Intelligent Transport System Implementation in Road Transportation in Manila, Philippines: A Four-Step Model Approach

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ABSTRACT. Traffic congestion is an enormous problem in today's society because of the vast number of vehicles. Currently, Manila has one of the worst traffic situations in the country. Although Manila utilizes an Intelligent Transport System (ITS), it still could not help the congestion in the city. One essential part of this paper is the integration of the Four-Step Model into the ITS. The Four-Step Model was utilized to solve the transportation crisis by projecting the number of vehicles that there will be in a certain time. The Four-Step Model was used to project the number of vehicles for the next ten years using the Annual Average Daily Traffic Volume (AADT) provided by the Metropolitan Manila Development Authority (MMDA). The researchers integrated the Four-Step Model with ITS by using a simulation software to showcase the projection results. The results indicated that by 2033, the current traffic would increase by 25 percent.

KEYWORDS*:* Intelligent Transport System (ITS), Annual Average Daily Traffic (AADT), Metropolitan Manila Development Authority (MMDA), Simulation of Urban Mobility (SUMO), Traffic Simulation, Road Transportation

1. INTRODUCTION

When there is too much traffic on the roads or highways, it slows down or even stops. Many factors, such as increased traffic, roadworks, accidents, or severe weather, could have been to blame. The adverse effects of traffic congestion on the environment included increased greenhouse gas emissions and air pollution, delays, increased travel times, and aggravation. It was a typical urban issue that could severely impact people's quality of life.

As the world's population increased at an alarming rate, so did the number of cars on the road, leading to congestion in major urban areas and decreased mobility for their residents. In order to reduce traffic congestion, enhance traffic safety, and boost road productivity, intelligent transportation systems utilize a combination of technological advancements, communication technologies, and reliable approaches to traffic management in the form of sensors and signals shared by drivers, vehicles, and the road itself.

In the book Intelligent Transport Systems Applications and Services for Users and Traffic Managers by Amador et al. (2015), the authors referred to Traffic Management as "The management of the movement of vehicles, travelers and pedestrians throughout the road transport network". In essence, traffic management focuses on utilizing efficient ways to operate a road network, optimize traffic flow, and ensure that road users are safe and comfortable while using the road. In this essence, the Four-Step Model is applicable to traffic management because it allows for better understanding of the volume of traffic in a specific place.

When it comes to transportation, ITS was all about science and technology. Since ITS was a combination of technology and everyday traffic management, it needed to be able to collect data from moving vehicles and share that data with other drivers. ITS has endless possibilities for enhancing traffic efficiency, decreasing commute times, raising road safety standards, and lessening adverse environmental effects. ITS anticipated the possibility of a smoother, more secure, and more economically feasible future for transportation, regardless of whether it be through autonomous vehicles capable of navigating city streets, intelligent traffic signals optimizing traffic patterns, or travelers receiving particular real-time routing help.

1.1 Background of the Study

In order to alleviate traffic and free up lanes, the Intelligent Transportation System (ITS) employed innovative technologies to deliver helpful directions and other services to drivers. The intelligent transportation system has to be used to reduce the negative consequences of traffic congestion. One way to accomplish this was to provide more convenient and safe modes of mobility. It was possible to mitigate the negative consequences that everyone felt by improving infrastructure and traffic management and cutting down on traffic congestion. In the end, reducing traffic congestion by implementing intelligent transportation systems positively contributed to the quality of life for all people.

ITS is a combination of technology, communication system and traditional method of traffic management that allows each user, vehicle, and the road to communicate with each other through sensors and signals to ease traffic congestion, further improve traffic safety, and overall improve road productivity. In addition to its definition, Lin et al. (2017) also stated in their paper that the main goal of ITS is to provide mobility, sustainable transportation, and convenience to all cars and commuters on the road. The authors referred to mobility as the efficiency of the transportation system. According to Figueiredo et al. (2001), ITS aims to solve the technological and scientific aspects of transportation. ITS is a collaborative transportation management that provides new solutions and services to different modes of transportation. For ITS to work, Sumalee & Ho (2018) stated that it must have three necessary components, namely: data collection, data analysis, and data transmission. ITS can also refer to simulation softwares that can be used in understanding and simulating traffic scenarios. With that in mind, in this paper ITS will be referring to the simulation software.

The "Four-Step Model" is a standard approach utilized in urban development and transportation planning. It is also utilized to forecast and analyze regional travel patterns and demand, which makes it helpful in the process of evaluating and designing transportation networks. It is a useful methodology to provide a systematic approach to analyzing and predicting travel patterns in certain areas.

1.2 Statement of the Problem

The main objective of this paper was to understand and apply an Intelligent Transportation System (ITS) software to further improve the quality of the transportation system in the country.

Specifically, the researchers aimed to find solutions and answer the following questions:

1. What was the extent of utilization of the ITS software used by MMDA in traffic management?
2. How could the Traffic Management Center (TMC) utilize ITS software for traffic visualization and traffic mapping to adjust for traffic congestion that the country experiences?
3. What are the possible mandates that the government could apply for both public and private vehicles to take part in this system of information?

1.3 Objectives

Congestion in the nation's roadways had long been an issue of concern, as it was responsible for a wide range of adverse effects on society. Some of the factors that contributed to traffic congestion in the Philippines included the population, the total number of vehicles on the road, and inadequate traffic management and enforcement.

The implementation of an intelligent transportation system in Metro Manila was the focus of this research. The main objective of this paper was to develop the integration of the Intelligent Transportation System and Four-Step Model to increase road efficiency, reduce travel time, and increase the overall safety and convenience of the road for all its users. All of which were attainable with the help of the Intelligent Transportation System. In addition to the main objective, the following were some of the goals that the researchers of this study hoped to accomplish.

1. Gather data from government agencies for the projection of the number of vehicles in 10 years.
2. Find related studies that showcased the computation for the projection of number of vehicles and apply the study's methodology.
3. Simulate the projected data of the number of vehicles in a traffic simulation software to showcase the findings of the projected data.

1.4 Significance of the Study

Many cities still have work to do to adequately alleviate traffic congestion, but much progress has been made in recent years. Considering the foregoing, it is clear that the intelligent transportation system (ITS) will play a crucial role in enhancing and modernizing transportation infrastructure across the country. Researchers in Metro Manila want to learn more about smart transportation systems because of the large population involved. Important to this research are the following:

1. **General Population** - Daily commuters and travelers stand to gain the most from an intelligent transportation system. A shorter total trip time is possible with the help of an intelligent transportation system. The intelligent transportation system uses real-time traffic monitoring and data-driven decision-making to identify congested regions, accidents, or roadwork and suggest other routes. With this up-to-date knowledge, commuters may avoid traffic jams and choose the best routes, reducing travel times and reducing delays brought on by crowded roadways. By constantly providing the most up-to-date and accurate information about traffic conditions, accidents, and potential threats, people are better equipped to plan their trips. Drivers have more information to avoid accident-prone locations or alter their driving behaviors thanks to real-time access to this data.

2. **Government** - By using advanced technologies like real-time tracking, automated fare collecting, and passenger information systems, public transport operators may provide a smoother and more user-friendly experience for passengers. Intelligent transportation systems can be of help to the government in enhancing the overall quality of both public and private modes of transportation, as well as enhancing the efficiency of traffic management and decreasing congestion. As an immediate result of this, they are able to enhance the level of service offered by public transit.

1.5 Scope and Limitations

This research into the four-step model implementation of an Intelligent Transportation System studied and evaluated the potential advantages associated with such a system, some of which included the decrease of traffic, the management of traffic, and the monitoring of real-time conditions. In order to have a better understanding of the effects that ITS had on the transportation system, it was necessary to create and implement comprehensive traffic simulation models, as well as determine what information was required and how to obtain it.

Nevertheless, there were limitations, including the intricate urban road network, resource limitations, stakeholder cooperation, data availability, and the difficulty in precisely measuring all advantages. Moreover, the origin-destination matrix that is typically used in the Four-Step Model was not utilized, due to the unavailability of the data. A way to overcome this limitation is to use the Annual Average Daily Traffic (AADT), which corresponds to how many vehicles pass through a certain road for each year. In order to improve Manila's road transportation through the integration of intelligent transportation systems, it was essential to recognize and address these limitations.

2. METHODOLOGY

This part of the paper showcased the entire process of the whole paper. The methodology encompassed the entire sequence of events on how the study was conducted. Divided into each subsection wherein the step-by-step process on how the data will be gathered, used, and analyzed will be discussed in this chapter. Each subsection aims to complete each objective mentioned in the paper.

2.1 Methodological Framework

This methodological framework demonstrated the visualization of the study's flow. The framework encapsulated the complete series of events detailing the methodology of the investigation. This paper is divided into distinct "phases" that correspond to each key purpose. Each phase was designed to accomplish every target outlined in the document. Each phase of the study included sub-phases that offered a more extensive description of how to accomplish the main objectives.

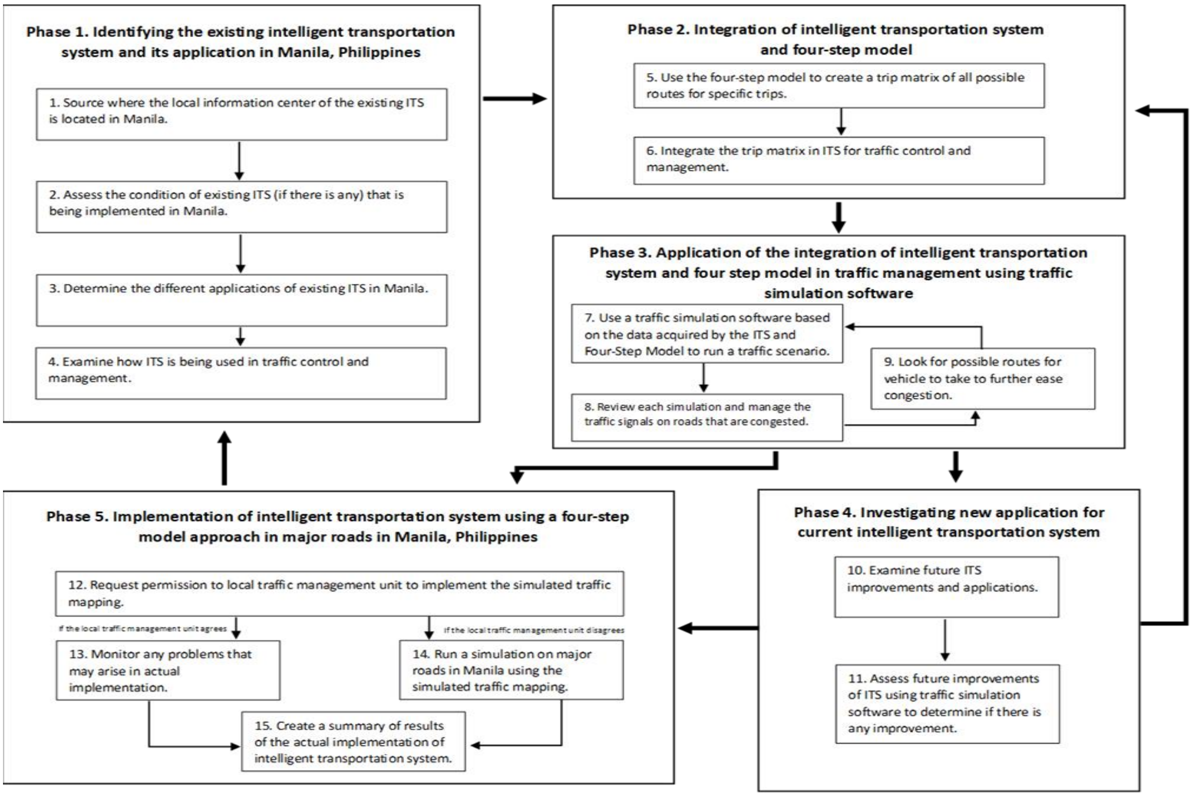

Figure 1. Methodological Framework

The first phase of the study achieved the first objective, which was to determine the current or existing intelligent transportation system in Manila, including its extent of application. An integral part of this phase was to determine the current application of the existing ITS in Manila. This was to determine how the local traffic management unit utilized ITS to make transportation efficient, safe, and convenient for all road users.

In the second phase, the researchers started to integrate the ITS into a Four-step model. The four-step model was essential in the following: getting the number of trips generated from zone A to zone B; assigning the best route and mode of transportation to take; identifying and predicting the volume of trips in the next 10 years using the Traffic Projection Formula. Because of data constraints as previously mentioned in the limitations, the researchers used the AADT in projecting the number of vehicles for the next 10 years on specific roads in Manila. This phase was crucial because the traffic matrix served as the data for ITS to use in traffic management.

For the third phase, the integration of ITS and the four-step model was utilized by applying it to a traffic simulation software, which in the case of this paper, was Simulation of Urban Mobility (SUMO). The group used the data from the previous step in a traffic simulation software wherein the existing traffic management tools available were present.

In this scenario, the current ITS of Manila city is being utilized. After running the scenario in the traffic simulation software, the researchers will review the simulation.

The fourth phase revolved around the exploration of other implementations of ITS in Manila. Stagnation was not a choice for transportation because vehicles were being revolutionized every year. In this phase, the researchers also reviewed and assessed future improvements of ITS using traffic simulation to determine if there was any improvement at all in traffic control.

Lastly, for phase 5, once all the simulations were reviewed and assessed thoroughly, the newly integrated ITS with the four-step model approach was submitted to the local traffic management unit of Manila. There were two scenarios that could happen during this phase: first was that the local traffic management unit agreed to implement the new system in real-life road traffic; second was that the local traffic management disagreed to implement the new system.

2.2 Research Setting

The proponents conducted on-site inspections of the main TMC in Manila, where all the traffic management data were being analyzed, interpreted, and controlled in real-time. The Traffic Management Center refers to the main operation hub of a particular place wherein all the traffic-related operations are conducted such as traffic management, traffic surveillance, etc. In addition, since this paper dealt with simulations of traffic scenarios in major roads in Manila, these areas were included as part of the study. The major roads that were currently congested with heavy traffic during rush hour or peak hours that this study used for simulation were: C:1 Recto, C:2 Mendoza; Pres. Quirino Avenue, R:1 Roxas Boulevard, R:2 Taft Avenue, and R:9 Rizal Avenue. The said roads were primarily intersections that were equipped with timed-signal lights and many traffic personnel that assisted in traffic management.

2.3 Data Gathering Procedure

The data used in this study came from the main TMC of Manila, and if there was no TMC in Manila, the main headquarters of the Metropolitan Manila Development Authority (MMDA), located in Orense Street, Guadalupe, Makati City. The researchers were able to understand the current state of traffic management in Manila by looking at the number of all the vehicles that passed the aforementioned roads in the research setting. The routes that vehicles would take to complete their trips were also gathered for the purpose of re-mapping or simulating a similar scenario in SUMO, which provided insights on how to properly manage and control traffic from the said locations or roads in the research setting. As for the vehicle growth rate of each vehicle type, the paper referred to a Traffic Impact Assessment report in X City made by Engr. Cueto himself.

2.4 Data Treatment

The traffic data gathered from the local TMC of Manila were treated differently in this paper. As part of the objectives of this study, the researchers integrated a four-step model to predict the number of trips that would be generated in the year 2034 based on the data given by the local traffic management unit. The traffic growth rate was utilized in this computation because it could clearly predict the number of trips that would be generated based on this equation:

$$A = P\,(1 + r)^n$$

Wherein:

A = Traffic in the year of work completion
P = Number of commercial vehicles as per last count
r = Passenger Car Unit
n = Number of years between the last traffic count and the year of completion

With this data, the researchers arrived at a certain number of trips that were generated from each zone in Manila. Furthermore, the future trip data was used as a scenario in the SUMO simulation to study what would happen to the traffic with such a volume of vehicles using the road (assuming that there was no road widening or construction taking place in the future) and how ITS would have helped in managing and controlling the said traffic situation in the future.

2.5 Simulation Software

This paper utilized traffic simulation software to further illustrate and demonstrate the impact of the number of vehicles in the projected years. The best simulation to use for this kind of simulation was PTV Vissim. However, due to a long response from the PTV group when the researchers applied for a thesis license of the software, this paper utilized Simulation of Urban Mobility (SUMO) software. SUMO provided almost all that PTV Vissim offered but only in simple demonstrations. SUMO was also an open-source application, which meant that everyone could have access to it and use it for traffic simulation purposes.

3. RESULTS AND DISCUSSION

3.1 Existing Intelligent Transport System in Manila

In the first phase, the paper aims to determine the existing ITS application of Manila city. Upon investigation, the authors found that although the city utilizes ITS application in terms of CCTVs, traffic monitoring tools, and traffic management tools, the city has yet to explore the use of traffic simulation softwares as a means to improve and study the current traffic situation in their city. The current ITS application of the city also includes automated traffic lights scattered throughout intersecting roads of the city that can be manually overridden when traffic on one end is of high volume.

3.2 Integration of Intelligent Transport System and Four-Step Model

For the second phase of the methodology, the authors wanted to calculate and project the number of vehicles using the Four-Step Model OD (Origin-Destination) Matrix. However, since the lack of available data, the AADT was used for this step. Albeit not producing the ideal result, the traffic projection using AADT can still be used to know how many vehicles will be traversing the specified roads. Furthermore, this projection can be crucial in determining the possible choke points. This will also help future studies in determining what type of measures can be utilized to reduce the congestion that would occur.

3.2.1 Current Data from Metropolitan Manila Development Authority

The Annual Average Daily Traffic (AADT) data that was obtained from the Metropolitan Manila Development Authority includes all the circumferential roads and radial roads in Metro Manila.

METROPOLITAN MANILA ANNUAL AVERAGE DAILY TRAFFIC (AADT) 2022

SUMMARY

CIRCUMFERENCIAL AND RADIAL ROAD		VOLUME									
		CAR	PUJ	UV	TAXI	PUB	TRUCK	TRAILER	MC	TRICYCLE	TOTAL
C:1	RECTO	27,587	6,749	756	3,554	90	651	169	44,687	1,854	86,097
C:2	MENDOZA	83,148	523	243	5,384	155	3,786	12	80,092	1,900	175,243
	PRES. QUIRINO AVE.	68,697	6	81	3,963	209	3,198	53	70,437	973	147,617
C:3	ARANETA AVE.	59,994	14	16	2,758	26	2,639	507	44,877	1,475	112,306
C:4	EDSA	202,764	1,803	2,475	18,186	5,588	2,295	119	151,847	20	385,096
C:5	C.P. GARCIA / KATIPUNAN AVE. / TANDANG SORA	93,513	405	2,668	4,123	789	8,993	1,151	100,133	44	211,819
R:1	ROXAS BLVD.	90,400	68	2,461	9,018	595	1,077	2,050	80,120	290	186,079
R:2	TAFT AVE.	73,942	14,622	7,648	4,923	1,174	1,647	164	83,705	6,639	194,464
R:3	SSH	146,455	4,413	246	7,920	4,893	6,870	3,497	86,204	51	260,549
R:4	SHAW BLVD.	47,568	2,545	1,412	5,385	48	1,041	98	52,739	21	110,857
R:5	ORTIGAS AVE.	66,372	24,357	4,454	3,505	901	3,988	549	75,422	113	179,661
R:6	MAGSAYSAY BLVD.	47,686	6,144	917	5,434	152	1,644	272	64,643	1,612	128,504
	AURORA BLVD.	43,305	7,954	2,121	5,600	522	1,988	42	57,926	167	119,625
R:7	QUEZON AVE.	130,465	2,806	2,963	13,003	853	4,088	314	125,966	149	280,606
	COMMONWEALTH AVE.	153,029	5,520	4,223	16,026	4,614	7,336	439	154,369	628	346,184
R:8	A. BONIFACIO	38,715	3,202	72	1,319	1,593	7,880	1,458	30,308	265	84,812
R:9	RIZAL AVE.	29,917	7,154	28	2,825	26	2,531	15	54,799	1,813	99,108
R:10	DEL PAN	34,415	656	43	1,950	163	6,051	8,610	43,733	2,481	98,102
	MARCOS HIGHWAY	100,373	7,861	805	6,473	542	4,853	343	106,963	257	228,470
	MCARTHUR HIGHWAY	24,724	4,074	8	3,659	479	2,386	169	64,759	298	100,556
TOTAL		1,563,069	100,876	33,639	125,008	23,412	74,942	20,030	1,573,729	21,050	3,535,755

Figure 2. MMDA 2022 AADT (Metropolitan Manila Development Authority [MMDA], 2022)

As the focus of this study, the scope will be limited to roads that are located in Manila City such as C:1 Recto, C:2 Mendoza; Pres. Quirino Avenue, R:1 Roxas Boulevard, R:2 Taft Avenue, and R:9 Rizal Avenue. The time frame of the AADT data was from the years 2018-2022, it includes the year 2019 and 2020 wherein the COVID-19 Pandemic struck the world.

3.2.2 Traffic Projection in 10 Years

By means of the given Passenger Car Equivalent Factor (PCEF) of the Department of Public Works and Highways (DPWH), the Passenger Car Unit (PCU) can be computed by multiplying the traffic count to the PCEF of each individual mode of transportation that is commonly found on the said roads. The following are the corresponding PCEF used in this paper (Department of Public Works and Highways, 2013):

Table 1. PCEF table

Mode of Transportation	Passenger Car Equivalent Factor (PCEF)
Cars	1
SUV	1.2
Jeepney	1.4
Bus	2.2
Trailer	2.2
Truck	2
Special Vehicle (Tricycles)	1.2
Motorcycle	0.5

C:1 Recto 10-year projection using 2022 AADT

Table 2.1. C:1 Recto 10-year projection

Mode of Transportation	Passenger Car Equivalent Factor (PCEF)	Traffic Count	PCU	Growth Rate
Cars	1	31141	31141	0.03061
SUV	1.2	756	907.2	0.03061
Jeepney	1.4	6749	9448.6	0.02468
Bus	2.2	90	198	0.02321
Trailer	2.2	169	371.8	0.0222
Truck	2	651	1302	0.0222
Special Vehicle (Tricycles)	1.2	1854	2224.8	0.02321
Motorcycle	0.5	44687	22343.5	0.02321

Table 2.2. C:1 Recto 10-year projection

Mode of Transportation	2024	2025	2026	2027	2028
Cars	33,076.63	34,089.11	35,132.57	36,207.98	37,316.31
SUV	963.59	993.08	1,023.48	1,054.81	1,087.10
Jeepney	9,920.74	10,165.58	10,416.47	10,673.55	10,936.97
Bus	207.30	212.11	217.03	222.07	227.22
Trailer	388.49	397.12	405.93	414.94	424.16
Truck	1,360.45	1,390.65	1,421.52	1,453.08	1,485.34
Special Vehicle (Tricycles)	2,329.27	2,383.34	2,438.65	2,495.25	2,553.17
Motorcycle	23,392.72	23,935.67	24,491.21	25,059.65	25,641.29

Table 2.3. C:1 Recto 10-year projection

Mode of Transportation	2029	2030	2031	2032	2033
Cars	38,458.56	39,635.78	40,849.03	42,099.42	43,388.08
SUV	1,120.38	1,154.67	1,190.01	1,226.44	1,263.98
Jeepney	11,206.89	11,483.48	11,766.89	12,057.30	12,354.87
Bus	232.50	237.89	243.42	249.07	254.85
Trailer	433.57	443.20	453.04	463.09	473.37
Truck	1,518.32	1,552.02	1,586.48	1,621.70	1,657.70
Special Vehicle (Tricycles)	2,612.43	2,673.06	2,735.10	2,798.59	2,863.54
Motorcycle	26,236.42	26,845.37	27,468.45	28,105.99	28,758.34

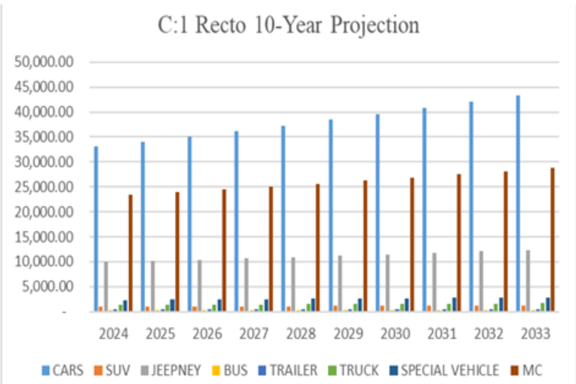

Figure 3. C:1 Recto 10-year projection graph.

C:2 Mendoza 10-year projection using 2022 AADT

Table 3.1. C:2 Mendoza 10-year projection

Mode of Transportation	Passenger Car Equivalent Factor (PCEF)	Traffic Count	PCU	Growth Rate
Cars	1	88532	88532	0.03061
SUV	1.2	243	291.6	0.03061
Jeepney	1.4	523	732.2	0.02468
Bus	2.2	155	341	0.02321
Trailer	2.2	12	26.4	0.0222
Truck	2	3786	7572	0.0222
Special Vehicle (Tricycles)	1.2	80092	96110.4	0.02321
Motorcycle	0.5	1900	950	0.02321

Table 3.2. C:2 Mendoza 10-year projection

Mode of Transportation	2024	2025	2026	2027	2028
Cars	94,034.88	96,913.29	99,879.80	102,937.13	106,088.03
SUV	309.72	319.21	328.98	339.05	349.42
Jeepney	768.79	787.76	807.20	827.12	847.54
Bus	357.01	365.30	373.78	382.45	391.33
Trailer	27.59	28.20	28.82	29.46	30.12
Truck	7,911.93	8,087.57	8,267.12	8,450.65	8,638.25
Special Vehicle (Tricycles)	100,623.62	102,959.09	105,348.77	107,793.92	110,295.82
Motorcycle	994.61	1,017.70	1,041.32	1,065.49	1,090.22

Table 3.3. C:2 Mendoza 10-year projection

Mode of Transportation	2029	2030	2031	2032	2033
Cars	109,335.39	112,682.14	116,131.34	119,686.12	123,349.71
SUV	360.12	371.14	382.50	394.21	406.28
Jeepney	868.46	889.89	911.85	934.36	957.42
Bus	400.41	409.71	419.22	428.95	438.90
Trailer	30.79	31.47	32.17	32.88	33.61
Truck	8,830.02	9,026.05	9,226.43	9,431.25	9,640.63
Special Vehicle (Tricycles)	112,855.78	115,475.17	118,155.34	120,897.73	123,703.77
Motorcycle	1,115.52	1,141.41	1,167.90	1,195.01	1,222.75

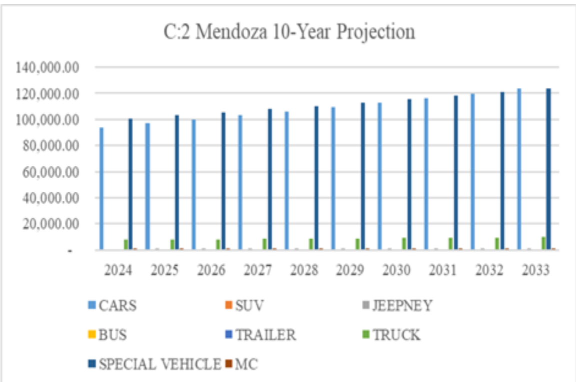

Figure 4. C:2 Mendoza 10-year projection graph.

C:2 Quirino Avenue 10-year projection using 2022 AADT

Table 4.1. C:2 Quirino Avenue 10-year projection

Mode of Transportation	Passenger Car Equivalent Factor (PCEF)	Traffic Count	PCU	Growth Rate
Cars	1	72660	72660	0.03061
SUV	1.2	81	97.2	0.03061
Jeepney	1.4	6	8.4	0.02468
Bus	2.2	209	459.8	0.02321
Trailer	2.2	53	116.6	0.0222
Truck	2	3198	6396	0.0222
Special Vehicle (Tricycles)	1.2	70437	84524.4	0.02321
Motorcycle	0.5	973	486.5	0.02321

Table 4.2. C:2 Quirino Avenue 10-year projection

Mode of Transportation	2024	2025	2026	2027	2028
Cars	77,176.33	79,538.69	81,973.37	84,482.58	87,068.59
SUV	103.24	106.40	109.66	113.02	116.47
Jeepney	8.82	9.04	9.26	9.49	9.72
Bus	481.39	492.56	504.00	515.69	527.66
Trailer	121.83	124.54	127.30	130.13	133.02
Truck	6,683.13	6,831.50	6,983.16	7,138.19	7,296.65
Special Vehicle (Tricycles)	88,493.56	90,547.49	92,649.10	94,799.48	96,999.78
Motorcycle	509.35	521.17	533.26	545.64	558.30

Table 4.3. C:2 Quirino Avenue 10-year projection

Mode of Transportation	2029	2030	2031	2032	2033
Cars	89,733.76	92,480.51	95,311.34	98,228.82	101,235.60
SUV	120.04	123.71	127.50	131.40	135.43
Jeepney	9.96	10.21	10.46	10.72	10.98
Bus	539.91	552.44	565.26	578.38	591.81
Trailer	135.97	138.99	142.08	145.23	148.45
Truck	7,458.64	7,624.22	7,793.48	7,966.49	8,143.35
Special Vehicle (Tricycles)	99,251.15	101,554.76	103,911.85	106,323.64	108,791.42
Motorcycle	571.26	584.52	598.09	611.97	626.17

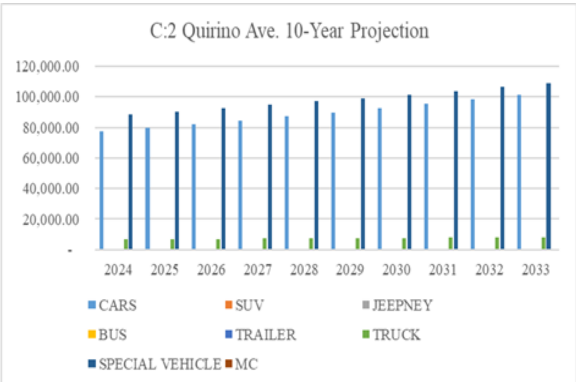

Figure 5. C:2 Quirino Avenue 10-year projection graph.

R:1 Roxas Boulevard 10-year projection using 2022 AADT

Table 5.1. R:1 Roxas Boulevard 10-year projection

Mode of Transportation	Passenger Car Equivalent Factor (PCEF)	Traffic Count	PCU	Growth Rate
Cars	1	99418	99418	0.03061
SUV	1.2	2461	2953.2	0.03061
Jeepney	1.4	68	95.2	0.02468
Bus	2.2	595	1309	0.02321
Trailer	2.2	2050	4510	0.0222
Truck	2	1077	2154	0.0222
Special Vehicle (Tricycles)	1.2	80120	96144	0.02321
Motorcycle	0.5	290	145	0.02321

Table 5.2. R:1 Roxas Boulevard 10-year projection

Mode of Transportation	2024	2025	2026	2027	2028
Cars	105,597.52	108,829.86	112,161.14	115,594.40	119,132.74
SUV	3,136.76	3,232.78	3,331.73	3,433.72	3,538.82
Jeepney	99.96	102.42	104.95	107.54	110.20
Bus	1,370.47	1,402.28	1,434.82	1,468.13	1,502.20
Trailer	4,712.47	4,817.08	4,924.02	5,033.34	5,145.08
Truck	2,250.70	2,300.66	2,351.74	2,403.95	2,457.32
Special Vehicle (Tricycles)	100,658.80	102,995.09	105,385.60	107,831.60	110,334.38
Motorcycle	151.81	155.33	158.94	162.63	166.40

Table 5.3. R:1 Roxas Boulevard 10-year projection

Mode of Transportation	2029	2030	2031	2032	2033
Cars	122,779.39	126,537.67	130,410.99	134,402.87	138,516.94
SUV	3,647.15	3,758.79	3,873.84	3,992.42	4,114.63
Jeepney	112.92	115.70	118.56	121.48	124.48
Bus	1,537.07	1,572.74	1,609.25	1,646.60	1,684.81
Trailer	5,259.30	5,376.05	5,495.40	5,617.40	5,742.11
Truck	2,511.87	2,567.63	2,624.63	2,682.90	2,742.46
Special Vehicle (Tricycles)	112,895.24	115,515.54	118,196.65	120,939.99	123,747.01
Motorcycle	170.26	174.22	178.26	182.40	186.63

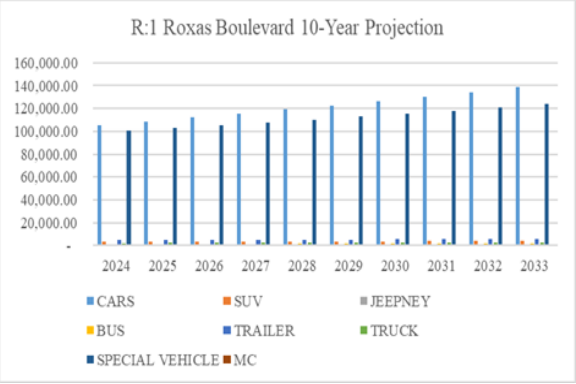

Figure 6. R:1 Roxas Boulevard 10-year projection graph.

R:2 Taft Avenue 10-year projection using 2022 AADT

Table 6.1. R:2 Taft Avenue 10-year projection

Mode of Transportation	Passenger Car Equivalent Factor (PCEF)	Traffic Count	PCU	Growth Rate
Cars	1	78865	78865	0.03061
SUV	1.2	7648	9177.6	0.03061
Jeepney	1.4	14622	20470.8	0.02468
Bus	2.2	1174	2582.8	0.02321
Trailer	2.2	164	360.8	0.0222
Truck	2	1647	3294	0.0222
Special Vehicle (Tricycles)	1.2	83705	100446	0.02321
Motorcycle	0.5	6639	3319.5	0.02321

Table 6.2. R:2 Taft Avenue 10-year projection

Mode of Transportation	2024	2025	2026	2027	2028
Cars	83,767.01	86,331.12	88,973.71	91,697.20	94,504.05
SUV	9,748.05	10,046.44	10,353.96	10,670.90	10,997.53
Jeepney	21,493.71	22,024.17	22,567.73	23,124.70	23,695.42
Bus	2,704.08	2,766.85	2,831.07	2,896.77	2,964.01
Trailer	377.00	385.37	393.92	402.67	411.61
Truck	3,441.88	3,518.29	3,596.39	3,676.23	3,757.84
Special Vehicle (Tricycles)	105,162.81	107,603.64	110,101.12	112,656.57	115,271.33
Motorcycle	3,475.38	3,556.04	3,638.58	3,723.03	3,809.44

Table 6.3. R:2 Taft Avenue 10-year projection

Mode of Transportation	2029	2030	2031	2032	2033
Cars	97,396.82	100,378.14	103,450.71	106,617.34	109,880.89
SUV	11,334.17	11,681.11	12,038.66	12,407.17	12,786.95
Jeepney	24,280.22	24,879.46	25,493.48	26,122.66	26,767.37
Bus	3,032.80	3,103.19	3,175.22	3,248.92	3,324.32
Trailer	420.74	430.08	439.63	449.39	459.37
Truck	3,841.27	3,926.55	4,013.71	4,102.82	4,193.90
Special Vehicle (Tricycles)	117,946.78	120,684.32	123,485.40	126,351.50	129,284.12
Motorcycle	3,897.86	3,988.33	4,080.90	4,175.61	4,272.53

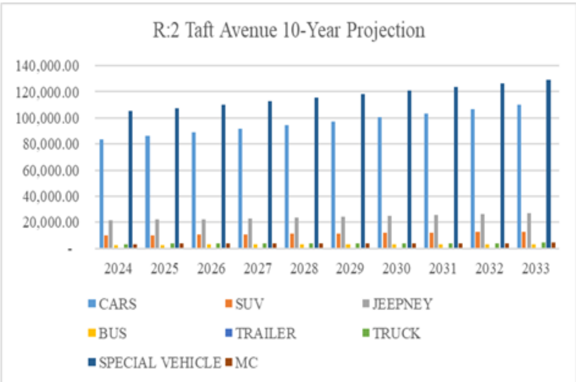

Figure 7. R:2 Taft Avenue 10-year projection graph.

R:9 Rizal Avenue 10-year projection using 2022 AADT

Table 7.1. R:9 Rizal Avenue 10-year projection

Mode of Transportation	Passenger Car Equivalent Factor (PCEF)	Traffic Count	PCU	Growth Rate
Cars	1	32742	32742	0.03061
SUV	1.2	28	33.6	0.03061
Jeepney	1.4	7154	10015.6	0.02468
Bus	2.2	26	57.2	0.02321
Trailer	2.2	15	33	0.0222
Truck	2	2531	5062	0.0222
Special Vehicle (Tricycles)	1.2	54799	65758.8	0.02321
Motorcycle	0.5	1813	906.5	0.02321

Table 7.2. R:9 Rizal Avenue 10-year projection

Mode of Transportation	2024	2025	2026	2027	2028
Cars	34,777.14	35,841.67	36,938.79	38,069.48	39,234.79
SUV	35.69	36.78	37.91	39.07	40.26
Jeepney	10,516.07	10,775.61	11,041.55	11,314.05	11,593.29
Bus	59.89	61.28	62.70	64.15	65.64
Trailer	34.48	35.25	36.03	36.83	37.65
Truck	5,289.25	5,406.67	5,526.70	5,649.39	5,774.81
Special Vehicle (Tricycles)	68,846.75	70,444.68	72,079.70	73,752.67	75,464.47
Motorcycle	949.07	971.10	993.64	1,016.70	1,040.29

Table 7.3. R:9 Rizal Avenue 10-year projection

Mode of Transportation	2029	2030	2031	2032	2033
Cars	40,435.77	41,673.50	42,949.13	44,263.80	45,618.72
SUV	41.50	42.77	44.07	45.42	46.81
Jeepney	11,879.41	12,172.59	12,473.01	12,780.84	13,096.28
Bus	67.17	68.72	70.32	71.95	73.62
Trailer	38.48	39.34	40.21	41.10	42.02
Truck	5,903.01	6,034.05	6,168.01	6,304.94	6,444.91
Special Vehicle (Tricycles)	77,216.00	79,008.19	80,841.97	82,718.31	84,638.20
Motorcycle	1,064.44	1,089.15	1,114.42	1,140.29	1,166.76

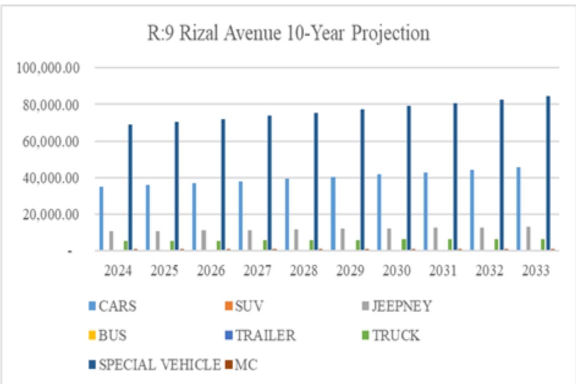

Figure 8. R:9 Rizal Avenue 10-year projection graph.

3.3 Simulation of C:1 Recto in Simulation of Mobile Utilization (SUMO)

For the simulation, the researchers used the AADT 10-year projection of C:1 Recto as data to be used. The specific area the researchers chose /’for the simulation is the intersection of R:9 Rizal Avenue and C:1 Recto, which has many commuters due to LRT lines 1 and 2. The Through Traffic Factor (TTF) indicates how many vehicles depart and arrive at the boundary of the simulation area. This setting was at five (5) to make way for the existing vehicles in the simulation area. One key disadvantage of SUMO is that it needs to recognize tricycles and trailers. Therefore, only primary vehicles such as cars, trucks, buses, and motorcycles are generated in the simulation. The researchers added pedestrians, but only to a limited amount since the study focuses more on vehicles.

Figure 9. Simulation settings for C:1 Recto 10-Year Projection.

The result of the simulation is showcased in the image below. C:1 Recto experienced a heavily congested scenario, which is expected since the number of vehicles that travel on this road significantly increased throughout the 10-year projection. One of the assumptions mentioned in this paper is that no road widening or construction will be made throughout the following years. As evident in the simulation, there is almost no movement of cars on the road, but motorcycles can still move from time to time. The congestion is mainly attributed to the increased number of vehicles and the need for proper traffic management. If public transportation is improved during the 10-year projection, more and more people will be able to buy their own vehicles, resulting in the following scenario. ITS utilization can also be a critical factor in solving this problem in the future since it is crucial in traffic flow management.

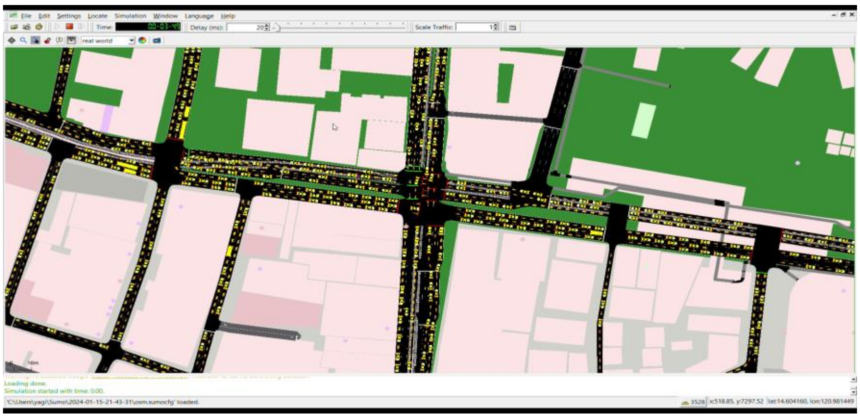
Figure 10. Simulation of C:1 Recto 10-Year Projection.

3.3.1 Impending Effect of Public Utility Vehicle Modernization Program (PUVMP)

According to the Land Transportation Franchising and Regulatory Board (LTFRB, n.d.), the PUV Modernization Program is the government's response to the impending problem of traditional PUVs. It also deals with the future of public transportation in the country. The goal of the PUVMP is to make the country's public transportation on par with those of other countries. To quote, "The program aims to fundamentally transform the public transport system in the country, making both commuting and public transportation operations more dignified, humane, and on par with global standards." The PUVMP also aims to provide Filipinos with a safe, efficient, reliable, convenient, affordable, climate-friendly, and environmentally sustainable mode of transportation.

With this in mind, if the government implements the program, the country will experience a dramatic decline in the number of PUVs. These, especially jeepneys, are by far the country's most common type of transportation in the country. If the program is to be implemented, the number of private cars or other vehicles on the road will drastically change, whether it will increase or decrease. In essence, the projection of the AADT in this paper should be taken moderately since it does not necessarily represent the number of vehicles on the road in the years of projection. For example, if jeepneys were to be phased out, most commuters would be forced to take another mode of transportation, such as buses, which would increase the number of buses on the road. This phenomenon can be said for all modes of transportation.

3.4 Future applications of current Intelligent Transport System

In the fourth phase, the authors wanted to explore the future possibilities of different applications of ITS that can be used to further ease the congestion in Manila. One such example of improvement for ITS was Vehicle-to-Infrastructure (V2I) communication, wherein vehicles could communicate to ITS devices and be their eyes and ears on the road. This allowed for real-time data if there were any congestion or traffic accidents that the TMC may not have been informed about due to proximity or other factors. Another future application can be made to future car models to be made that would have Vehicle-to-Vehicle (V2V) communication. This feature can be crucial since it will reduce the occurrences of the so-called “phantom traffic” that occur when cars are tailgating from one another.

3.5 Implementation of Intelligent Transport System in Real Life

The main objective of phase 5 is for the paper to be submitted to the local government of Manila and be used as a guide in creating a more efficient traffic flow in the city. However, due to time constraints and the lack of operational abilities of the software to manually control the traffic lights in the simulation, this was not achieved.

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

Reiterating the main objective of this research, to develop and apply the integration of the Intelligent Transportation System and Four-Step Model to increase road efficiency, reduce travel time, and increase the overall safety and convenience of the road to all its users. Lanke (2013) emphasized that congestion occurs when the volume of cars exceeds the capacity of the road. According to Lin et. al. (2017), ITS is a great way to minimize these congestions by making a more efficient traffic flow and improving the traffic management on the road. Highlighted in this study is the projection of the number of cars on specified roads in Manila. The Annual Average Daily Traffic data was used to perform a 10-year projection on the volume of cars on the road. By simulating these projections, the researchers conclude the following:

- The Average Daily Traffic Volume data that was used to project the number of vehicles in the next years in this study was collected from the Metropolitan Manila Development Authority. The AADT represents the number of vehicles that traversed through a specific road within a time period, in this study's case, annually.
- Various studies have shown that using AADT as a means to forecast traffic volume is viable and requires an extensive number of calculations and modeling to perform. In the case of this paper, the researchers opted to use a simple growth rate equation based on the PCEF and PCU mandated by the government.
- The number of vehicles in the future will tremendously grow exponentially if the trajectory of growth rate of the vehicles will continue in the next 10 years. Adding to the fact that PUVMP is on the horizon, it is only a matter of time till most of the road users (including pedestrians) will drive their own vehicles because of lack of transportation means.
- Without further improvement on the road infrastructures and traffic management tools, congestion will be evident in the future due to the increase in vehicles and road users.

4.2 Recommendation

Future researchers who intend to advance learning on ITS shall consider the following recommendations. In order to further enhance this research, it could be beneficial for researchers in the future to carry out more simulations and use a more robust and complete simulation, such as PTV Vissim and the like. Also, using actual traffic counts of the number of automobiles, pedestrians, and bicycle traffic on particular routes, scholars can understand traffic trends, pinpoint areas of high traffic, and create more potent approaches to enhance traffic movement. Finally, an in-depth analysis of how innovative technologies like real-time data analytics and adaptive traffic signal control are integrated is necessary to comprehend the advantages and difficulties of intelligent transportation systems fully.

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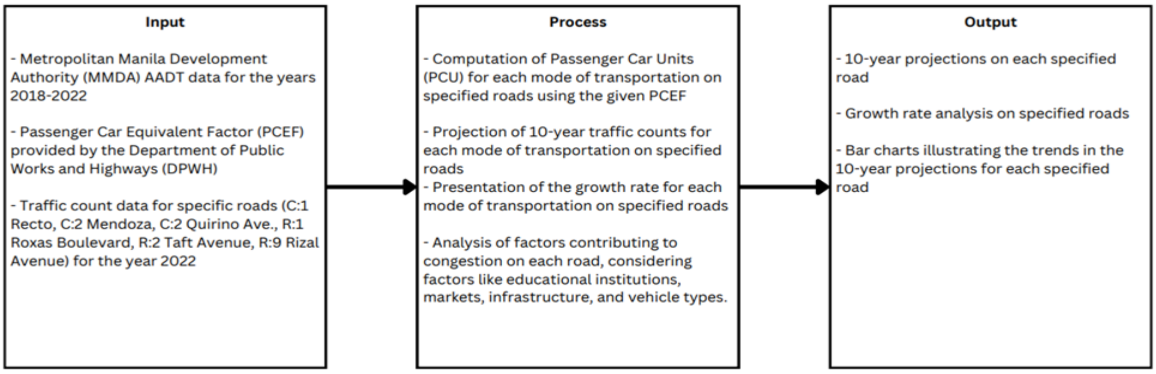
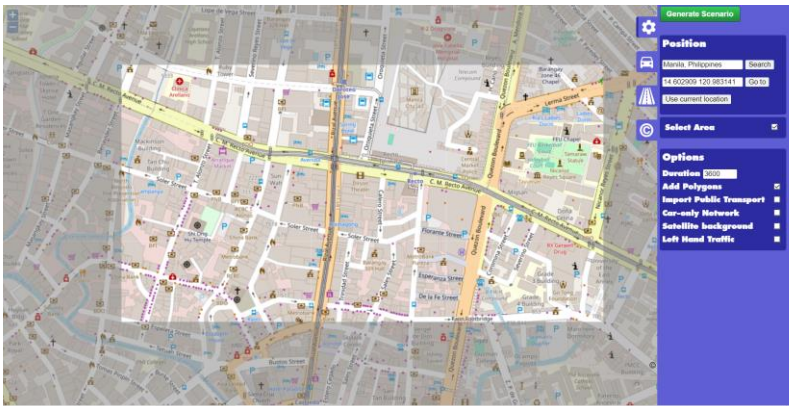
APPENDICES



APPENDIX A. Input-Process-Output diagram



APPENDIX B. Recto Avenue traffic options in SUMO.

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