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# Developing Quantitative Model for Evaluating the Impact of Roadside Friction Factors on Traffic Capacity of Roads in Divisoria, City of Manila

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***ABSTRACT***
*In the Philippines, roadside friction factors are prevalent even on busy roads – pedestrians, parked vehicles, market stalls and carts, moving carts, and loading and unloading vehicles occupy portions of roads designed to be utilized by flowing vehicles; hence, it's crucial to quantitatively evaluate how these roadside friction factors interact with traffic flow and contribute to heavy traffic. This study delves into analyzing roadside friction impact on traffic capacity. Roadside friction and traffic data were gathered from four roads – Claro M. Recto Avenue, Juan Luna, Reina Regente, and Ylaya Streets. The traffic capacity of roads and the impact of roadside friction factors on it were analyzed using multiple regression analysis. For all roads, the p-values obtained for dynamic friction are less than 0.05 – indicating that dynamic friction has significant impact on road traffic capacity, while static friction has significant impact only in one road. Subsequently, utilizing a four-phase modeling process involving validation and cross-validation through mean absolute percentage error (MAPE), a quantitative model was developed to determine the impact of roadside friction factors to traffic capacity of roads in Divisoria, City of Manila. J-Model was selected to represent the quantitative model as it has an adjusted r-squared of 0.87307, a MAPE of 9.6%, a highly accurate prediction on three roads, and a good prediction on one road. Utilizing the same model, a quantitative indicator through percent reduction in traffic capacity was established, which describes the quantity of impact of roadside friction factors on traffic capacity of roads in the locale.*

***Keywords –*** *Roadside Friction Factors, Traffic Capacity, Quantitative Model, MAPE*

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## I. INTRODUCTION

One of the key factors in the nation's economic progress is transportation. Located at the largest and most densely populated part of the Philippines, Luzon, Metro Manila is considered as the official capital region of the Philippines and the center of government, businesses, education, and urban culture in the country. Since the metro is visibly a highly urbanized area for its vibrant urban life, it is also expected to be highly dense. Due to this, it faces few challenges such as traffic congestion, air pollution, and issues related to the urban development of the metro. According to the 2022 Urban Mobility Readiness Index, among sixty cities with the poorest transportation system, the capital of the Philippines was ranked at 58th place for its "Urban Mobility Readiness" and placed 48th for Sustainable Mobility and ranked 56th for Public Transit [1]. As mentioned in Oliver Wyman Forum, the inadequate quality of roads in the metro area and the meager regional connectivity offered by the national road network are just two of the difficulties that face the road transportation industry. Despite having different modes of transportation available in Manila including jeepneys, rail transit system and some active transportation, the city's public transportation can be improved in some aspects like speed, waiting time, road density and cheap fare [2].

Traffic congestion is a significant problem in many cities around the world [3]. Vehicular traffic and travel demand have increased because of population growth and economic activity [4]. The rapid urbanization of both developed and developing countries caused severe impact on the road transportation sector especially because of the urban vehicular growth. From the year 2015, the City of Manila has had a 3.7% increase in population in keeping with the 2020 census of population and housing. In terms of motorcycle vehicles, the number of motor vehicles registered between the year 2014 and the pre-pandemic year, 2019 increased by 38% [5].

The Highway Planning Manual Volume 2 published by then Ministry of Public Works and Highways – now known as the Department of Public Works and Highways (DPWH) – defines the regular capacity for a 7-meter-wide highway with a sufficient shoulder width in good condition and light to moderate roadside friction would be roughly 16,000 cars during numerous peak hours, with each one accounting for no more than 8% of the daily traffic, on flat terrain. Around 20,000 vehicles should be able to travel in both directions on a highway with comparable configuration. Only at low proportions of heavy vehicles or by sacrificing the ideal travel hour to prevent heavy flows might traffic levels exceed these capabilities.

Roadside friction is a composite variable that indicates how much normal traffic flow, and other nearby activities interact. Roadside frictions can be classified into two. Bitangaza, et al. categorized it into two – dynamic roadside friction factors and static friction factors. Dynamic friction factors are moving factors including, but not limited to, merchants, cyclists, and parked motorized and non-powered vehicles. On the other hand, Static friction factors are the unchanging factors like vegetable market, lay-by, gas station, mechanic stop, vulcanizing activities, and mini mart. Due to the occupancy of these side frictions, most especially during market operations, the carriageway cannot serve its designed capacity due to the presence of roadside frictions randomly crossing through it causing a disruption to the speed of the motorized passing through and also the traffic flow.

In multiple studies about effects and impacts of roadside friction, many of these in general used methods like multiple linear regression analysis of the vehicle interactions related to curb side bus stops and bus bays to evaluate the impact of bus stops on traffic flow. Using the U.S Highway Capacity Manual 2010 and these techniques are the most appropriate for use in low-friction situations and yet became the basis of most transportation engineers in India [6]. Nevertheless, methods like these only show the factors on qualitative lenses since they only analyze these factors. However, the study about "Influence of Bus Stops on Flow Characteristics of Mixed Traffic, In Journal of Transportation Engineering", it pointed out that planners and designers would benefit from a quantitative examination of the individual and combined effects of the friction characteristics to properly include urban street systems and minimize any adverse consequences they may have [7].

The Pasig River and North Harbor border the thriving market district of Divisoria, which is situated on the western edge of Metro Manila. It is still active as a conventional commercial and business district. Divisoria is considered as the largest and cheapest marketplace in Metro Manila with 0.5 square kilometers – where consumers can buy affordable items of all kinds [8]. Evidently, roads between Tondo and Binondo are packed with different bazaars, stores and markets. Traffic congestion is prominent within the market areas due to the presence of roadside friction that interrupts the flow of traffic. This claim by Assaury is apparent in the roads of Divisoria, Manila. In addition to its commercial and retail activity, Divisoria serves as a significant interchange for commuters, which increases the congestions in the road [9].

("Divisoria Mode Interchange Area Study Technical Report," 1985). Although there are existing designs and plans for the roads in Manila there is a lack of research about the factors affecting the traffic capacity of roads. Attributable to the visible expeditious urbanization of the City of Manila, roadside frictions are a result of the rising vehicular population and the constrained availability of urban road space.

Therefore, it is vital that the impact of roadside friction on the traffic capacity of roads must be evaluated. In this study, the study will come up with a method for assessing the impact of roadside friction factors on the traffic capacity of roads in Divisoria, City of Manila. This paper is primarily focused on developing a quantitative model that will measure the impact of roadside frictions on the road traffic capacity.

When one is within the vicinity of the road, it can be observed that roadside friction factors interact with a road's traffic flow. Portions on roadsides occupied by various roadside friction factors – such as pedestrians, parked vehicles, market stalls and carts, moving carts, as well as loading and unloading vehicles could have been utilized by flowing vehicles instead. Through the proliferation of these friction elements, roads are not able to cater to the vehicle capacity that they are originally designed for. The combination of friction factors contributes to heavy traffic – thereby diminishing economic health and productivity, aside from the inconvenience as well as safety and health risks it already causes road users. It is critical to quantitatively assess the impact of roadside friction factors on road traffic capacity.

In the Philippine context, there exists no quantitative model to quantify the impact of roadside friction factors to the traffic capacity of roads. Furthermore, through the Highway Planning Manual Volume 2 and Volume 5, the impact of roadside friction factors to the traffic capacity of roads is described merely in qualitative and indefinite terms. With this, this study seeks to establish a quantitative indicator for assessing the impact of roadside friction factors on road traffic capacity – with definite quantitative boundaries between categories.

From the data gathered and processed from the evaluation of roadside friction factors to the traffic capacity of roads in Divisoria, City of Manila, the study aims to develop a quantitative model that quantifies the impact of roadside friction factors on traffic capacity of any road.

## II. METHODOLOGY

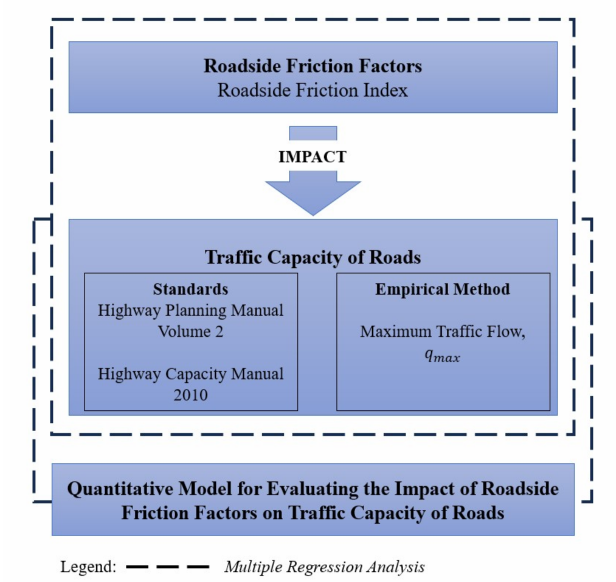


**Figure 1. Framework**

The study had chosen the research locale to be the commercial district of Divisoria in the City of Manila found in the center where the boundary of the first and third legislative districts of the City of Manila is – specifically along the area around Claro M. Recto Avenue separating Tondo from both Binondo and San Nicholas. The study chose this area to be the research locale owing to the fact that the various roadside friction factors that will be considered in the study are somehow present on the roads within the said research locale. Additionally, the research locale contains several types of roads – from national to local roads – that enabled the study to further expand their horizon for evaluating the impact of various roadside friction factors to the traffic capacity of roads.

Furthermore, due to the indefinite and vague nature of the boundaries of Divisoria, the study confined the research locale within the geographical area to be bounded by Lakandula, Asuncion, San Fernando, Juna Luna, and Reina Regente Streets, Abad Santos Avenue, Padre Algue, Balintawak, Mayhaligue, Dagupan, Juan Luna, L. Chacon, Nicholas Zamora, and Soliman Streets as shown in Figure 2.

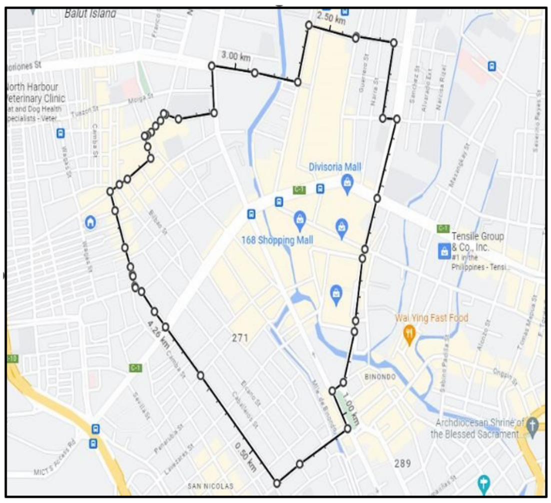


**Figure 2. Research Locale**

The study focused on the following roads since these have a continuous flow of vehicles throughout the day: (1) Juan Luna Street from Reina Regente Street to Claro M. Recto Avenue (2) Claro M. Recto Avenue from Asuncion Street to Juan Luna Street (3) Reina Regente Street from Soler to Dela Reina Street and (4) Ylaya Street from Lakandula Street to Padre Rada Street.

The road classification, type, estimated length, and width data of the road sections mentioned in the preceding paragraph is listed in Table 1.

**Table 1** *Classification and Type of Roads to be Studied*

| Road Name | Classification | Estimated Length (m) | Carriageway Width (m) | Road Type |
|---|---|---|---|---|
| **Juan Luna Street** | National Road Tertiary | 600 | 9.00 | Two Lane |
| **Claro M. Recto Avenue** | National Road Secondary | 450 | 15.6 | Six Lane |
| **Reina Regente Street** | National Road Tertiary | 250 | 15.9 | Six Lane |
| **Ylaya Street** | Local Road | 220 | 8.60 | Unmarked |

**Data Gathering:**

1. Traffic Count using Tally Sheet:
Considered traffic counts as a fundamental unit of measurement that can be used to get variables such as flow or occupation. The study established three national roads, specifically Juan Luna Street and Reina Regente Street which are national tertiary roads as well as Claro M. Recto Avenue which is a national secondary road; also, a local road named Ylaya Street within the mentioned research locale, in which the data had been gathered and collected.

2. Dynamic Friction Count using Tally Sheet
Dynamic friction factor count relates to the quantification or measurement of events or cycles within a system – in terms of this matter, the carriageway. This count estimates the total number of moving friction factors specifically, pedestrians, moving carts, as well as loading and unloading vehicles.
3. Static Friction Count using Tally Sheet
Similar to the manual counting of traffic and dynamic friction factors, motionless elements found within the carriageway were quantified by the countmen on the site using the static friction factor count tally sheet by measuring the area being occupied by the static factor such as parked vehicles as well as the market stalls and carts.

**Data Analysis:**

In this study, the raw data gathered from the field observation and inspection through the CCTV footages were tabulated and formulated using Microsoft Office Excel application to obtain such values for traffic capacity, roadside friction values (both static and dynamic), normalized capacity and normalized roadside friction that are essential to meet the objectives of the study, to more conveniently calculate numerous data.

The Statistical tool that the study utilized is the Regression Analysis, particularly, Multiple Linear Regression Analysis due to the number of dependent variables in this study. In the regression analysis, the roadside friction count served as the dependent variable, while the traffic capacity functioned as the independent variable. This analysis aimed to discern the relationship between traffic capacity and roadside friction factors.

For the data processing part of the study, the following were the necessary data needed for the data analysis and quantitative modelling – and their respective descriptions – utilized by the study:

*Item 1*: The first step that was made by the study was to calculate the traffic flow through the obtained number of vehicles from the observation. Due to variations in the types of vehicles present on the roads of Divisoria, all vehicles were converted into one unit as PCU using the PCEF. unit of traffic flow will be in PCU per hour.

*Item 2*: Next is for static roadside friction – the market stalls and carts, as well as parked vehicles were measured on-site, considering the whole one lane on the road. While, for the dynamic roadside friction – specifically for the number of pedestrians – the measurement was assumed as having 2 people per square meter. This assumption was based on the estimation presented in Crowd Safety and Crowd Risk Analysis, where he showed that 5 people can fit inside a square meter in static condition while 2 people per square meter can fit in free-flowing condition comfortably [10]. The study used weight factors for the roadside friction factors [11]. The product of the number of roadside friction and the weight factors became the RSFI value, and the summation of the RSFI that occurred on a specific period was treated as the total roadside friction value.

*Item 3*: After preparation of the dependent and independent variables such as traffic capacity and roadside friction, these variables were then processed by the study using the Multiple Linear Regression Analysis.

*Item 4*: For the normalized value of the variables, because of the variation in the carriageway of the roads on Claro M. Recto Avenue, Juan Luna Street, Ylaya Street, and Reina Regente Street, the data gathered on the actual capacity of each road needed to be uniformed. The roadside friction factors were also converted into normalized values using the standard measure of the carriageway width and considered trap length of the road which are 8 and 500 meters, respectively.

For the data analysis, there are statistical measurements that the study observed to evaluate the effect of the roadside friction factor to the traffic capacity of the roads. For the multiple linear regression analysis, there were cases tested to check if the independent variables significantly affect the dependent variable. The cases include case 1 which is the static friction is considered as the only independent variable, case 2 which is the dynamic friction as the only independent variable, and case three which includes both independent variables tested for the multiple regression analysis. The highest F-value observed for the following cases will be the prevailing case for evaluating the impact of roadside friction on the traffic capacity. The p-value of the data set for each road is obtained based on the prevailing case tested. The p-value was used to determine the significance of the roadside friction factors, were for the impact to be significant, a p-value of less than 0.05 shall be obtained. For the quantitative modeling, the adjusted R-squared was also used for the validation, where it must have a value of 0.7 to 1. The Pearson's coefficient of skewness was also utilized as the basis of the operation for the variable transformation for obtaining the best model for formulating the quantitative model. For the Mean Absolute Percentage Error (MAPE), the study aims to obtain a value of MAPE of 0-10% which reads as highly accurate forecast of the formulated model on the quantitative modelling

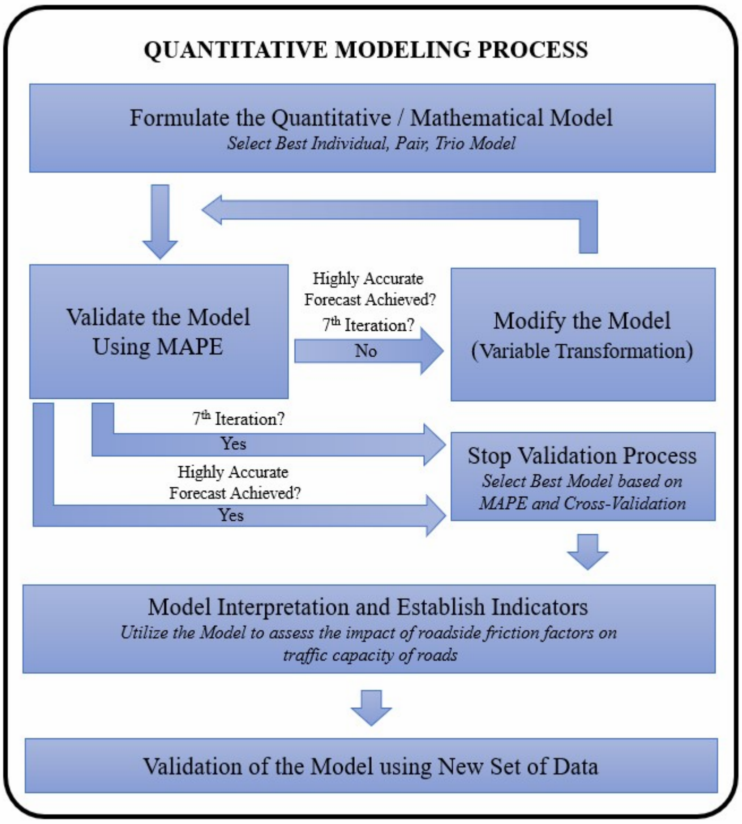


**Figure 3. Quantitative Modeling Process Flow**

## III. RESULTS

The onsite measured data of the roads considered in the study are given in Table 2. The section length and width of the road was measured using synthetic tape measure and marking chalk, and the number of lanes was based on the marking on the roads. The direction of the road was based on the actual direction of the flow observed in the roads. As shown in the table, Reina Regente Street has the widest section width among the roads with section width of 15.9 meters, and Juan Luna Street has the longest section length among the roads with section length of 600 meters. On the other hand, Ylaya Street, among all the roads, has the narrowest width and shortest length, with 8.6 meters and 221 meters, respectively/.

**Table 2** *Actual Measured Road Data*

| Road Section | Section Length (m) | Section Width (m) | Lanes | Direction |
|---|---|---|---|---|
| **Claro M. Recto Avenue** | 451 | 15.8 | 6 | One-Way |
| **Juan Luna Street** | 600 | 10.0 | 2 | One-Way |
| **Reina Regente Street** | 252 | 15.9 | 6 | Two-Way |
| **Ylaya Street** | 221 | 8.60 | None | One-Way |

The maximum traffic capacity of road occurs when both the static friction and dynamic friction factor is set to zero – the maximum traffic capacity as the dynamic friction was set to zero and the static friction remains constant and vice versa is set to be 2902.96. Table 3 shows the value of the static friction and dynamic friction for each quartile, which shows the minimum and maximum value for both static friction and dynamic friction that was acquired in the data onsite, and the value per quartile.

**Table 3** *Quartile Value of Static Friction and Dynamic Friction*

| Quartile | Static Friction | Dynamic Friction |
|---|---|---|
| Min | 90 | 922 |
| 1st Quartile | 117 | 1399 |
| 2nd Quartile | 149 | 1778 |
| 3rd Quartile | 228 | 2286 |
| Max | 555 | 3539 |

To assess the impact of the dynamic friction to the traffic capacity based on the J-Model, the value of the dynamic friction was set to the value of zero and the respective quartile value of dynamic friction as shown in Table 3, while the actual value of the static friction is held constant. Figure 4 shows the graph of the line for each traffic flow prediction made by setting the dynamic friction value in zero and its quartile values, it can be observed that all the regression lines have similar coefficient value for X, which is the value for the cube root of the static friction value, since the value of static friction was held constant. It also can be noted that the coefficient is equal to the coefficient for the static friction of the J-Model.

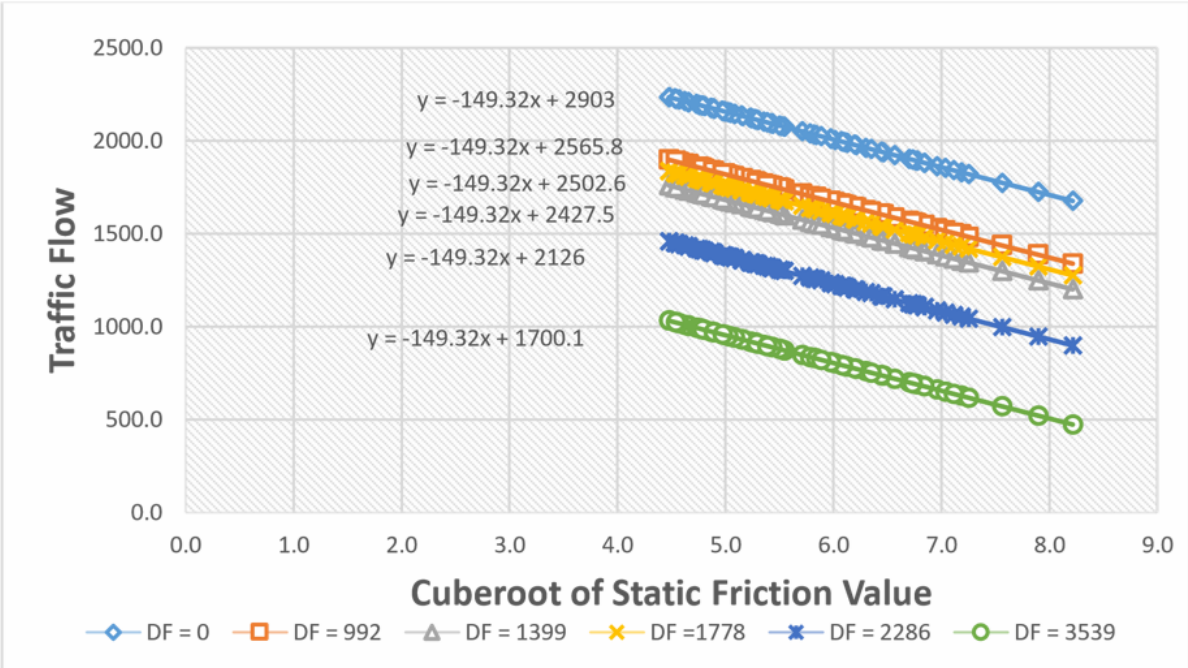


**Figure 4** *Graph of the Traffic Flow Prediction using Dynamic Friction Value per Quartile and Static Friction is held constant*

Table 4 summarizes the percentage of traffic capacity reduced for the assigned dynamic friction value, while holding the static friction values constant. It can be observed that the intercept values for each regression line as shown in the equations in Figure 5 decrease as the assigned value of the dynamic friction increases. Since the intercept acts as the maximum flow for existing conditions, it can be said the value of the traffic capacity is observed to be decreasing while the dynamic friction value increases.

**Table 4.** *Traffic Capacity Reduction per Quartile Dynamic Friction*

| Quartile | Dynamic Friction Value | Traffic Capacity | Traffic Capacity Reduced |
|---|---|---|---|
| - | 0 | 2903 | 0% |
| Min | 922 | 2565.8 | 12% |
| 1st Quartile | 1399 | 2502.6 | 14% |
| 2nd Quartile | 1778 | 2427.5 | 16% |
| 3rd Quartile | 2286 | 2126 | 27% |
| Max | 3539 | 1700.1 | 41% |

On the other hand, the impact of static friction on the traffic capacity was assessed using the J-Model. The value of the static friction was set to the value of zero and the respective quartile value of static friction as shown in Table 4, while the actual value of the dynamic friction is held constant. Figure 5 shows the graph of the line for each traffic flow prediction made by setting the static friction value in zero and its quartile values, it can be observed that all the regression lines have similar coefficient value of the variable X, since the value of dynamic friction was held constant. It also can be noted that the coefficient is equal to the coefficient for the dynamic friction of the J-Model.

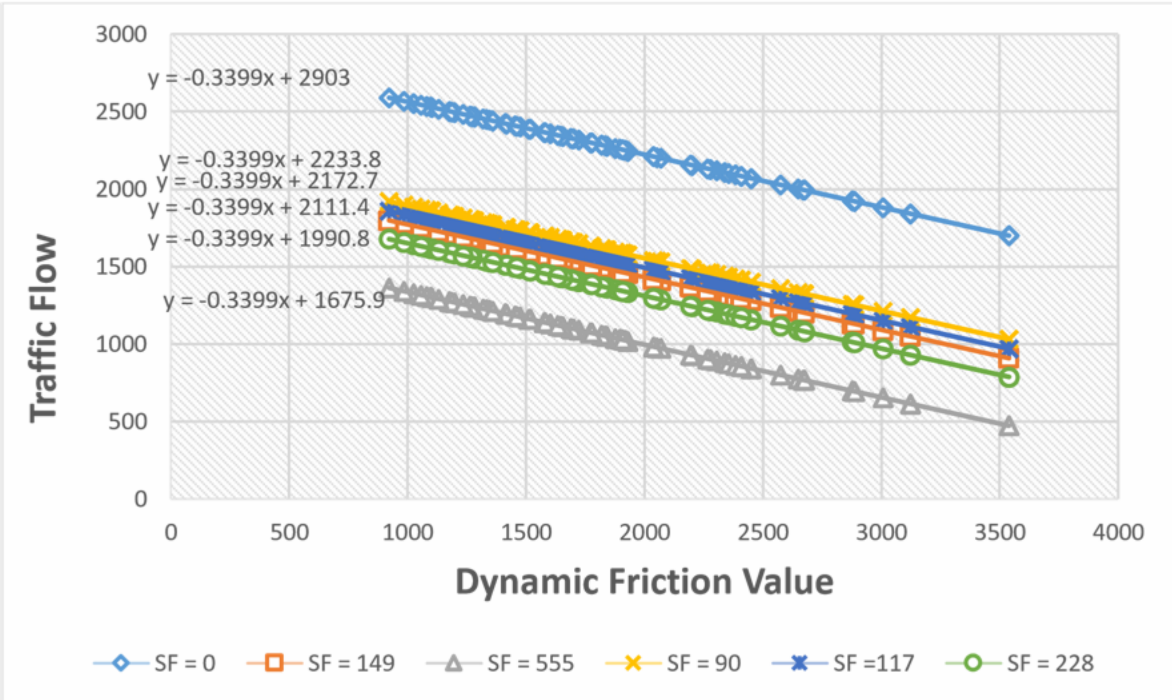


**Figure 5** *Graph of the Traffic Flow Prediction using Static Friction Value per Quartile and Dynamic Friction is held constant*

## IV. CONCLUSION

This study had aimed to address a fundamental aspect of roadway efficiency by developing a quantitative model to assess the impact of roadside friction factors on traffic capacity of roads. With the stain on transportation networks, it is of paramount importance to understand how roadside friction impacts the traffic capacity of roads. Furthermore, through rigorous analysis and modeling, this research had sought to provide insights into how variations in roadside friction value impacts the overall ability traffic capacity of roads. The conclusions drawn from this study are as follows:

The p-value for static friction for Ylaya Street is 7.24469 x$10^{-7}$. Since the p-value for static friction for Ylaya Street is less than 0.05, it can be concluded that static friction has a significant impact on the traffic capacity of the said road. While the p-values for dynamic friction for the four roads are 2.56011 x $10^{-9}$, 7.86257 x$10^{-11}$, 9.88668 x$10^{-9}$, and 1.87195 x$10^{-10}$, respectively. Since the p-values for dynamic friction for all the roads are less than 0.05, it can be concluded that dynamic friction has a significant impact on the traffic capacity of all roads.

J-Model, represents the developed quantitative model that determines the impact of roadside friction factors on traffic capacity of roads in Divisoria, City of Manila. J-Model had been developed through a thorough fourphase quantitative modeling process: in Modeling Phase I, J-Model had been generated from data from the preliminary test multiple regression analysis and selected as the best among the individual models based on its adjusted r-squared 0.87307; in Modeling Phase II, J-Model had been validated through mean absolute percentage error (MAPE) where it had obtained a MAPE value of 9.6% which is less than 10%, which also indicates a highly-accurate forecast; in Modeling Phase III, J-Model had been cross-validated for its performance on all four roads, where in it was determined that J-Model had been able to make highly-accurate predictions for three of the roads and a good prediction for the other road; and in Modeling Phase IV, J-Model had been simplified into a general equation, and utilized as basis for the quantitative indicator.

The percent reduction in traffic capacity or %RTC, represents the quantitative indicator that describes the quantity of impact of roadside friction factors on traffic capacity of roads in Divisoria, City of Manila.

The $Y$ represents the traffic capacity when $A_{SF}$ and $A_{DF}$ are set to zero or when there are no static and dynamic friction factors present, while $Y$ represents the actual traffic capacity when $A_{SF}$ and $A_{DF}$ are set to certain values or when there are static and dynamic friction factors present. $Y$ can be obtained through while $Y$ can be obtained utilizing the developed quantitative model.

## REFERENCES


[1]. Luna, F. (2022, November 25). Metro Manila public transportation among the worst in the world: study. Philstar.com; Philstar.com. https://www.philstar.com/headlines/2022/11/25/2226400/metro-manila-publictransportation-among-worst-world-study

[2]. Wyman, O. (2022, April 16). Ranking. Oliver Wyman Forum. https://www.oliverwymanforum.com/mobility/urban-mobility-readinessindex/ranking.html

[3]. Ilahi, A., Belgiawan, P. F., & Axhausen, K. W. (2020). Influence of pricing on mode choice decision integrated with latent variable. In Elsevier eBooks. https://doi.org/10.1016/b978-0-12-817340-4.00008-5

[4]. Bitangaza, M. & Bwire, H. (2020). Effects of Roadside Friction Elements on Travel Performance and Level of Service in Kigali. International Journal for Traffic and Transport Engineering, 10(2), 236-251. http://dx.doi.org/10.7708/ijtte.2020.10(2) .09

[5]. Gaspay, S. M. A. (2021). Sustainable urban transport index for Metro Manila and impacts of COVID-19 on mobility. https://repository.unescap.org/handle/20.500. 12870/4156

[6]. Salini, S., George, S., & Ashalatha, D. R. (2016). Effect of side frictions on traffic characteristics of urban arterials. Transportation research procedia, 17, 636-643. https://www.sciencedirect.com/science/article/pii/S2352146516307335?ref=pdf_d download=RR-2&rr=8205aacc2960bc37

[7]. Koshy, R. Z., & Arasan, V. T. (2005). Influence of bus stops on flow characteristics of mixed traffic. ResearchGate. https://doi.org/10.1061/(ASCE)0733-947X(2005)131:8(640)

[8]. Marpa, A. G. (2022, February 2). Divisoria - The Largest street market in Manila - Island Times. Island Times. https://islandtimes.com/divisoria-the-largest-street-marketin-manila/McCombes, S. (2023, June 22). Descriptive Research | Definition, Types, Methods & Examples. Scribbr. Retrieved November 18, 2023, from https://www.scribbr.com/ methodology/descriptive-research

[9]. Assaury, M. S., Sutrisno, M., & Astor, Y. (2020). The solution of traffic congestion due to side frictions along the market area at national arterial road Tanjungsari Sumedang. IOP Conference Series, 732(1), 012034. https://doi.org/10.1088/1757-899x/732/1/012034

[10]. Still, G. K. (2001). Crowd Safety and Crowd Risk Analysis. https://www.gkstill.com/ExpertWitness/CrowdRiskAnalysis.html

[11]. Ahad A. & Mor P. (2018). Impact of Roadside Friction Elements on Average Travel Speed and LOS of Urban Two-Lane Streets. Journal of Emerging Technologies and Innovative Research, September 2018, Volume 5, Issue 9. ISSN-2349-5162