

Modeling Impacts of Proposed Mobility and Accessibility Interventions in Intramuros, Manila

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Abstract: Intramuros represents the lone district of Manila where old Spanish Colonial-era influences were kept. This setting attracts many tourists in visiting the area. But throughout the years, keeping the area the way it used to be has become a problem especially in terms of accessibility and mobility. With this, the World Bank suggested measures to address such issues of transportation in the area.

For this study, the primary objective was to model proposed mobility and accessibility interventions in Intramuros. This was done by evaluating the preliminary measures to address mobility and accessibility in Intramuros through the use of traffic simulation models and actual site investigation. Measures evaluated in this study were those that can be applied readily like changes in policy (e.g. change of two-way road to a one-way road), and those that can easily be adopted.

In establishing the baseline model, the system studied was defined – road, road users profile, and zonal data. From this, the baseline traffic simulation model was developed. Before applying test scenarios, the said model has also been calibrated and validated with the use of existing traffic count on selected road links within the study area. Test scenarios which were based from the selected interventions as enumerated in the World Bank study were also developed. Then evaluation had been carried out by comparing the baseline model and scenario tests done. Finally, key issues in achieving a smoother traffic flow, referred in this study as “barriers,” were identified through actual site investigation. Results were shown to give insights to which streets are to prioritize in road maintenance and improvement.

Revitalized and a more mobilized Intramuros will primarily address traffic flow, and is expected when improved, can attract more tourists and potential stakeholders such as developers and residents.

Key words: *GIS, Policy Making, Mobility, Accessibility, Traffic Simulation*

1. INTRODUCTION

Recently, the Intramuros Administration (IA) invited the Mapua Institute of Technology (MIT) to be its institutional private partner with its goal of achieving revitalization and mobilization of Intramuros. Last March 31, 2015, there was a signing of the Memorandum of Agreement (MOA) between IA and MIT. In the said MOA, as stated in its Article II - Responsibilities, included in the obligations of Mapúa to provide technical assistance for the conduct of identified studies in

improving sustainability, mobility and the transport plan of Intramuros; so as an initial response to the aforementioned obligation, this study has come to its purpose.

Mobility within the area is a problem pointed out in the 2014 report prepared by the Integrated Transport Planning Ltd (ITP) which was issued by the World Bank for the Intramuros Administration (IA). In their report, they found the following problems for Intramuros concerning mobility: poor pedestrian access throughout the area, through traffic creates noise, pollution, and pedestrian conflict, poor access to public transit routes, poor integration with rest of Manila, on-street parking impacts the enjoyment of some streets and spaces, and problems concerning heavy goods vehicles (HGVs) and coach movements. The study also indicated poor road surface observed on a number of streets in Intramuros.

These problems according to the report mentioned above could be solved by the interventions enumerated in the report. Therefore, as for this study, the main objective is to model impacts of proposed mobility and accessibility interventions. Specifically, it sought to (1) define the system to be studied – road, vehicle and other road users profile, and zonal data; (2) baseline model development through (a) road network mapping of Intramuros; (b) delineation of zonal areas within Intramuros; (c) traffic simulation of Intramuros; (3) model calibration and validation; and (4) evaluate measures to address mobility and accessibility in the area.

Mobility and accessibility in this study will cover the ease of movement from one point to another within the area of Intramuros, Manila only. It will also be limited in addressing the movement of vehicles that normally can be found inside the Walled City which creates significant impact in its traffic flow, namely cars (including taxis, sedans, SUVs, FX express, etc.), public utility jeepneys (PUJs), buses, motorcycles, trucks, and pedicabs. Furthermore, the pedestrians not including special provisions for persons with disabilities (PWDs) were considered.

This study concentrated primarily in modeling transportation within Intramuros. Due to time constraint, it will be first employing the interventions enumerated in Phase 1: measures that can be tested immediately, and Phase 3: measures (to be applied inside the walls) which can be implemented within 2 years for the models that will be generated. Creating the model for simulation of Phase 2: measures which support those immediately implemented, and Phase 4: long-term vision interventions would take more time or different techniques and are recommended for further studies.

The researchers had also been limited with the available functionalities of Cube Voyager as the traffic simulation modeling software. Also, the models are created with respect to Weekday AM Peak Hour average because according to the World Bank study, this is the one that is critical for the area of Intramuros.

It is expected that this study would help in revitalizing Intramuros. Also, the residents and regular travelers like students and people working in the area could also be increased by giving them more convenience and safety. Walking and other forms of non-motorized transport (NMT) would also be promoted for those who want to indulge themselves into healthy living.

Furthermore, with the goal of mobility, having the baseline and simulation models would be of great help in addressing the issue. There are many various advantages on the use of simulation models. For instance, the forecasting capabilities are present as long as the data and input closely reflect real conditions, the flexibility to run any what-if scenario, and also lower cost on experiments in a simulation compared with experimental physical implementation. The IA and the primary stakeholders of Intramuros – its people would be benefiting from this study.

All of these support the efforts of the IA towards achieving its vision of mobility for Intramuros and serving its function in managing traffic within its walls. In addition, the researchers who are pursuing studies in transportation modelling will find materials to check that will, in one way or another, augment supporting studies in their undertaking.

2. METHODOLOGY

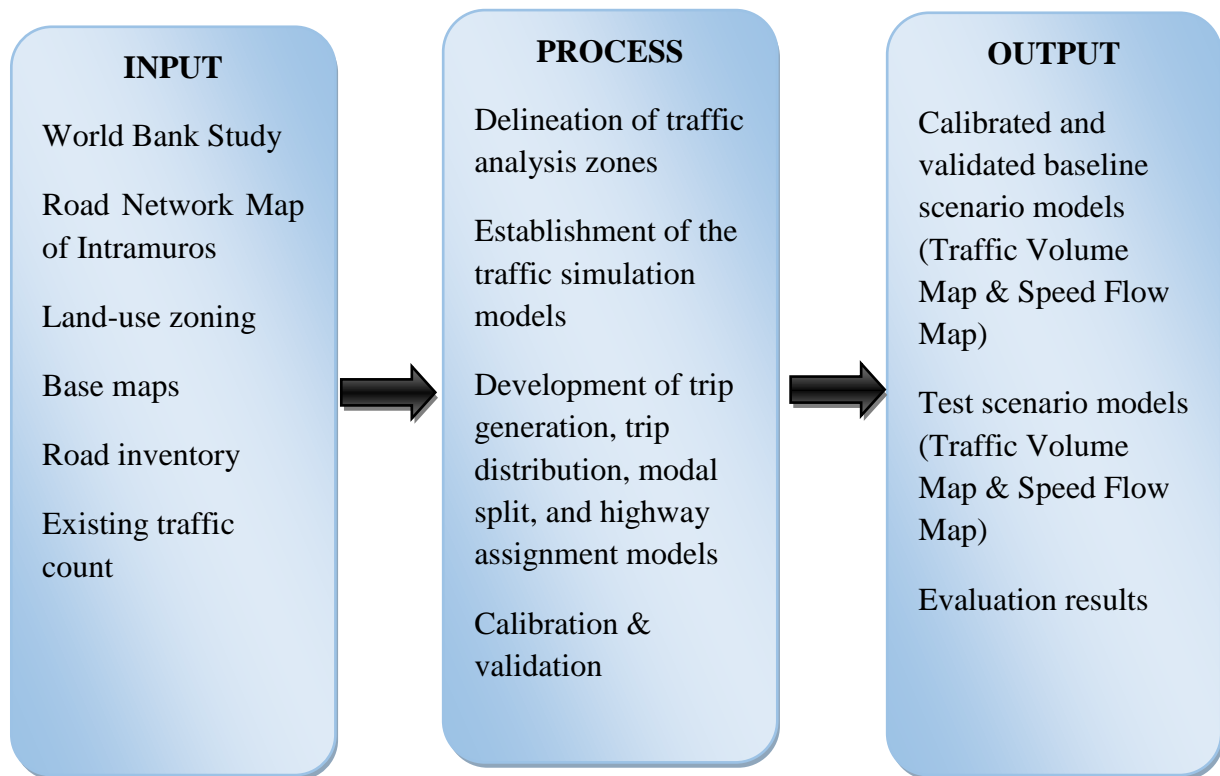


Figure 1. Conceptual Framework

The basic approach for this study was initially to have a baseline model of the original flow of traffic in Intramuros wherein GIS was used in the modelling of the area concerning digitization the roads within the walls and entries of traffic going in and out of Intramuros. This was done by the use of data coming from the Intramuros Administration, World Bank study done for Intramuros, Google Earth, Google Maps, the Light Detection and Ranging (LiDAR) orthophoto map of Intramuros, and the data gathered through surveys. Using the baseline traffic simulation model, the measures as enumerated in the World Bank study are applied to model the “what-if” scenarios if said measures are applied.

2.1 Research Design

Main classification of research would be experimental. Experimentation though would be created by the establishment of simulation models. In the creation of the simulation models, first goal is to model the original flow of traffic in Intramuros – that is the baseline model of the area. Parameters for the baseline model will be determined both by the use of qualitative and quantitative form of research. Qualitative will be used to describe the present condition of traffic in the area while quantitative will be used for the calculation and description of the behavior and characteristics of traffic including pedestrians in terms of equations and matrices. Then, for the actual modelling, Cube was used as the simulation software.

2.2 Computer software

ArcGIS version 10.2.2 was used for the establishment of road network for the area in Intramuros, Manila. The specific of component of ArcGIS that will be used is ArcMap 10.2.2, which is used for mapping and editing tasks.

After using ArcMap, it would then be processed in Cube version 6.1.1 for the division of zoning and for building the baseline model leading to the traffic simulation.

Cube Base is expected to handle the data prepared in ArcGIS then bringing it for use inside the Cube platform. Cube Base provides tools for (1) development, editing, manipulation, mapping and graphing of data using geographic information system (GIS) techniques and other functions, (2) design and application of the modeling and micro-simulation process, and (3) creation, management, comparison and analysis of scenarios.

From the seven components of Cube, namely: Voyager, Avenue, Dynasim, Land, Cargo, Analyst, and Cloud. The component of Cube which is available to the researchers, which is Cube Voyager allowed the integration of the standard four-step models of transportation engineering, namely trip generation, trip distribution, modal split and route assignment in the model. Furthermore, it was used to analyze the road network of Intramuros, for matrix calculations and for the detailed comparison of scenarios, especially during the application of the interventions enumerated by the World Bank study.

It will serve as the framework for modeling a wide variety of planning policies and improvements within the quasi-municipality of Intramuros.

2.3 Methods/Procedures

Baseline modelling

With regards to having the baseline model, it is a must to conduct the following:

1. Delineate traffic analysis zones - the basis was the land use zoning established by IA; general land use classes include residential, commercial, educational, offices. Following are the data needed to be done in delineating the traffic zones:
 - a. projected base maps using World Geodetic System (WGS) Universal Transverse Mercator (UTM) Zone 51N with metric units so that distances can be properly computed;
 - b. attributes for each zone: zone number, zone name, total land area, land area by land use, gross floor area by type, number of residents (nighttime population), number of workers by type, number of students by level, number of tourists.
2. Conduct an inventory of roads to include number of lanes and lane widths in the model.
3. Develop the four-step model using Cube Voyager.
4. Conduct model calibration and validation using existing traffic counts.

Model Calibration and Validation

The base scenario has been calibrated and validated using the volume of traffic entering Intramuros through the traffic count conducted in 2014 by the World Bank which was adjusted to account for the increase in traffic flow since zonal data are based from the current year which, 2016 then by comparing it to the volume of vehicles entering Intramuros as generated by Cube.

R-squared statistics was used to measure the closeness of data compared to the fitted regression line. R-squared value was generated using Microsoft Excel by comparing the data described above.

Scenario Testing

With the use of the baseline model, scenario tests are developed using the interventions as suggested by the World Bank study. The tables below describe how certain interventions are applied in the base traffic scenario of Intramuros.

Table 1 Phase I Interventions

No.	Intervention to pilot	Purpose, notes	Actions undertaken in the model
1	One-way on General Luna St., southbound	To allow sidewalk widening in the future, to discourage through traffic to the port	Changed the directional flow of traffic on the said stretch of the street from two-way street to one-way
2	One-way on Arzobispo, northbound only from Anda to Postigo	Forms part of the Gen. Luna one-way system. This road is narrow and should be one-way in any case	Changed the directional flow of traffic on the said stretch of the street from two-way street to one-way
3	Removal of Intendencia gyratory and installation of two-way traffic on west and north side of Intendencia	The Intendencia gyratory is used by HGVs and other vehicles to access the petrol station located at Anda Circle. Blocking off the gyratory should help reduce HGV traffic. The two-way flow also narrows the useable road space which will reduce the speed of vehicles as they enter Soriano Avenue	Removal of link in the mentioned location and adjustment of road links for the new two-way traffic
4	Closing off to traffic along Postigo St. beside Plaza Sto. Tomas	To better connect the Cathedral to Plaza Roma	Removal of link in the mentioned location
5	Closing off traffic along Sto. Tomas in front of Manila Cathedral	Provide more space for vendors, dining, and socializing in this popular plaza	Removal of link in the mentioned location
6	Installation of bollards on Muralla St. between Beaterio and Plaza España	To prevent through traffic	Removal of link in the mentioned location as bollards will also prevent vehicular traffic in the said location

Table 2 Phase III Interventions

No.	Intervention to pilot	Purpose, notes	Actions undertaken in the model
1	Pedestrianisation on Real St between Sta Lucia and Cabildo	First phase to pedestrianize the length of Real St. The western end ties in with more tourist attractions	Delete link so as no traffic will be assigned
2	Short section of pedestrianisation of Gen Luna between Sta Clara and Soriano Ave	To provide unobstructed pedestrian access from Fort Santiago to Plaza Roma and beyond	Delete link so as no traffic will be assigned
3	Shared space along Magallanes St	To support on-street activity	Reduction of maximum speed on the described street to simulate the concept of shared space
4	Shared space on Sto. Tomas between Cabildo and Magallanes	To complete the pedestrian link between Manila Cathedral and Plaza Sto Tomas	Reduction of maximum speed on the described street to simulate the concept of shared space
5	Shared space on Sta Potencia St	To support the existing on-street activity including vendors and student dining areas	Reduction of maximum speed on the described street to simulate the concept of shared space
6	Shared space on Muralla and San Francisco St	To support the existing on-street activity including vendors and student dining areas	Reduction of maximum speed on the described street to simulate the concept of shared space
7	Shared space on Real St between Legazpi and Muralla	As part of the project to pedestrianize Real St. The length between Legazpi and Muralla should be developed as shared space to maintain access to Mapua and Lyceum Universities	Reduction of maximum speed on the described street to simulate the concept of shared space
8	Sidewalk widening along the length of Soriano and change from perpendicular to parallel parking	To reduce the width of Soriano Ave down to two lanes and reduce the speed, to limit through traffic and make crossing easier for pedestrians	Reduction of street capacity due to sidewalk widening taking some space from the carriageway
9	Sidewalk widening on Sta Lucia	To allow pedestrian access to the Light and Sound Museum	Reduction of street capacity due to sidewalk widening taking some space from the carriageway
10	Sidewalk widening on Muralla	To provide proper access for students walking to schools	Reduction of street capacity due to sidewalk widening taking some space from the carriageway

3. RESULTS AND DISCUSSION



Figure 2. Road Network Map of Intramuros

The figure above shows the road network map of Intramuros. The road network map was digitized with the use of ArcGIS (ArcMap) 10.2.2. Mapping of streets is drawn over a Light Detection and Ranging (LiDAR) generated orthophoto map with the cell size of 0.25 by 0.25, and has the spatial reference based on the World Geodetic System (WGS) 1984 Universal Transverse Mercator (UTM) Zone 51N which brings a high level of accuracy especially in calculating the length of each road segment. Digitization of the roads are based from the Intramuros traffic flow map provided by the Intramuros Administration, together with the road links are their corresponding attributes including length calculated with ArcGIS, capacity, number of lanes per direction, and directional flow (one-way or two-way).



Figure 3. Traffic Analysis Zones

Figure 3 shows the area coverage for each internal traffic analysis zone. This was also generated by the use of ArcGIS (ArcMap) 10.2.2. Zones are based from the barangay boundaries which are also provided by the Intramuros Administration. Also noticeable in the figure above are the red points which are used to represent the external zones assigned based from the entry points of vehicles going inside the area. Five (5) external zones are considered which are represented by nodal points (6-10) so that external-internal trips are considered in the model. Other than delineation of the zones, used in the simulation models are important inputs for each zone such as population data and gross floor area according to land use.

Gross floor areas of each zone according to land use are key input for estimating the number of production-attraction trips. It can be seen on the table that the zone with the largest total gross floor area is Zone 2 having a value of 209,795.37 sq.m; while the zone with the least GFA is Zone 3 having a value of only 18,938.95 sq. m. If GFA is to be the sole basis of the production-attraction table, then it can be expected that the highest value for the number trips would be obtained from Zone 2 and the least expected would be coming from Zone 3. Other than the GFA according to land-use for each zone, population data had also been an important input for the traffic simulation models. It can be seen on the two tables above that the area with the highest number of total daytime population is Zone 5 where this can be related to the fact that two colleges, namely the Mapua Institute of Technology and the Lyceum of the Philippines University generated a total number of students equal to 28,153 which was about 40.50% of the total daytime population of Intramuros.

Furthermore, by looking at the total population during daytime versus nighttime, one can discern that Intramuros' many trips actually originated from outside of the walls as nighttime population represents the number of residents in each zone. On the other hand, Zone 2 which was shown earlier had the highest value in terms of its GFA in square meters comes only as third from the highest, if daytime population is considered. Zone 3 still has the least number of population.

Meanwhile, for the modal split, the modes of transportation available to travelers in Intramuros include walking, PUJs, FX (UV Express), cars, trucks, motorcycles, taxis, buses, bicycles, and pedicabs.

3.1 Baseline Model

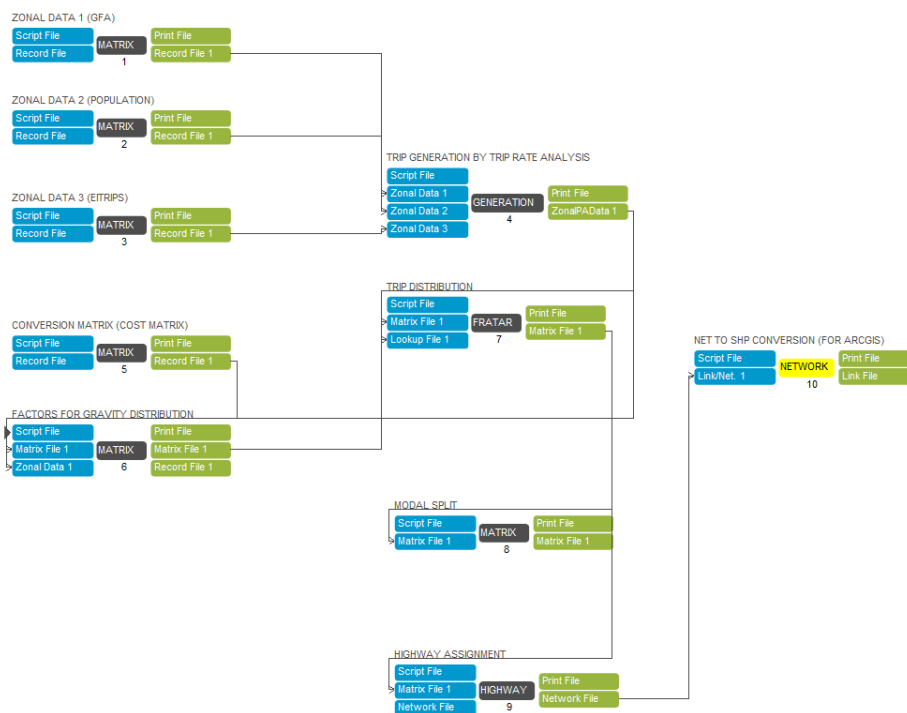


Figure 4. Base Scenario Model Structure in Cube

The Base Scenario Model Structure in Cube shows how the researchers utilized the software in developing the base scenario. Each step has been numbered according to its sequence once the application is ran. It can be noticed that within the structure or algorithm are file conversions. These were added so that Cube Voyager would be able to read the inputs and take them into account in producing the basic four-step model, namely trip generation, trip distribution, modal split, and highway assignment. The final output is a road network in SHP format so it can also be loaded in ArcMap.

Table 1 Production-Attraction Table

TAZ	HOME P	SHOP P	OFFICE P	SCHOOL P	OTHERS P	EXTERNAL P	TOTAL P	HOME A	SHOP A	OFFICE A	SCHOOL A	OTHERS A	EXTERNAL A	TOTAL A
1	59	6	57	198	3	0	322	59	6	57	200	3	291	616
2	150	49	170	9	15	0	392	150	49	170	9	15	349	741
3	4	10	24	0	1	0	38	4	10	24	0	1	34	73
4	31	41	84	694	2	0	851	31	41	84	660	2	729	1545
5	91	156	51	1182	57	0	1541	91	156	51	1215	57	1401	2971
6	0	0	0	0	0	643	643	0	0	0	0	0	0	0
7	0	0	0	0	0	680	680	0	0	0	0	0	0	0
8	0	0	0	0	0	861	861	0	0	0	0	0	0	0
9	0	0	0	0	0	464	464	0	0	0	0	0	0	0
10	0	0	0	0	0	155	155	0	0	0	0	0	0	0

Shown above is the result of the trip generation model through the production-attraction table which was developed using Cube Voyager. This was calculated using the trip rates for AM Peak from the Institute of Transportation Engineers Trip Generation Manual 2000.

It can be seen that the highest number of total production trips (TOTALP) and total attraction trips (TOTALA) which are equal to 1,541 and 2,971, respectively are from traffic analysis Zone 5. This may be related with the fact that this zone has the highest daytime population. Zone 3 has the lowest number of TOTALP and TOTALA which are 38 and 73, respectively. This can be correlated that this zone also has the least GFA and least number of population. Furthermore, the sum of balanced attraction to production is equal to 5947 trips which was then used as input for the Trip Distribution Model.

Table 2 Origin-Destination Table

	Sum	1	2	3	4	5	6	7	8	9	10
	5947.00	611.96	736.14	72.52	1534.87	2951.52	7.98	7.99	7.83	8.11	8.08
1	322.00	36.79	40.84	4.16	80.27	157.80	0.46	0.43	0.37	0.42	0.45
2	392.00	41.72	53.71	5.39	93.62	195.03	0.50	0.59	0.47	0.48	0.49
3	38.00	4.23	5.37	0.60	8.90	18.64	0.05	0.06	0.04	0.05	0.05
4	851.00	80.19	99.18	9.47	238.56	418.03	1.03	1.08	1.25	1.15	1.06
5	1541.00	157.23	190.24	18.25	384.89	780.47	1.96	2.01	1.92	2.03	1.99
6	643.00	75.00	79.44	8.11	154.88	320.73	1.14	0.84	0.79	0.96	1.12
7	680.00	71.16	95.83	9.99	164.55	334.00	0.85	1.13	0.82	0.83	0.84
8	861.00	80.28	98.70	9.42	249.58	417.25	1.05	1.08	1.35	1.20	1.09
9	464.00	47.87	54.06	5.25	121.48	232.00	0.67	0.57	0.63	0.75	0.71
10	155.00	17.50	18.76	1.88	38.14	77.57	0.27	0.20	0.20	0.24	0.27

The Origin-Destination Table shows the distribution of trips among zones. Most trips originate from Zone 5 and are towards the same zone. This is due to the high activity in the area because of the high number of population as well. Least trips originates and are destined to Zone 3.

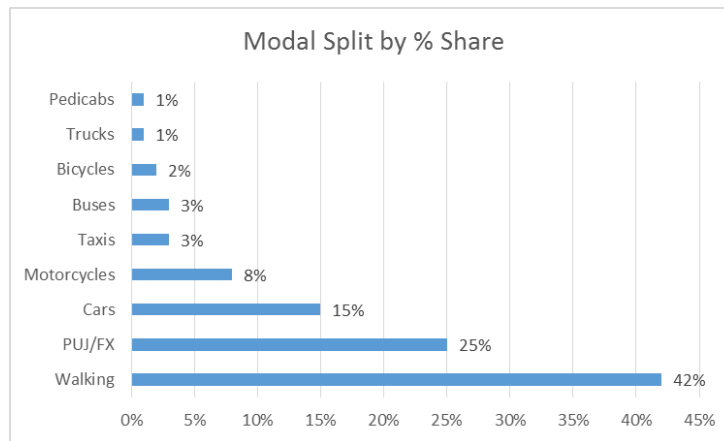


Figure 5. Modal Split by Percentage Share

These trips as calculated in the trip generation and trip distribution are then divided among the available modes of travel in Intramuros, which are as follows: walking, PUJs, FX (UV Express), cars, trucks, motorcycles, taxis, buses, bicycles, and pedicabs. Walking as seen on the chart show the highest share in terms of the number of trips which is equal to 42%.

Table 3 Comparison of Traffic Count to Traffic Assignment

No.	Location	AM Peak Hourly Average Traffic Count (in pcu)	Volume of Traffic Generated from the Model (in pcu)
1	Entry point from Riverside Drive	643	614.86
2	Gate at A. Soriano Ave. (Aduana)	680	678.87
3	Gate at Gen. Luna Street	861	859.65
4	Gate at Victoria Street	464	463.25
5	Gate at Anda Street	155	154.73

It can be observed on Table 3 that AM peak hourly average traffic count of entering vehicles in Intramuros are not far from the result traffic assignment result. The data presented are the results of several calibrations and validation in the model so as to achieve desired results.

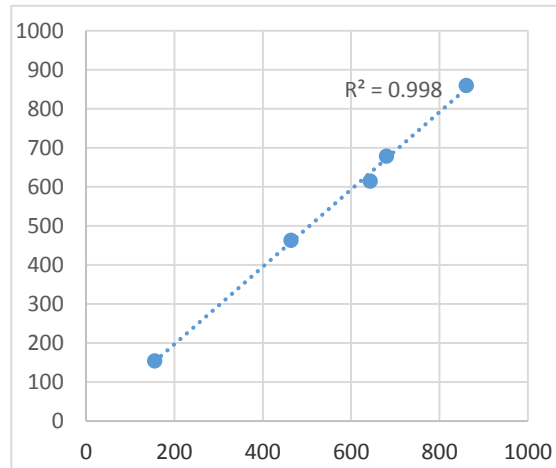


Figure 6. Graph showing R-squared value

R-squared statistics that is based on the previous table displays that there is less than 1% of relative gap in the actual traffic count and the assigned volume traffic as generated by the model.

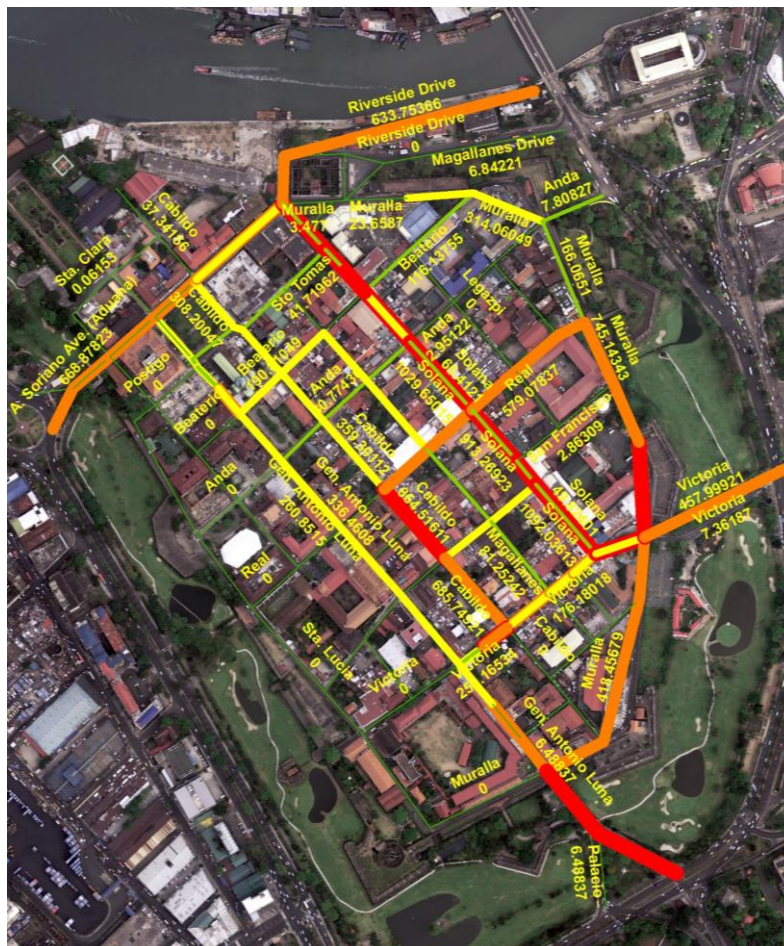


Figure 7. Sample Map (Traffic Volume) Output

Final results of traffic assignment are maps which show the result of highway assignment with regards to the volume of assigned traffic in each link and the speed as processed from Cube Voyager.

It can be noticed in the traffic volume map that there is a stretch of Gen. Luna which has 607.79 or approximately 608 trips traveling the link; and, based the ideal speed of 20 km/hr, there is an expected speed reduction to about 19.80 km/hr. This may be related to the fact that in the base scenario, it is currently a two-way highway thus an easy and shortest choice for vehicles to go around Intramuros. Other streets that might be able to generate high number of trips are Solano, Magallanes, and Cabildo as these streets provides inter-zonal connections.

3.2 Scenario Tests

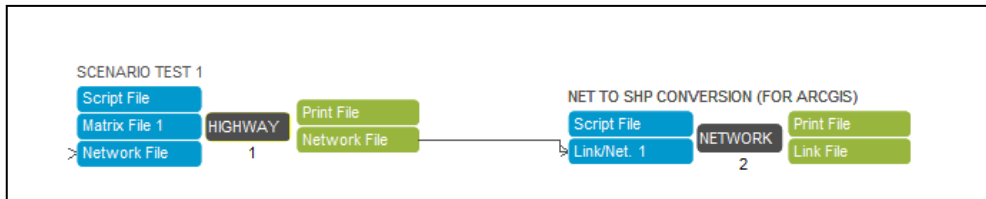


Figure 8. Scenario Testing Structure in Cube

Since this model structure is intended for scenario testing, this is a much more simple structure. The adjusted road network so as to fit the proposed measure and values resulting from the base scenario are adopted. Final output is also an SHP file compatible to ArcMap. Note that the same structure for scenario testing of Phase III interventions has been used.

Maps were also generated to show the results of highway assignment with regards to the volume of assigned traffic in each link and the speed as processed from Cube Voyager.



Figure 9. Traffic Volume Map (Phase I Intervention)

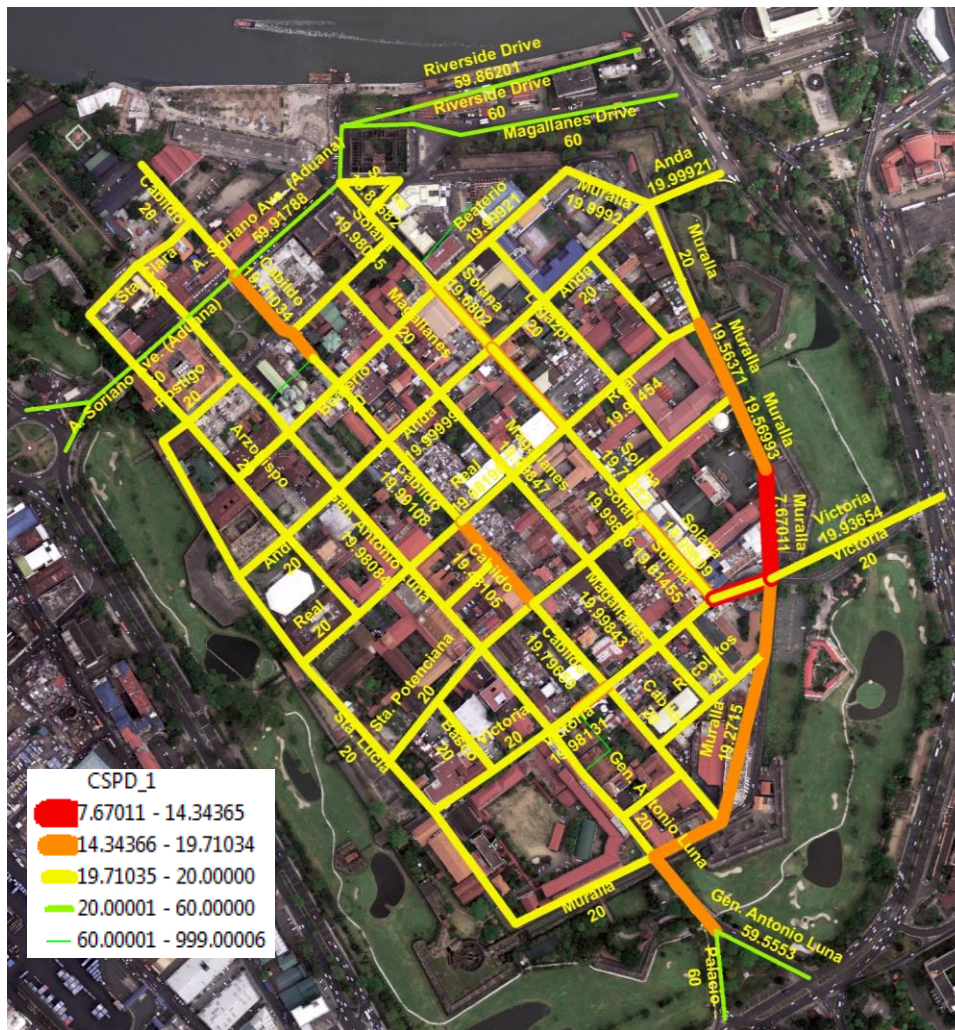


Figure 10. Speed Flow Map (Phase I Interventions)

As the Phase I interventions are applied in the baseline model the result has been translated into maps which show the result in terms of volume of assigned traffic in each link (Figure 9), and its corresponding flow speed (Figure 10) as processed from Cube Voyager. Key findings corresponding the interventions applied as the result of the evaluation are tabulated below:

Table 4. Evaluation Results Using Phase I Interventions

No.	Intervention applied	Purpose, notes	Evaluation results	Remarks
1	One-way on General Luna St., southbound	To allow sidewalk widening in the future, to discourage through traffic to the port	Reduction in trips directly assigned to General Luna; planned sidewalk widening can be done	Increase in traffic flow along Muralla, trips are now also assigned in Sta. Lucia
2	One-way on Arzobispo, northbound only from Anda to Postigo	Forms part of the Gen. Luna one-way system. This road is narrow and should be one-way in any case	No significant findings in the traffic simulation models	A validation of the area suggests that this section do not generate traffic much but this is narrow and ideal for one way traffic flow only
3	Removal of Intendencia gyratory and installation of two-way traffic on west and north side of Intendencia	The Intendencia gyratory is used by HGVs and other vehicles to access the petrol station located at Anda Circle. Blocking off the gyratory should help reduce HGV traffic. The two-way flow also narrows the useable road space which will reduce the speed of vehicles as they enter Soriano Avenue	There is an expected minimal speed reduction along Soriano Ave; No trips are now expected to be assigned along the side of Intendencia facing Plaza España; about 195 trips displaced	Corresponds with its purpose; It will now be safer for pedestrians to use
4	Closing off to traffic along Postigo St. beside Plaza Sto. Tomas	To better connect the Cathedral to Plaza Roma	No traffic assigned since it is assumed in Cube that the link is non-existent	Traffic volume in Magallanes would be reduced but this leads in the increase on trips assigned in Solana
5	Closing off traffic along Sto. Tomas in front of Manila Cathedral	Provide more space for vendors, dining, and socializing in this popular plaza	No traffic assigned since it is assumed in Cube that the link is non-existent; about 100 trips is displaced from the area	Space can be used for more activities; Traffic is expected to be reassigned in surrounding roads like Cabildo
6	Installation of bollards on Muralla St. between Beaterio and Plaza España	To prevent through traffic	No traffic assigned since it is assumed in Cube that the link is non-existent; about 198 trips is displaced from the area	Significant increase (about 30-40%) on no. of trips assigned on Solana

Scenario Test II

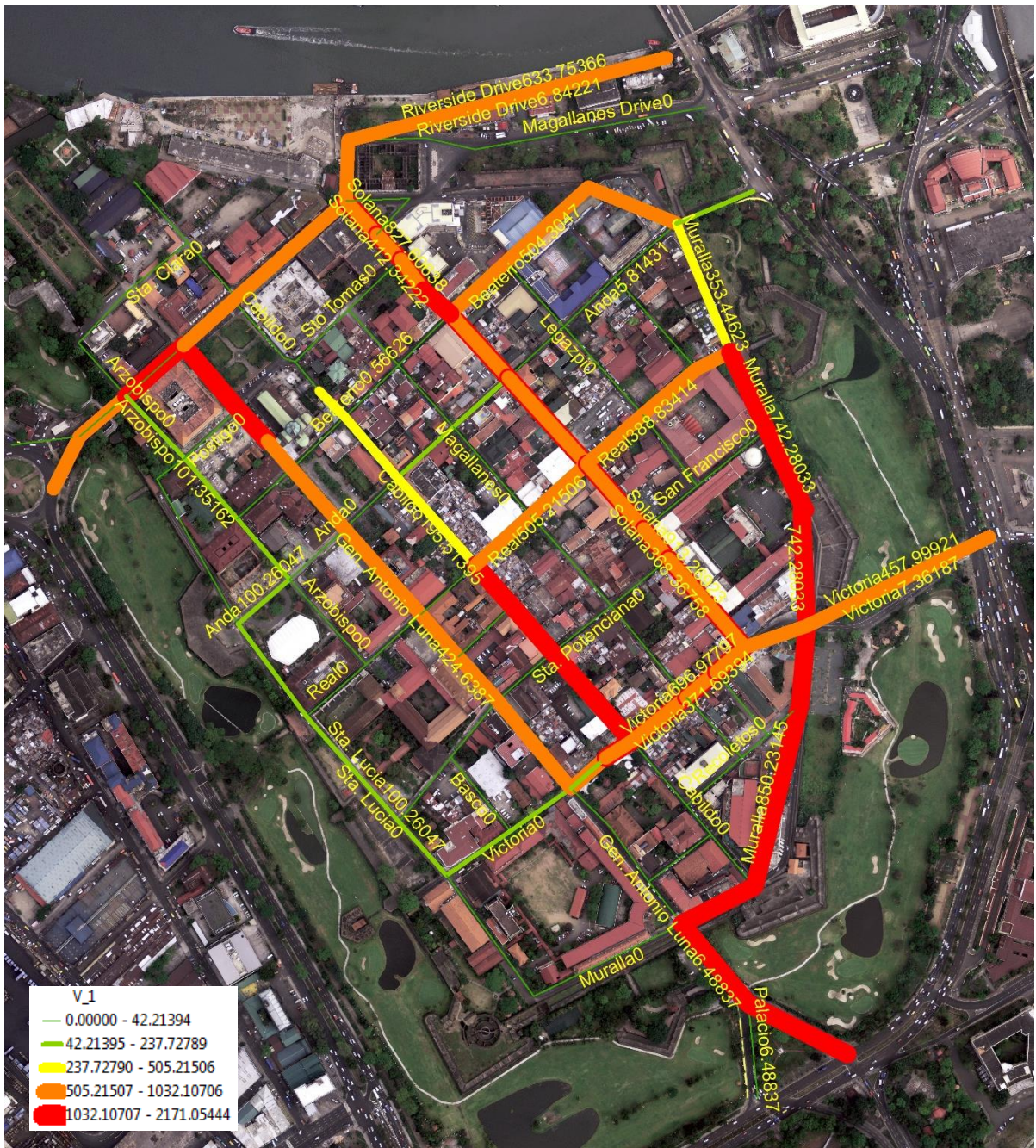


Figure 11. Traffic Volume Map (Phase III Interventions)

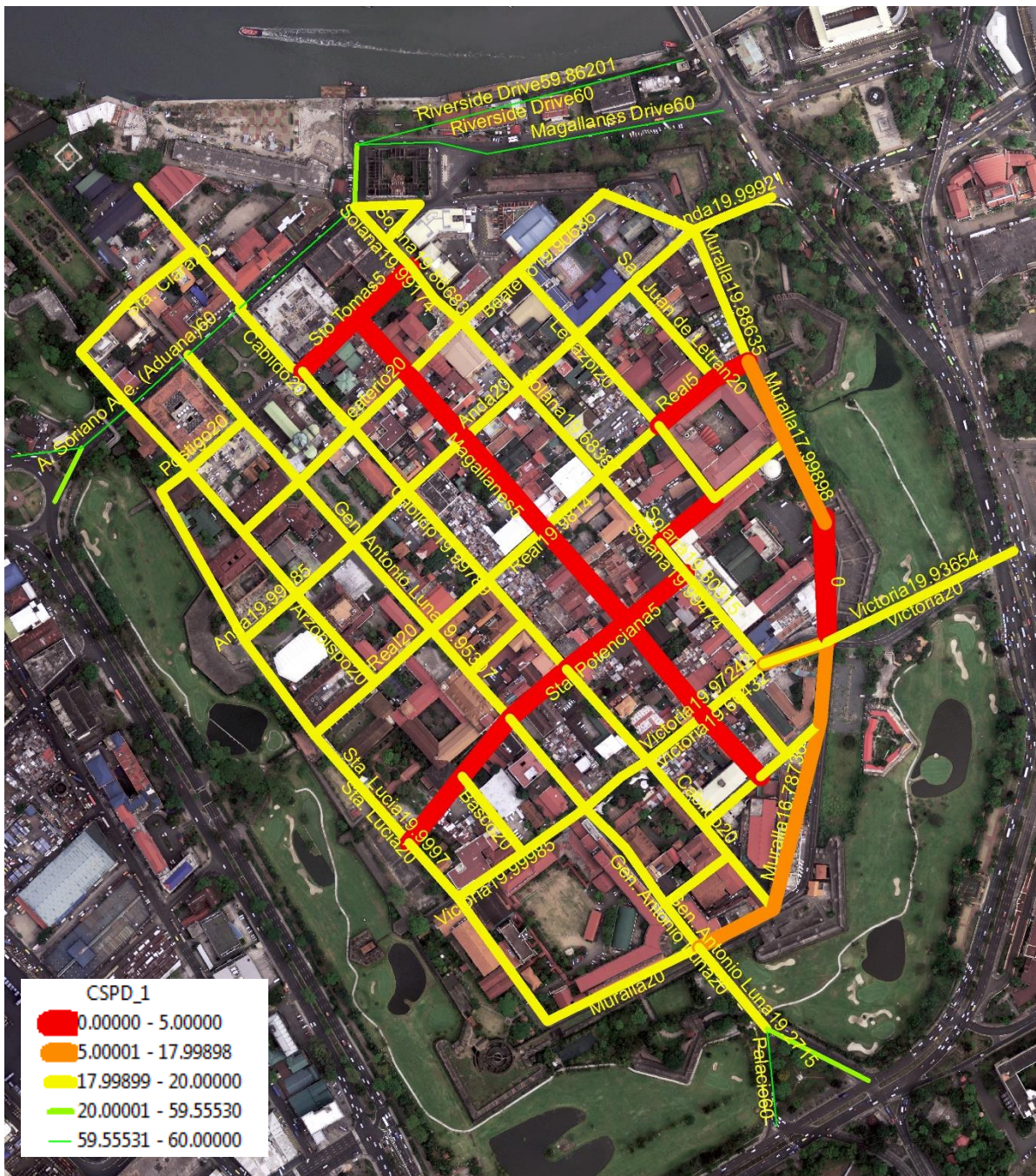


Figure 12. Speed Flow Map (Phase III Interventions)

It is assumed that in the application of Phase III interventions where its results are shown above through the traffic volume map (Figure 11) and speed flow map (Figure 12) as processed from Cube Voyager, network features from the application of Phase I Interventions were adopted and modified to apply said additional measures. One significant finding in the model is that when all

the Phase III interventions are applied, the proposed pedestrianization and introduction of share space concept on nearby roads resulted to a re-increase in the number of trips assigned in Gen. Luna Street compared to when only Phase I interventions are considered in the model. Nonetheless, following are the key findings as the result of the evaluation:

Table 5. Evaluation Results Using Phase III Interventions

No.	Intervention applied	Purpose, notes	Evaluation results	Remarks
1	Pedestrianization on Real St between Sta Lucia and Cabildo	First phase to pedestrianize the length of Real St. The western end ties in with more tourist attractions	No trips are assigned in the link	Based on the highway/trip assignment result, pedestrianization of Real Street is possible
2	Short section of pedestrianization of Gen Luna between Sta Clara and Soriano Ave	To provide unobstructed pedestrian access from Fort Santiago to Plaza Roma and beyond	No traffic assigned since it is assumed in Cube that the link is non-existent	Part of zone 3 where only few trips are attracted and produced; Pedestrianization is possible
3	Shared space along Magallanes St	To support on-street activity	No trips are assigned in the link; there is a stretch where about 180 of trips assigned are expected to be displaced	Shared space concept can easily be implemented; trips displaced are expected to use other nearby roads
4	Shared space on Sto. Tomas between Cabildo and Magallanes	To complete the pedestrian link between Manila Cathedral and Plaza Sto Tomas	No trips are assigned in the link	Shared space concept can easily be implemented
5	Shared space on Sta Potenciana St	To support the existing on-street activity including vendors and student dining areas	There is segment of Sta Potenciana where about 418 trips are to be displaced	Traffic displaced from Sta Potenciana is expected to be distributed on nearby roads
6	Shared space on Muralla and San Francisco St	To support the existing on-street activity including vendors and student dining areas	No significant changes between the traffic simulation models	As validation is done in the area, it can be observed that this is used for on-street parking and a venue for student dining which reduces capacity; already having the concept of shared space

7	Shared space on Real St between Legazpi and Muralla	As part of the project to pedestrianize Real St. The length between Legazpi and Muralla should be developed as shared space to maintain access to Mapua and Lyceum Universities	No significant changes between the traffic simulation models	As validation is done in the area, it can be observed that this is used for on-street parking which reduces capacity; pedestrianization is possible
8	Sidewalk widening along the length of Soriano and change from perpendicular to parallel parking	To reduce the width of Soriano Ave down to two lanes and reduce the speed, to limit through traffic and make crossing easier for pedestrians	Reduction in the number of trips assigned in the area	It means that the traffic would be less likely to choose Soriano Ave. which meets the purpose of the intervention - to limit through traffic
9	Sidewalk widening on Sta Lucia	To allow pedestrian access to the Light and Sound Museum	Decrease in the already few assigned trips in Sta Lucia	This is a good indication that sidewalk widening is possible.
10	Sidewalk widening on Muralla	To provide proper access for students walking to schools	No significant changes between the traffic simulation models	This may be related to the fact that Muralla Street is already a one-way street and has enough breadth to accommodate sidewalk widening

With the maps generated, the researchers are able to found out where the streets with expected delays and high volumes are expected in the implementation of the measures to address mobility and accessibility in Intramuros.

The conditions of these streets trace back the barriers as to the road condition and irregularities in their design which are expected to be the problems in implementing the interventions and achieving desired results.

3.3 Barriers Identified

With the use of the test scenarios, the authors were able to determine the road links or streets that are likely to accommodate increase in traffic assigned to it that is caused by the trips displaced from links that flow will be disrupted due to closure of roads, converting two-way streets to one-way streets, and introduction of shared space concept.

A revisit to these sites traces back the barriers to the following problems as identified through actual site investigation:

1. Most of the roads are poorly maintained; poor drainage in most cases. Local roads are less taken care of compared to national roads because road conditions.
2. Most of the roads either lacks or has faded pavement marking that needs to be addressed. Pavement markings are important road safety features that guide road users traversing along a stretch of road.
3. There are traffic signs that are unnoticeable or damaged. Also, during observation of traffic flow, road users often disregard these signs. These traffic signs are not placed there without any reason. Traffic signs aims to regulate and ensure correct traffic flow. Disregarding traffic signs can cause conflicts in traffic flow and in worse cases, vehicular accidents.

4. There have been found out that vendors and on-street parked vehicles occupying portions of the roads' carriageway, thus reducing capacity and affecting traffic flow.

4. CONCLUSION

The researchers are able to first, define the system studied – delineation of the area, digitization of roads, attribution of each road link, and determination of zonal data which have all been deliberately taken into account and served as important inputs which are coded in ArcGIS (ArcMap) 10.2.2 and later on utilized in the models generated with the use of Cube Voyager.

Next, the baseline model was developed. Four-step model of transportation forecasting, namely: trip generation, trip distribution, modal split, and highway assignment has been utilized for such. Zonal production-attraction table, origin-destination matrix, modal split in terms of percentages, and data from highway assignment were then presented.

Coming from this, the output has been calibrated and validated so as to meet the desired results; it has been made sure that the number of trips entering Intramuros are well accounted as the researchers have chosen the five gates of Intramuros as the calibration points.

Next, scenario testing is done by applying the interventions from the World Bank study which are referred in this study as measures towards addressing mobility and accessibility. The results were compared to the base scenario in which evaluation results were noted and remarks were drawn from.

Key findings in the evaluation are: (1) once a segment of a road is closed for traffic use, it is expected that the trips that were supposed to be assigned in such segments are displaced and distributed to nearby roads; (2) concept of shared space if introduced in a simulation model with the use of Cube Voyager shows that it is unlikely that trips will be assigned on those links as a significant reduction of speed is used in the simulation to interpret the applied concept; and, this could also be explained by the reason that Cube only calculates the routes that are to be favored the most; (3) there are some interventions that once applied, no significant findings are seen so the researchers revisited the site to validate such results; and, (4) increase in the width of sidewalks in certain streets of Intramuros is highly possible.

As for the overall result, it could be expected that no problems or only a very few might be encountered once Phase I interventions are applied. But upon evaluation of Phase III interventions, there was a recorded re-increase in the number of trips assigned in General Luna but the original goal was to reduce it; unfortunately, with the models generated, the specific reason why it resulted that way cannot easily be identified. However, this might be related to the pedestrianization and use of shared space on nearby roads.

To better facilitate continuous traffic movement thus addressing mobility and accessibility, the researchers are able to point out which among the streets are to accommodate huge number of trips and these streets must be prioritized for road improvement and maintenance.

Evaluation results presented then satisfy the main objective of this study: to model impacts of proposed mobility and accessibility interventions in Intramuros, Manila.

Furthermore, with this study, the researchers are able to take advantage of the capabilities of geographic information systems (GIS) through ArcGIS, and the computational strength especially intended for transportation modelling through Cube. The two platforms complement each other.

Despite this, the researchers have also been able to identify the disadvantages of using Cube Voyager as a traffic simulation software – (1) it assumes that the pedestrians move in the same direction and share road space with all the other road users, thus making it difficult to model, (2) other non-motorized mode of transport like bicycles and pedicabs in which many counters the

flow of traffic cannot be integrated in the models done, and (3) behavior of the drivers, street design, and road condition are also difficult to be considered in the traffic simulation software used.

Nonetheless, it can be concluded that the kind of models generated from Cube Voyager can be best replicated on bigger road networks, say on a regional level, which will best serve its purpose as a traffic macroscopic simulation software.

In the end, this augments the study done by World Bank by providing simulation models as tool in evaluating the effects of their suggested measures to address mobility and accessibility of Intramuros. Better visualization of traffic flow inside the walls were seen through the models generated which can be of great help in future policy making with regards to traffic management in the area.

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