Characterizing Student Travel Behavior During Heavy Rainfall and Flooding

Lexter Strike S. IBASCO
Undergraduate Student
Civil Engineering Department
De La Salle University
2401 Taft Avenue, Manila
E-mail: lexter_ibasco@dlsu.edu.ph

Dr. Alexis M. FILLONE
Full Professor
Civil Engineering Department
De La Salle University
2401 Taft Avenue, Manila
E-mail: alexis.fillone@dlsu.edu.ph

Abstract: Yearly, the Philippines experiences heavy rainfall, which results in flooding. In this kind of environment, students are put to risk and vulnerable when commuting. Understanding the behavior of students is still unclear with regards to their decision making during heavy rainfall and flooding. Disaster decision-making studies are still relatively new. Thus previous researches did not fully investigate or capture the whole scenario, especially on the explanatory variables that affect people's decisions. The goal of the study is to model and understand the general decisions made by tertiary students in the City of Manila during heavy rainfall and flooding. Decision trends were investigated. Based on preliminary data, 16% of the sample remained in school during heavy rainfall and flooding while 84% went home. Compared to normal scenario, travel time, and waiting time is seen to increase as well. Since the study can be used in formulating transportation and other policies, further expansion of study area and/or other types of commuters can be investigated in the future.

Keywords: Heavy Rain, Flood, Travel Behavior Analysis

1. INTRODUCTION

In the last decade, the National Capital Region (NCR) was ravaged by strong weather disturbances that paralyzed the region due to flooding and other negative effects. Last September 2009, Tropical Storm Ondoy' (Internationally named 'Ketsana') caused widespread flooding in Metro Manila and surrounding provinces that resulted in P4.299 Billion infrastructure damage (NDRRMC, 2009). The storm disrupted major urban activities, including transportation services, stock exchange, and classes in school and universities for several days. Class suspension lasted for several days. A total of 37 major roads in Metro Manila was also impassable to light vehicles due to flooding (NDRRMC, 2009).

Recently,Filipinos living in the region with an epic flooding caused by south west monsoonal rains (Rains induced by Hanging Habagat) were affected by, which was enhanced by Tropical Storm 'Maring' (2012) and Typhoon 'Haikui' of (2013). Once again, it disrupted transport operation and services. Classes and work were also suspended during these disruptive events.

In the Philippines, the Department of Education (DepEd) and Commission on Higher Education (CHED) abides by a systematic process in relation to the suspension of classes during inclement weather. In case of impending tropical cyclones, automatic suspension of preschool classes is enforced when Public Storm Warning Signal No. 1 (PSWS#1) is issued by the official weather agency of the Philippines, PAGASA (Philippine Atmospheric Geophysical, Astronomical Services Administration). Elementary and secondary classes are suspended when Public Storm Warning Signal No. 2 is raised. Colleges and work are suspended when Public Storm Warning Signal No. 3 is enforced. PAGASA normally issues cyclone bulletin every 6 hours (ie. 5AM, 11AM, 5PM, 11PM).

When it comes to heavy rainfall events, there are no guidelines on implementing automatic suspension. The Department of Education has authorized local government units and school heads to suspend the classes if authorities deem it is unsafe to conduct normal activities (DepEd, 2008). There were instances when students were asked to attend classes in the morning then a sudden suspension is called in the afternoon during or after a heavy rainfall event.

An example of this scenario happened in 2013 of mid-July. Unexpected heavy rainfall fell over the metropolis and surrounding provinces during the day, prompting the immediate suspension of classes by noon time. Students were dismissed immediately, but clogged the transportation network system of the metropolis. The immediate release of students and workers added to the demand on that hour as road capacity continued to fall as roads started to be inundated by floods.

Several people got stranded on their way home as floods partially or fully submerged the road networks. Transportation modes were rendered useless due to the unexpected flood heights. Train operations were grounded, and services suspensions left people clueless on how to reach their respective destinations.

The behavior of commuters during flood events is not well understood in the past studies. Not all commuters will take the pre-trip, which sticks to the original path to be traversed during travel, but there is a chance of taking an en route, which is a deviation from the original list of link to be traversed during travel**.**

2. RELATED LITERATURE

2.1 Exceptional and Normal Scenario

Researches regarding unwanted scenarios, such as natural disasters and terrorist attack, have been studied in the past and has undergone modelling utilizing the 4-step model. It still utilizes trip generation, trip distribution, modal choice and route choice regardless of the scenario type, either normal or unwanted scenarios. Though a difference on decision making is expected during a different scenario (Setunge & Withanaarachchi, 2014).

Most of the studies done in the past and until now use modelling of traffic and commuter's behavior under a normal weather conditions. When an exceptional event happens such as flooding or massive evacuation, congestions is likely to happen at a different level (Pe et al, 2010 and Bujed, 2014). It is also expected to change the travel behavior as well as the supply of the network and infrastructure (Hoogendoorn, 2009), thus making it essential to model the behavior and operation when it occurs. Few studies have been conducted where the scenario is under an unwanted event such as disaster and terrorist attack, which occasionally happens.

Weather impacts the operation and capacity of roads, mobility, and as well as the choice of people towards different transportation options, which includes route choice, behavior and trip generation, according to past studies conducted and collected by the Federal Highway Administration (FHWA, 2015). Traffic speed, flow, travel time and accident risk are expected to be affected as adverse weather affects the network (FHWA, 2015).

2.2 Behavior and Risk Attitude

According to past studies, there is a change in behavior of commuters on whether to take pre trip route or en route. An example of this is the study conducted by Ahmed et al. (2010) which shows the changes of bicycle ridership due to different weather hazards. It also affects the modal and route choice of people.

There are many factors that affect the commuter behavior, depending on the situation factor, demographic factors. When an unwanted or exceptional event strikes, it changes the way individual respond and behaves on transportation choice (Otto, 2010) as well as the driving attitude and psychological impacts (Hoogendorn, 2009). In terms of decision making, we are to consider the type of risk attitude a person has. This is categorized into 3 types: risk averse, risk seeking and risk neutral (Kisky, 2015). This factor is not to be generalized since it depends on how one sees the event. When unexpected events are to be extracted from interviewee, it is important to obtain ones' personal experience and the location's risk (Viscusi and Zeckhause, 2006). Though it was also stated that people has a limited comprehension level when it comes to risk. People may tend to overestimate or underestimate (Gutscher and Siegrist, 2006). This is due to the past experience of the interviewee. Time also plays a very big role and influence as well in risk assessment (Hufschmidt et al, 2005).

2.3 Past Studies

Majority of disaster-related transportation modelling studies only cover the evacuation of people. In terms of heavy rainfall and flooding, the scenario usually focuses on the forecast period rather than after the event itself. An example was conducted by Lim et al which focuses on the flood evacuation route modelling for sub districts. It uncovers the important explanatory variables and behavior that must be considered in modelling evacuation routes (Lim etal, 2015). Some of the variables/ attributes included in this research are the mode used by the people, the departure time, level of education, house ownership and etc. The variables included in the analysis are socio-demographic information of evacuees, hazard-related and evacuation-related information. It also included personal experiences. Logit models were used in identifying the necessary attributes. It also introduced some possible routing categories such as shortest path, familiar path, usual path and etc. (Lim etal, 2010).

Another study regarding the commuter's behavior towards heavy rainfall forecasts was conducted in Nagoya prefecture of Japan (Sakamoto et al, 2015). The study explored the relationship of people's behavior towards their trip, focusing more on the return trip. Logit model was also used by the researcher in the study. Characteristics and attributes such as socio demographics, frequency of information access, and other transportation attributes were considered (Sakamoto etal, 2015).

Other studies include disaster resiliency, mobility, serviceability and evacuation modelling.

2.4 Transportation Network Failure

Links connect nodes, which resembles to a road. Studies regarding resiliency and vulnerability covers the original network system and the damaged system in order to compare the performance of the system (Lu & Peng, 2010). When a change of performance is seen to be at its greatest extent when a particular link is removed, it was said to be the most important and critical link in the network system. Majority of the studies regarding vulnerability of network results in the identifying of the critical links.

Most of the studies and models that was investigated in the past considers impacts or failures on the link thus this was represented by removing that link (roads) in the network. There were also very few studies regarding the impact on nodes which can be represented by removing all links, whether it is exit or entry point, as long as it passes the said node. Meanwhile it is also stated that it is not very accurate since the assumption is always either operational or non-operational, which in reality it may just be partially damaged. (Konstantinidou, etal, 2014). Studies regarding network failure and its effects had been carried out throughout the years by different researchers in different places already. A study regarding on people's access to relief goods due to network failure was investigated by Horner and Widener (2011) .

3. METHODOLOGY

3.1 Survey Collection

Two (2) sets of surveys were conducted. A total of 460 questionnaires was randomly administered to college students in the city of Manila. The first 400 respondents were asked regarding their trips from home to school considering two (2) scenarios: (a) when commuting under normal condition, and (b) commuting in bad weather, specifically with strong rains, accompanied by flooding. The respondents were asked to describe the differences between the two scenarios, including trip attributes such as cost and time on the taken route in general. In addition, factors affecting their decision whether to either stay or go home immediately from school was also asked.

The second set of survey questionnaire involved, a total of 60 respondents. Technically a smaller number of respondents was obtained due to time constraints. This survey is almost the same with the first one with an inclusion of more detail than the first one, which includes on the alternative route taken other than the usual route utilized during severe weather.

3.2 Public Transportation Layout

This step is primarily secondary data. Flood Hazard Data in connection with LIDAR Philippines was obtained. A five (5) year return period hazard map was utilized since it has a bigger chance representing possible flooded areas in the metropolis; at the same time this is the least return period map that is processed and available from LIDAR. Another set of data, public transportation links, are obtained from previous studies conducted in connection with De La Salle University.

Both data sets were overlaid under one EMME software worksheet. A total of three (3) scenarios were made. Scenario one (1) represents a normal scenario that includes all public transportation lines. Scenario two (2) represents a segmental deletion of public transportation lines. Under the said scenario, all public transportation lines that is expected to get affected in flooded area will be terminating on those areas. Both directions were considered in this scenario. The model focused on the total deletion of the whole line. Under this scenario, all lines that pass through moderate to high hazard areas are to be deleted. Scenario three (3) focuses on the whole line deletion. As long as it passes through a moderate – high hazard area, the lines are to be suspended.

The major assumption in this method is that once the service lines passes through a moderate hazard (assuming a full 5 year rainfall return period fell, it is on Waist Level) and high hazard (assuming a full 5 year rainfall return period fell, it is on Above Chest Level) public transportation lines will be suspended. Scenario 3 is assumed when the operator or driver decides to cancel their trips before they start to travel. Scenario 2 is assumed when the operator is caught by heavy rains and flooding in the streets. It is also assumed that these units are not yet in the middle of their "respective lines", where segments will be cut off from the whole line. There are several scenarios can be formulated but due to software capability constraints, these 2 scenarios only are presented.

Using three (3) scenarios, comparisons of total network length and lines, and among others were analyzed, including the number of modes and lines in particular mode. Zones with and without access with public transportation were also studied.

4. RESULTS
4.1 Response Descriptive

For the first set of respondents, a total of 417 samples used. More than half of the samples were female. Majority of the total respondents hailed from private tertiary institutions (91.8 %). A great proportion of them (81 %) performs information check before travelling. Most of the respondents answered they experienced flooding. With the last experience they can remember, 85.10 % did go home immediately after classes.

With the preliminary results from the first survey, it was deduced that travel and waiting time increases abruptly from normal scenario compared with its counterpart from the unwanted weather scenario. (See tables 1 and 2.)

Table 1. Trip Characteristic Means for Go Home Respondents

	Bad Weather	Normal Weather	Diff (B->N)
Total Travel Time	81.25 minutes	45.49 minutes	35.76 minutes
Total Wait Time	35.99 minutes	14.92 minutes	21.07 minutes
Total Cost	70.93 Pesos	52.36 Pesos	18.57 Pesos

Table 2. Trip Characteristic Means for Remain Respondents

	Bad Weather	Normal Weather	Diff (B->N)
Total Travel Time	97.14 minutes	53.99 minutes	43.14 minutes
Total Wait Time	47.86 minutes	15.20 minutes	32.66 minutes
Total Cost	88.22Pesos	80.24 Pesos	7.98 Pesos

Regardless of flood height, travel time, waiting time and cost increased as well. Table 3 shows that, there is also an increase in delay as flood height increases.

Table 3. Trip Characteristics Categorized by Flood Level

	Bad Weather	Good Weather	Difference
Flood Level:	Below Ankle Deep		
Travel	81.08 min	46.15 min	34.92 min
Wait	34.92 min	15.04 min	19.87 min
Cost	71.49 peso	56.10 peso	15.38 peso
Flood Level:	Ankle Deep		
Travel	85.55 min	48.00 min	37.55 min
Wait	38.51 min	14.98 min	23.53 min
Cost	74.78 peso	51.42 peso	23.35 peso
Flood Level:	Knee Deep		
Travel	84.18 min	46.43 min	37.75 min
Wait	38.63 min	14.76 min	23.86 min
Cost	74.02 peso	60.78 peso	13.23 peso
Flood Level:	Waist Deep		
Travel	90.5 min	48.75 min	41.75 min
Wait	48.5 min	18.25 min	30.25 min
Cost	77 peso	67.5 peso	9.5 peso

A related survey was conducted to see how people, especially students, decide during bad weather, complementing the first survey that only captured the trend of students travel. This second survey used, detailed questions such as flood height indicator and alternative routes. Table 5 shows the indicator, with regards to flood height, of what the respondent will most likely do after classes during a heavy rainfall event. The study results showed that 30 respondents are going to remain at school if ever the flood height along their trip was expected to hit Knee Level, and 31 respondents are going home if the flood level is just at ankle height.

Table 5. Willingness to Go Home and Remain

	Below Ankle	Ankle	Knee	Waist	Chest
Go Home	23	31	11	0	0
Remain	8	20	30	7	0

Alternative routes taken by respondents were also analyzed, which is technically a blind spot to the researcher due to wide range of roads, and incomplete information on flood levels and among other factors. Table 6 shows the number of respondents who tried taking up the alternative route. Presented below are three (3) examples on the itinerary changes within the vicinity of Manila.

Table 6. Alternative Route Experience

Have tried alternative routes	48
Never tried alternative routes	17

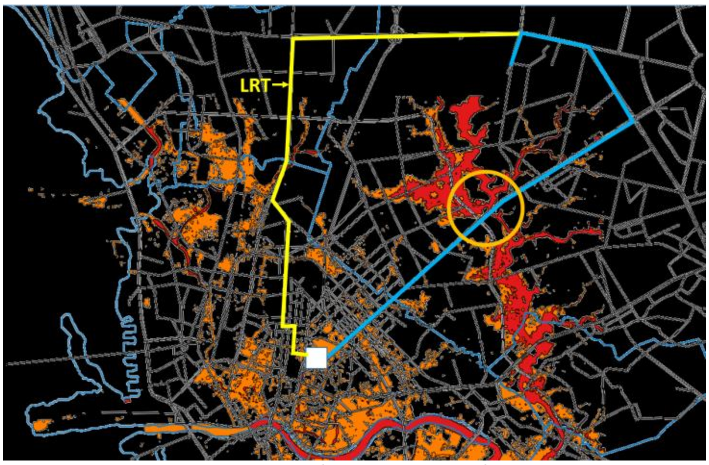

Figure 1. Sample Itinerary Change 1

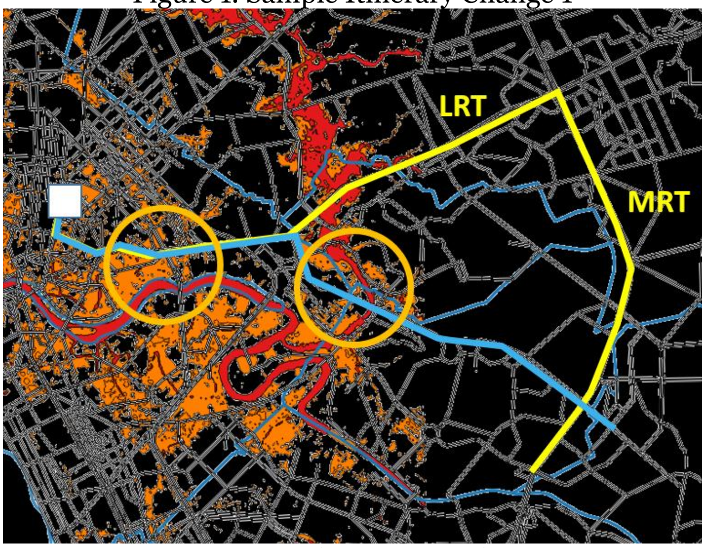

Figure 2. Sample Itinerary Change 2

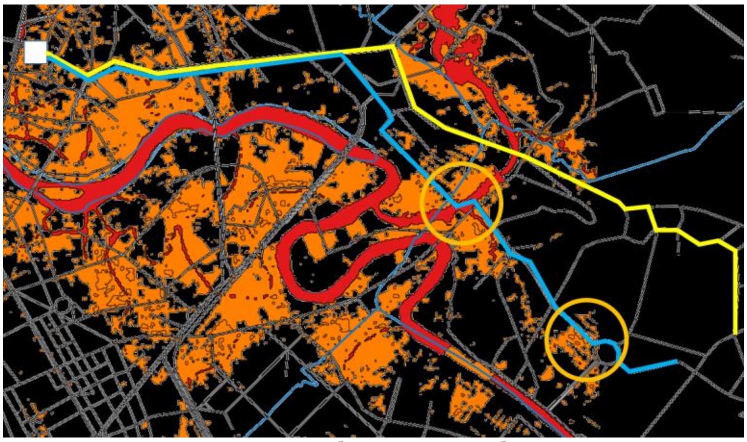

Figure 3. Sample Itinerary Change 3

Using data on alternative roads provided by the respondents, the researcher plotted all public transportation lines on the hazard map to further visualize the scenario

4.2 Transportation Lines Affected

Figure 4 below shows three (3) scenarios that includes (a) normal scenario, (b) segmental line deletion and (c) total line deletion. Figures 4 and 5 presents the differences on the transportation line availability and MUCEP Zones access to public transportation lines, respectively.

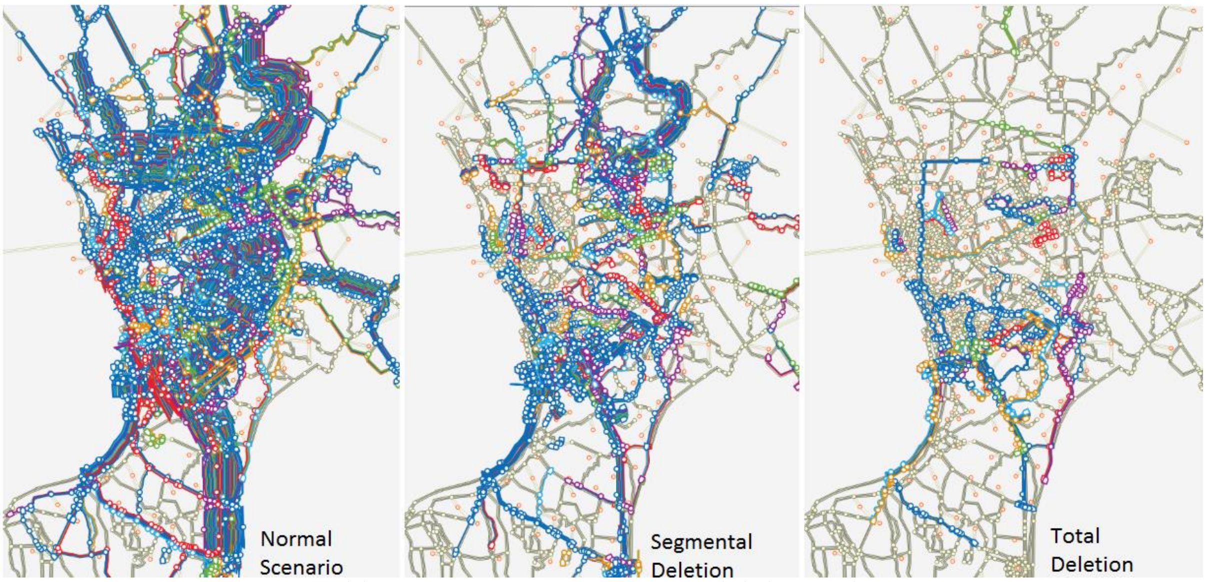

Figure 4. Public Transportation Lines Availability with 3 scenarios

The network line summary provided in Table 7, shows that more than half of the total network length can be affected when heavy rainfall occurs (5 year return period). Almost all lines (city bus lines) are likely to be affected when the third scenario is considered. All lines, regardless of mode type, is greatly reduced in terms of lines it can serve and network length.

Table 7. Public Transportation Line Network Summary Changes

	Normal Scenario		Segmental Deletion		Total Deletion	
Total Lines	689	Lines	564	Lines	114	Lines
Total Network Length	10,773	km	3,091	km	783	km
Bus Lines	107	Lines	96	Lines	2	Lines
Bus Network Length	3,977	km	665	km	9.66	km
Jeep Lines	357	Lines	268	Lines	85	Lines
Jeep Network Length	2,774	km	1,188	km	498	km
FX Lines	173	Lines	155	Lines	21	Lines
FX Network Length	2,616	km	928	km	207	km

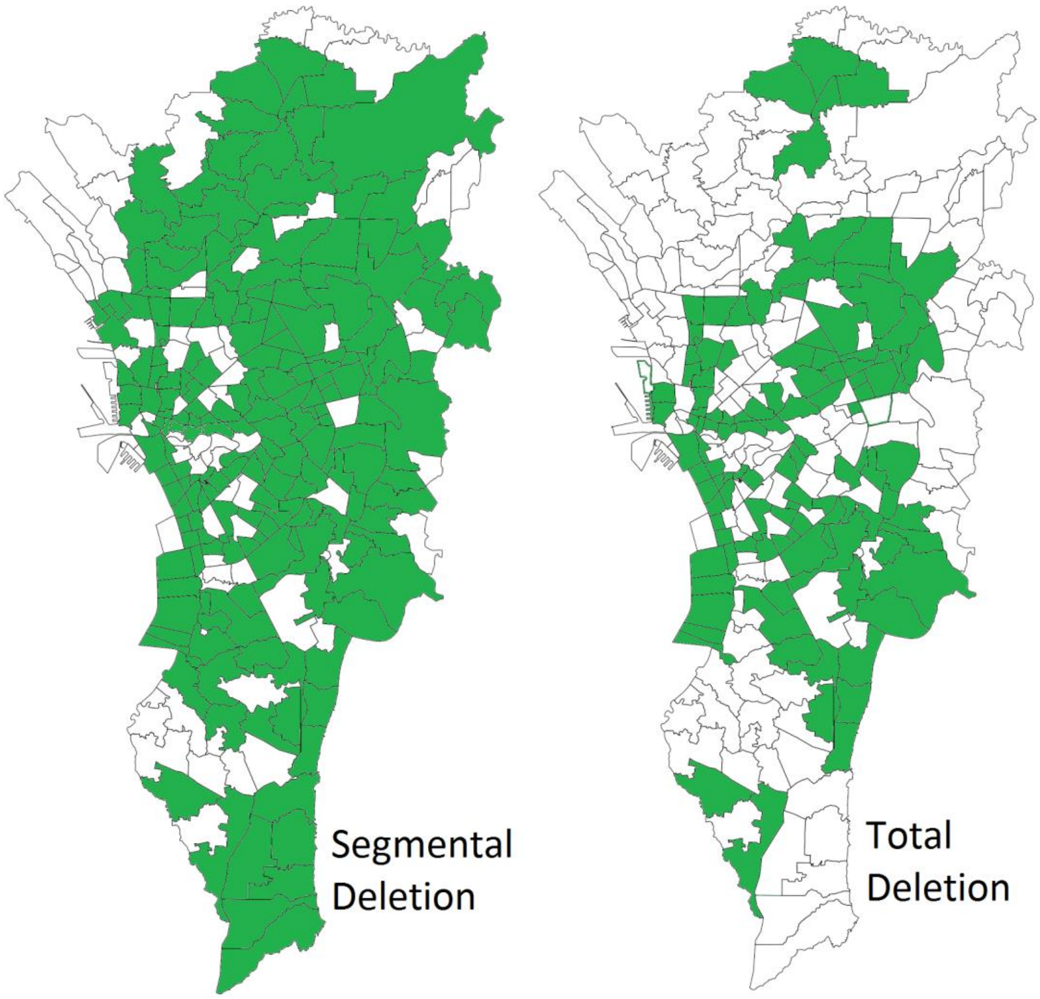

Figure 5. MUCEP Zones with available transportation lines.

Table 8. Zone Summary In Case of Public Transportation Link Failure

	With Access	Without Access
Segmental Deletion	193 Zones (71.74%)	76 Zones (28.25%)
Total Deletion	114 Zones (42.38%)	155 Zones (57.62%)

Even with a 5-year return period flood, it is seen in figure 5 that majority of the areas in Metro Manila can still be served with different public transportation lines, though this considers both directional trips. One direction might not be able to serve some zones in the map (Fig. 5) if segmental deletion scenario is considered. Majority of the lines are likely to be terminated once it encounters a flood along its path, thus it may not fully serve all zones along its path. When total deletion scenario is to be used, it is seen that Northern Metro Manila (Navotas, Malabon, Valenzuela, Marikina, and Northern Quezon City) will most probably be isolated due to flooding, as well as Southern Metro Manila (Pasay, Muntinlupa, Las Pinas, and Paranaque). Those along riverbanks and creeks will also lose public transportation services as well. More details regarding on zones with and without access is shown in Table 8. About 71.74 % MUCEP zones still has at least 1 public transportation line traversing it. About 42.38 % MUCEP Zones are with access in case of the whole line being suspended.

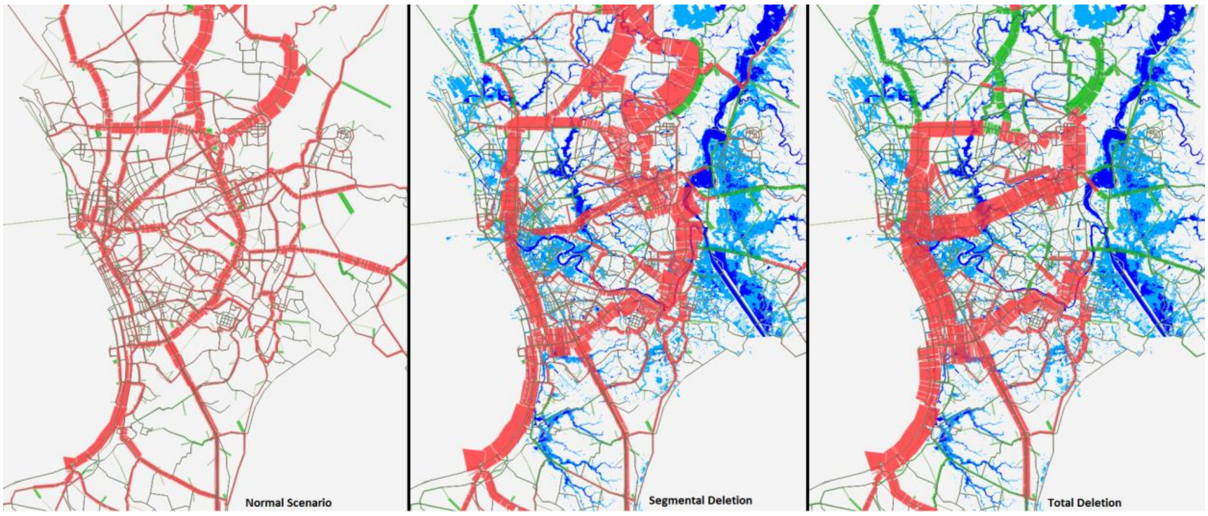

Figure 6. Public Mode Users Link Volume in Three (3) Scenarios

In figure 6, left most part shows the probable user volumes of public transportation. As public transportation lines slowly cut off by segments, users have lesser choice to go from one's destination. Thicker lines are seen in the next two images, from center to right. As public transportation lines are suspended, previous choices of modes depletes. By looking at the image alone, people will most likely to use the elevated train systems (LRT Line 1 and Line 2). MRT Operations are assumed to be suspended due to series of at grade crossing along EDSA. Red lines depict public mode users while green lines depict walking due to line suspension.

Areas situated along the coastline of Northern Metro Manila and eastern boundary line of Metro Manila is expected to be affected greatly due to lack of operating lines during heavy rainfall.

5. CONCLUSION

With the first set of data from the first survey, it was concluded that there is an increase in travel, waiting time and cost when normal and unwanted scenarios are to be compared. An average of 35 to 40 minutes of delay in travel time is seen. Regardless of the inundation level, it is assured that travel time is to increase. By comparing the flood levels, the trend was seen that the delay (travel time and waiting time) is to increase as the inundation increases.

With the second set of data, it was deduced that majority of the respondent is willing to continue their trip to home from school if the flood level on their trip is expected to hit at ankle level. If the inundation level is expected to hit at knee level, respondents will most likely to remain at school, by looking at the values from the data. About 74 % of the respondents were able to travel using an alternative route. With more than half of the respondents taking up other routes, it prompted the researcher to lay out the available public transportation lines and services during heavy rainfall.

Finally, with the public transportation lines, it was seen that more than half of public transportation lines are going to be affected 5 year return period flood is to happen. About 16.55 % of total lines would be able to continue the operation even with a 5 year return period of flood is to happen. Around 7.3 % of the total network line is relatively safe from flooding when lines were suspended. The mode that is most likely to be affected greatly is the city buses with only 2 lines un affected by floods, this is not yet including the indirect effects such as congestion, damages and etc. This is then followed by FX services which can be reduced to 17% and then Jeepney services with about 23% of the original line services.

In terms of zoning by MUCEP, about 57.6% of the total zones are to be affected in case of public transportation line suspension due to impassable roads. With this scenario, Metro Manila would be separated into different clusters namely the Northern Quadrant of Metro Manila (which includes CAMANAVA Area and Northern Quezon City), Eastern Quadrant of Metro Manila (which includes Marikina and Pasig City), Southern Quadrant of Metro Manila (which is mainly composed of Las Pinas, Paranaque and Muntinlupa) and Central Part of Metro Manila. Only Central Manila will most likely have access from public transportation lines if flooding occurs.

Lastly, with the decrease of operation and suspension of lines, public transport users will most likely to use the elevated railway system in case of flooding which was modeled by using 3 scenarios. Majority of the segments in EDSA will be rendered useless due to floods in both ends (Caloocan Area and Pasay Area) which may cut off from the whole highway network.

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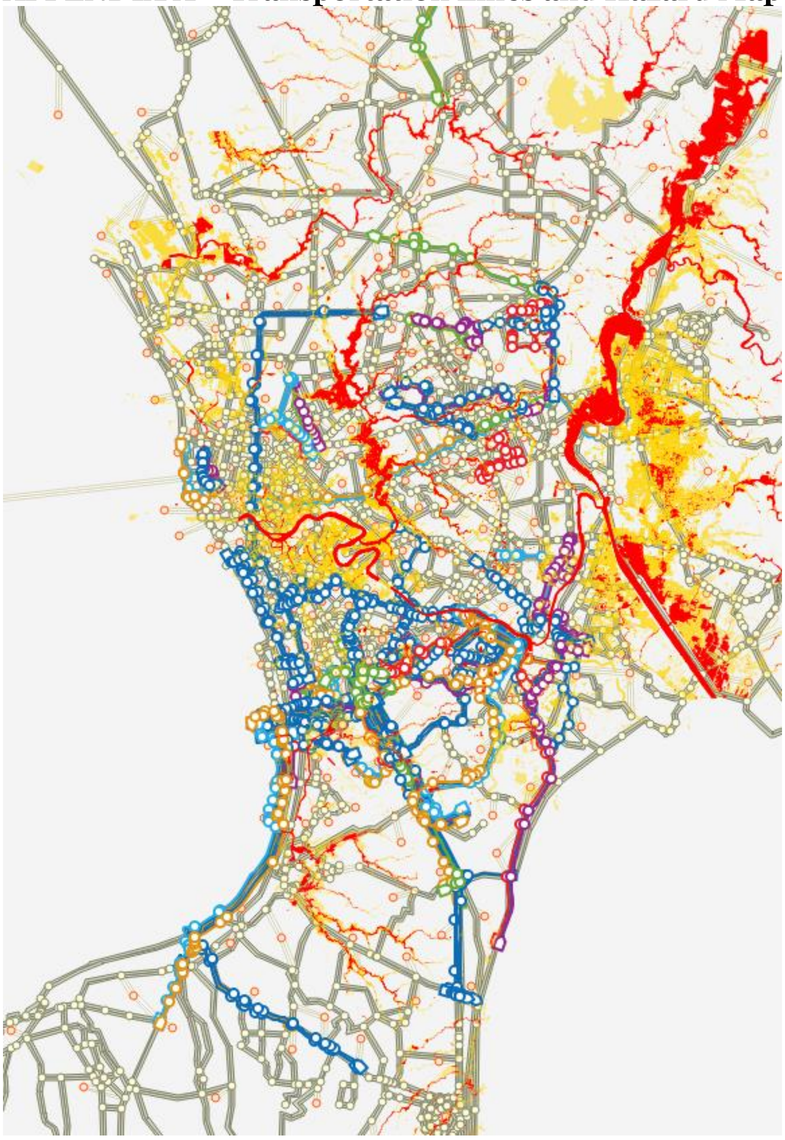
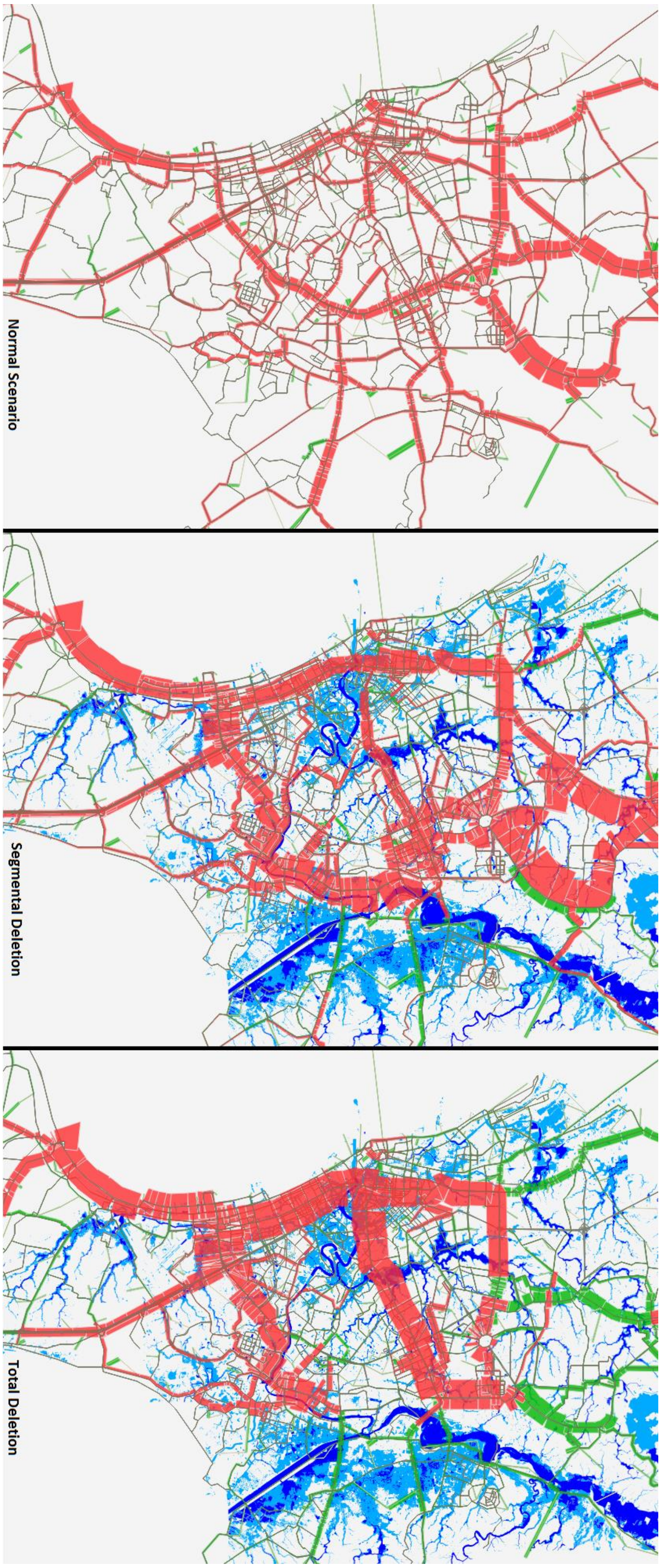
APPENDIX A – Transportation Lines and Hazard Map




Normal Scenario
Segmental Deletion
Total Deletion