driving above 60 mph on the highway

In addition, eco driving indicator should be done according to Green Communities Canada [15] namely:
a. Keeping speed and driving safely, driving with speed limits not exceeding 100 km / h is more efficient in reducing fuel usage by 10%
b. Drive smoothly and keep pace always stable
c. Avoid hard braking / abruptly by leaving space with vehicles in front
d. Smooth but fast switch to higher gears for the engine to work more efficiently

Other indicators of eco driving according to Barkenbus J N [13] are successfully implemented for:
a. When accelerating, change to gear to higher until 2000-2500 rpm
b. Anticipating traffic flows and traffic signs to avoid unnecessary braking
c. Avoid starting abruptly and stopping unexpectedly by always maintaining speed while driving
d. Driving safely or driving with a maximum speed limit of 80 km / h

Based on the eco driving indicator that has been shown by the experts above, the indicator is appropriate and applicable by BRT drivers in Semarang. In this study, the indicators can be summarized as below
Before Driving
1. Tire pressure Always check the tire pressure before traveling
2. Heating machine Heating machine is better done less than 30 seconds if more than that can eat more fuel
While Riding
1. Braking Do not brake suddenly or quickly because it can increase the use of fuel up to 40%
2. Speed Maintain a constant / steady speed and drive with a maximum speed limit of 80 km / h
3. Acceleration To avoid rough or unnecessary acceleration
4. Rapid gear change Replace to higher gears up to 2000-2500 rpm for the engine to work more efficiently
5. Avoid start with high speed Accelerate to a maximum limit of 20 km / hour
6. Deceleration Avoiding abrasive or unnecessary slowdown
[3,13,14]

In this study to assess the level of eco driving requires data or information obtained from the survey of primary data with field observation techniques. Field observations conducted aim to determine the behavior of BRT drivers related to eco driving indicators. The tool used during observation is a checklist of data containing the eco driving indicator. The checklist data is used for 1 trip per driver or can be said for each driver and performed on 16 drivers. The observations made on 16 BRT Corridor VI drivers using checklist data will be assessed at each bus stop or segment of BRT in corridor VI. This

assessment was conducted at 26 stops from a total of 27 stops in corridor VI.Observation was performed 16 times with different drivers in the same corridor and observations were conducted on a day and hours relatively similar to the purpose of assessing traffic conditions not much different or tends to be the same. Observation on driver behavior of BRT Corridor VI of Semarang City is done every Monday-Monday and done not during peak hour in the morning or afternoon.

2.*1 Assessing Eco Driving Level*

After obtaining primary data it will then assess the level of eco driving at every stop or segment of dismissal. In assessing the level of eco driving is done by categorizing the data.
The level category of eco driving in this study uses Azwar's categorization [16] and will be classified into 3 categories, high, medium and low based on the normal curve distribution by dividing the data into the standard deviation formula as shown in Table 1.

Table 1. Range of Categorical Level

RANGE	LEVEL
$X \geq (\mu + 1\sigma)$	HIGH
$(\mu - 1\sigma) \leq X < (\mu + 1\sigma)$	MEDIUM
$X < (\mu - 1\sigma)$	LOW

Source: Range Of Categorical Level [16]

Where,
X = Subject Score
μ = Hypotetic Mean
σ = Standard Deviation

To obtain an eco driving level at each stop or segment of the stops then perform some stage of eco driving assessment. The first stage is to find the level of eco driving BRT Corridor VI which at this stage becomes the overall level of eco driving on the corridor. The second is finding an eco driving level based on BRT driver Corridor VI. At this stage each driver BRT Corridor VI will be categorized into low eco driving, medium eco driving and high eco driving. Third is to find the level of eco driving based on the indicators used. This stage is still tied to the previous stage of the eco driving level of each driver. After getting the category of each driver then categorize every indicator of eco driving that affects the driver is not driving by eco driving. Finally, identify the factors that influence based on the results of the level of eco driving indicators. To know the factors that influence then first done to the category of eco driving at every stop or segment dismissal. At this stage it is done by more detailed sorting of non-eco driving behavior by BRT driver Corridor VI per-indicator at each stop or segment of dismissal.

Slope classification (Table 2) will be presented in map form. Therefore, in the classification of slopes slope requires SRTM data to then be processed into a map of slopes. To process the data using a tool processing in the form of Arcgis. The slope of the processed slope will be classified into 5 slope classes. The 5 classes of slopes will be classified into flat, sloping, steep and steep. The slope classification has different slope levels for each class of slope. In the classification of the slope is based on Guidelines for the Land Rehabilitation and Soil Conservation by Ministry of Forestry Indonesia as shown in the Table 2.

Table 2. Slope Classification

Class	Slope (%)	Description
Class I	0-8	Flat
Class II	8-15	Sloping
Class III	15-25	Rather Steep
Class IV	25-45	Steep
Class V	>45	Extremly Steep

Source: Minister of Forestry Indonesia, 1986

This 3rd phase brings together the results of the eco-driving level and the slope of the slopes that had been previously obtained. The eco driving level map at each stop or segment will be overlaid with a slope slope map. Then the results obtained in the form of new maps overlay both. After obtaining a new map, the data is combined with the level of eco driving and slope to obtain more informative data. The combined data will be used for more in-depth analysis of the eco driving level with slope inclination.

3. Result and Discussion

In this study, the first stage of data processing is to assess the level of eco driving at each stop or segment of dismissal and mapping using GIS. This is done to find out more detail the level of eco driving at every stop or segment of dismissal. It will also be used as a material to perform analysis at the next stage of slope factors that affect the level of eco driving at each stop or segment dismissal. To more easily understand the results of these calculations will be presented in the form of maps. The map will be displayed as a route map of BRT Corridor VI. The route shown illustrates the level of eco driving at each stop or segment of stops. The level of eco driving described on the map is a different color. To know more clearly can be seen in the Figure 1.

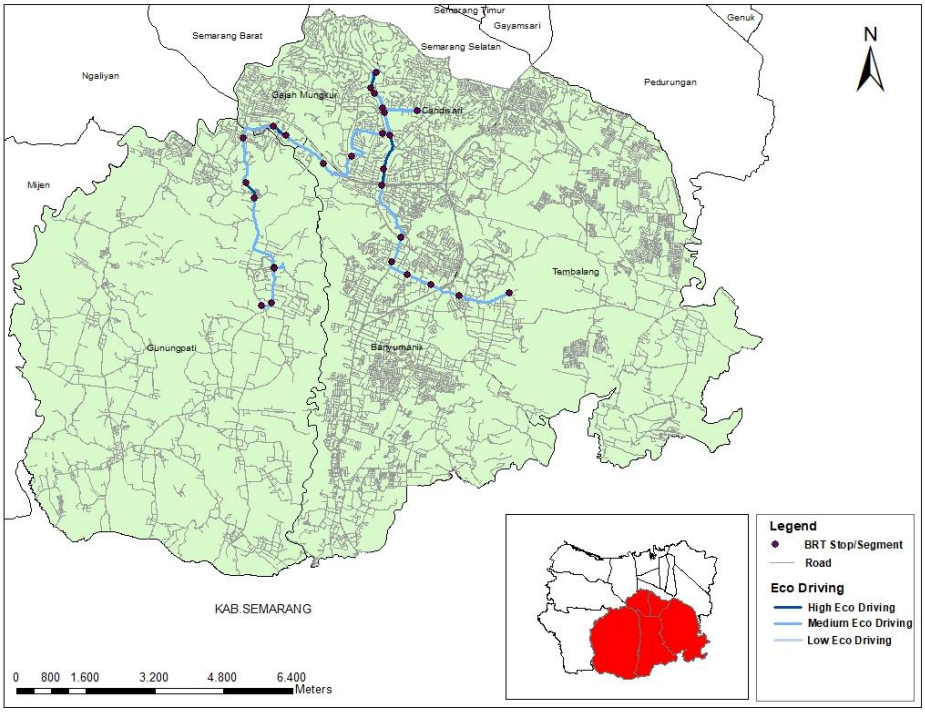

Figure 1. Eco Driving Level in Corridor VI BRT Semarang

The map formation as seen in Figure 1 above requires materials such as shp stop points or segments of BRT discharges in Corridor VI and sub-district administration map where the stop or segment is located. Shp dot or segment points are then processed to serve as a new shp that is BRT route. The calculation of the eco-driving level at each stop or segment that has been previously obtained will be compared with the BRT route shp. Therefore, in the picture above can be seen that there is no stop or segment dismissal belonging to the low eco-driving and there are 21 stops or segment dismissal belonging to the eco driving is. As for the high eco driving there are 5 stops or segment dismissal. Stop or segment belonging to high eco driving that is stop 7, stop 8, stop 12, stop 19 and stop 22. The rest of the stop or segments are categorized to medium eco driving level. This level represent that there are still

several indicator non eco driving such as braking suddenly or quickly, speed maintain a constant / steady, rapid gear change, start with low speed, and unnecessary slowdown.

The level of eco driving at every stop or segment of BRT's suspension of Corridor VI has been known, so then look at the influencing factors. There are various types of factors both internal and external that can affect the level of eco driving. But in this study only focus on one of the factors that influence the slope of the slope. The slope of the slope includes factors from the external side and is related to the physical character or environmental conditions so that can not be avoided from the influence of eco driving provided.

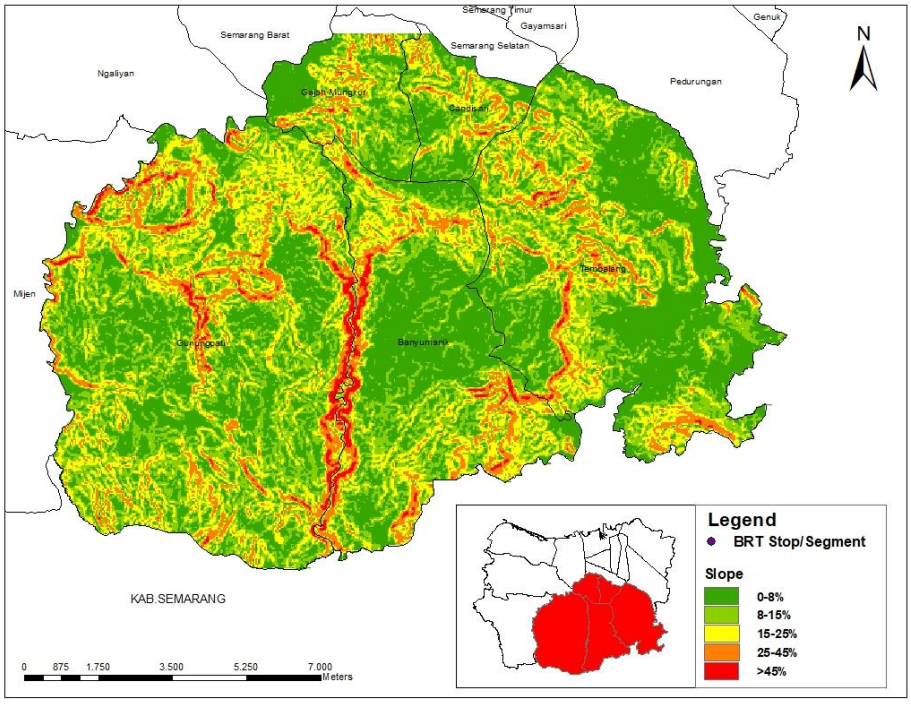

Figure 2. Slope of Corridor VI BRT Semarang

The route of BRT Corridor VI includes 5 districts in Semarang, Tembalang, Banyumanik, Gajahmungkur, Candisari and Gunungpati districts. The 5 sub-districts have different slope slopes as seen in Figure 2 or can be passed through the up and down route. Based on the classification of slope with Arcgis analysis tool, it is found that there are 5 types of slope class in 5 sub-districts passed by BRT Corridor VI. 5 types of classes of slopes are flat, sloping, somewhat steep, steep and very steep. As for the route BRT Corridor VI as a whole passes a varied slope at each stop or segment of the dismissal. The varied slopes that are skirted as a whole include flat slopes, slopes and somewhat steep.

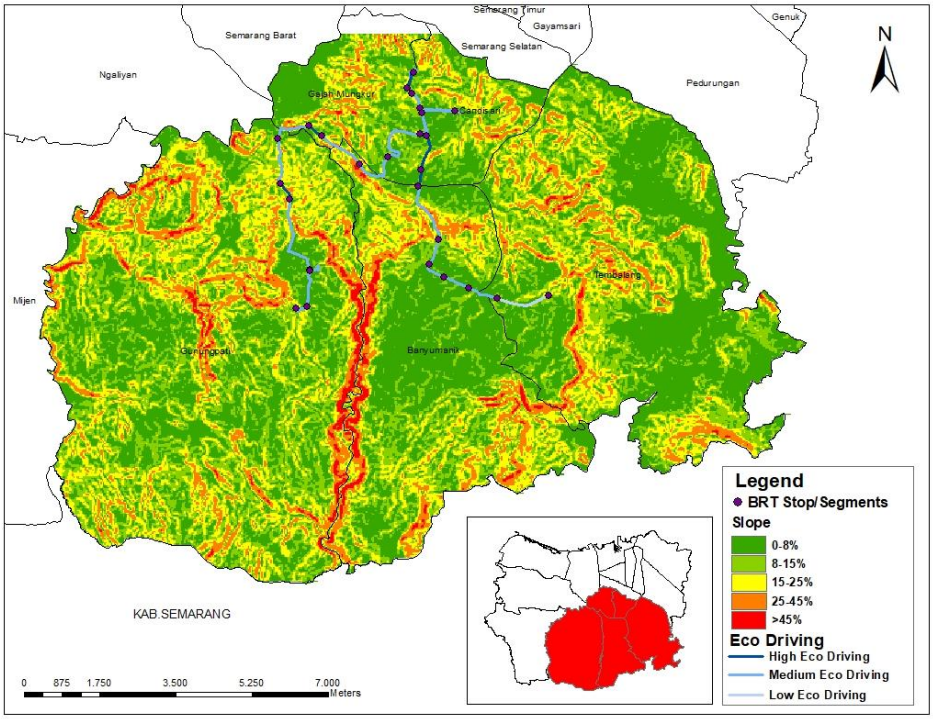

Figure 3. Slope and Eco Driving Level of Corridor VI BRT Semarang

Once known level of eco driving at every stop or segment stops and slope of the BRT route slope then the next will overlay both (Figure 3). The purpose of overlay is to know how the influence of slope to the level of eco driving. From the overlay process that has been done then the result is quite significant. 4 out of 5 stops or segment stops are classified as low eco driving ie stop 7, stop 8, stop 19 and stop 22 through a varied slope. Stop 7, stop 8 and stop 19 through 3 types of slope classes are flat, sloping and somewhat steep. For stop 22 passes 4 types of slope classes that are flat, sloping, somewhat steep and steep. While 1 of the 5 bus stops or segments are classified as low eco-driving ie stop 12 only through 2 types of slope classes are flat and ramps. At the stop 12 the slope factor is less significant in influencing the eco driving level but there are other factors that are more influential. From the results that have been obtained 4 of 5 bus stops through the varied slope so that it can be said that the slope factor can affect the level of eco driving. To know more clearly about the slope that is passed and the level of eco driving in every stop or segment of dismissal can be seen in Table 3.

Table 3. Slope and Level of Eco driving

Halte/segment	Slope	Level of ecodriving
1	Flat, Sloping and Rather Steeping	Medium
2	Flat	Medium
3	Flat	Medium
4	Flat	Medium
5	Flat, Sloping and Rather Steeping	Medium
6	Flat, Sloping, Rather Steeping and Steeping	Medium
7	Flat, Sloping and Rather Steeping	High
8	Flat, Sloping and Rather Steeping	High

9	Flat and Sloping	Medium
10	Flat, Sloping and Rather Steeping	Medium
11	Flat, Sloping and Rather Steeping	Medium
12	Flat and Sloping	High
13	Flat, Sloping and Rather Steeping	Medium
14	Flat, Sloping and Rather Steeping	Medium
15	Flat, Sloping and Rather Steeping	Medium
16	Flat, Sloping and Rather Steeping	Medium
17	Flat, Sloping, Rather Steeping and Steeping	Medium
18	Flat, Sloping, Rather Steeping and Steeping	Medium
19	Flat, Sloping and Rather Steeping	High
20	Flat, Sloping, Rather Steeping and Steeping	Medium
21	Flat, Sloping and Rather Steeping	Medium
22	Flat, Sloping, Rather Steeping and Steeping	High
23	Flat, Sloping, Rather Steeping and Steeping	Medium
24	Flat, Sloping and Rather Steeping	Medium
25	Flat and Sloping	Medium
26	Flat, Sloping and Rather Steeping	Medium

Source: Analysis, 2018

From the table 3 the eco driving levels can be grouped into two classes, high level and medium level. For high eco driving level occurs in segments that have the characteristics of flat, sloping and rather steeping topography (segments 7, 8 and 19). It also occurs in segments with flat and sloping characteristics (segment 12). On more diverse characteristics such as flat, sloping, rather steeping and steeping, the level of eco driving occurs in segment 22. From this data it can be concluded that high levels of eco driving occur in various topographic characteristics (more than 2 types). It shows that the driver tends to be careful in the condition of the segment that has a varied topography.

As for the medium level of eco driving being found on topographic characteristics that are flat and do not vary in segments 2, 3, 4. However this medium level of eco driving also occurs in various topographic characteristics (Flat, Sloping and Rather Steeping). It could be found in segments 1, 5, 10, 11, 13, 14, 15, 16, 24 and 26. From this data it can be conclude that the level of eco driving is happening in two types of topography which are not varied and varied. This means that the topography that does not vary such as the flat, driver does not do the eco driving indicator. So, do in various topography. There are several indicators that represent non eco driving such as braking suddenly or quickly, not speed maintain a constant / steady, rapid gear change, start with high speed, and unnecessary slowdown.

4. Conclusion

It can be concluded that there are influence topography at the level of eco driving. For high eco driving level the variation of topographic types is mostly flat, sloping, and steeping. It is influenced by the driver have to be carefully to pass the slope variation in the segment.

The medium eco driving level occurred in the segment that has flat and sloping topographic type, and the segment with variation topographic such as sloping, and steeping. It represented that in this segment the drivers do carelessly and not eco driving.

5. Acknowledgments

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