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Influence of Maintenance Funds on Improve Road Steadiness with the *Curva Expert* Program

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Abstract

Sustainable road construction is instrumental in improving connectivity among regions and economies while also offering road users a diverse range of options within the traffic network. To ensure optimal road performance for users, it becomes essential to allocate adequate maintenance funds that correlate with the planned service life. This necessity originates from a profound understanding of the significant influence maintenance funds have on road steadiness. Therefore, this study aims to establish a comprehensive road steadiness model, investigating the influence of toll roads as new routes and the impact on maintenance funds. The analysis included national roads across 15 cities in Central Java Province, Indonesia, covering a distance of 759.75 km from 2018–2023. Using a quantitative approach, the study adopted the *Curva Expert* program to evaluate the values of road steadiness and maintenance funds. The results showed a 5.78% enhancement in road steadiness over the period from 2018 to 2023, underscoring the positive impact of sustainable road construction practices and the allocation of adequate maintenance funds. The establishment of relationship between road steadiness and maintenance funds was established through a regression value of R^2=0.94. This statistical correlation is represented by the equation y= 90.521 + 0.022x, providing a quantitative understanding of how maintenance funds influence road steadiness. The insights obtained from the outcomes of road steadiness modeling reiterate the significance of investing in additional routes and ensuring sufficient maintenance funds to improve performance.

Keywords: IRI; Road Steadiness; Maintenance Funds; *Curva* Expert.

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1. Introduction

Sustainable road development is instrumental in enhancing connectivity between regions and fostering community economies [1, 2]. An exemplary manifestation of the infrastructure developments is the construction of the Trans Java toll road in Central Java Province, Indonesia. This toll road serves as a new route option, altering traffic patterns and positively impacting road performance on existing sections [3]. Despite governmental support for road improvement initiatives and the allocation of maintenance funds to adhere to planned service life [4], reality shows a persistent need for rehabilitation and repair [5].

The increasing steadiness of roads and the reduction of damage do not eliminate the continual need for maintenance funds. This critical gap becomes essential as the study shows that the actual need for maintenance funds and the precise impact on road steadiness remain unknown. A lack of modeling further compounds the issue, leaving unexplored insights into the dynamics between maintenance funds and road steadiness. Additionally, the uneven distribution of the Trans Java toll road across Central Java Province contributes to poor road connectivity, resulting in congestion and

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extended travel times [6, 7]. Recognizing the importance of addressing these challenges, the study aims to determine the road steadiness model, focusing on the influence of toll roads as a new route and the correlation with maintenance funds. Using quantitative methods, the study includes an in-depth analysis of national roads in 15 cities across Central Java Province, covering a distance of 759.75 km from 2018 to 2023. The analysis comprises a comprehensive six-year road steadiness modeling period, and the maintenance funds are conducted using the *Curva Expert* program.

2. Literature Review

2.1. Road Performance Appraisal

Consistent maintenance and rehabilitation were imperative for optimizing the effectiveness of road infrastructure, a judgment made through a thorough evaluation of pavement performance. This included a comprehensive evaluation of both the structural and functional aspects of road pavement. The structural analysis used Falling Weight Deflectometer (FWD) data to measure road deflection [8, 9]. Additionally, the functional evaluation considered the International Roughness Index (IRI) value data, facilitating recommendations for route handling [10–12]. Routine inspections played a crucial role in promptly identifying road damage, enabling more accessible and cost-effective interventions compared to addressing conditions during heavy wear [13]. The assessment of pavement condition allowed for the calculation of the remaining service life of the road [14].

In the context of sustainable road infrastructure development, the focus was on ensuring that roads had a planned service life. This commitment necessitated routine road maintenance to uphold good route conditions [15, 16]. The correlation of road maintenance practices with available funds became crucial to ensuring continuous infrastructure upkeep. A significant relationship evolved, showing a 30.46% increase in the correlation between road steadiness and maintenance funds [17].

2.2. Road Steadiness

The operational toll route introduced in 2018 had an impact on the steadiness of national roads in Central Java Province. This toll road complemented other routes connecting sections in the region to neighboring provinces, including West Java, East Java, and Yogyakarta. The study examined the impact of traffic flow on both existing and future conditions, focusing on 15 cities/regencies with toll roads in Central Java Province. An essential method used in functional road condition assessment was the IRI. This index quantifies road surface unevenness by measuring the cumulative length of surface fluctuations per unit length. The IRI value was obtained through surveys conducted using cars equipped with the Roaddroid application, a tool developed by a Swedish company specifically for measuring road roughness on Android smartphones.

The study further used the IRI method for assessing road conditions. The values obtained from this method offered a comprehensive overview of national road conditions, serving as a crucial database for implementing road rehabilitation and maintenance [18]. In accordance with the *National Cooperative Highway Research Program* (NCHRP) [19], the IRI scores were categorized into four groups, namely:

- Good Condition, showing values between 0 and 4,
- Medium Condition, signifying values between 4 and 8,
- Condition of Light Deer, denoting values between 8 and 12,
- Severely Damaged Condition, showing values greater than 12.

2.3. Volume-Capacity Ratio (VCR)

The NVR played a crucial role in the ratio of traffic flow to road network capacity in assessing the performance levels. The measure of road performance was evident in speed and travel time metrics, where improved road conditions correlated with increased traffic speed and decreased travel time. The evaluation of road value conditions based on VCR values classified routes into stable, unstable, and critical categories, providing insights into potential capacity issues for each road segment.

2.4. IRI

The IRI quantified the flatness of road surface by expressing the vertical change for each unit of length (m/km). Roads with an IRI value ≤ 8 fell into the stable category, while values > 8 were classified as unstable. Allocating financial resources for road development was crucial to improving public services, especially in ensuring reliable road access and influencing economic conditions in a given area. Previous studies [18-20] stated that the correlation between IRI values and maintenance funds had the potential to improve the modern economy in Russia.

The condition of road surface pavement structure directly influenced the comfort parameters of road users [21, 22]. Specifically, the IRI value played a crucial role in affecting various factors, such as driver safety, traffic conditions, driving comfort, fuel consumption, air quality, and the entire road conditions [23, 24]. Recognizing the interconnected relationships underscored the importance of considering IRI values in road development and maintenance to ensure a comprehensive enhancement in the quality of infrastructure and the well-being of road users.

2.5. Maintenance Funds

Road maintenance funds represented the costs associated with addressing road repair needs. The funds played a critical role in determining the extent of road networks within districts or cities in Central Java Province [15]. Significantly, the presence of maintenance funds wielded a significant impact on traffic generation. This was because the inclusion of road repairs within the funds contributed to enhanced traffic management performance in the road network, subsequently improving transportation services [18]. The costs allocated for road maintenance were dependent on the field conditions but can be adjusted to correlate with the available funds and the state budget. The infrastructure maintenance funds were considered necessary for upholding the quality of routes, serving as an essential allocation to enhance public facilities and foster the economy. Recognizing the essential role of maintenance funds was crucial for optimizing infrastructure quality and ensuring the roads met the planned service life [25, 26].

3. Study Methods

3.1. Study Sites

The study comprised an examination of national roads in 15 cities within Central Java Province, Indonesia, specifically areas with toll routes. The selected study locations included Brebes Regency, Tegal City, Pemalang Regency, Pekalongan City, Tegal Regency, Batang Regency, Kendal Regency, Semarang City, Pekalongan Regency, Salatiga Regency, Boyolali Regency, Sragen Regency, Semarang Regency, Surakarta City, and Karanganyar Regency. Covering a total distance of 759.75 km from 2018 to 2023, the study used quantitative methods to analyze the values of road steadiness and maintenance funds on national roads. This analysis covered the duration from the commencement of the Trans Java toll road's operation, introduced as a new route to enhance connectivity in Central Java Province (Figure 1).

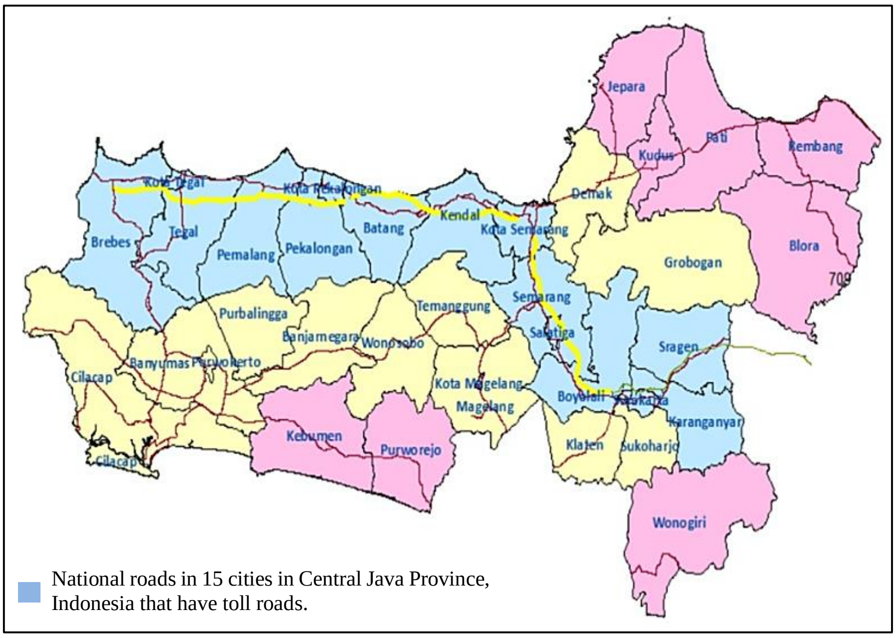

Figure 1. Map of national roads in 15 cities in Central Java Province, Indonesia, featuring toll roads

3.2. Data Analysis Method

Quantitative methods were adopted to assess the performance of national roads in 15 cities over the specified distance and timeframe. This included modeling the influence of toll roads as new routes on road steadiness and examining the impact on maintenance funds, using the *Curva Expert* program. The program was instrumental in processing data such as road network, *Volume-Capacity Ratio*, IRI, and maintenance funds from 2018 to 2023. Through meticulous calculations, processing, and analysis within the *Curva Expert* program, the study obtained an equation describing the relationship between road steadiness and maintenance funds.

Figure 2 shows the flowchart of the research methodology through which the objectives of this study were achieved.

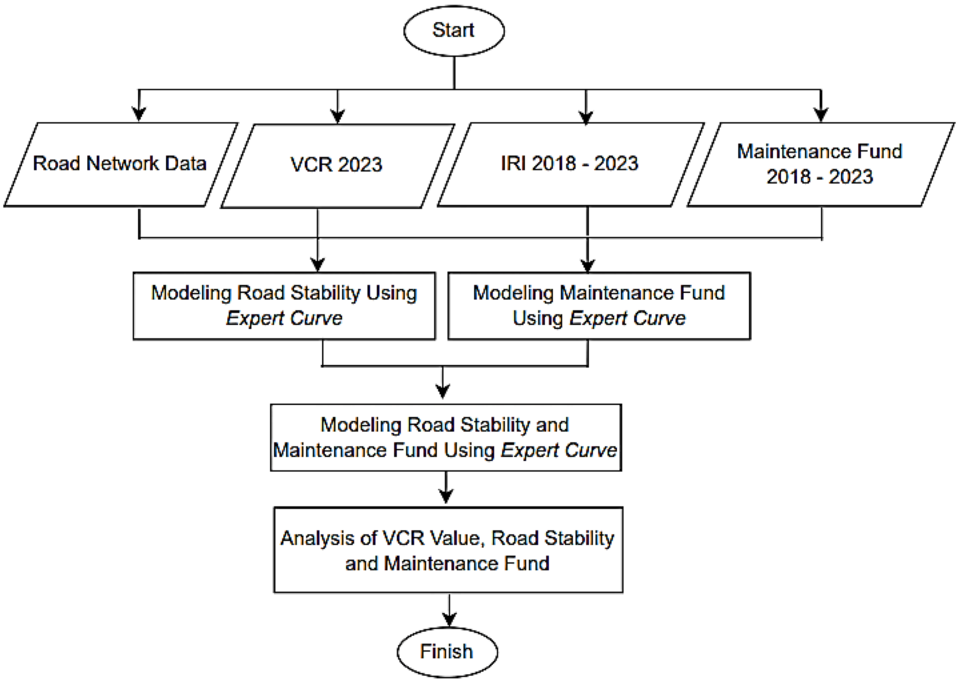

Figure 2. The flow chart of the development models

4. Results and Discussion

4.1. Road Steadiness

Steadiness of national roads in Central Java Province was significantly influenced by the operational Trans Java toll road, which commenced its services in 2018. This toll route provided additional connections, connecting sections from Central Java to neighboring provinces such as West Java, East Java, and Yogyakarta. The analysis focused on reviewing the impact of traffic flow on existing and future conditions.

To assess the effect of traffic flow on existing and future conditions, the distance between national and toll roads was considered. Table 1 and Figure 3 presented a comparison of IRI values for national roads from 2018 to 2023.

Table 1. IRI Values from 2018 to 2023

IRI	Years					
	2018	2019	2020	2021	2022	2023
0 - ≤4	12	20	25	31	36	44
4 - ≤8	86	80	75	72	67	60
8 - ≤12	9	7	6	4	4	3
> 12	0	0	0	0	0	0
Number of Roads	107	107	107	107	107	107

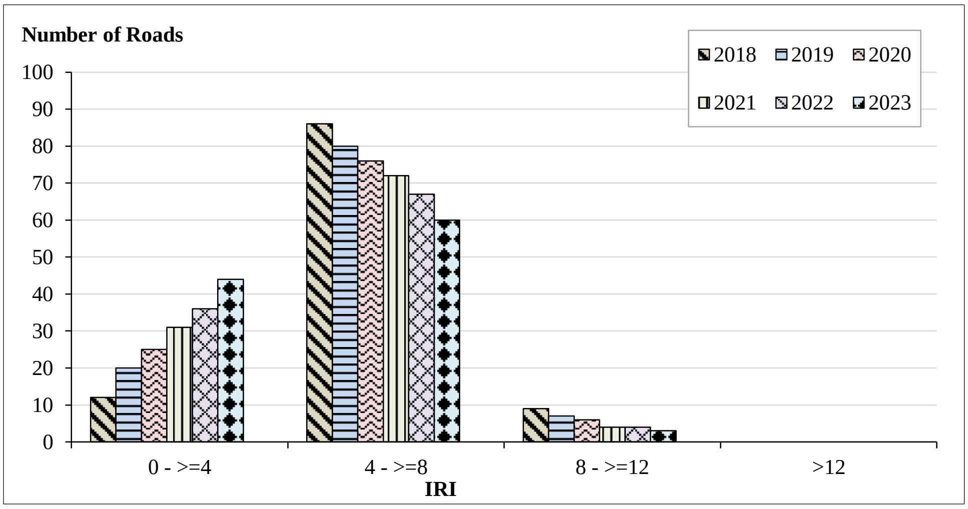

Figure 3. IRI from 2018 to 2023

In 2023, all 107 road sections showed VCR values with $0 \leq VCR < 0.4$, accounting for 100.0% of the sections. The 107 roads in 15 cities/regencies of Central Java Province were examined for IRI values. In 2018, 12 routes had an IRI value below 4, and 86 routes had between 4 – 8, classified as stable roads. By 2023, the scenario changed with 44 routes having an IRI value less than 4, and 60 routes falling within the 4 to 8 range, categorized as stable roads.

In 2022, the road steadiness of all 107 sections showed an average of 96.27% in stable conditions, with VCR values consistently below 0.40. This categorized the traffic flow as steady, but vehicle operating speeds were limited by traffic conditions. Road steadiness increased from 91.58% in 2018 to 97.20% in 2023, influenced by the operational Trans Java toll road, as detailed in Table 2 and Figure 4.

Table 2. National Road Steadiness Value from 2018 to 2023

IRI	Years					
	2018	**2019**	**2020**	**2021**	**2022**	**2023**
Road Steadiness (%)	91.59	93.46	94.39	96.26	96.26	97.20

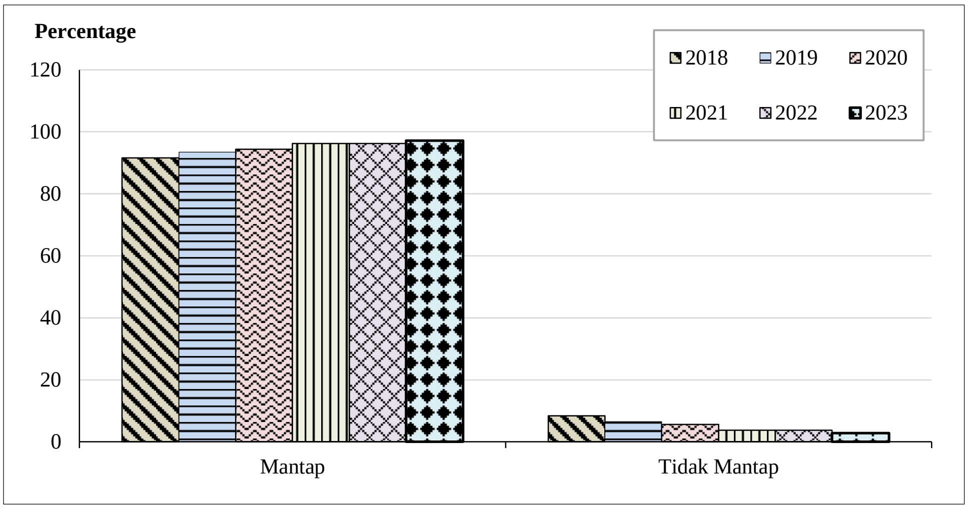

Figure 4. National Road Steadiness Value from 2018 to 2023

The stability of national roads in Central Java Province had a direct impact on the operations of the Trans Java toll road. At the outset of Trans Java toll roads operations in early 2018, road steadiness value was relatively low. This was primarily due to the route serving as a favoured middle cross lane for heavy vehicles before the establishment of the Trans Java toll road. The vehicles transported various products across regions in Central Java, specifically between West Java and East Java Provinces.

The annual average increase in road steadiness on national roads within Central Java Province was 1.12%. Since the commencement of Trans Java toll road operations in 2018, users have been provided with alternative options regarding traffic lanes, such as opting for either national or toll routes. This shift in options indirectly relieved the traffic volume on lanes surrounding toll roads, as vehicles were divided between national and toll sections. The subsequent reduction in passing vehicles contributed to improved road capacity services by decreasing travel time and enhancing speed. Over the years, road steadiness in Central Java Province showed a significant increase, from 91.59% in 2018 to 97.20% in 2023. Using the *Curva Expert* program, the equation representing this increment in road steadiness was derived and presented in Figure 5 as follows:

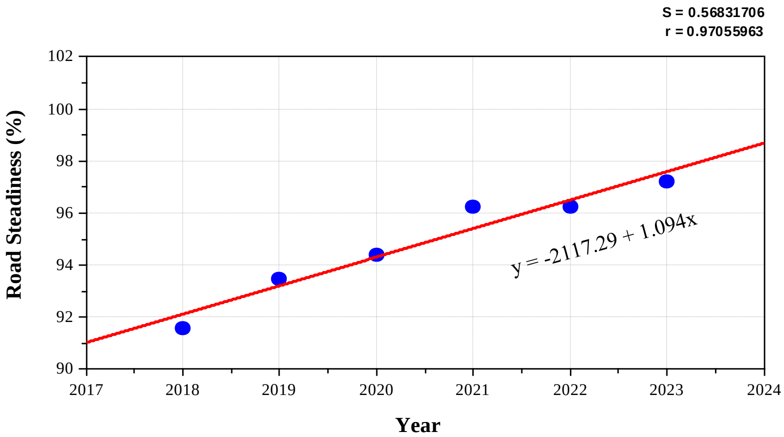

Figure 5. Road Steadiness Value from 2018 to 2023 using the *Curva Expert*

The linear graph, selected based on the highest correlation value of the equation (r = 0.97), proved to be the most significant correlation compared to quadratic and polynomial values. The high correlation value was instrumental in determining the relationship between variables and evaluating the model's descriptive accuracy. The standard deviation value S=0.56 was examined to determine data distribution, with a smaller deviation value showing a more favorable outcome. Additionally, the Linear Fit regression method yielded the highest regression rank value of R^2=0.97, resulting in the following equation.

$$y = -2117.29 + 1.094x \tag{1}$$

4.2. Maintenance Budget Funds

Road maintenance funds were allocated to cover the necessary costs for road repairs, ensuring the continual upkeep and adherence to the planned service life. The determination of maintenance funds depended on road management plan, incorporating both routine and periodic servicing strategies. Calculations for the costs were based on field conditions and were adaptable to the available funds and the state budget. The funds were essential in improving road services, sustaining existing infrastructure, promoting enhanced connectivity between regions, and fostering community economic growth.

In 2018, the budget for road maintenance amounted to IDR 25,871,840,000 (Twenty-Five Billion, Eight Hundred Seventy-One Million, Eight Hundred Forty Thousand Rupiahs), witnessing a substantial increase to IDR 275,205,072,000 (Two Hundred Seventy-Five Billion, Two Hundred Five Million, Seventy-Two Thousand Rupiahs) by 2023. The progression of road maintenance budget increase was meticulously modeled using the *Curva expert* program. Figure 6 provided a graphical representation of the road steadiness equation by fiscal year.

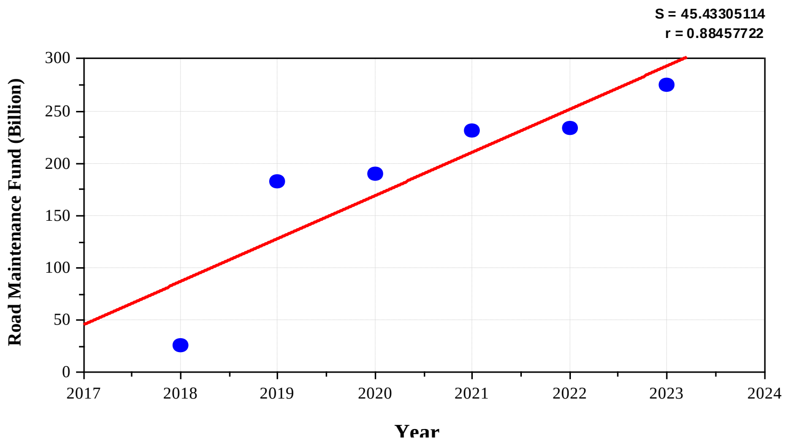

Figure 6. Road Maintenance Funds for 2018 to 2023 using *Curva Expert*

The decision to use a linear graph was based on the equation's correlation value (r = 0.88), which surpassed quadratic and polynomial values. This correlation value helped determine the relationship between variables and assessed how well the model described the calculated equation. The analysis of the standard deviation (S=0.45) was conducted to gain insights into the distribution of data within the sample, where a good standard deviation value showed a lower outcome. Furthermore, applying the Linear Fit regression method produced the highest regression rank value, showing an R^2 of 0.88, which eventually led to the formulation of the below equation.

$$y = -83048.47 + 41.197\,x \tag{2}$$

The government's yearly increase in maintenance funds was evident in the administration's dedication to effective maintenance tailored to road conditions and ensuring the planned service life. Furthermore, the *Curva Expert* modeling showed a direct proportionality between maintenance funds and the year, reinforcing efforts to sustain and enhance road infrastructure.

4.3. The Relationship between Road Steadiness and National Road Maintenance Funds

The availability of budget funds played a significant role in influencing road steadiness. A lower road steadiness showed more substantial road damage, necessitating higher maintenance funds, and vice versa. Road steadiness increased from 91.58% in 2018 to 97.20% in 2023, a substantial improvement attributed to the operations of Trans Java toll road during the period, resulting in a 5.78% increase. Simultaneously, road maintenance budget witnessed a significant increase from IDR 25,871,840,000 in 2018 to IDR 275,205,100,000 in 2023. The correlation between road steadiness and maintenance funds was graphically represented in Figure 7.

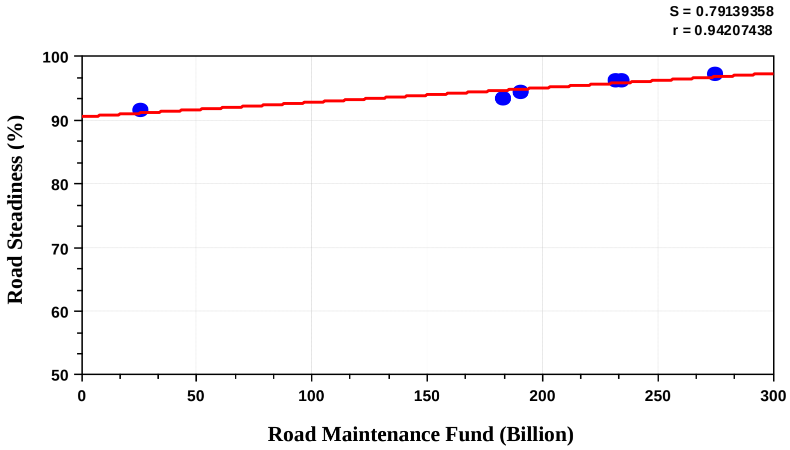

Figure 7. Road Steadiness Relationship and Maintenance Funds using the *Curva Expert*

The selection of a linear graph was based on the equation's correlation value (r = 0.94), representing the most significant association when compared to quadratic and polynomial values. This correlation value played a crucial role in measuring the connection between variables and evaluating the model's effectiveness in accurately representing the calculated equation. A lower standard deviation value (S=0.79) further showed a favorable data distribution in the sample. The correlation between road steadiness and maintenance funds, as calculated through the Linear Fit regression method with $R^2 = 0.94$, was expressed in the following equation.

$$y = 90.521 + 0.022x \tag{3}$$

The equation implied that every additional $1 billion in maintenance funds will increase road steadiness value by 0.022%. The *Curva Expert* program modeling clearly showed a direct correlation between maintenance funds and road steadiness, showing the essential role of costs in enhancing road stability. A larger maintenance funds directly corresponded to higher road steadiness, influencing the selection of road repair methods to enhance stability and meet the planned service life.

5. Conclusion

The study focused on enhancing road steadiness through additional maintenance funds using the *Curva Expert*, conducted on national roads covering 759.75 km in 15 cities within Central Java Province, Indonesia, from 2018 to 2023. During this timeframe, there was a significant improvement in road steadiness, increasing from 91.58% in 2018 to 97.20% in 2023. This increase was influenced by the impact of the Trans Java toll road's operations. The regression equation y=90.521+0.022x, with a significant R^2=0.94, showed the relationship between road steadiness and maintenance funds. The correlation value r=0.94 in the linear equation was the most substantial, guiding the assessment of relationships between variables and the model's efficacy. The *Curva Expert* modeling showed a standard deviation value of S=0.79, influencing the data distribution within the sample.

Accessing road steadiness scores from 2018 to 2023 using *Curva Expert* yielded the highest regression rating of R^2 = 0.97. The obtained correlation equation r=0.97 in the *Curva* Expert modeling maintained its significance, with a standard deviation value of S=0.56 shaping the data distribution. Changes in road steadiness from 2018 to 2023, as determined by the *Curva Expert* program using the *Linear Fit regression* method, resulted in the equation y = -2117.29 + 1.094x. This modeling showed a direct correlation between road steadiness and maintenance funds, reiterating that additional routes and sufficient funds contributed to improved road performance.

6. Declarations

6.1. Author Contributions

Conceptualization, W.T.H., B.Y., and E.G.; methodology, A.S., W.T.H., and B.Y.; software, A.S. and W.T.H.; validation, W.T.H. and B.Y.; formal analysis, A.S. and W.T.H.; investigation, B.Y. and E.G.; resources, W.T.H.; data curation, A.S.; writing—original draft preparation, W.T.H. and E.G.; writing—review and editing, A.S. and B.Y.; visualization, A.S.; supervision, B.Y.; project administration, E.G.; funding acquisition, A.S., W.T.H., B.Y., and E.G. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available in the article.

6.3. Funding

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6.4. Acknowledgements

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6.5. Conflicts of Interest

The authors declare no conflict of interest.

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