IMPACTS OF EXTREME FLOODING EVENT ON THE VOLUME-TO-CAPACITY RATIO OF SELECTED ROAD NETWORKS: THE CASE OF TUGUEGARAO CITY

Ralph Angelo ESTILLER [a], Emer QUEZON [b], John Michael CASIBANG [c]

[a,b,c] *College of Engineering and Architecture, Cagayan State University-Carig Campus, Tuguegarao City, Philippines*
[a] *engr_raffy29@yahoo.com*
[b] *rde@csucarig.edu.ph*
[c] *jmcasibang@csu.edu.ph*

Abstract: Land transportation networks such as roads and other transportation facilities underpin socioeconomic development of communities by enabling fast and efficient movement of goods and people from one point to another. However, like any other infrastructures road networks are also vulnerable to natural calamities such as earthquakes and floods that disrupts the natural flow of traffic. In the occurrence of flooding incidents, several road networks are submerged in water making it impassable for traffic especially those located in low-lying areas. In this cases, traffic that were originally catered by these flooded roads will be re-routed to other alternate routes which will then affect the traffic performance of those alternate routes.
This study assessed the effect of flooding events on the traffic stream performance measured through its Level of Service (LOS). Greenshields's linear modelling was used to estimate the maximum capacity of roads based on observed data and the corresponding volume-to-capacity ratio during normal weather condition and using travel survey to estimate the additional re-routed volume to assess the volume-to-capacity ratio during flooding events. The v/c ratio for Enrile Avenue changes from 0.483 (LOS B) to 0.515 (LOS C), while the v/c ratio for Maharlika Highway changes from 0.541 (LOS C) to 1.257 (LOS F), and Lastly, Luna extension's v/c ratio increases from 0.523 to 0.590, though the LOS remains the same.
The researcher concluded that the Level of Service (LOS) in the three selected road sections were greatly affected as their v/c ratio increases. Moreover, formulating and enforcing policies on roadway clearing operations especially on the outer lanes of all major roads could help improve the traffic performance of this roads even during flooding events.

Keywords: *Level of Service, Traffic Stream Modelling, Traffic Performance, Flooding events, volume-to-capacity ratio*

1. INTRODUCTION

1.1. Background/Rationale of the Study

Land transportation networks such as roads and transportation facilities underpin socioeconomic development of communities by enabling fast and efficient movement of goods and people from one point to another. However, like any other infrastructures, road networks are also vulnerable to natural calamities such as earthquakes and floods that disrupts the natural flow of traffic. This disruption of traffic flow often leads to irregular traffic movement thus causing moderate to severe traffic congestion especially on major arterials.

Flooding is one of the most destructive natural calamities that causes significant damages in the field of agriculture and infrastructures every year especially in countries belonging to the Asia Pacific region where most of world's destructive typhoons develop (Khurana et.al, 2017). Correspondingly, in a report published by the Philippine Astronomical Geophysical and

Astronomical Services Administration (DOST-PAGASA), there are more tropical cyclones (TCs) that enters the Philippine Area of Responsibility (PAR) than anywhere else in the world with an average of twenty TCs entering this region annually, with about eight or nine of these tropical cyclones crossing the Philippine archipelago (pagasa.dost.gov.ph). Due to this intensified rains brought by these typhoons coupled with the effect of climate change, flooding incidents in the Philippines are even more destructive leaving significant damages to the agriculture and infrastructure sector and even affecting the economy in the long run.

The Cagayan Valley Region is the second largest Philippine administrative region in terms of land area located at the north-eastern portion of the mainland Luzon. Its mainland area is situated between the Cordilleras and the Sierra Madre mountain ranges which is drained by the Philippines' longest river system--the Cagayan River. During the occurrences of heavy rainfall, significant volume of storm water runs down from the two mountain ranges causing overflowing of the Cagayan River leaving the areas along the Cagayan River especially those situated in the low-lying areas under water. In addition to the water coming from the mountain ranges, the Magat Dam, whenever it reaches its critical level, open its gates releasing enormous volume of water to the Cagayan River, making the flash floods even worse for those towns and barangays located along the Cagayan River including Tuguegarao City.

In the occurrence of flooding incidents in the City, several road networks are submerged in water making it impassable for traffic especially those located in low-lying areas. In this cases, traffic that were originally catered by these flooded roads will be re-routed to other alternate routes which will then affect the traffic performance of those alternate routes. Aside from its impact on the traffic performance, flooding also cause damages to the road pavement and even causes scouring of the base and sub-base courses of roads (Oyediji et al., 2019).

In traffic engineering, mobility and accessibility are the key measures of vulnerability of transportation networks during natural calamities. Both mobility and accessibility is limited during the occurrences of extreme flooding events, which makes it difficult to travel due to some impassable roads which often results to multiple traffic re-routing. Due to these changes in trip/route assignments, alternate routes becomes congested, and the corresponding volume-to-capacity ratio of highways increases significantly which results to the change in its Level of Service (Othman et.al, 2014). To further understand the effect of flooding on the traffic stream characteristics or performance of roads, it is necessary to conduct comprehensive studies on traffic stream behaviour during flooding events and assess the driver's route choice behaviour.

The route choice behaviour of road users could help us understand the possible effect of flooding events on the traffic performance of other alternate routes, and could help Local Government Units in their planning and policy formulation especially those policies regarding improvement of traffic performances of the City's main arterials.

Hence, this study will assess traffic performance of select roads by comparing their Level of Service (LOS) during normal weather condition with that of the LOS during flooding events. The Level of Service (LOS) is a method used to qualitatively describe the traffic flow condition of road networks and is often conducted to assess and improve traffic performances on a given road section (Pandey et.al, 2022). The result of this research study will help provide road users with idea on the possible traffic scenario on other available alternate routes when their usual route is no longer available due to flooding events.

1.2. Objectives/Statement of the Problem

The main objective of this study is to determine the effects of extreme flooding events on traffic Level of Service (LOS) in Tuguegarao City.

Specifically, it aims to:

a. Study the spot speeds and traffic flow volume during morning peak hour on normal traffic flow condition.
b. Analyze traveler's travel behavior using a structured travel survey.
c. Derive the traffic Stream Models and estimate the maximum capacity of the road networks to be studied.
d. Determine and compare the Level of Service (LOS) of the selected road networks during normal conditions and during extreme flooding events.

1.3. Conceptual/Theoretical Framework

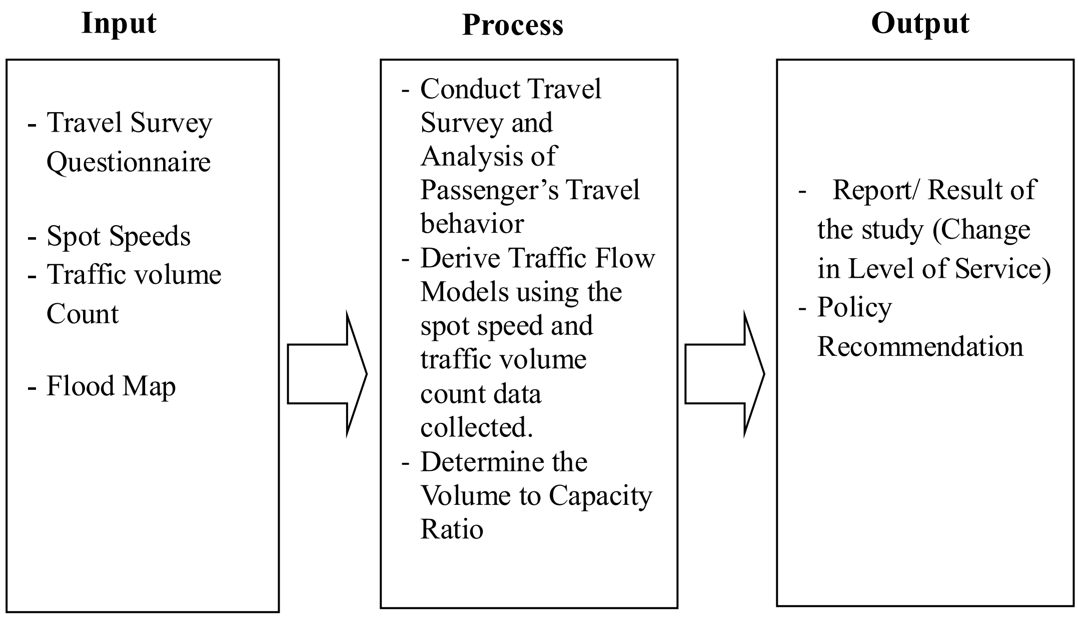

Figure 1-1. *Paradigm of the Study*

The main objective of this study is to assess the changes in traffic flow characteristics during the occurrence of flooding. The Level of Service (LOS) will be used as the unit of measure. This was achieved by comparing the volume to capacity ratio of the roads/highways during regular or normal traffic condition with that of the Level of Service during extreme flooding events. In determining the LOS of the road networks, the traffic volume and the corresponding space mean speeds were gathered through traffic volume count and manual spot speed study respectively which was conducted during peak hour period under mixed traffic conditions. The data gathered were analyzed using the Greenshields's Linear modelling to determine the maximum capacity of the road which was then used in estimating the volume to capacity ratio.

In estimating the additional volume re-routed during flooding incidents, a comprehensive travel demand questionnaire was designed and used. The volume derived in this survey was considered to be the representative traffic volume during extreme flooding events and was used in estimating the volume to capacity ratio.

2. PROCEDURE/METHODOLOGY

2.1. Research Design

The researcher used a mixed-method observational study using combination of qualitative and quantitative approach in the study employing different data collection techniques specifically in conducting travel survey. A structured Travel Survey questionnaire was designed specifically to determine or estimate the travel demand during the occurrence of extreme flooding events. A descriptive statistics was used to examine the broad inquiries regarding respondent's social information and travel behavior.

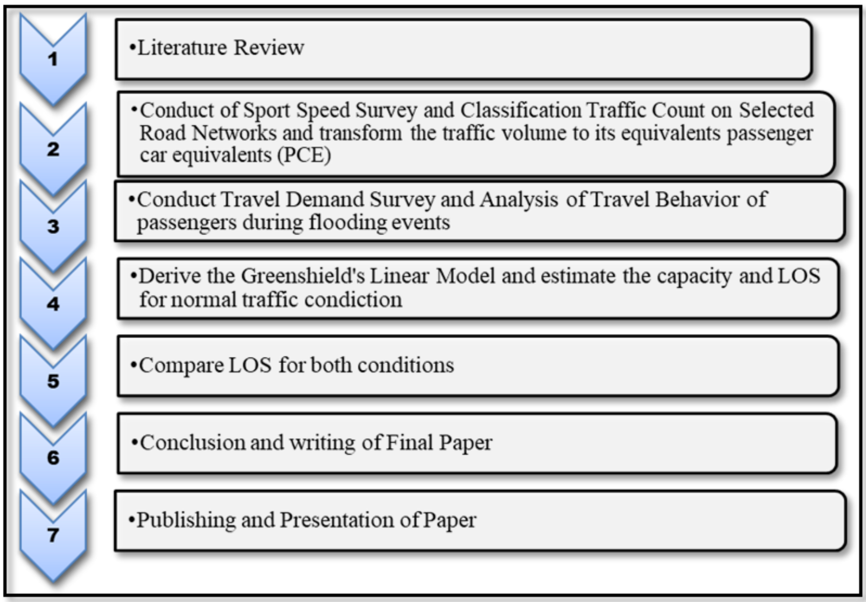

Figure 2.1: *Research Design Process*

First Objective:

The Level of Service (LOS) of the road networks during normal traffic condition was determined using Greenshields's Linear Modelling and the volume to capacity ratio having both spot speed and travel volume as input variables. The spot speed survey and traffic volume count was conducted during morning peak hour and the maximum capacity of each of the roads was derived using Greenshields's linear modelling. Manual method in Spot Speed study was employed using a trap length of 40m which was drawn transversely on the pavement and a stopwatch is then used to measure the corresponding travel time spent by the vehicle within the "trap" and the clock reading was recorded in the spot speed survey form. The speed of each vehicle was computed by dividing the trap length by the travel time (Sigua, 2008). The spot speed data collected was summarized in a frequency table and the data was grouped together in a predetermined class intervals, and the distributions are calculated.

Meanwhile to determine the hourly traffic volume, a classification traffic volume count (mid-block counts) on a morning peak hour during normal traffic flow conditions was conducted using tallying method. A short-term count (15-minute) was employed which is the most suitable type of volume count method used to estimate maximum flow rate and determine the characteristics of peak hour volume.

Morning peak hour was considered in this study because this time reflects the highest and most consistent travel demand within a typical day. During the morning peak, road networks experience heavy movements from workers, students, public transport vehicles, and service providers, making it the period when traffic flow is most sensitive to disruptions (Cherrett, T., & McDonald, M. 2002). This time of day captures the highest traffic flow in the area, as it coincides with people commuting to work and attending school.

Second Objective:

To estimate the traffic volume during flooding events, a structured travel survey questionnaire was designed. Details such as passenger Trip Characteristics and factors affecting travel decision during flooding events was determined using the questionnaire.The computed volume is then added to the peak hourly volume road sections and the corresponding v/c ratio during flooding events was estimated.

The semi-structured questionnaire was developed to assess trip characteristics of the respondents during flooding events (Appendix A). Roadside survey was employed to gather data. Drivers and commuters were chosen as respondents for this study because they are the primary users of the road networks being evaluated. Their daily travel routines expose them directly to the impacts of extreme flooding events, particularly in terms of congestion, delays, changes in route choice, and overall travel experience. Because they experience real-time traffic conditions, they can provide reliable insights into how flooding affects the volume of vehicles using the roads, the availability of passable routes, and the resulting changes in roadway capacity.

The instrument was structured into two parts:

1. Part I: Profile of Respondents

Part I was gathering of demographic and economic data, including age, gender, and driving license type.

2. Part II: Trip Characteristics

Part II consisted of six (6) questions designed to gather information on the respondents' trip characteristics, specifically the routes they usually take when traveling for work, school, or other purposes.

Third Objective:

The maximum highway capacity of each of the road can be estimated using Greenshields's Linear Model supplying it with both the traffic data (volume and speed) collected during the field surveys (Sigua, 2008). The traffic volume to be supplied must be converted to its equivalent passenger car units (PCU values) to have uniform operational conditions as a single heavy vehicle of a particular type under identical roadway, traffic, and control conditions. This relationship is can be modelled through the equation:

$$\mu = \mu_f(1 - \frac{k}{k_j}) \qquad (1)$$

Where: $\mu_f =$ Free flow speed

$k_j =$ Jam Density

The relation between the spot speed data and the corresponding traffic volume collected through traffic studies will be analyzed using linear regression and derive the best-fit line that represents the data points with the least error. The statistical functions in Microsoft excel will be utilized to perform this operation. The correlation coefficient, R will also be determined in order to statistically measure of the strength of a linear relationship between the speed and volume of traffic. It can be evaluated using the Pearson's product moment correlation coefficient.

After deriving the equation of the regression line that best represents the collected traffic data, the free-flow speed and the jam density can be obtained using the same equation.

Fourth Objective:

The Level of Service (LOS) is a term used to qualitatively describe the operating conditions of a roadway based on factors such as travel speed, travel time, maneuverability, delay, and safety (Sigua, 2008). It can be computed using the formula:

$$LOS = v/c \tag{2}$$

Where v, is the peak hour volume and c, is the capacity of the highway. The level of service of multilane highways can be determined using the condition indices shown in the table below

Table 1: *Level of Service Condition Indices or criteria*

LOS	*Traffic Condition*	*v/c ratio*
A	Free Flowing traffic	0-0.20
B	Stable Flow with unaffected speed	0.21-0.50
C	Stable Flow but speed is affected	0.51-0.70
D	High-density but stable flow	0.71-0.85
E	Traffic volume near or at capacity level with low speed	0.86-1.0
F	Breakdown Flow	>1.0

Source: *Department of Public Works and Highways Department Order no. 22 series of 2013.*

3. RESULTS/FINDINGS AND DISCUSSIONS

3.1 Profile of Respondents

3.1.1. Gender

Table 3.1 shows the frequency distribution of the respondents' gender based on the total sample size of 403. Most respondents are male, with a frequency of 271 (67.25%), while female respondents has a frequency of 132 (32.75%). This indicates that male road users dominates the roads of Tuguegarao City.

Table 2: *Frequency Distribution of Respondent's Gender*

Gender	*Frequency*	*Percentage*
Male	271	67.25%
Female	132	32.75%
TOTAL	403	100.0%

3.1.2. Age

Table 3.2 presents the frequency distribution of the respondent's age gathered from a sample of 403 respondents. The results show that majority of the respondents are aged 21 30 years old, with a frequency of 180 (44.67%), followed by respondents aged 31-40, years old with a frequency of 75.0 (18.61%) and so on. The smallest age group of respondents are those aged more than 60 years old, with a frequency of 8.0 (1.99%). This indicates that road users or drivers are from different age brackets.

Table 3: *Frequency Distribution of Respondent's Age*

Age Group	*Frequency*	*Percentage*
20 years old and below	64.0	15.88%
21-30 years old	180.0	44.67%
31-40 years old	75.0	18.61%
41-50 years old	57.0	14.14%
51-60 years old	19.0	4.71%
More than 60 years old	8.00	1.99%
TOTAL	403	100.0%

3.1.3. Driving License Type

The Table 3.3 shows the frequency distribution of the respondent's driving license type gathered from a 403 respondents. It can be noted that majority of the respondents have a Non-Professional Driver's license with a frequency of 240 (59.55%), followed by Professional Driver's License holder with a frequency of 93 (23.08%), then those with Student permit with a frequency of 70 (17.37%). This data shows that almost all of driver's in the City of Tuguegarao have driving license.

Table 4: *Frequency Distribution of Respondents' Driving License Type*

Driving License Type	*Frequency*	*Percentage*
Professional	93.0	23.08%
Non-professional	240.0	59.55%
Student Permit	70.0	17.37%
TOTAL	403	100.0%

3.2 Trip Characteristics

3.2.1. Primary mode of Transport

Table 3.4 shows the frequency distribution of respondent's primary mode of transport used in going to work or school. Results show that tricycle is the dominating mode of transport used with frequency of 179 (44.42%). Followed by motorcycle with frequency of 154 (38.21%), then private car with frequency of 65 (16.12%) and so on. Alternative mode of transport like bicycle is also used by minority of travelers with frequency of 1.0 (0.25%). This indicates that the dominating transportation modalities in Tuguegarao City are tricycles and motorcycles respectively.

Table 5: *Frequency Distribution of Respondent's Daily Mode of Transportation*

Mode of Transport	*Frequency*	*Percentage*
Tricycle	179	44.42%
Private Car	65.0	16.12%
Motorcycle	154	38.21%
Bicycle	1.0	0.25%
Heavy Vehicles	2.0	0.50%
TOTAL	403	100.0%

3.2.2. Trip Purpose

The data shown in Table 3.5 shows the frequency distribution of the respondent's usual trip purpose. The results of the study shows that attending school is the primary trip purpose of the respondents having a frequency of 218 (54.09%), followed by work-related trip purpose with a frequency of 131 (32.51%), recreational/social with frequency of 42 (10.42%) and shopping with frequency of 10 (2.48%). There were also respondents whose trip purpose was to attend to errands with frequency of 2.0 (0.50%). This indicates that majority of the respondents are students and office workers from the regional government center and originating from different zones.

Table 6. *Frequency Distribution of Respondent's Trip Purpose*

Trip Purpose	*Frequency*	*Percentage*
Work-related	131	32.51%
Attend School	218	54.09%
Recreational/Social	42.0	10.42%
Shopping	10.0	2.48%
others	2.00	0.50%
TOTAL	403	100.0%

3.2.3. Route Choice of travelers during Normal Weather Condition

Table 3.6 shows the route choice of travelers during normal weather conditions. Based on the results, The Linao-Carig Road is the most popular route for the respondents having a frequency of 172 (42.67%), followed by Macapagal Avenue with frequency of 78 (19.35%), Diversion Road with frequency of 77 (19.11%), Atulayan Road with frequency of 30 (7.44%) and lastly, Cataggamman-Pallua Highway with frequency of 7.00 (1.74%). The Linao-Carig Road is one of the most travelled alternate route in the city which connects western barangays to Carig Regional Government Center, bypassing the City's Central Business District. Macapagal Avenue is also one of the popular route for travelers originating from the Eastern barangays.

Table 7. *Frequency distribution of respondent's route choice during normal weather condition*

Route Choice	*Frequency*	*Percentage*
Pallua-Buntun Highway	39.0	9.68%
Macapagal Avenue	78.0	19.35%
Atulayan Road	30.0	7.44%
Linao-Carig Road	172.0	42.67%
Diversion Road	77.0	19.11%
Cataggamman-Pallua Highway	7.00	1.74%
TOTAL	403	100.0%

3.2.4. Route choice of travelers during flooding events

The table below shows the frequency distribution of the respondent's route choice during flooding events. Based on the results, majority of the respondents choose to use Maharlika Highway during flooding events when their usual route is not passable with a frequency of 226 (56.08%), followed by Enrile Avenue with frequency of 91 (22.58%), and Luna Extension with a frequency of 86.0 (21.40%).

Table 8. *Frequency distribution of respondent's route choice during flooding events.*

Route Choice	*Frequency*	*Percentage*
Enrile Avenue	91.0	22.58%
Luna Extension	86.0	21.40%
Maharlika Highway	226.0	56.08%
TOTAL	403	100.0%

3.3 Level of Service during Normal Traffic Condition

3.3.1. Traffic volume during normal traffic condition

The Level of Service (LOS) of the road networks were computed based on the volume to capacity ratio. The corresponding capacity of each road networks were estimated using the Greenshields's Linear Modeling. The traffic volume and spot speed data were gathered through traffic studies conducted during morning peak hour (from 6:00AM to 10:00AM) last May 03, 2023 (Wednesday). Abnormal traffic situation such as adverse weather condition and unusually heavy traffic condition was avoided in setting the date for traffic study to avoid bias in the data collection. Manual peak period counts was employed in traffic volume count and the data collected were then converted to its equivalent Passenger Car Equivalents.

Based on the traffic volume count conducted along Enrile Avenue, the peak fifteen (15) minute count happens between 7:45AM to 8:00AM with PCU value of 439.5 dominated by tricycle with PCU value of 227.5, followed by passenger cars with PCU of 110.0 while it can also be noted that there were no jeepneys, bus and bicycle passing through this section during the said 15-minute count. The Enrile Avenue is one of the major highways found in the Regional Government Center where most offices are located.

Maharlika Highway has the highest 15 minutes count happening between 7:30AM-7:45AM with a PCU value of 659.50 which is composed of tricycles with a total PCU value of 412.5 followed by passenger cars with PCU value of 163.0, motorcycles with PCU value of 65.5, medium truck with PCU value of 8.0, large truck with PCU value of 5.0 and so on. The Maharlika Highway is one of the major highways in the City of Tuguegarao that leads to the Regional Government Center, Cagayan State University Carig Campus, Cagayan Valley Medical Center and offices.

Luna Extension has the highest 15 minute count happening between 8:00AM-8:15AM having tricycle as the dominating mode of transport with a PCU value of 195.0 followed by motorcycle with a PCU value of 77.50, passenger car with a PCU value of 59.0 and so on.

3.3.2 Spot Speed during normal traffic condition

The spot speeds or the time mean speeds were gathered using a trap length of forty (40) meters. Eighty (80) vehicles were considered every hour (from 6:00AM to 10:00AM) to cover all representative vehicles passing through the given section of the road. The data collected were summarized in a frequency table and the data were grouped together in predetermined class intervals and corresponding distributions were calculated. Please refer to the frequency table of the speeds during the peak hours shown in the tables below.

Table 9: *Spot Speed frequency table for Enrile Avenue during morning peak hour*

Speed Class	**Mid-Class, x**	**Frequency, f**	**% frequency**	**Cum. frequency**	**f*x**	**f*x^2**
25.53-31.48	28.5	8	10.0	10.0	228.0	6498
31.49-37.44	34.46	21	26.25	36.25	723.66	24937.3236
37.45-43.40	40.42	15	18.75	55.00	606.30	24506.646
43.41-49.36	46.38	13	16.25	71.25	602.94	27964.3572
49.37-55.32	52.34	13	16.25	87.5	680.42	35613.1828
55.33-61.28	58.3	8	10.0	97.5	466.40	27191.12
61.29-67.24	64.26	1	1.25	98.75	64.26	4129.3476
67.25-73.10	70.22	1	1.25	100.0	70.22	4930.8484
	TOTAL	80.00	100		3442.2	155770.82

The Table 9 presented above is the spot speed frequency table for the peak hour volume along Enrile Avenue. The maximum speed recorded was 73.10 kph and the minimum speed was 25.53 kph. The mean speed is computed to be at 43.03 kph with standard deviation of 9.85.

Table 10: *Spot Speed frequency table for Maharlika Highway during morning peak hour*

Speed Class	Mid-Class, x	Frequency, f	% frequency	Cum. frequency	f*x	f*x²
9.36-13.08	11.22	1	1.25	1.25	11.22	125.8884
13.09-16.81	14.95	7	8.75	10	104.65	1564.5175
16.82-20.54	18.68	19	23.75	33.75	354.92	6629.9056
20.55-24.27	22.41	27	33.75	67.5	605.07	13559.6187
24.58-28.3	26.44	19	23.75	91.25	502.36	13282.3984
28.31-32.03	30.17	1	1.25	92.5	30.17	910.2289
32.04-35.76	33.9	2	2.5	95	67.8	2298.42
35.77-39.13	37.63	4	5	100	150.52	5664.0676
	TOTAL	80.00	100		1826.71	44035.05

Table 10 presents the spot speed frequency table for the morning peak hour at Maharlika Highway. The recorded maximum spot speed was 39.13 kph while the minimum spot speed recorded was 9.36 kph. The computed mean speed was 22.83 kph with a standard deviation of 5.42.

Table 11: *Spot Speed frequency table for Luna Extension during morning peak hour*

Speed Class	Mid-Class, x	Frequency, f	% frequency	Cum. frequency	f*x	f*x²
14.90-17.19	16.05	13	16.25	16.25	208.65	3348.8325
17.20-19.49	18.35	11	13.75	30.00	201.85	3703.9475
19.50-21.79	20.65	13	16.25	46.25	268.45	5543.4925
21.80-24.09	22.95	20	25.00	71.25	459.0	10534.05
24.10-26.39	25.25	8	10.0	81.25	202.0	5100.5
26.40-28.69	27.55	5	6.25	87.50	137.75	3795.0125
28.70-30.99	29.85	6	7.50	95.00	179.1	5346.135
31.00-33.29	32.15	4	5.00	100.0	128.6	4134.49
	TOTAL	80.00	100		1785.4	41506.46

The spot speed frequency table for the morning peak hour along Luna Extension is presented in Table 4.14. The maximum recorded speed for this hour was 33.23 kph and the minimum recorded speed was 14.90 kph. The computed mean speed was 22.32 kph with standard deviation of 4.59.

3.3.3. Volume to Capacity Ratio

The volume to capacity ratio for each of the following road sections were computed using the Greenshields's Linear Model. The peak hour volume for each of the road sections is considered as the peak volume for the road

Figure 1 *Speed-Density Relationship using Greenshields's Linear Modeling for Enrile Avenue.*

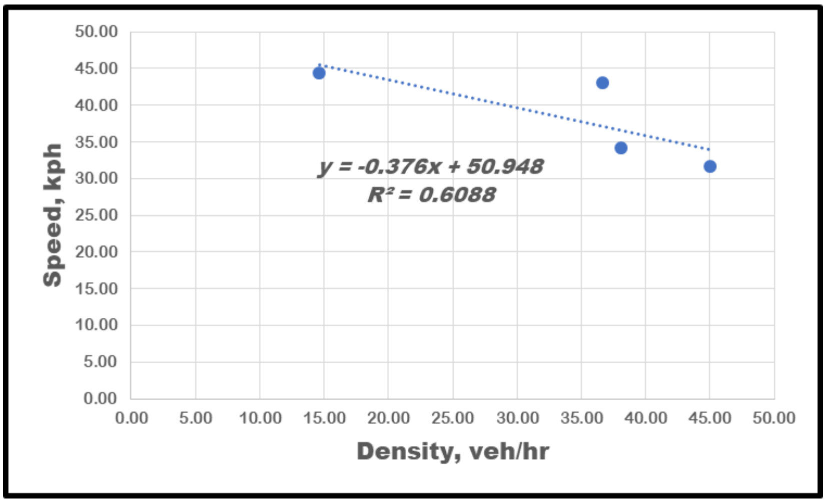

Figure 1 presents the speed-density relationship on Enrile Avenue. The derived relationship was used to estimate the free-flow speed and the corresponding jam density which are used to compute the maximum capacity of the road. The maximum capacity for Enrile Avenue was computed to be 3451.73 veh/hour and the resulting volume-to-capacity ratio is 0.4832 which corresponds to Level of Service B (LOS B). Level of Service B indicates slight congestion with some impingement of maneuverability and limited lane changing (Litman, 2011). The model generated also shows a strong negative relationship between the speed and density with an r squared value of 0.609, which means speed increases when traffic density decreases this is similar to the results of the studies of Yu, et al, 2016, and Dhale, et.al 2017.

Figure 2 *Speed-Density Relationship using Greenshields's Linear Modeling for Maharlika Highway.*

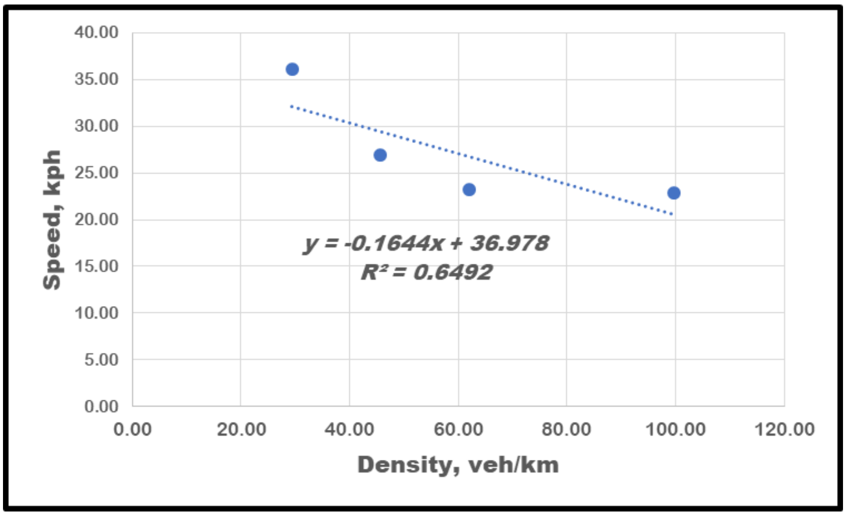

Figure 2 presents the speed-density relationship on Maharlika Highway. The derived relationship was used to estimate the free-flow speed and the corresponding jam density which are used to compute the maximum capacity of the road. The maximum capacity for Maharlika Highway was computed to be 2079.338 veh/hour and the resulting volume-to-capacity ratio is 0.541 which corresponds to Level of Service C (LOS C). The Level of Service C is still in the zone of stable flow but the speed and maneuverability are most closely controlled by higher volumes. The level of comfort and convenience declines noticeably at this level (Sigua, 2008).

The r squared value is computed to be 0.649 which suggest a strong negative relationship between the variables.

Figure 3 *Speed-Density Relationship using Greenshields's Linear Modeling for Luna Extension.*

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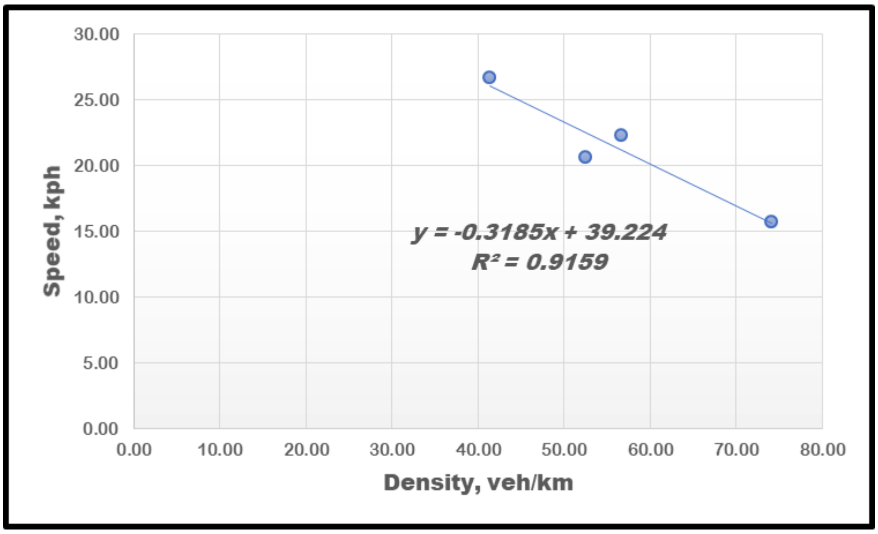

Figure 3 shows the speed-density relationship on Luna Extension. The derived relationship was used to estimate the free-flow speed and the corresponding jam density which are used to compute the maximum capacity of the road. The maximum capacity for Luna Extension was computed to be 2415.262 veh/hour and the resulting volume-to-capacity ratio is 0.523 which corresponds to Level of Service C (LOS C). The r squared value is computed to be 0.916 which suggests a very strong negative relationship between the traffic speed and traffic density.

Table 12: *Level of Service (LOS) of the different road sections during normal traffic condition*.

Road Section	***v/c ratio***	***R-Squared value***	***Level of Service***
Enrile Avenue	0.483	0.609	LOS B
Maharlika Highway	0.541	0.649	LOS C
Luna Extension	0.523	0.916	LOS C

The table shows the summary of the values of the volume-to-capacity ratio of the three different roads and their corresponding Level of Service (LOS). Based on the results, the corresponding r-squared values for Enrile Avenue and Maharlika Highway are 0.609 and 0.649 respectively. Which indicates a strong negative relationship between the traffic speed and traffic density. While Luna extension has an r-squared value of 0.916 which suggests that there is a very strong negative relationship between the variables. The negative relationship between the traffic speed and traffic density means that as traffic density increases, traffic speed decreases. This result is similar with the studies of Yu, et al, 2016, and Dhale, et.al 2017.

3.4 Traffic Level of Service during flooding events

3.4.1. Additional Traffic volume converted to its PCEs

Table 13: *Additional Volume to the three road sections due to Route Change caused by flooding incidents.*

Road Section	*Volume*	*PCU equivalent*
Enrile Avenue	91.0	108
Maharlika Highway	226.0	327
Luna Extension	86.0	161

Table 13 shows the additional volume for the three road sections due to route change caused by flooding incidents. Based on the results, Maharlika Highway is the most popular alternate route in case of flooding events in Tuguegarao City this due to the location of the highway, it connects the Central Business District and the Regional Government Center which most of the offices are located. Followed by Enrile Avenue which is popular alternate route for travelers from the eastern barangays if the Macapagal Avenue is not passable. While Luna Extension caters travelers from western barangays when Linao-Carig bypass road is not passable.

3.4.2. Volume to Capacity Ratio and corresponding LOS during flooding incidents

Table 14: *Volume-to-capacity ratio and the corresponding Level of Service (LOS) during flooding incidents*

Road Section	*Volume to Capacity Ratio*	*Level of Service (LOS)*
Enrile Avenue	0.515	LOS C
Maharlika Highway	1.257	LOS F
Luna Extension	0.590	LOS C

Table 14 shows the volume-to-capacity ratio and the corresponding Level of Service (LOS) computed during flooding incidents. It can be noted that Maharlika Highway has already exceeded its capacity since its v/c ratio is already more than 1.0. This means that during flooding incidents, travelers using Maharlika Highway will experience severe to traffic flow breakdown during peak hours. On the other hand, both Enrile Avenue and Luna Extension has a level of service C which means that there will be a stable flow but the traffic speed is affected (Sigua, 2008)

3.5. Comparison between the Level of Service (LOS) during normal traffic condition and during flooding incidents

Table 15 Volume-to-Capacity Ratio and the corresponding *Level of Service (LOS) during normal weather and during flooding incidents*

Road Section	**During Normal Weather condition**		**During Flooding Incidents**	
	v/c ratio	**LOS**	**v/c ratio**	**LOS**
Enrile Avenue	0.483	B	0.515	C
Maharlika Highway	0.541	C	1.257	F
Luna Extension	0.523	C	0.590	C

Table 15 presents the volume to capacity ratio and the corresponding Level of Services of the road sections during normal weather condition and during flooding incidents. Based on the results, there is a substantial change in the volume to capacity ratio of the road sections. This changes in the v/c ratio were caused by the increase in traffic volume coming from the flooded roads. Results shows that Maharlika Highway is the most affected among the three road sections whose level of service changes from LOS C to LOS F followed by Enrile Avenue whose level of service changes from LOS B to LOS C. Though it can be observed that there is no changes in the Level of Service on the Luna Extension, its volume-to-capacity ratio changes from 0.523 to 0.590.

4. CONCLUSIONS

Based on the study results and analysis conducted, the following conclusions were drawn:

1. All of the observed space mean speeds were below the maximum speed limit of 60 kph as required for national highways. Also, upon comparing the morning peak hourly volume for Enrile Avenue, Maharlika Highway, and Luna Extension it can be noted that even during normal weather condition, Maharlika Highway caters the most number of vehicles per day among the three road sections.
2. This study found that majority of the respondents are male, belonging to age group 20-30 years old, with non-professional driving license. Also, the main trip purpose was found to be attending school, using tricycle as their primary mode of transport, and travels using Linao-Carig Road during normal weather condition and tends to shift to Maharlika Highway as alternative route during flooding incidents.
3. With the use of Greenshields's Linear Modeling, it is found out that the corresponding maximum traffic capacity (in veh/hour) for Enrile Avenue, Maharlika Highway, and Luna Extension are 3451.73, 2079.34, and 2415.26 respectively. It can be noted that Enrile Avenue has the highest capacity since it is composed of four lanes (two per direction), while both Maharlika highway and Luna Extension also have four lanes, it can be observed that most of the time, especially during peak hour, the outer lanes were used as parking space thus contributing to the limiting of its capacity.
4. Lastly, this study found that the traffic Level of Service (LOS) in the three pre-determined road sections were greatly affected as their volume-to-capacity ratio increases. This is because the traffic volume increases as a result of traffic re-routing caused by flooding incidents.

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Appendix A:

SURVEY QUESTIONNAIRE

Dear Respondent,

The undersigned is conducting a study entitled **EFFECTS OF EXTREME FLOODING EVENT ON TRAFFIC LEVEL OF SERVICES IN TUGUEGARAO CITY** in partial fulfilment of the requirements for the degree Master in Climate Resilience and Sustainable Development Management. Please answer the following questionnaire according to your honest opinion and perception. Rest assured that your answers will be dealt with most confidentiality. Your kind effort to accomplish it will surely help in the completion of the study.

Thank you very much!

Sincerely yours,

Researcher

I. PROFILE OF RESPONDENTS

Name (optional): ______________________________ Date: ____________

Home Address: ____

II. TRIP CHARACTERISTICS

Please tell us something about your transportation modal choice for your daily activities (going to work, school, or other daily activities).

1. What is the primary mode of transportation you use to commute going to work? *Please check only one*

   ☐ Tricycle ☐ Bicycle

   ☐ Motorcycle ☐ Heavy Vehicles (Trucks, Buses, vehicles with more than four tires)

   ☐ Private Car ☐ Others, please specify ____________

2. How far is your workplace/school from your house?

   ☐ ≤ 1km ☐ 3.0-4.0 km

   ☐ 1.0– 2.0 km ☐ 4.0-5.0 km

   ☐ 2.0– 3.0 km ☐ more than 5.0 km

3. If your travel is not school or work-related, how far is your usual destination from your house?

   ☐ ≤ 1km ☐ 3.0-4.0 km

   ☐ 1.0 – 2.0 km ☐ 4.0-5.0 km

☐ 1.1 – 3.0 km ☐ more than 5.0 km

4. During normal weather condition (sunny), which of the following major road networks in city do you usually take when travelling?

____

5. The following road networks are vulnerable to flooding during heavy rainfall. Which of the following highways/routes do you usually take when going to work/school?

☐ Macapagal Avenue ☐ Pallua Road
☐ Linao Road ☐ Bagay Road
☐ Diversion Road ☐ Caritan Highway
☐ Pallua-Buntun Highway
☐ Cataggaman-Pallua Highway

6. During extreme flooding event, which of the following alternate major highways do you take when traveling?

☐ Balzain Highway ☐ Enrile Avenue
☐ Caggay Highway ☐ Carig Highway
☐ Pengue Highway other please specify:
____