Street Lighting Infrastructure Assessment Using Discriminant and GIS Method on Mount Merapi Evacuation Road

R P Izdihar¹, M Maryono¹, W Widjonarko¹, and S Rahayu¹

¹Department of Urban and Regional Planning, Diponegoro University, Semarang 50275, Indonesia
Email: rakanpramoe@gmail.com

Abstract. This research aims to assess street lighting infrastructure in rural-urban of Mount Merapi Evacuation road. Three evacuation road/corridor; Mriyan-Boyolali, Wonodoyo-Boyolali and Samiran-Boyolali are selected as case study. By using discriminant this study examine 6 variables namely type of lamp, physical component, height, time, power and cons consumption. In addition this study also using GIS method to assessing geographical feature as of previous result. According to the discriminant analysis, the characteristic of street lighting could be distinguished as two characteristic, while from the GIS assessment, the study found three characteristic of geographical street lighting feature.

Keywords: street lighting infrastructure, Mt. Merapi, evacuation road corridor

1. Introduction

Study concerning to street lighting infrastructure have been conducted worldwide. Many theme have been researched such as concerning to crime [1,2], accident [3,4] energy and efficiency [5,6], smart and intelligent system [7,8]. However, research associated toward evacuation and characteristic of corridor very limited. This study aims to assess the quality street lighting infrastructure in associated with preparedness of evacuation process in mount merapi hazard. Three corridor surrounding mount Merapi namely Mriyan-Boyolali, Wonodoyo-Boyolali and Samiran-Boyolali are selected as case study. In addition this study will explore the physical and management aspect. The physical variable such as type of lamp, physical component, height, time, power and cons consumption, while the management variable such as providing and maintenance system

2. Methods and Study Area

This research utilized discriminant method to analysis street lighting characteristic in the three corridors. This method is one of the powerful method to classify the characteristic of infrastructure, since many study have been conduct by using this method at least for 27 years. For example, study of
infrastructure impact [9], study to define significant urban rail infrastructure [10]. Moreover, this research utilized spatial method such as GIS to explore the spatial aspect between corridors. This study also assess the management aspect namely, providing and maintenance system, in associated with community concern in preparedness. Different with previous, for example, community concern in disaster waste [11], lava flow [12], vulnerability of infrastructure [13], this study utilized interview, simple FGD and observation method during data collection. Data characteristic classified by 6 variables for discriminant analysis and classification as three group for final assessment such as good, medium, and bad.

The study area covers 3 villages spread in 3 different sub-districts, namely Mriyan - Boyolali, wonodoyo - Boyolali, and Samiran- Boyolali. The three villages have geographical characteristic such as geographical slopes, classification of disaster prone area. The length of each corridor as follow (figure 1):

a. Mriyan Village - Boyolali City corridor has length 12,672 km;
b. Wonodoyo Village - Boyolali City corridor has a length 14,616 km;
c. Samiran Village - Boyolali City corridor has a length 17,724 km

![Figure 1. Study Area, Mriyan, Wonodoyo, Samiran Corridor](image)
3. **Result and Discussion**

3.1. **Physical Data and Characteristic of Street Lighting**

**Table 1. Description of Corridor, Sub Corridor, Number of Street Lighting, Average of Power and Time of Lighting in Study Area**

| Corridor         | Sub corridors | Zone and classification of prone Area | Number of street lighting | Average of Power | Time of Lighting |
|------------------|---------------|----------------------------------------|---------------------------|------------------|-----------------|
| Mriyan – Boyolali |               |                                        |                           |                  |                 |
| Mriyan           | Disaster Prone II |                                        | 27 point                  | 15 watt           | 12 hours        |
| Sruni            | Disaster Prone II |                                        | 13 point                  | 15 watt           | 10 hours        |
| Ringinlarik      | Disaster Prone III |                                      | 16 point                  | 20 watt           | 10 hours        |
| Musuk            | Disaster Prone III |                                      | 25 point                  | 50 watt           | 12 hours        |
| Sukorame         | Disaster Prone III |                                      | 10 point                  | 50 watt           | 10 hours        |
| Pusporeenro       | Non – Disaster Prone |                                  | 6 point                   | 150 watt          | 10 hours        |
| Sambung B          |               |                                        |                           |                  |                 |
| Musuk            | Disaster Prone III |                                      |                           |                  |                 |
| Sambung           | Disaster Prone III |                                      | 20 point                  | 20 watt           | 12 hours        |
| Paras             | Disaster Prone III |                                      | 9 point                   | 50 watt           | 12 hours        |
| Jelok             | Disaster Prone III |                                      | 7 point                   | 50 watt           | 10 hours        |
| Winong             | Non – Disaster Prone |                                  | 10 point                  | 150 watt          | 10 hours        |
| Sambung C          |               |                                        |                           |                  |                 |
| Samiran           | Disaster Prone II |                                        | 10 point                  | 15 watt           | 12 hours        |
| Selo              | Disaster Prone II |                                        | 10 point                  | 15 watt           | 12 hours        |
| Genting           | Disaster Prone III |                                      | 15 point                  | 20 watt           | 10 hours        |
| Mliwis            | Disaster Prone III |                                      | 10 point                  | 50 watt           | 10 hours        |
| Winong             | Non – Disaster Prone |                                  | 10 point                  | 150 watt          | 10 hours        |

As depicted in table 1, totally there are 17 sub corridor in with represent rural-urban region. The length of corridors are 17,724 km. The upstream corridors are dominated with area as classify for disaster prone II at while the downstream corridor are disaster prone III. Sub corridor of Mriyan and Wonodoyo are classify as rural zone, sub corridor of Sruni, Gedangan are classify as rural-urban, while Ringinlarik, Musuk Sukorame, Purporenggo, Sambung, Paras, Jelok, Winong, Samiran, Selo, Genting, Mliwis, Winong are classify urban zone [14]. The physical condition such as power of street lighting is diverse among 15-150 what. The highest power of street lighting in corridor of study area is 150 what while the highest is 150 what. The time of street lighting on tend to similar between 10-12 our per day.
As depicted in table 2, Fluorescent Tube Lamp, is used in sub corridor of Mriyan, Wonodoyo, Samiran, Gedangan, Sambung, Selo and Genting. This is the sub corridors 1. In this areas, the physical material used for street lighting is still reasonable, for example made of wood / bamboo so that not good enough resilience. The height of the lamp in this area is no more than 5 meters. The average time of street

### Table 2. Description of Physical Characteristic of Street Lighting in Study Area

| Physic                                 | Sub Corridor and Area                                      |
|----------------------------------------|-----------------------------------------------------------|
| Height                                 |                                                           |
| Height of street lighting no more than 5 meters | Mriyan, Wonodoyo Samiran, Gedangan, Sambung Selo and Genting (sub corridor 1) |
|                                                          |                                                           |
| Quite varied, there street lighting which has a height of less than 5 meters, there is also 5 - 10 meters | Ringinlarik, Pusporenggo, Jelok, Mliwis, and Winong (sub corridor 2) |
| Cost & Energy                          |                                                           |
| Time of Lighting                        |                                                           |
| The average time of street lighting in the village area is for 12 hours / day. |                                                           |
| P day : Average Power of lamp x Time of Lighting x street lighting | Cost Analysis : P month x Electricity Rates  |
| Exist : 15 watt x 10 hours/ day x 177 street lighting : 26,550 watt/hour | 796.5 kWh x Rp 1,385.00 |
| P month : P day x 30 days : 26,550 watt/hour x 30 : 796,500 watt/hour : 796.5 kWh | Rp 1,103,152.50 |
| The average time of street lighting in the village area is for 10 hours / day. | Cost Analysis : Cost Incurred |
| P day : Average Power of lamp x Time of Lighting x street lighting Exist : 150 watt x 12 hours/ day x 53 street lighting : 95.400 watt/hour | P month x Electricity Rates  |
| P month : P day x 30 daysi : 95.400 watt/hour x 30 : 2,862,000 watt/hour : 2,862 kWh | 1,800 kWh x Rp 1,385.00 |
|                                            | Rp 3,963,870.00 |

Source : Authors, 2017
lighting in the village area is for 12 hours / day. The consumption of power estimated 796, 5 kWh per month with the cost of energy is IDR 1,103,152.50 per month.

In sub corridor 2 namely; Ringinlarik, Pusporenggo, Jelok, Mliwis, and Winong, type of lamp that used is SOX. In this area l-urban areas, the physical material of street lighting is good enough. Made of metal, has a lamp shield, so good enough resilience. The height of lamp is Quite varied, there PJU which has a height of less than 5 meters, there is also 5 – 10 meters. The average time of street lighting lighting in the village area is for 10 hours / day. Energy consumption per month estimated 2.862 kWh and cost of energy per month estimated IDR 3,963,870.00.

According to the characteristic of physical of street lighting could be shown that there is a significant different between sub corridor 1 group of corridors Mriyan, Mriyan, Wonodoyo, Samiran, Gedangan, Sambung, Selo and Genting comparing to the physical characteristic of street lighting in sub corridors 2 group of corridors Ringinlarik, Pusporenggo, Jelok, Mliwis, and Winong.

3.2. Characteristic of Management System of Street Lighting

As depicted in table 3, In the sub corridor 1 as group of Mriyan, Wonodoyo, Samiran, Gedangan, Sambung, Selo and Genting, the providing system of street lighting is Community base. However the level of understanding toward energy efficiency is very limited. In sub corridor 2 as group of corridors Ringinlarik, Pusporenggo, Jelok, Mliwis, and Winong, they received support from the government. So in this sub corridors the role of community in providing and management system not dominant.

| Provide And Maintenance | Management System | Area |
|-------------------------|-------------------|------|
| - Community based       | Community based   | Mriyan, Wonodoyo, Samiran, Gedangan, Sambung, Selo dan Genting (sub corridor 1) |
| - The ability of the community is limited, so they need an assistance from government | (People who pay their own electricity bills, and for lamp replacement by their self) | |
| - Received a direct assistance from the government | Rely on government assistance (both for electricity bills and cost maintenance) | Ringinlarik, Pusporenggo, Jelok, Mliwis, dan Winong (sub corridor 2) |
| - The role of the community not dominant | | |

Source: Authors, 2017

3.3. Discriminant Analysis

The discriminant analysis is used to understanding dominant faktor or variable in the clasification. The result of discriminant analysis is that the physical variable of lamp type is the most influential. The discriminant function according to sub corridor 1 and sub corridor 2 of this study are as follow:

Sub corridor 1  = -11,988 – 8,673 X1 + 0,332 X2,
Sub corridor 2  = -4,895 – 2,525 X1 + 0,139 X2
### Tabel 4. Variables in the Analysis

| Step | Tolerance | Sig. of F to Remove |
|------|-----------|--------------------|
| 1    | Type of Lamp | 1.000 | .000 |

*Source: Authors, 2017*

### Tabel 5. Eigenvalues

| Function | Eigenvalue | % of Variance | Cumulative % | Canonical Correlation |
|----------|------------|---------------|--------------|-----------------------|
| 1        | 3.694a     | 100.0         | 100.0        | .887                  |

*Source: Authors, 2017*

### Tabel 6. Structure Matrix

| Function |
|----------|
| 1        |

|    | type_lamp | height_street_lighting<sup>a</sup> | cost<sup>a</sup> | power_consumption<sup>a</sup> | time_lighting<sup>a</sup> | ketersediaan<sup>a</sup> |
|----|-----------|-----------------------------------|-----------------|-----------------------------|------------------------|-----------------------|
|    | 1.000     | .594                              | .456            | .456                        | -.382                  | .071                  |

*Source: Authors, 2017*

### 3.4. GIS analysis of Street Lighting

The GIS analysis the overall quality of street lighting. The result of assessment by using scoring system. The street lighting quality of sub corridor of Musuk Pusorenggo Sukorame Wonodoyo, Paras, Sumbung, and Gedangan is less quality. Sub corridor of Mriyan, Srini, Lanjaran, and Ringinlarik is moderate quality. And the sub corridor of Samiran, Selo Genting, Mliwis, Manyaran, Sukabumi, Bakulan, Bolo, Jelok Village, Winong the street lighting quality is good.
### Tabel 7. Street Lighting Quality

| Quality                           | Red Zone                                                                 | Yellow Zone                                                              | Green Zone                                                                 |
|-----------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------------------------------------------|
| That is a corridor which has Public Street Lighting with less quality | That is a corridor which has Public Street Lighting with medium quality | That is a corridor which has Public Street Lighting with good quality    |
| **Sub corridors**                 | Musuk Pusporenggo Sukorame Wonodoyo Paras, Sumbung, and Gedangan         | Mriyan, Sruni, Lanjaran, and Ringinlarik                                  | Samiran, Selo Genting, Mliwis, Manyaran, Sukabumi, Bakulan, Bolo, Jelok Village, Winong |

*Source: Authors, 2017*

#### Figure 2. Assesment Based on Discriminant and GIS Aplication

4. **Conclusions**

The study have been Analysis Street lighting characteristic as follow:

a. Two characteristic of street lighting with the model could be distinguished by using discriminant parametric model:

1) Sub corridor 1 = -11,988 – 8,673 X1 + 0,332 X2
2) Sub corridor 2 = - 4,895 – 2,525 X1 + 0,139 X2

With the Group of sub corridor 1 are Mriyan, Wonodoyo, Samiran, Gedangan, Sambung, Selo and Genting and Group of sub corridor 2 are Ringinlarik, Pusporenggo, Jelok, Mliwis, and Winong.

b. Three characteristic of geographical feature of street lighting are

1) Sub corridor with less quality of street lighting quality at Musuk Pusporenggo Sukorame Wonodoyo, Paras, Sumbung, and Gedangan is less quality.
2) Sub corridor with moderate of street lighting quality at Mriyan, Sruni, Lanjaran, and Ringinlarik is.
3) sub corridor with good quality of street lighting at Samiran, Selo Genting, Mliwis, Manyaran, Sukabumi, Bakulan, Bolo, Jelok Village, Winong

5. Acknowledgment

This research was funded by Anual year Budget of Faculty Engineering Research Schema for year 2017, under contract No. 434/UN7.P/HK/2016. I would like to thank my partners during discussion and help in this study. The Government of Boyolali for the permission, Pak Sukardi, Ibu Suparmi who help for motorcycle. The Leader of Mriyan, Wonodoyo and Samiran Village for many information during FGD and interview, Laras Kun Rahmanti and Intan Hapsari Hasmatika for the survey and collecting data, Mr. Darno for providing the motorcycle during survey, my friend Hafiz Satria in helping me to understand the framework of this study; and also Anindya Putri Tamara for helped me in editorial writing.

6. References

[1] Ramsay M and Newton R 1991 The effect of better street lighting on crime and fear: A review
[2] Farrington D P and Welsh B C 2002 Effects of improved street lighting on crime: a systematic review (Home Office London)
[3] Beyer F R and Ker K 2009 Street lighting for preventing road traffic injuries Cochrane Libr.
[4] Wanvik P O 2009 Effects of road lighting: an analysis based on Dutch accident statistics 1987--2006 Accid. Anal. Prev. 41 123–128
[5] Kostic M and Djokic L 2009 Recommendations for energy efficient and visually acceptable street lighting Energy 34 1565–1572
[6] Müllner R and Rienner A 2011 An energy efficient pedestrian aware Smart Street Lighting system Int. J. Pervasive Comput. Commun. 7 147–161
[7] Popa M and Cepi$scs$ua C 2011 Energy consumption saving solutions based on intelligent street lighting control system UPB Sci. Bull., Ser. C 73 297–308
[8] Wojnicki I, Ernst S, Kotulski L, Se A and Others 2014 Advanced street lighting control Expert Syst. Appl. 41 999–1005
[9] Looney R and Frederiksen P 1981 The regional impact of infrastructure investment in Mexico Reg. Stud. 15 285–296
[10] Lane B W 2008 Significant characteristics of the urban rail renaissance in the United States: A discriminant analysis Transp. Res. Part A Policy Pract. 42 279–295
[11] Nakayama H, Shimaoka T and Others 2015 Identification of Factors Affecting Stakeholders’ Intentions to Promote Preparedness in Disaster Waste Management: A Structural Equation Modeling Approach 九州大学工学紀要 74 79–98
[12] Gregg C E, Houghton B F, Paton D, Swanson D A and Johnston D M 2004 Community preparedness for lava flows from Mauna Loa and Hual{l}$^{a}$ai volcanoes, Kona, Hawai ‘i Bull. Volcanol. 66 531–540
[13] Wilson T M, Stewart C, Wardman J B, Wilson G, Johnston D M, Hill D, Hampton S J, Villemure M, McBride S, Leonard G and Others 2014 Volcanic ashfall preparedness poster series: a collaborative process for reducing the vulnerability of critical infrastructure J. Appl. Volcanol. 3 10
[14] Bappeda Boyolali 2016 Study of Rural-Urban classification in Boyolali