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Research paper

Relationship between Traffic Volume and Economic Loss From Delays Along President Jose P. Laurel Highway, Lipa City, Batangas

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Abstract

Traffic congestion is a persistent urban transportation problem that imposes substantial economic losses through travel delays, increased fuel consumption, and reduced productivity. This study examines the relationship between traffic volume and economic loss resulting from traffic delays along President Jose P. Laurel Highway, a major arterial corridor in Lipa City, Batangas. Using one week of peak-hour field observations, data were collected on vehicle volume, average delay per vehicle, and additional fuel consumption. Economic losses were estimated using standard transportation economics approaches, including the Value of Time (VOT) method and fuel cost valuation. Pearson correlation and simple linear regression analyses were employed to quantify the relationship between traffic volume and congestion-related economic losses. The results reveal a strong and statistically significant positive relationship between traffic volume and economic loss, with delay duration identified as the primary contributor to congestion costs. Comparative analysis further shows that PM peak periods generate higher marginal economic losses than AM peak periods, reflecting intensified end-of-day travel demand. These findings demonstrate that traffic congestion along President Jose P. Laurel Highway is not merely an operational concern but a significant economic burden. The study provides empirical evidence to support targeted traffic management measures, infrastructure improvements, and demand management strategies aimed at reducing congestion-related economic losses in Lipa City.

Keywords: *Economic Loss; Traffic Congestion; Traffic Volume; Travel Delay; Value of Time (VOT).*

1. Introduction

Rapid urbanization and increasing motorization have intensified traffic congestion in many developing cities, particularly in rapidly growing urban centers in the Philippines. As economic activities expand and population density increases, the demand for road space frequently exceeds available capacity, leading to recurring congestion, especially during peak travel periods. Traffic congestion imposes high economic costs by increasing travel time, fuel consumption, vehicle operating expenses, and stress levels, while simultaneously reducing productivity and overall urban efficiency.

Lipa City, a first-class component city in Batangas Province, functions as a major commercial, educational, and transportation hub connecting nearby municipalities and provinces. Due to its strategic location, the city experiences consistently high traffic demand. President Jose P. Laurel Highway is one of the most critical transport corridors in Lipa City, accommodating a diverse mix of private vehicles, public utility vehicles, delivery trucks, and intercity traffic. The corridor is characterized by mixed land use, frequent access points, pedestrian activity, and limited opportunities for roadway expansion, making it highly susceptible to congestion, particularly during morning and afternoon peak hours.

While previous local studies have documented congestion issues and estimated delay-related costs, there remains limited empirical research explicitly examining the quantitative relationship between traffic volume and economic loss from delays along specific urban corridors in Lipa City. Understanding this relationship is essential for identifying priority interventions, optimizing traffic management strategies, and supporting evidence-based transport policy formulation at the local government level.

1.1. Research objectives

The general objective of this study is to examine the influence of traffic volume on economic loss arising from traffic delays along President Jose P. Laurel Highway in Lipa City.

Specifically, the study aims to:

1) Determine the relationship between traffic volume and economic loss resulting from traffic delays.

2) measure the strength and direction of this relationship using appropriate statistical methods; and
3) provide empirical insights to support traffic management strategies and urban transport policy decisions in Lipa City.

1.2. Theoretical framework

This study is anchored in traffic flow theory and transportation economics, particularly the concepts of roadway capacity, congestion delay, and Value of Time (VOT). Traffic flow theory explains that as traffic volume increases relative to roadway capacity, vehicle interactions intensify, leading to reduced speeds, unstable flow conditions, and increased delays. According to the Highway Capacity Manual, delay increases rapidly as traffic demand approaches or exceeds roadway capacity, particularly on urban arterials with frequent intersections and access points (Transportation Research Board, 2016).

From an economic perspective, transportation economics treats travel time as a scarce resource with an opportunity cost. The VOT represents the monetary value that travelers assign to time spent traveling or delayed due to congestion. Vickrey's congestion theory emphasizes that each additional vehicle entering a congested roadway imposes external costs on other road users by increasing overall delay (Vickrey, 1969). In addition, congestion leads to higher fuel consumption due to idling and stop-and-go driving, further increasing vehicle operating costs and environmental impacts (Litman, 2023). Together, these theories suggest a direct and measurable link between traffic volume, delay, and economic loss.

1.3. Hypothesis

H_0: There is no significant relationship between traffic volume and economic loss from delays along President Jose P. Laurel Highway in Lipa City.

2. Review of Related Literature

This section reviews relevant literature on traffic congestion and its associated economic impacts, with particular emphasis on traffic volume, travel delay, and the valuation of congestion costs. These studies provide the conceptual and empirical foundation for examining the relationship between traffic volume and economic loss from delays along President Jose P. Laurel Highway in Lipa City.

2.1. Traffic volume, delay, and congestion dynamics

Traffic volume is a primary indicator of travel demand and a key determinant of roadway performance. The Highway Capacity Manual identifies traffic volume as a central variable in congestion analysis, explaining that as demand approaches roadway capacity, traffic flow becomes unstable, resulting in sharp increases in delay and travel time variability (Transportation Research Board, 2016). Under such conditions, even small increases in vehicle volume can significantly degrade the level of service.

Average delay is widely used in traffic engineering as a performance measure because it directly captures the additional travel time experienced relative to free-flow conditions. Vickrey's congestion theory demonstrates that delay increases at an accelerating rate as traffic demand rises, particularly in urban corridors characterized by frequent intersections, access points, and operational interruptions (Vickrey, 1969). Beyond physical capacity constraints, delay also reflects inefficiencies arising from signal timing, roadside activities, loading and unloading behavior, and driver interactions.

Local empirical studies support these theoretical insights. Research conducted in Batangas Province shows that high traffic volumes during peak periods are strongly associated with increased congestion severity and reduced level of service on urban corridors (Escabel et al., 2016). These findings highlight the relevance of volume–delay relationships in secondary cities experiencing rapid urban growth.

2.2. Economic costs of traffic delay and corridor-level analysis

The economic cost of traffic congestion is commonly estimated through the valuation of time losses and additional fuel consumption incurred during delays. Delay-related costs represent one of the largest components of congestion-related externalities in urban transport systems, often exceeding vehicle operating, infrastructure, and accident-related costs (Litman, 2023). Time lost to congestion reflects foregone productive or leisure activities, while excess fuel consumption increases travel expenses and contributes to environmental degradation.

Recent international literature emphasizes the importance of corridor-level congestion analysis in supporting localized traffic management and policy interventions, particularly in rapidly urbanizing cities where network-wide data may be limited. Facility- and corridor-based assessments allow congestion impacts to be directly linked to operational conditions, demand patterns, and capacity constraints (Transportation Research Board, 2016). Studies in Asian urban contexts further indicate that traffic volume and peak-hour delay explain a substantial share of congestion-related productivity losses, with economic costs rising disproportionately during peak periods on major arterial roads serving mixed land uses (Asian Development Bank, 2019).

Compared with broader metropolitan or network-level studies, corridor-specific analyses provide more actionable insights for targeted congestion mitigation. Within the Philippine urban context—characterized by mixed traffic composition, roadside activities, and limited opportunities for roadway expansion—such localized assessments remain relatively scarce. By focusing on a major arterial corridor in Lipa City, the present study complements existing international findings while addressing a documented gap in congestion cost estimation for secondary cities, offering evidence directly relevant to corridor-level traffic management and urban transport policy formulation.

3. Research Methodology

This section describes the research design, data collection procedures, and statistical methods employed to examine the relationship between traffic volume and economic loss resulting from traffic delays. Appropriate statistical tools were then applied to ensure objective and reliable analysis of the relationship between traffic volume and economic loss along the study corridor.

3.1. Research design

The study employed a quantitative, correlational research design to analyze the relationship between traffic volume and economic loss from delays. This approach is appropriate for examining naturally occurring traffic conditions without experimental manipulation.

3.2. Data collection procedure

Traffic data were collected through systematic field observations conducted for seven consecutive days along President Jose P. Laurel Highway. Observations focused on AM and PM peak hours to capture periods of highest congestion. Data collected included hourly vehicle counts, average delay per vehicle, and estimated additional fuel consumption during delays. Interviews with personnel from the Lipa City Traffic Management Office (LCTMO) supplemented field observations and provided contextual insights into traffic conditions and management practices.

Economic loss was calculated by estimating the cost of time lost using a VOT of ₱100 per hour and computing fuel costs based on prevailing fuel prices and additional fuel consumption rates during congestion.

3.3. Statistical treatment of data

Pearson correlation analysis was used to determine the relationship, strength, and direction between traffic volume and economic loss. Simple linear regression analysis was conducted to estimate the effect of traffic volume on economic loss, with traffic volume as the independent variable and economic loss as the dependent variable. A scatter plot was generated to visually assess the relationship between variables.

4. Results and Discussion

This section presents and interprets the results of the statistical analyses conducted in the study, focusing on the relationship between traffic volume and economic loss from congestion. The findings are discussed in the context of traffic flow theory and transportation economics to explain observed congestion patterns and their economic implications. Emphasis is placed on peak-period variations and their significance for traffic management and policy formulation in Lipa City.

Table 1: Pearson Correlation Matrix of Traffic Volume, Average Delay, and Economic Loss

Variable	Traffic Volume (veh/hr)	Average Delay (hr/veh)	Economic Loss (₱/hr)
Traffic Volume (veh/hr)	1.000	0.812**	0.889**
Average Delay (hr/veh)	0.812**	1.000	0.934**
Economic Loss (₱/hr)	0.889**	0.934**	1.000

Note. $p < .01$.

Table 1 presents the Pearson correlation coefficients among traffic volume, average delay, and economic loss from delays along President Jose P. Laurel Highway. Traffic volume shows a strong positive correlation with economic loss ($r = .889$, $p < .01$), indicating that increases in vehicle count are associated with substantial increases in congestion-related costs. Average delay exhibits an even stronger relationship with economic loss ($r = .934$, $p < .01$), confirming that delay duration is the primary mechanism through which congestion translates into economic loss. The strong correlation between traffic volume and average delay ($r = .812$, $p < .01$) further supports traffic flow theory, which posits that rising demand near capacity leads to unstable flow and rapidly increasing delays.

Table 2: Simple Linear Regression Results Predicting Economic Loss from Traffic Volume

Variable	Coefficient (β)	Standard Error	t-value	p-value
Constant	−14,325.72	4,128.66	−3.47	.004
Traffic Volume (veh/hr)	10.75	1.84	5.84	< .001

Table 2 summarizes the results of the simple linear regression analysis examining the effect of traffic volume on economic loss from delays. Traffic volume is a statistically significant predictor of economic loss ($\beta = 10.75$, $p < .001$), indicating that each additional vehicle per hour contributes approximately ₱10.75 in delay-related economic costs. The negative intercept reflects the theoretical condition of minimal or negligible congestion-related losses at very low traffic volumes. These results empirically confirm that increasing traffic demand directly increases congestion costs along the study corridor.

Table 3: Model Summary for Regression of Economic Loss on Traffic Volume

R	R^2	Adjusted R^2	Standard Error
0.889	0.791	0.778	1,514.23

Table 3 presents the model summary for the regression analysis. The coefficient of determination ($R^2 = .791$) indicates that approximately 79.1% of the variation in economic loss from delays can be explained by changes in traffic volume alone. This high explanatory power suggests that traffic volume is a dominant factor influencing congestion-related economic losses along President Jose P. Laurel Highway. The strong correlation coefficient ($R = .889$) further reinforces the robustness of the model and the reliability of the estimated relationship.

Table 4: Regression Comparison by Peak Period

Peak Period	R	R^2	Coefficient (₱/vehicle)	Significance (p)
AM Peak	0.842	0.709	8.64	.001
PM Peak	0.916	0.839	12.91	< .001

Table 4 compares regression results for AM and PM peak periods. Both peak periods exhibit statistically significant relationships between traffic volume and economic loss ($p < .01$). However, the PM peak period shows a higher coefficient (₱12.91 per vehicle) and a higher R^2 value (.839) compared to the AM peak period (₱8.64 per vehicle; $R^2 = .709$). This indicates that congestion during the PM peak period generates higher marginal economic losses, likely due to increased travel demand, reduced route flexibility, and overlapping work, school, and commercial trips.

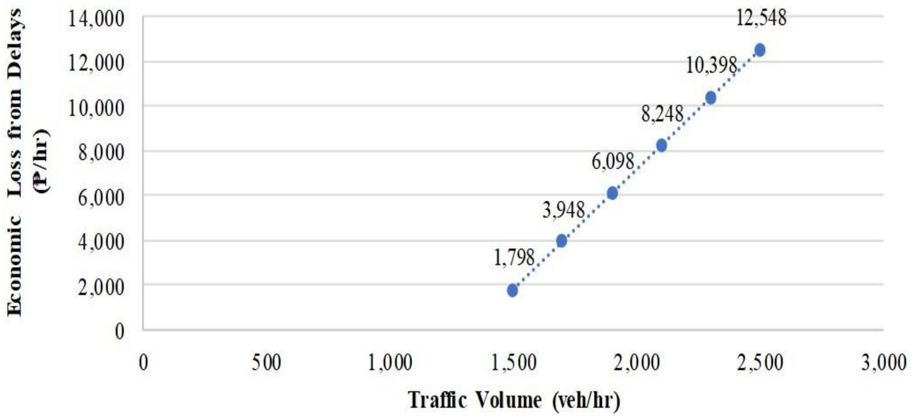

Fig. 1: Scatter Plot of Traffic Volume and Economic Loss from Delays.

Fig. 1 illustrates the relationship between traffic volume and economic loss from delays through a scatter plot. The upward-sloping pattern of the data points indicates a clear positive linear relationship, consistent with the correlation and regression results. Greater dispersion at higher traffic volumes suggests that congestion effects intensify and become more variable as roadway capacity is approached or exceeded. This visual evidence supports traffic flow theory, which predicts nonlinear increases in delay and cost under high-demand conditions.

5. Conclusion

This study empirically demonstrated a strong and statistically significant positive relationship between traffic volume and economic loss from delays along President Jose P. Laurel Highway in Lipa City. The results confirm that increases in traffic volume led to longer delays, which in turn generate substantial economic costs through lost time and additional fuel consumption. Peak-period analysis revealed that congestion during the PM peak produces higher marginal economic losses than during the AM peak, highlighting the intensified impact of end-of-day travel demand.

The findings reinforce traffic flow theory and congestion cost literature, which suggest that even modest increases in demand near roadway capacity can result in disproportionately large economic losses. Overall, the study establishes that traffic congestion along the study corridor is not merely an operational issue but a significant economic concern with direct implications for urban productivity and efficiency.

6. Policy Implications

The results of this study emphasize the importance of traffic demand management and operational improvements in reducing congestion-related economic losses along President Jose P. Laurel Highway in Lipa City. Given the strong positive relationship between traffic volume and economic loss, policy efforts should prioritize managing peak-hour demand, as even small increases in traffic volume during these periods result in disproportionately high economic costs. Short-term interventions such as traffic signal optimization, coordinated intersection control, and stricter enforcement of public utility vehicle loading and unloading regulations can significantly reduce delays and improve roadway efficiency.

Pedestrian and roadside management measures should also be strengthened to minimize traffic disruptions. The provision of improved pedestrian facilities, including footbridges or properly signalized crossings, can reduce conflicts between vehicles and pedestrians that contribute to congestion. Regulating roadside activities, limiting uncontrolled access points, and improving enforcement against illegal parking can further enhance traffic flow and safety along the corridor.

In the long term, sustainable congestion reduction requires integrated land-use and transport planning. Enhancing public transportation systems, promoting transit-oriented development, and encouraging behavioral changes through road user education can reduce reliance on private vehicles and distribute travel demand more efficiently. These coordinated policy measures can help mitigate congestion-related economic losses while supporting sustainable urban mobility and economic development in Lipa City.

7. Limitations and Recommendations

This study is subject to several methodological limitations that should be considered when interpreting the results. First, the analysis is based on one week of peak-hour observations, which captures short-term traffic conditions but may not fully reflect weekly, monthly, or seasonal variations in traffic demand. Traffic volumes and delays may differ during holidays, school breaks, adverse weather conditions, or special events. As such, the estimated economic losses represent short-term observed conditions along the study corridor and should be interpreted with caution when extrapolating to longer time horizons.

Second, the study employed simple linear regression to examine the relationship between traffic volume and economic loss. While this approach is appropriate for exploratory corridor-level analysis and provides clear interpretability, congestion effects – particularly near roadway capacity – are often nonlinear, with delays increasing at an accelerating rate as demand approaches or exceeds capacity. The linear model may therefore underestimate congestion costs under extreme traffic conditions. Future research may consider nonlinear modeling approaches or simulation-based methods to capture more complex congestion dynamics.

Third, the estimation of economic loss from traffic delays in this study adopts a uniform VOT of ₱100 per hour. While VOT is known to vary by income level, trip purpose, and vehicle type, the use of a single average value is a deliberate and acceptable simplification given the study's scope and data availability.

The primary objective of the study is to analyze the relationship between traffic volume and economic loss, rather than to estimate disaggregated user-specific welfare impacts. Applying a uniform VOT ensures internal consistency across observations and allows changes in economic loss to be attributed primarily to variations in traffic volume and delay, rather than to assumed differences in traveler characteristics.

Further, the selected VOT falls within the range commonly used in Philippine transport appraisal and planning studies, particularly for mixed urban traffic conditions involving both private and public transport users. It represents a conservative average that balances wage-based valuations and practical policy applications, thereby avoiding overestimation of congestion costs.

Finally, the absence of sensitivity analysis does not undermine the validity of the findings, as the study's conclusions focus on relative changes and statistical relationships, not absolute cost magnitudes. While alternative VOT values would proportionally scale the estimated economic losses, they would not alter the observed positive and significant relationship between traffic volume and congestion cost. Future studies may extend the analysis by incorporating income-based or trip-purpose-specific VOT estimates to refine cost estimates.

Despite these limitations, the adopted methodology remains suitable for the study's objective of identifying and quantifying the direction and strength of the relationship between traffic volume and economic loss under observed peak-period conditions.

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