ASSESSMENT OF TRAFFIC IMPACT OF PORT DEVELOPMENT PROJECTS (THE CASE OF PORT OF MANILA)

Jane R. ROMERO
Graduate Student
M.S. Civil Engineering
(Transportation) Program
College of Engineering/National Center
for Transportation Studies
University of the Philippines
Diliman, Quezon City 1101
Metro Manila, Philippines
Tel: 929-04-95 local 217
E-mail: jane@up-ncts.org.ph

Ricardo G. SIGUA, Dr.Eng.
Associate Professor
Department of Civil Engineering
College of Engineering
University of the Philippines
Diliman, Quezon City 1101
Metro Manila, Philippines
Tel: 929-04-95 local 213
Fax: 929-56-64
E-mail: rsigua@up-ncts.org.ph

Abstract: The Port District of Manila drafted a 25-year development plan that will cover the improvement of the South Harbor, the North Harbor and the Manila International Container Terminal (MICT). The objectives of that master plan are urgent port extensions for coping with the growing cargo and passenger traffic. Numerous studies in the past recommended that port development projects should be evaluated considering their traffic impact considering that the port's land operation is severely hampered by Metro Manila's traffic congestion. In this study, traffic impacts of the projected vehicles to be generated by the proposed port expansion were analyzed using the TRAF-NETSIM simulation software. Since these port projects will generate mostly freight/cargo traffic, the focus of the this study will be on truck traffic and will incorporate related issues like the effect of the proposed infrastructure along truck routes and the utilization of railroad as an alternative to trucks in cargo distribution.

Key Words: traffic impact analysis, traffic simulation, truck traffic

1. INTRODUCTION

The Port of Manila is the center of the Philippine port system. It is composed of the South Harbor, North Harbor and the Manila International Container Terminal (MICT). The port serves as the country's link to major cities of the world and the junction of domestic and international trade. Its economic importance is reflected on employment generation, business opportunities in shipping, cargo handling and other services related to the shipping industry.

Despite the planned transfer of international cargo to other areas, the planned expansions of port facilities at the Port of Manila will always continue to serve the needs of Manila commerce and industry in the foreseeable future. Based on the Port of Manila 25-Year Port Development Plan that was drafted in 1995, total sea-borne cargo for the Port of Manila is expected to grow at 10% per annum, so that in 2010 it is expected to be four times the 1995 throughput. This projection by not be realistic today considering the slowdown due to the Asian financial crisis. However, for planning purposes, the projections based on that study were adopted.

There is a particular problem in the port strategy for the Port of Manila being the dominant source of and market of port traffic. Basically, land transport to and from the Port of Manila is undertaken by road transport. The port's land operations are severely hampered by Metro Manila's traffic congestion. The increasing demands for port services and the growing congestion require improvements in the road system to keep up with the demands for efficiency. This particular study aims to assess the traffic impact of the proposed port developments through traffic simulation. This will also discuss the applicability of the traffic simulation software TRAF-NETSIM in evaluating the traffic impact scenarios.

2. METHODOLOGY

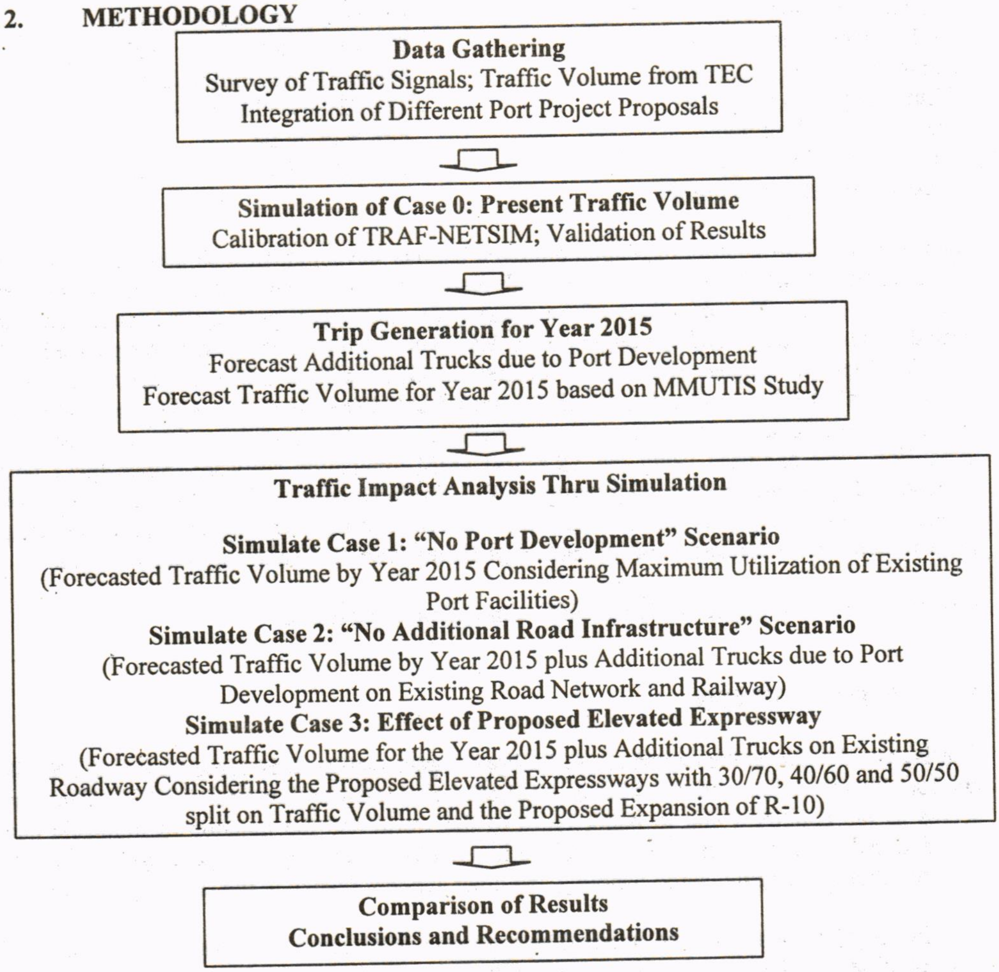

Figure 2.1 Flow of Study

Four cases will be simulated to represent the different scenarios prior and upon completion of the said development projects. Case 0 depicts the present condition that is, present traffic volume on the existing roadway facilities. Case 1 represents the scenario for the year 2015 assuming that the proposed port development projects will not materialize. The growth in port traffic until the port reaches its saturation level is included in the assumption of Case 1. Case 2 will simulate the scenario for the year 2015 wherein forecasted traffic volume as per the

MMUTIS study plus the forecasted truck traffic to be generated by the port development will be tested on the existing roadway facilities considering the effect of the railway. Since the railway facilities are already in place, it is assumed to take an important part in the distribution of the containerized traffic. The MMUTIS Study proposed a port access improvement plan consisting of the elevated expressways that would help decongest the existing road network and the planned R-10 expansion to have a 50-m ROW. Case 3 considers the effect of these proposed infrastructures on the existing road network.

2.1 Data Gathering for Simulation of Base Case

Data necessary for the simulation run are topology and geometrics of each roadway component (in the form of link node diagram), channelization of traffic, traffic signal timing, traffic volumes, turning volumes, specification of transportation modes and designated vehicle routes.

2.1.1 Survey of Traffic Signals and Roadway Geometrics

The study area for simulation (**Figure 2.1**) is bounded by R-10, Tayuman St. (C-2), A. H. Lacson St. (Gov. Forbes St.) and P. Burgos St. The study area consists of 73 signalized intersection. Of the 73 intersections, 5 signals were out of order. Ten signal cycle times per intersection were observed to check the stability of the count. The recorded cycle time of the intersections varied from 80 seconds to 180 seconds. The allocated green time per phase for left-turners varied from 10 seconds to 80 seconds. Allocated green time for through traffic per phase ranged from 35 seconds to 110 seconds. The observed amber time is 3 seconds.

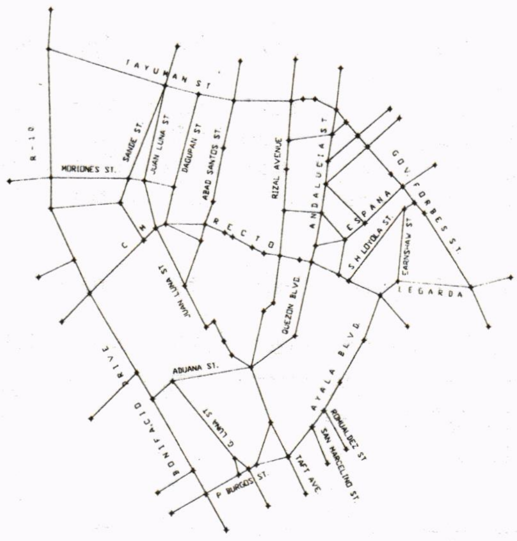

Figure 2.1 Study Area for Simulation

2.1.2 Traffic Volume Data

The traffic volume data was taken from the periodic traffic survey gathered by the Traffic Engineering Center (TEC). The morning peak volume was used in the simulation.

2.1.3 Identification of Truck Routes

Metro Manila experiences traffic congestion on major routes throughout the day prompting the imposition of the truck ban scheme, which limits cargo movements within, to and from Manila. Truck routes and other prohibitions of truck movement have been in force in Metro Manila since 1978. The designated truck routes to and from the Port defined by MMC Ordinance No. 5, S.1994 that are not included in the truck ban scheme are used in this study.

2.2 Trip Generation for the Year 2015

One basic factor needed to evaluate site traffic impacts is an estimate of the amount of traffic generation associated with the development. For the year 2015, the increase of traffic volume in the study area is based on the factors generated by the MMUTIS Study. The estimate of the amount of freight traffic to be generated by the port development was based on the projected cargo to be handled by the port.

2.2.1 Factors Used in Forecasting Traffic Volume by Year 2015

There are three (3) major factors identified by the MMUTIS Study which will contribute to the increase of traffic load on the roads in the future:

a.) population growth 1.58 times
b.) relative increase of private mode 1.35 times
c.) increase in average trip length 1.40 times

2.2.2 Forecasting of Additional Trucks to be generated by Port Development

The projected port cargoes based on the Port of Manila 25-Year Port development Plan were converted to the number of trucks that will be used for its hauling and distribution to evaluate the traffic impact on the road network. The result of the O/D survey conducted by JICA in 1994 was adopted to locate the destination of the cargoes. An average truckload equal to 1.75 TEU was used.

Table 2.1 shows the additional trucks to be generated by the proposed development projects.

Table 2.1 Forecasted Average Truck Traffic (Truck/Hour)

	1996[1]	2015	2015/1996
South Harbor	83	345	4.15
North Harbor	88	145	1.65
MICT	126	440	3.50
Total	297	930	3.13

Source: MMUTIS

The present truck traffic generated by the port is expected to increase 3 times after the completion of the port development plan as shown in **Table 2.2**. Metro Manila will remain as the major hinterland of the Port of Manila.

Table 2.2 Distribution of Forecasted Truck Traffic

Destination	Number of Trucks/Hour
Southbound	345
Northbound	145
Eastbound	440
Total	930

2.3 Assumption for Optimum Rail Operations

Considering the same capacity for the northbound rail, 41 TEUs per trip (one-way), tabulated in **Table 2.3** are following assumptions for the optimum operations of rail in handling freight distribution to alleviate road traffic.

Table 2.3 Assumptions for Optimum Operations of Rail

Length of train (21 15-meter long rail cars)	315 meters
Speed of train	20 kph
Time, in seconds, to cross road intersections	57 seconds (approximately 1 minute)
Number of trips per hour	2 trips/hour

2.4 Simulation Using TRAF-NETSIM

Simulation is advantageous in analyzing large networks wherein controlled experiments are not practical. TRAF-NETSIM is a simulation model that allows the traffic engineer to evaluate complex strategies on a real-time basis for a given network. It models traffic stochastically, using the Monte Carlo technique to represent different driver behaviors. TRAF-NETSIM consists of an integrated set of simulation models, which in aggregate represent the traffic environment. The choice of using TRAF-NETSIM in this study was mainly because it is the only simulation software available to the researcher that has capability for network simulation.

The TRAF-NETSIM model accurately replicates the flow of traffic through an intersection, arterial network, or grid network. The simulation describes in detail the operational performance of vehicles traversing the network on a microscopic level. For example, each vehicle's position, speed, and amount of time in the network are kept in memory throughout the run. This provides a trajectory for each vehicle throughout the simulation run.

2.4.1 Building of Simulation Network

The model network is composed of 79 internal nodes, 23 entry/exit nodes and 32 signalized intersections. Although data for 68 traffic signals are available, only 32 signals were used in the simulation because minor signalized intersections within the study area that are not affected by truck traffic were no longer modeled. Initial attempt to model even the minor links proved to be too large for the software resulting to no graphics output. In links wherein traffic signal timing was not used, the free flow speed was reduced accordingly to reflect the stopping at intersections.

2.4.2 Calibrating TRAF-NETSIM

The following traffic parameters shown in **Table 2.4**, which reflect the local conditions, were adjusted to calibrate the model. The truck routes were modeled using the record types for bus routes. The initial bus/truck headway is 90 seconds or equivalent to 40 trucks per hour per lane. The jeepney was treated as carpool vehicle in the simulation to distinguish it from cars.

Table 2.4 Traffic Parameters

mean value of start-up lost time for 1st vehicle	3.0 sec
mean queue discharge headway	2.0 sec[1]
desired free flow speed	15 mph/24 kph
start-up acceleration rate	
passenger cars	5.5 mph/sec[2]
jeepneys (carpools)	3.0 mph/sec[3]
trucks	2.0 mph/sec[4]

Note: [1] Analysis of Road Traffic Flow and Traffic Environment in Metro Manila. (Vergel, 1999)
[2] default value (2.44 m/s^2)
[3] slow moving vehicles (1.33 m/s^2)
[4] default value for buses (0.9 m/s^2)

2.4.3 Checking of Stability of Simulation

After calibration, there is a need to check the stability of the simulation model. The initialization process affects initial simulation cycles so stability of the simulation should be validated. An initialization of 11 minutes was necessary as "fill-up time" prior to simulation. The base data was simulated for 30 minutes. The flow rate of vehicles entering the network was graphed relative to cycle time. Of the 17 entry nodes, 2 entry nodes were presented here: nodes 701 (R-10) and 714 (Taft Ave.). From **Figure 2.2** and **Figure 2.3**, after 10 cycles, the flow rates were already stable.

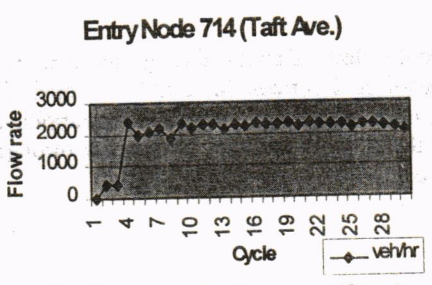

Figure 2.2 Stability Check at Node 714 (Taft Ave.)

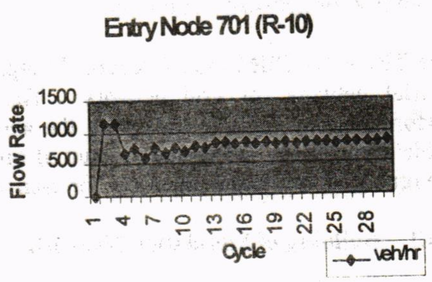

Figure 2.3 Stability Check at Node 701 (R-10)

2.4.4 Validation of Results

To validate the results of the simulation, the actual flow rates through the links are compared with the simulated flow rates. The longest path in the network was selected for the comparison of flow rates. Referring to **Figure 2.1**, these are the streets fronting the North Harbor and South Harbor, Bonifacio Drive and R-10, which are composed of 18 links (southbound and northbound).

Figure 2.4 shows the comparison between the actual and simulated traffic count along Bonifacio Drive and R-10 (Northbound). **Figure 2.5** shows the comparison between the actual and simulated traffic count along Bonifacio Drive and R-10 (Southbound).

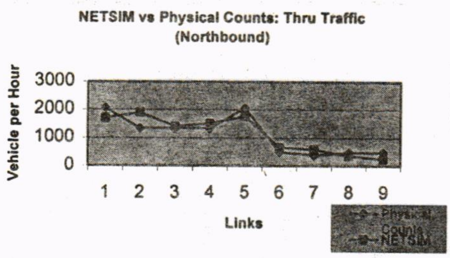

Figure 2.4 Comparison Between Simulated and Actual Traffic Count along Bonifacio Drive and R-10 (Northbound)

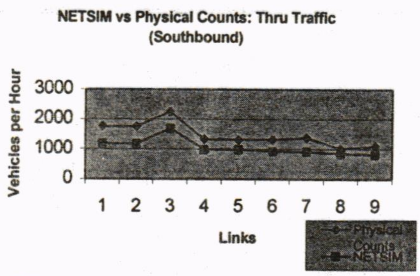

Figure 2.5 Comparison Between Simulated and Actual Traffic Count along Bonifacio Drive and R-10 (Southbound)

The actual values were graphed relative to the simulated values to check the relationship between the actual and simulated values as shown in Figures 4.4a and 4.4b. The resulting R^2 for the northbound section is $R^2 = 0.8175$ and $R^2 = 0.9243$ for the southbound section. These indicate strong relationship between the actual and simulated values.

3. TRAFFIC IMPACT ANALYSIS USING SIMULATION

3.1 Scenarios for Traffic Simulation

Four cases representing different scenarios will be evaluated through traffic simulation. Summarized in **Table 3.1** are the assumptions for each case.

Table 3.1 Scenarios for Traffic Simulation

	TRAFFIC VOLUME		PORT ACCESS		
	1998	2015	PORT	ROAD NETWORK	RAILWAY
CASE 0					
CASE 1					
CASE 2					
CASE 3					

- with proposed improvements

3.2 Simulation of Base Case (Case 0)

Simulation of Base Case (Case 0) is the simulation of the present traffic situation at the study area. **Figure 3.2a** shows the simulated present average speed along the Study Area. The average network speed is 15.84 kph. The simulation captures the actual trend of the average speed in the study area. The resulting average speed already denotes a congested traffic situation. As it is, the road network is inadequate in handling the present traffic volume. On the other hand, the proposed port development is also inevitable, as it is needed to cope up with the growing port traffic. It is for this reason that the forecasted scenarios are necessary for evaluation to assess their traffic impact.

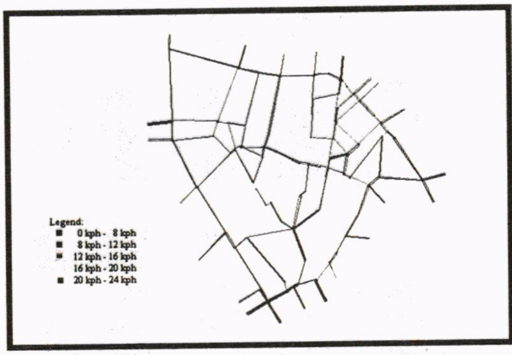

Fig. 3.2a CASE 0 Average Speed (kph)

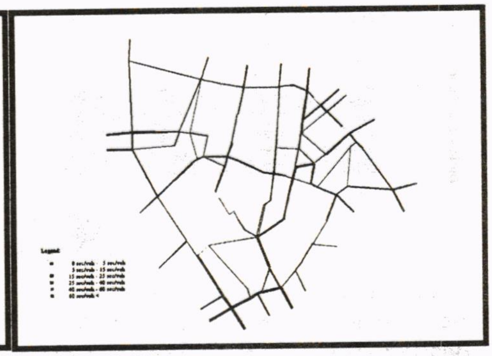

Fig. 3.2b CASE 0 Delay (sec/veh)

Figure 3.2b shows the simulated delay, in seconds per vehicle, along the Study Area. The TRAF-NETSIM output is on per link basis wherein phase failures instead of cycle failures at intersections are calculated.

3.3 Simulation of CASE 1: " No Port Development Until 2015"

Figure 3.3a shows the simulated average speed considering this scenario. The average network speed for CASE 1is 10.52 kph. **Figure 3.3b** shows the simulated delay for CASE 1.

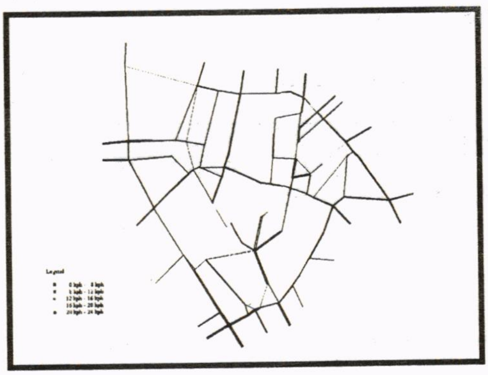

Fig. 3.3a CASE 1 Average Speed (kph)

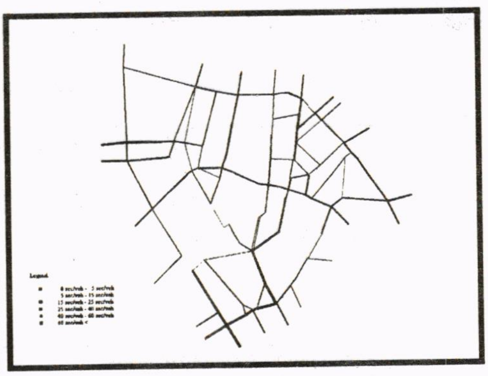

Fig. 3.3b CASE 1 Delay (sec/veh)

The average speed of 10.52 kph has a corresponding move/total ratio equal to 0.32. This means that move time is 32% of the total travel time and delay time (queuing time and stopping time) comprises 68% of the total travel time. This scenario is definitely worse than CASE 0, specifically 34 % slower than the present average speed. Additional road infrastructure projects and/or optimized rail operations should be considered to mitigate the traffic congestion manifested by the results of the simulation of this scenario.

3.4 Simulation of CASE 2: "Do Nothing Scenario" - Forecasted Traffic Volume (2015) Plus Forecasted Trucks Considering No Additional Road Infrastructure

The average network speed considering the "do nothing" scenario is 10.96 kph as shown in **Figure 3.4a** and **Figure 3.4b** shows the simulated delay.

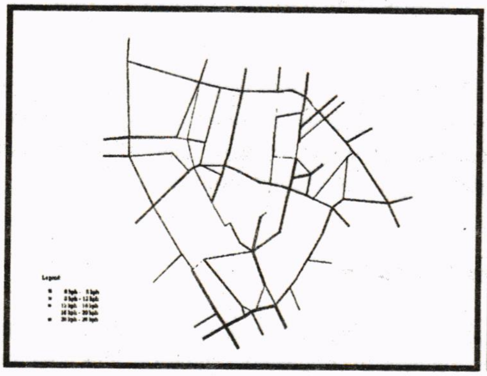

Fig. 3.4a CASE 2 Average Speed (kph)

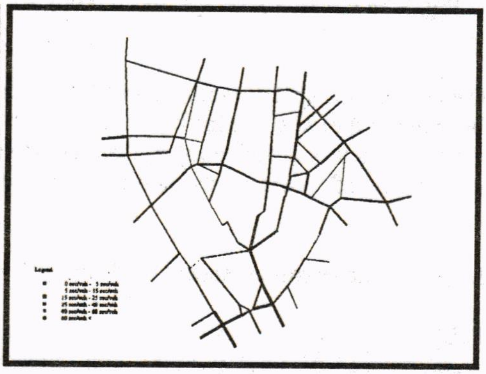

Fig. 3.4b CASE 2 Delay (sec/veh)

CASE 1 assumed no port development projects, no improvement in road network and no growth in rail operations while CASE 2 considered no improvement in road network but with port development and optimized rail operations. The resulting average speed considering the scenario of CASE 2 is 10.96 kph, which is slightly an improvement (+4%) compared to the results of CASE 1. This indicates that the additional truck traffic to be generated by the proposed port development projects can be handled by the assumed optimum rail operations. Promoting the utilization of rail in freight handling and distribution should be encouraged.

However, the resulting average speed is still way below the present average speed, 15.84 kph.. This means that improvement in road network should be taken into consideration to alleviate traffic congestion.

3.5 Simulation of CASE 3: Forecasted Traffic Volume (2015) Plus Forecasted Trucks Considering the Proposed Elevated Expressway and Expansion of R-10

The average network speed is 13.28 kph as shown in **Figure 3.5a**. This improves the average speed of the "do nothing" case by almost 21%. However, this is 16% lower than the present average speed. **Figure 3.5b** shows the simulated delay.

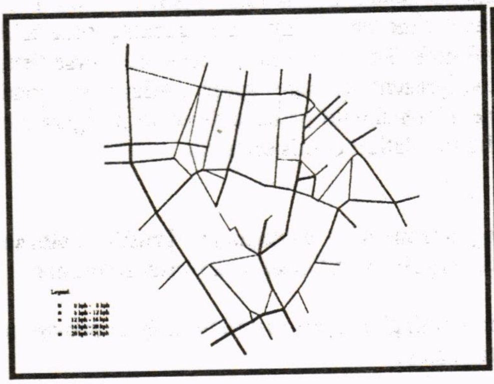

Fig. 3.5a CASE 3 Average Speed (kph)

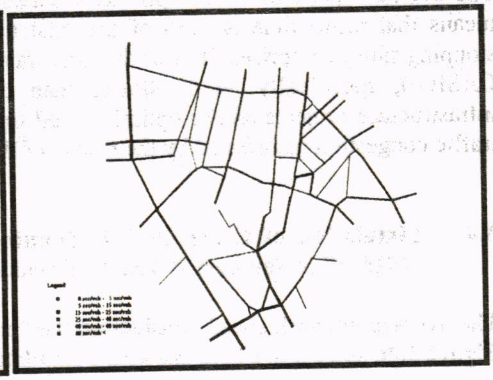

Fig. 3.5b CASE 3 Delay (sec/veh)

The results of CASE 3 improved in comparison to the results of the CASES 1 and 2. Some of the average speeds along the links are even better than the average network speed, 13.28 kph.. However, these values are lower than the present average speed. Improvement of other links and opening of access points should be considered to serve as alternate routes.

3.6 Comparison of Results and Analysis of Simulation

Table 3.2 shows the results of the simulation considering the four cases. The resulting average speed of Case 0, 15.84 kph, already denotes a congested scenario. This can be validated by the move/total ratio wherein only 45% of the total travel time are the vehicles moving.

Table 3.2 Results of Simulation (Network)

CASE	Ratio Move/Total	Delay Time (veh-min)	Total Time (veh-min)	Average Speed (kph)
CASE 0	0.45	1266.86	2314.44	15.84
CASE 1	0.32	2065.10	3059.15	10.52
CASE 2	0.32	2135.98	3143.74	10.96
CASE 3	0.38	1574.92	2540.33	13.28

The "no port development" scenario of CASE 1 yielded an average speed equal to 10.52 kph, or a 34% reduction (5.32 kph) on the present average speed. The scenario of CASE 2 wherein the effect of additional truck traffic to be generated by the proposed port development projects are considered as well as the effect of an optimized rail service yielded an average speed equal to 10.96 kph. Comparing this to the result of CASE 1, there is a slight improvement (4%) in the average speed. This denotes that the optimized rail service is needed to facilitate the hauling and distribution of the additional cargo traffic to be generated by the proposed port projects. The effect of the proposed elevated expressway and R-10 road expansion considered in CASE 3 yielded an average speed of 13.48 kph. This improves the average speed of CASE 2 by 21%. However, even with the proposed additional road infrastructures and optimized rail service, the simulated speed for the year 2015 is still lower than the present average speed by 16%. TSM and TDM measures are necessary to help improve the average network speed.

To validate the network results and to check the effect of the different scenarios along major streets, significant simulation outputs were tabulated on per street per direction basis.

Table 3.3a Bonifacio Drive (Southbound)

Case	Vehicle Miles	Vehicle Trips	Delay Time	Total Time	Travel Time (sec/veh-trip)	Average Speed (kph)
0	760.22	2024	3899.57	6940.43	205.7	10.56
1	496.14	1388	3210.06	5194.63	224.6	9.12
2	794.47	2239	4137.72	7315.58	196.0	10.40
3	800.24	2239	3777.91	6978.88	187.0	11.04

Table 3.3b Bonifacio Drive (Northbound)

Case	Vehicle Miles	Vehicle Trips	Delay Time	Total Time	Travel Time (sec/veh-trip)	Average Speed (kph)
0	696.99	2060	2223.09	5011.07	146.0	13.28
1	559.50	1542	2490.44	4728.43	184.0	11.36
2	556.96	1541	2366.19	4594.02	178.9	11.68
3	561.13	1536	3455.53	3455.53	135.0	15.52

Table 3.3c R-10 (Southbound)

Case	Vehicle Miles	Vehicle Trips	Delay Time	Total Time	Travel Time (sec/veh-trip)	Average Speed (kph)
0	684.79	1578	4.65.27	6804.45	258.7	9.60
1	593.42	1370	4601.72	6975.38	305.5	8.16
2	553.55	1330	5659.78	7873.98	355.2	6.72
3	1482.22	3431	2852.21	8781.08	153.6	16.16

Table 3.3d R-10 (Northbound)

Case	Vehicle Miles	Vehicle Trips	Delay Time	Total Time	Travel Time (sec/veh-trip)	Average Speed (kph)
0	514.17	1203	3058.70	5115.38	255.1	9.60
1	453.50	1062	3152.59	4966.60	280.6	8.80
2	477.09	1125	3208.32	5116.68	272.9	8.96
3	704.58	1644	1249.28	4067.62	148.5	16.64

Table 3.3e P. Burgos (Westbound)

Case	Vehicle Miles	Vehicle Trips	Delay Time	Total Time	Travel Time (sec/veh-trip)	Average Speed (kph)
0	56.95	428	321.44	549.25	77.0	9.92
1	72.21	544	504.71	793.57	87.5	8.80
2	199.96	1680	1895.83	2695.67	96.3	7.20
3	75.80	577	456.76	759.95	79.0	9.60

Table 3.3f P. Burgos (Eastbound)

Case	Vehicle Miles	Vehicle Trips	Delay Time	Total Time	Travel Time (sec/veh-trip)	Average Speed (kph)
0	111.46	830	647.71	1093.55	79.1	9.76
1	157.12	1241	1107.10	1735.58	83.9	8.64
2	90.46	681	840.11	1201.97	105.9	8.64
3	117.78	878	778.68	1249.78	85.4	9.12

Table 3.3g España (Westbound)

Case	Vehicle Miles	Vehicle Trips	Delay Time	Total Time	Travel Time (sec/veh-trip)	Average Speed (kph)
0	882.39	3665	3950.26	7479.82	122.5	11.36
1	608.64	2524	5011.71	7446.28	177.0	7.84
2	674.83	2819	4846.67	7546.00	160.6	8.64
3	682.14	2848	4707.08	7415.63	159.9	8.74

Table 3.3h España (Eastbound)

Case	Vehicle Miles	Vehicle Trips	Delay Time	Total Time	Travel Time (sec/veh-trip)	Average Speed (kph)
0	211.79	877	133.08	980.25	67.1	20.80
1	229.53	957	146.01	1064.13	66.7	20.64
2	191.04	793	129.68	893.83	67.6	20.48
3	170.11	701	102.21	782.67	67.0	20.80

The results of the simulation are on per link basis so it cannot be directly compared to the intersection analysis used in the Highway Capacity Manual (HCM). In addition, The Highway Capacity Manual (HCM) signalized intersection procedure analyzes one intersection at a time. In TRAF-NETSIM, the impact of one intersection, if any, will carry to another, which is critical in urban signalized areas. Parameters or factors affecting capacity and level of service interacted to produce secondary effects.

4. CONCLUSION AND RECOMMENDATIONS

Traffic simulation using TRAF-NETSIM can be used to assess and analyze traffic impact scenarios as in the case of the proposed port development projects. The software could be calibrated to adopt and reflect local settings.

The results of the simulation of CASE 0 confirm the traffic congestion presently experienced in the Study Area. The resulting average network speed, 15.84 kph., with corresponding move/total ratio of 0.45 denotes that the present road network is inadequate to handle the present traffic volume. However, the proposed port development projects are also inevitable to cope up with the growing freight and passenger traffic and to be competitive to the ports of the world.

The proposed port development projects must include in its implementation strategies on how to facilitate and improve roadside traffic. This is necessary for efficient distribution of cargo to the port's hinterland. This study simulated 3 scenarios wherein the growth of the port as well as some measures to alleviate road congestion were considered.

From the results of the simulations of CASE 0 and CASE 1, the effect of the prèsent rail operations in handling containerized traffic has little impact in decongesting the road network. In CASE 2, the optimization of railway operations in freight distribution can offset the additional traffic forecast by the proposed port development projects. The proposed road network improvement like the elevated expressway and expansion of R-10 are also necessary to cope up with the traffic forecast as tested in CASE 3. However, these are not sufficient to counterbalance the combined traffic impact of the proposed port development projects and growth of traffic volume based on the MMUTIS Study.

The following countermeasures are recommended for the improvement of traffic flow and freight distribution.

1. Utilization of rail in freight distribution and inland container depot
2. Improvement of road network
3. Recommendation for further studies on port related traffic in relation to logistics flow

REFERENCES

a) Books and Book chapters

Hoyle, B.S. and D. Hilling (1984) **Seaport Systems and Spatial Change**. John Wiley and Sons.

b) Journal papers

Athanailos, Ernest G. (1994) The integration of the highway capacity manual and the TRAF-NETSIM simulation model. **ITE Journal.**

Dey, Soumya S. and Jon D. Fricker (1994) Traffic impact analysis and impact fees in state departments of transportation. **ITE Journal**.

Wong, S.Y. (1990) TRAF-NETSIM: How it works, what it does. **ITE Journal**, April, 22-27.

c) Other documents

Asian Terminals, Inc. Website, http://www.asianterminals.com.ph.

Feasibility Study of Smokey Mountain Port Terminal, (1995) R-II Builders, Inc., Diliman, Quezon City.

Fujita Ikuo (1997) Lecture Ports and Harbors in Japan: Institutional Frame, Planning Process and Financing Scheme, University of the Philippines, Diliman, Quezon City.

Highway Capacity Manual (1985) Transportation Research Board.

International Container Terminal Services, Inc. Website, http://www.ictsi.com.

JUMSUT: Metro Manila Transportation Planning Study (1983) Japan International Cooperation Agency.

Metro Manila Development Authority Website, http://www.mmda@evoserve.com.

Metro Manila Urban Road Transport Integration Project (1998), Halcrow Fox.

Philippine Ports Authority Website, http://www.ppa.gov.ph.

Philippine Transport Strategy Study, Final Report, Vol. 2: Main Text, Halcrow Fox.

Review of Master Plan and Feasibility Study for Rail Served Inland Container Depots (1986), Renardet S.A. Consulting Engineers.

South Harbor Expanded Port Zone (1999) Planning Resources and Operations Systems, San Juan, Metro Manila.

The Greater Capital Region Integrated Port Development Study in the Philippines (1994) Japan International Cooperation Agency.

The Port of Manila's 25-Year Development Plan, Philippine Ports Authority, Manila.

TRAF-NETSIM User's Guide Version 4.2 (1995) Office of Traffic Operations, Federal Highway Administration, Washington D.C.

Vergel, K. (1999) Analysis of Road Traffic Flow and Traffic Environment in Metro Manila, Tokyo Institute of Technology, Tokyo, Japan.