PREDICTION OF ROAD SECTION LENGTH WITH LIGHT DAMAGE AND ANALYSIS OF INFLUENCING FACTORS: A CASE STUDY IN JAWA TENGAH USING LINEAR REGRESSION

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Abstract:

Road maintenance planning can be optimized by identifying the road's performance in the next period. Bina Marga Jawa Tengah, who is responsible for roads and bridges performance in the province of Jawa Tengah releases data containing every road section's condition status along with the length of each section, Annual Average Daily Traffic volume with the volume of each type of vehicle that passed on every road section. The data also contains every section type of pavement along with the length of each type of pavement on every road section. Using this secondary data, this research aimed to predict the length of 83 road sections that fell into the category of Light Damage from 2019 to 2024, the predictions are for 2025 and 2026. The projections are 53.04 KM and 47.88 KM for 2025 and 2026, respectively. The investigation of the most influencing factor in the 'Light Damage' road category could not perform very well as we lack the schedule and type of maintenance data. The lack of such data yielded a very low R^2 (mostly less than 0.3) as the lack of such data made the existing data irrelevant.

Keywords: *Prediction, Light Damage, Road Section Length, Road Maintenance, Optimization*

Introduction

1.1. Background

To plan a maintenance program for every road section in the province of Jawa Tengah, Bina Marga as the road administrator releases a report containing data on every road condition each year. The conditions are 'Good', 'Moderate', 'Light Damage', and 'Heavy Damage'. Bina Marga Jawa Tengah also releases the Annual Average Daily Traffic and the type of vehicle volume passed on each road section every year. The type of vehicles are motorcycles, cars, buses, and trucks.

Maintenance planning optimization can be achieved through road performance prediction, as the maintenance budget will have projections for one and two years ahead. Light Damage is the border of a road condition that can perform well before it turns to Heavy Damage; moreover, maintenance will require more budget.

1.2. Literature Review

Predicting road performance for maintenance optimization has already been done before. Sari et al. (2018), using data released by the Yogyakarta road administrator, the Satker P2JN DIY, analyzed the Milir-Sentolo road section's functional condition and remaining life as it is prone to accidents using PCI and RCI data. The result showed that the Milir-Sentolo section had a PSI value of 1.41 and a pavement surface value of 6.93, which means it was in good condition. Pamungkas et al. (2021) using secondary data from the test results conducted by the Minister of Public Works, PUPR, predicted the functional condition of the Sleman–Yogyakarta City Border section using HDM-4 (Highway Development and Management) software for maintenance optimization. This research predicted road performance under three categories, *do-nothing, do-minimum*, and *do-something*. The study revealed that the *do-something* option was the most appropriate scenario. Pambudi et al.(2024) evaluated the remaining life of the Solo-Ngawi highway road section. The study used Annual Average Daily Traffic data. It stated that the remaining life of the Ngawi-Solo section was 64.04% and the Solo-Ngawi was 81.37%.

1.3. Research Gap

Many studies in maintenance optimization within the Bina Marga authorized road network have been done before. Pamungkas et al.(2021) predicted the pavement performance using HDM-4 software. The prediction used three scenarios: 1). Do-nothing, 2). Do-minimum, 3). Do-something. HDM-4 (Highway Development and Management) is a model predicting software that predicts the commencement and development of cracks on the pavement based on empirical analysis of traffic loadings and road structure as the predictable variables. Setyawan et al. (2023) studied the remaining life of Pati Ringroad using PCI (Pavement Condition Index) data. The study used a descriptive analysis method that described the pavement condition using PCI data. Pambudi et al.(2024) used quantitative methods and secondary data such as Annual Average Daily Traffic, shop drawings, and technical data of drainage channels to evaluate the remaining service life of the rigid pavement section of the Solo-Ngawi toll road.

The maintenance program can also be optimized by predicting a road length that falls on a certain condition or category within one or two years ahead, as the maintenance budget can be projected based on the prediction. This research objective was to predict the 83 road section length within the category of Light Damage under the authority of Bina Marga Jawa Tengah.

2. Materials and Method

2.1. Data Source

To predict the length of the 83 road sections within the category of 'Light Damage', we used the data released by Bina Marga Jawa Tengah from 2019 to 2024 while to investigate the most influencing factor to the 'Light Damage' category, we used Annual Average Daily Traffic, and motorcycles, cars, buses, trucks yearly volumes and the length of each pavement type for every section data in the year of 2022. There were only two kinds of pavement for the sections we studied, they are flexible and rigid pavement. The reason was that the 2022 data contained complete data for a whole year, while the 2023 year data was only the data until the first trimester and the 2024 year data was only until the second trimester of the year. We studied 83 road sections under the authority of Bina Marga Jawa Tengah.

2.2. Methodology

We used Linear Regression to predict the length of 83 road sections within the 'Light Damage' category for 2025 and 2026 and to investigate the relationship and the most influencing factor in the 'Light Damage' road category. According to Ali et al.(2023), a classic regression approach is a comprehensive tool for assessing the input and output parameter correlations. Bhandari et al. (2021) used a Generalized Linear Models (GLM) algorithm to investigate the impact of structural factors and traffic loading on flexible pavement. Makendran et al. (2015) employed a Multiple Linear Regression algorithm to model flexible pavement performance on a low-volume road.

2.3. Data Processing

The data were acquired and extracted from Bina Marga Jawa Tengah's website. The data were then grouped on the Excel spreadsheet. We input the data of the same sections from 2019 to 2024. We did not include the data from new section names in 2021 that did not exist in 2019 and 2020. The flow chart of the methodology is as follows:

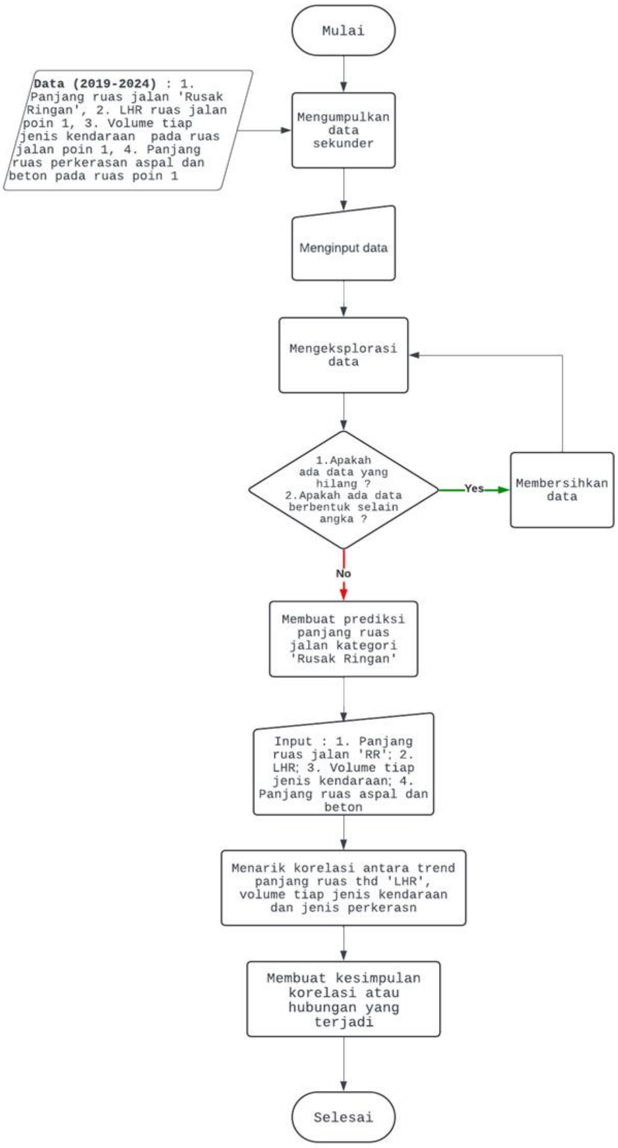

Fig. 1. Flowchart of the Study

3. Result

As a result, the predictions of the road length for the 83 roads within the category of Light Damage are 53.04 KM and 43.88 KM for 2025 and 2026 respectively, shown in Fig. 2. The results of the correlation analysis for each type of vehicle volume and each section length for the Light Damage category from 2019 to 2024 were as follows: The correlation between Cars and road section length is shown in Fig. 3, although the data seemed to be accumulated close to Y-axis, it was concluded that the lower the car volume, the longer the section within the 'Light Damage' category. The correlation analysis between the motorcycle and road sections, as shown in Fig. 4, also showed accumulated data close to the Y-axis, however, it is concluded that the lower the motorcycle volume, the longer the 'Light Damage' section. Figures 5 and 6 depict the relationship between road length and Bus and Truck volume, respectively. There were no certain trends on the graph, as we can see that the data accumulated on the Y-axis and the others spread away.

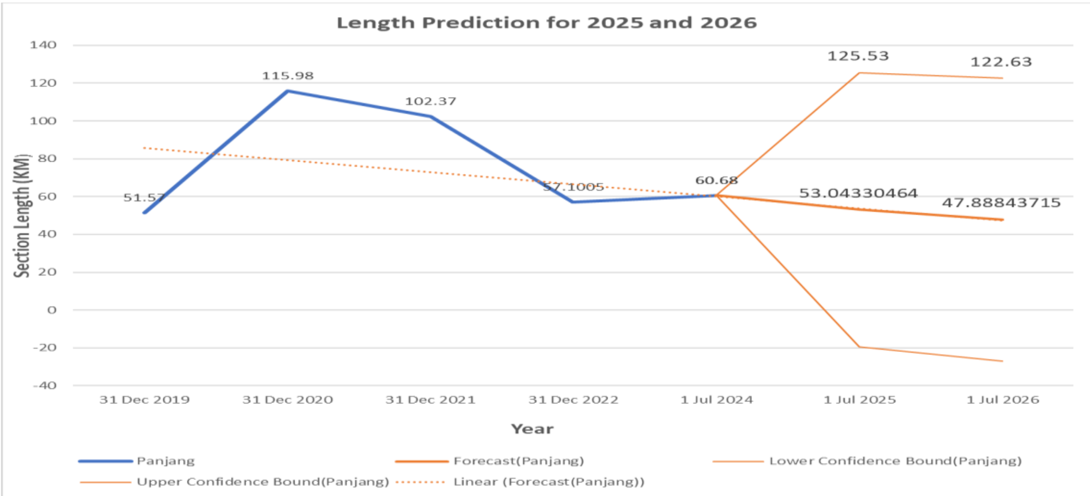

Fig. 2. Length Prediction of 83 sections Within the Category of Light Damage for 2025 and 2026.

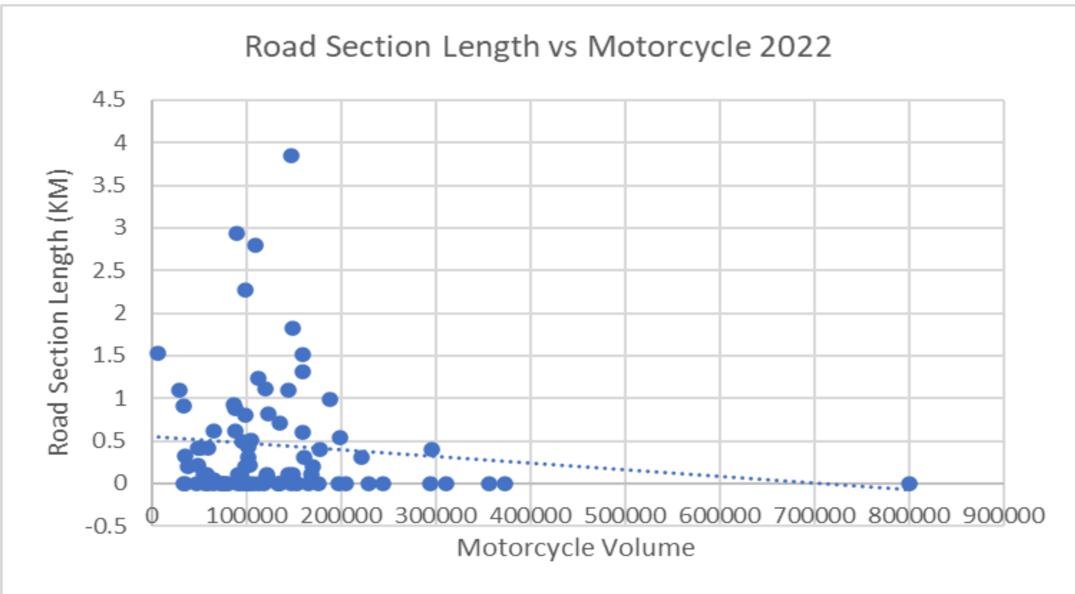

Fig. 3. Road Length vs Motorcycle Volume

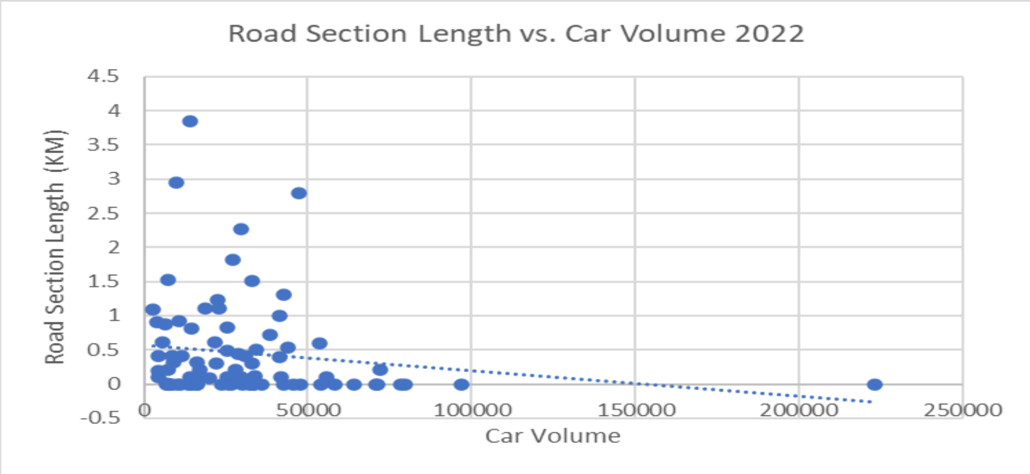

Fig. 4. Road Length vs. Car Volume

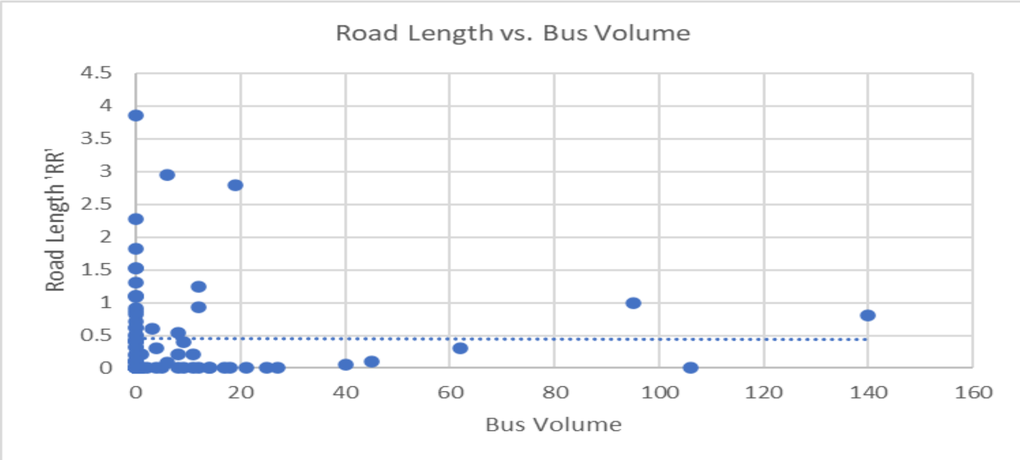

Fig. 5. Road Length vs. Bus Volume

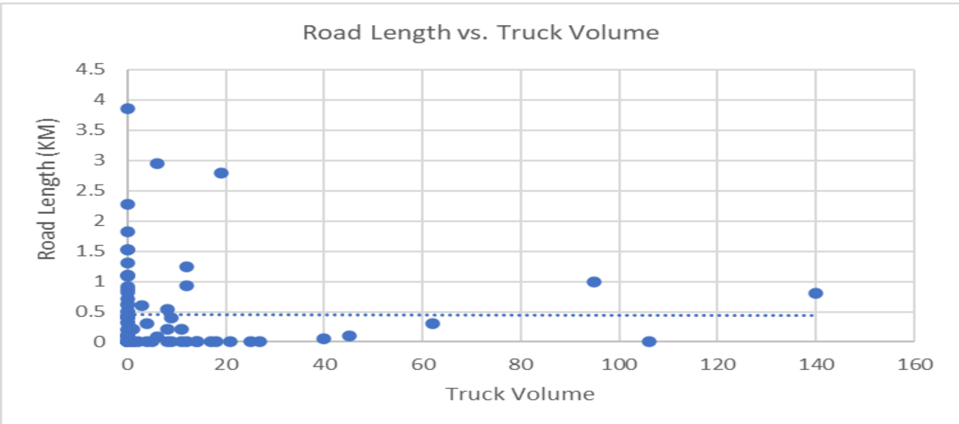

Fig. 6. Road Length vs. Truck Volume

The analysis of the most influencing factor on the road section length within the category of Light Damage in terms of pavement type, as shown in Fig. 7, showed that the longer the length of the flexible pavement section, the longer the 'Light Damage' section. On the other hand, as seen in Fig. 8, the longer the rigid pavement section, the lesser the length of the 'Light Damage' section.

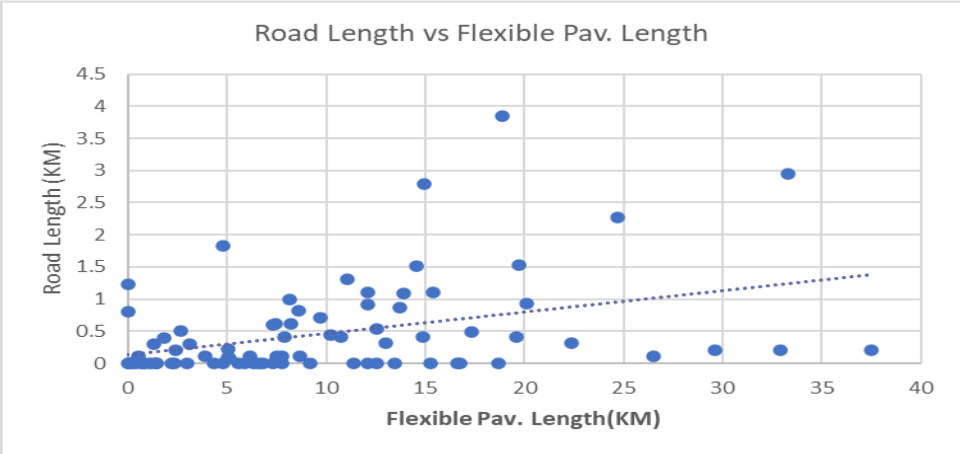

Fig. 7. Road Section Length vs. Flexible Pavement Section Length

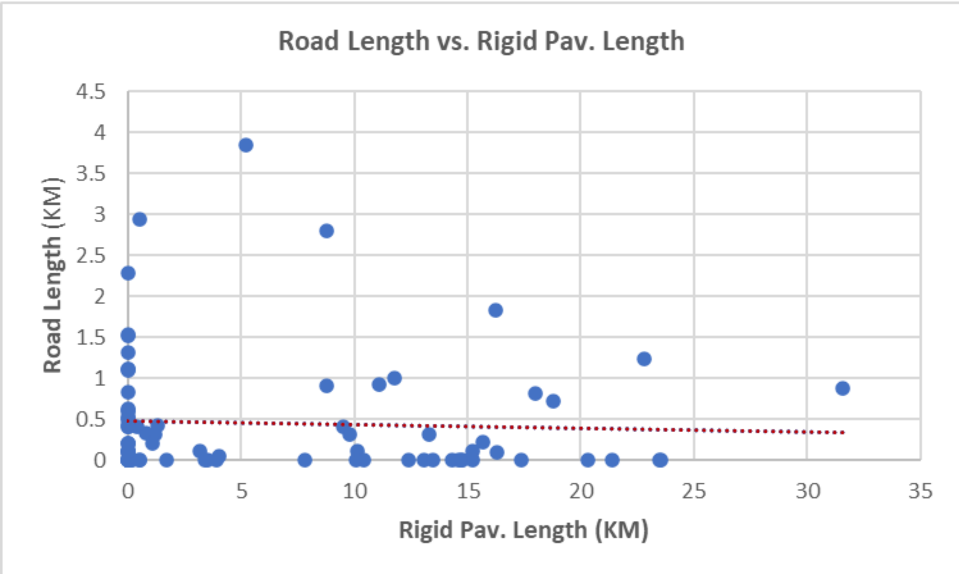

Fig. 8. Road Section Length vs. Rigid Pavement Section Length

4. Discussion

The prediction of road section length within the category of 'Light Damage' in 2025 and 2026 came with an assumption that the maintenance program would remain the same as the maintenance program from 2019 to 2024, should there be a different maintenance program from 2019 to 2024, the prediction should take it into account by giving it a weighted percentage because a section with a different maintenance program can yield a different outcome than the same as before maintenance program.

The study experienced difficulty in investigating the relationship between road section length in the Light Damage category and the types of vehicle volume that passed every section in a given year. The study of the correlation between the two variables yielded low R^2, which means there was no correlation between the two variables. The low R^2 was due to the lack of schedule and types of maintenance of each section, which in turn made the data irrelevant from one to another as each section had different ages. Schedule and types of maintenance for each section data were important because each section would be grouped based on the same schedule (determining the age of the most recent section condition) and the maintenance type.

Aging is one of the most influencing factors in any pavement-type performance. Saleh et al.(2020) studied the effects of long-term aging on pavement performance under realistic traffic and thermal conditions. Using the NCHRP 09-54 aging procedure, a systematic study of the effects of aging on asphalt mixture linear viscoelastic and fatigue properties was conducted. The computational engine of the FlexPAVE^{TM} V1.1, a simulation software, was modified to run a more realistic pavement performance simulation. The result suggested that the effect of aging on pavement performance was evident only when the simulation employed more realistic traffic and climatic conditions. In the absence of thermal conditions, the impact of changes in mixture properties on pavement performance was insignificant. Purnamasari and Nataadmadja (2023) developed a pavement deterioration model for a rigid pavement with the Cikopo-Palimanan Toll Road in Indonesia as the case study. The study aimed to build a mathematical model to predict pavement condition by using the International Roughness Index (IRI) value for some sections constructed with rigid pavement. In this study, several parameters were analyzed to determine which parameter(s) affected the IRI value including pavement age, traffic volume, and heavy commercial vehicles (HCV). It was found that pavement age had the most significant effect on IRI values. The type of maintenance to a section was also important because a section could have different conditions under different kinds of maintenance.

5. Conclusion

Based on the study, it can be concluded:

1. The length predictions of 83 road sections under the category of Light Damage were 54.03 KM and 47.88 KM for 2025 and 2026, respectively.
2. Cars and motorcycles seemed to be the most influencing vehicles for the 83 roads in the category of Light Damage in 2022.
3. It is necessary to carry out further study incorporating schedule and type of maintenance, pavement structure and materials, and weather conditions.

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