ASSESSMENT OF THE TRAFFIC IMPACTS AND GAS EMISSIONS OF LARGE FREIGHT VEHICLE RESTRICTION SCHEMES IN METRO MANILA

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ABSTRACT

This paper investigates the impacts to traffic and the environment of large freight vehicle restrictions in Metro Manila. Vehicle flows and emissions are estimated for a range of alternative schemes of large truck restrictions on urban roads. Traffic flows in the road network are approximated by a user-equilibrium traffic assignment model. The vehicles on the road are modeled as a line source which approximates the effects of many vehicles moving along a road as a line; emitting a defined amount of pollution, per unit of time, along its length. Three types of pollutant emissions were estimated; i.e. CO, NOx, and SPM.

With the aid of GIS, particularly in setting-up the transportation network and in data manipulation and visualization, the alternative schemes are compared and analyzed for two spatial areas; i.e. region-wide and area-specific areas. The results of the study show that the existing large freight vehicle restriction policy in Metro Manila is not very effective from a regional point of view, although if viewed from an area-specific scale, the policy may be effective in reducing traffic and environmental impacts. From a region-wide perspective, abolishing the existing large truck vehicle restriction would lead to lower traffic and environmental impacts because heavy trucks would be free to use direct and shorter routes. For the area-specific analysis, the effects of various alternatives on freight regulation were assessed for three zones to determine their impacts on localized traffic and pollutant emissions. The analysis reveals that the effectiveness of the scenario is dependent upon the area, with each scenario having mixed traffic and environmental impacts.

As an application to planning and policy making, the results of the study could be useful for decision-makers to determine how certain travel demand management measures such as large freight vehicle restrictions can impact and improve traffic flow and reduce emissions. Information on the emissions is important to the design of effective strategies consistent with the pertinent provisions of the Philippine's Republic Act 8749 of 1999 or the Clean Air Act.

Keywords: large freight vehicle restrictions, traffic impact, vehicle emission, GIS

1. INTRODUCTION

Urban transportation has become a key concern among planners, policy makers, and environmentalists who are seeking ways in which to minimize its negative impacts, including traffic congestion, greenhouse gas emissions, and air pollution. Any policy aimed at reducing traffic congestion in cities and mitigating the effects of climate change must, therefore, list urban transport among its priorities.

As an alternative approach to tackling transportation and environmental problems, Transportation Demand Management (TDM) has been suggested to improve the efficiency of existing transportation systems through the application of strategies which reduce vehicle travel demand or redistribute this demand in space or in time. One of the TDM strategies that can be applied in freight transport is the implementation of large freight vehicle restrictions. The impacts of large freight vehicle restrictions, however, have not been fully understood especially in cities of developing countries such as Metro Manila.

Metro Manila, with an area of only 636 square kilometres, is the most populous and the most densely populated metropolitan area in the Philippines. This metropolis has a total population of about 12 million growing at an annual rate of 2.1 percent (NSO, 2007), and has about 1.6 million registered vehicles increasing at an annual rate of 2.4 percent (LTO, 2008). Combined with a limited road network and an inefficient public transportation system, the metropolis is severely confronted with various urban problems such as traffic congestion and air pollution.

Vehicle emissions remain a serious issue in Metro Manila, as manifested by suspended particulate matter (SPM) levels which exceed World Health Organization standards (UNDP/DENR, 2007; ADB, 2003). Different compounds of carbon monoxide (CO), nitrogen oxides (NOx), sulphur oxides (SOx), and particulate matter (PM) are generated through the combustion of fossil fuels which contribute to climate change and are hazardous to human health causing upper respiratory diseases such as chronic bronchitis, emphysema, and some forms of asthma, among others. Diesel engines which are often used in large trucks produce higher NOx and PM emissions than vehicles using gasoline. These vehicles will continue to be a major contributor to environmental pollution due to increased economic activities in freight distribution (Huai *et al.*, 2006).

The government agency in charge of the development of the metropolis, including urban planning and traffic management, is the Metropolitan Manila Development Authority (MMDA).

The entry and circulation of large freight vehicles are governed by existing rules and regulations of the MMDA. The MMDA truck ban ordinance (Figure 1) prohibits large trucks from using ten major thoroughfares from 6-9 AM and 5-9 PM, in addition to the all-day truck ban at the main circumferential road C4 (EDSA) from 6 AM-9 PM during weekdays (MMDA, 1999). The regulation also provides a few designated truck routes for the truckers to utilize all the time.

As a consequence of the current large freight vehicle restrictions, truckers are forced to use circuitous alternate routes and shift their delivery times during non-restricted times such as early and/or night time deliveries (Castro *et al.*, 2005; Punzalan, 2000). These have substantial impacts to traffic and the environment in the form of increased travel distances, travel times, and emissions.

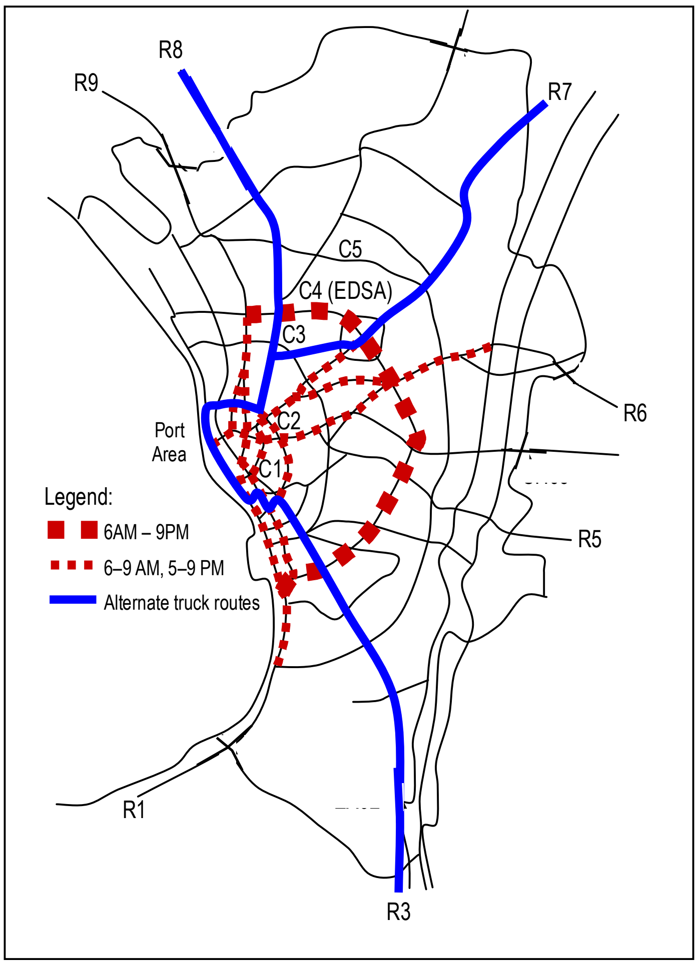


Figure 1 - Large freight vehicle restrictions in Metro Manila

Past studies (e.g. Castro *et al*., 2003; MMUTIS, 1997) have characterized freight transport in Metro Manila as:

- agricultural products are the major type of goods transported to Metro Manila,
- overall share of truck traffic is only 10 percent of the total vehicle traffic,
- majority of trucks (about 60 percent) entering Metro Manila are empty,
- majority of trucks (about 70 percent) circulating in Metro Manila are light trucks (e.g. jeepneys, container vans, 2-axle trucks),
- average loading weight is only 2 tons per truck,
- night time truck volumes relatively higher than other modes (due to night time deliveries),
- minimum truck movements during peak-hour ban periods, and
- peak truck volumes observed during off-peak ban period.

The paper tries to assess the traffic and environmental impacts of various schemes of large freight vehicle restrictions in Metro Manila in order to identify suitable truck regulation strategies that could reduce vehicular traffic and gas emissions. The results of the study could be useful for decision-makers to determine how TDM measures such as large freight vehicle restrictions can impact and improve traffic flow and reduce emissions.

2. METHODOLOGY

Traffic flows and emissions are estimated for a range of scenarios of large truck restrictions in Metro Manila. Traffic flows in the road network are approximated using a user-equilibrium (UE) traffic assignment model, while the amount of vehicle emissions are estimated by modeling the vehicles as a line source, which approximates the effects of many vehicles moving along a road as a line, emitting a defined amount of pollution per unit of time, along its length.

2.1 Estimation of traffic flows

Road network traffic flows are approximated by a User Equilibrium Traffic Assignment Model, which assumes that each user tries to minimize travel time without considering its impact or consequences to other users in the network. The objective is to find the link flows that satisfy the user-equilibrium criterion when all the origin-destination demand has been appropriately assigned (Sheffi, 1985). A stable condition is attained when no user can improve its travel time by changing its route. The details of the user equilibrium traffic assignment model as used in this study are discussed in previous papers of the author (e.g. Castro *et al.,* 2007; Yamada *et al.,* 2009; Russ *et al.,* 2006). The model allows the estimation of traffic volumes and vehicle speeds on each link of the road network, as well as the share of travel demand served by each mode.

Transportation and demographic data (e.g. road network, link-based traffic volumes and travel speeds, traffic analysis zones (TAZ), travel demand between TAZs, etc.) are used to provide input for executing the traffic assignment model. These data are stored and processed in ArcGIS, a Geographic Information System (GIS) software, to facilitate manipulation, checking, validation and visualization. GIS easily stores and manipulates spatial objects such as polygons, lines, and points which relate to real-world features such as administrative boundaries, roads and spatial demographic information (ESRI, 2009).

Travel demand characteristics are expressed in terms of the origin-destination (O-D) matrix of road vehicles. Truck O-D matrices for Metro Manila, which are grouped into 28 traffic analysis zones, are generated from a survey of about 4000 freight vehicles sampled in MMUTIS (1999). The truck driver roadside interview survey included questions on origin and destination, loading capacities, commodity types, and loading factors. From traffic counts simultaneously conducted with the truck driver roadside interview survey, the samples are expanded to the population, and the number of trips for each TAZ was obtained for the morning peak, off-peak and afternoon peak hours. Morning peak refers to 6-9 AM, off-peak from 9AM to 5PM, and afternoon peak from 5-9 PM for a total analysis period of 15 hours.

The relative mean speed along with the mode split are established once traffic flows on each link have been identified by the traffic assignment model enabling the estimation of pollutant emissions over the entire road network.

2.2 Estimation of pollutant emissions

Based on current vehicle composition in Metro Manila, three types of pollutant emissions were estimated; i.e., CO, NOx, and SPM. About seventy (70) percent of the registered vehicles in Metro Manila are gasoline-fuelled while the remaining thirty (30) percent are diesel-fuelled. Most trucks are powered by diesel engines, particularly the larger ones, while smaller trucks such as vans and other utility vehicles are mostly powered by gasoline engines (LTO, 2008). Generally, gasoline engine vehicles emit more CO but diesel-powered trucks pose more public health risks due to higher emissions of NOx and SPM. Studies by Gertler (2005), Forkenbrock (2001), and Sydbom *et al.* (2001) have identified diesel engines to have serious impacts on air quality and public health.

The vehicles on the road are modelled as a line source, approximating the effects of several vehicles moving along a road as a line and emitting a defined amount of pollution per unit of time along its length (Nagendra *et al.*, 2002). The amount of emissions can therefore be computed as the product of the number of vehicles and the emission factor per unit length for each vehicle type. Using Equation 1, the emissions on each link of the road network are calculated for the different time periods.

$$P_{ai} = \frac{F_a \; L_a \; E_{ai}}{1 \times 10^3} \qquad (1)$$

where

P_{ai}: pollutant *i* on link *a* (kg)
F_a : flow of vehicles on link *a* (veh)
L_a : length of link *a* (km)
E_{ai} : emission factor of pollutant *i* (g/km/veh)

The MMUTIS (1999) study recommended an emission factor table for CO, NOx and SPM based on type and size of the vehicle, fuel type, and travel speed, which is utilized to estimate the total amount of emissions. Although emission rates depend on a variety of factors such as vehicle operating conditions, vehicle age, and environmental characteristics (e.g. altitude and temperature), among others (Brodrick, 2004; Campbell, 1995), the MMUTIS table is probably the most comprehensive dataset available on emission factors for Metro Manila.

3. ALTERNATIVE SCHEMES OF LARGE FREIGHT VEHICLE RESTRICTIONS

Apart from the current large truck restriction scheme, four other large freight vehicle restriction schemes are tested. Current traffic conditions data, as well as traffic interventions in the form of large freight vehicle regulations in the area, are taken into account in the development of the alternative scenarios. The alternative schemes that are examined for traffic and environmental impacts are described below and are shown in Figure 2.

3.1 Existing scenario (Base scenario)

This is the base scenario which assumes that the current truck ban regulation is enforced in accordance with government ordinance; i.e. truck ban at 10 major arterials from 6AM-9AM and 5PM-9PM and truck ban at the main circumferential road C4 from 6AM-9PM. The base case will be useful for comparison purposes to assess the effectiveness of the other alternative scenarios.

3.2 Scenario 1 (Abolition of the truck ban regulation)

This assumes the abolition of the truck ban regulation. This scenario explores the impacts of eliminating the truck ban, and hence, all freight vehicles have the freedom to use all the roads at any time.

3.3 Scenario 2 (Abolition of truck ban during off-peak period at main circumferential road)

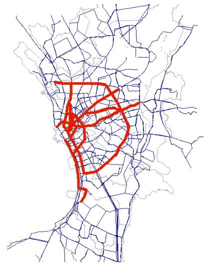
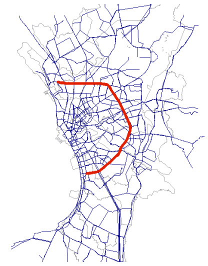
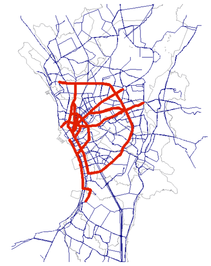
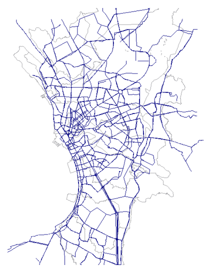
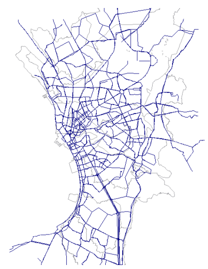
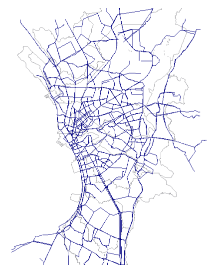
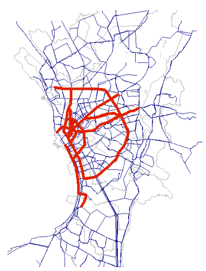
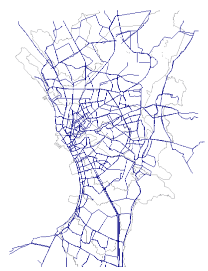
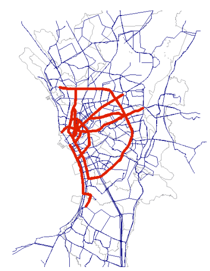
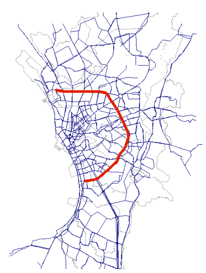
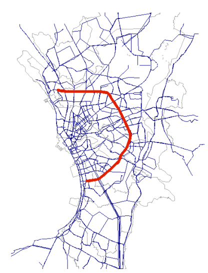
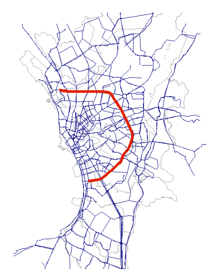
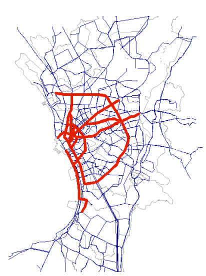
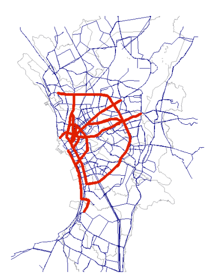
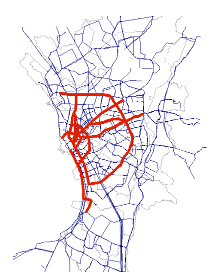
This assumes the abolition of the truck ban during off-peak period at the major circumferential road. Therefore, large freight vehicle restrictions are enforced during the morning and afternoon peak-hours only at the 10 major arterials and the main circumferential road C4.

3.4 Scenario 3 (Abolition of truck ban at 10 major arterial roads)

This assumes the abolition of the truck ban at the 10 major roads. This scenario examines the impacts of lifting the ban at the 10 major arterials, and thus, all freight vehicles can use these roads anytime. Still, a total ban is enforced at the main circumferential road C4 from 6AM-9PM.

3.5 Scenario 4 (Implementation of additional ban at 10 major arterial roads)

This assumes the implementation of additional ban at the 10 major arterials. This scenario explores the impacts of extending the truck ban period to the arterial roads not presently covered. Therefore, a total ban is enforced from 6AM-9PM at the 10 major arterials and the main circumferential road C4.

Scenario	AM peak	Off peak	PM peak
Existing scenario			
Scenario 1			
Scenario 2			
Scenario 3			
Scenario 4			

Note: Thick lines indicate prohibited roads for large freight vehicles.

Figure 2 - Graphical representation of the existing and alternative scenarios

4. VALIDATION OF FLOWS

The result of the traffic assignment model is the loading of traffic flows into the road network. To determine the level of accuracy by which the model is representing real-life conditions, it is imperative that actual traffic flows on the roadways are compared and validated with model results. The validation process involves adjustments to model parameters to validate traffic counts in the field.

The final result of the validation process is shown in Figure 3. Actual traffic counts at selected roads (y-axis) are compared with the modelled traffic flows at equivalent sites (x-axis). The results revealed that most of the differences fall below the 25% error level, and therefore, the model warrants a reliable estimation of traffic flows and emissions.

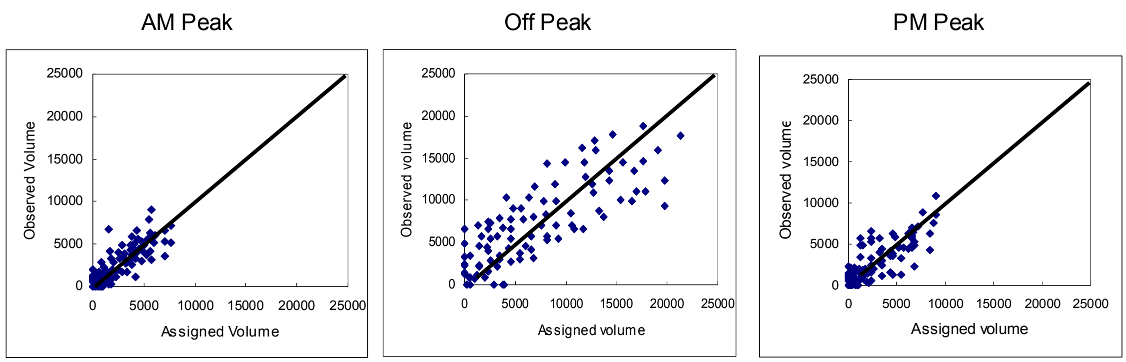


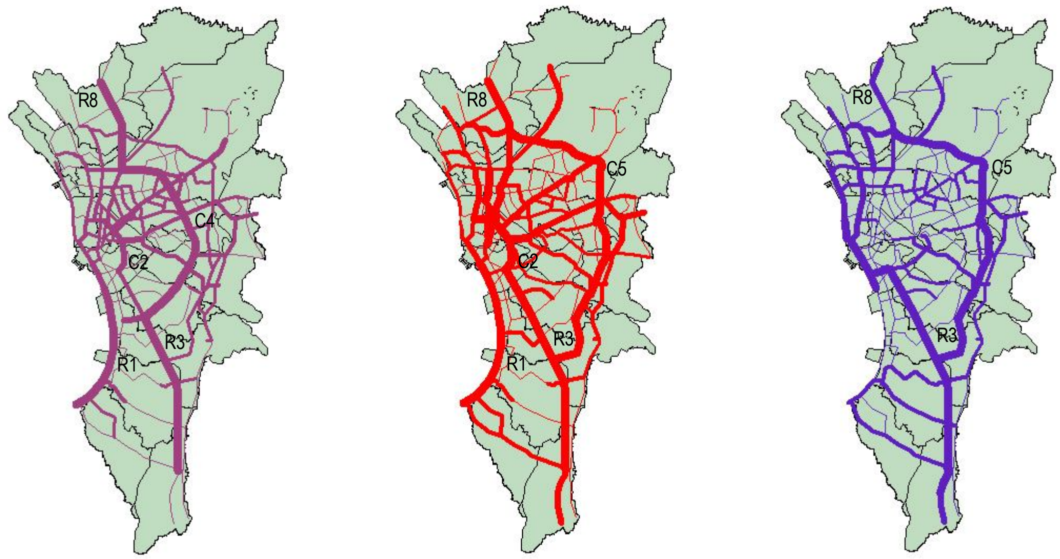
Figure 3 - Comparison of model results with actual traffic flows

5. TRAFFIC AND ENVIRONMENTAL IMPACTS

Two types of spatial analysis are performed: region-wide and area-specific analysis. For the region-wide analysis, the spatial area considered is the entire Metro Manila area. For the area-specific analysis, Metro Manila is further subdivided into three smaller zones. An area-specific analysis is needed to identify local traffic and environmental impacts which is not possible in a region-wide analysis.

5.1 Region-wide analysis

Taking the entire region of Metro Manila as the traffic analysis area, based on the results of the traffic assignment, the alternative scenarios showed remarkable differences in the transport network in terms of redistribution of flows. The traffic flow patterns of large freight vehicles for the different restriction conditions are shown in Figure 4.



(a) No restriction

(b) Restriction at main circumferential road C4

(c) Restriction at main circumferential road C4 and ten arterial roads

Figure 4 – Traffic flow patterns of large freight vehicles for different restriction conditions

Without the restriction (Fig. 4a), large freight vehicles mainly use the two circumferential roads C2 and C4, and the northbound R8 and southbound R1 and R3 routes. When the restriction is enforced at the major circumferential road C4 as shown in Fig. 4b, large trucks use R1, R3, R8, and the circumferential roads C2 and C5, which serves as the alternate route for C4. When the restrictions are extended to cover the major circumferential road C4 and the ten major arterial roads (Fig. 4c), large freight vehicles utilize R3, R8, and C5.

5.1.1 Traffic impacts

Traffic impacts in terms of changes in total vehicle-kilometers (travel distance) and total vehicle-hours (travel time) are determined for each scenario (Table 1). Scenario 1 or abolishing the current truck restriction measure has the least total travel distance of 653,342 veh-kms and total travel time of 26,449 veh-hrs. On the contrary, Scenario 4 or implementing additional restrictions on the ten major arterial roads has the highest total travel distance of 727,358 veh-kms and highest total travel time of 30,811 veh-hrs.

Table 1 - Traffic impacts for the existing and alternative scenarios

Alternative Scenarios	Veh-km	Veh-hr
Existing Scenario	681,708	28,810
Scenario 1	653,342	26,449
Scenario 2	676,092	27,789
Scenario 3	661,482	27,924
Scenario 4	727,358	30,811

5.1.2 Environmental impacts

Figure 5 shows the environmental impacts in terms of the amount of pollutant emissions for CO, NOx, and SPM calculated for the various scenarios. The chart shows that Scenario 1 has the least amount of pollutant emissions out of the five scenarios, while Scenario 4 has the highest.

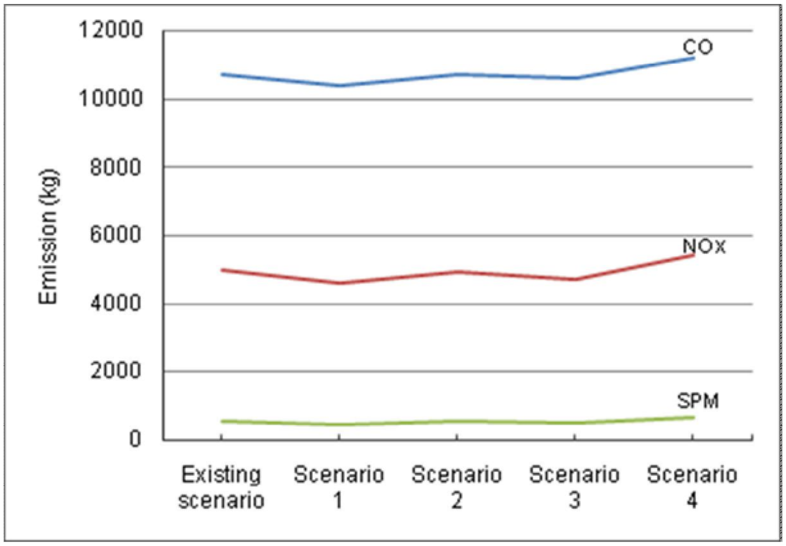


Figure 5 - Amount of emissions for the existing and alternative scenarios

5.1.3 Comparison of alternative scenarios

Using Equation 2, the change in traffic and environmental impacts can be calculated to compare the alternative scenarios ("after" case) with the existing scenario ("before" case).

$$\Delta I_i = \frac{I_{ai} - I_{bi}}{I_{bi}} \times 100 \tag{2}$$

where
ΔI_i: Percentage change of traffic or environmental impact *i* (%)
I_{ai} : Impact for the "after" case (i.e. alternative scenario)
I_{bi} : Impact for the "before" case (i.e. existing scenario)

Table 2 gives a summary of the percentage changes of the above traffic and environmental impacts.

Table 2 - Percentage changes of traffic and environmental impacts for each scenario

Alternative Scenarios	Veh-km (%)	Veh-hr (%)	CO (%)	NOx (%)	SPM (%)
Scenario 1	-4.2	-8.2	-1.7	-5.4	-5.5
Scenario 2	-0.8	-3.5	+1.4	+4.6	+4.7
Scenario 3	-3.0	-3.1	-0.9	-2.8	-2.9
Scenario 4	+6.7	+6.9	+4.1	+13.0	+13.3

Scenario 1 performs better than the existing scenario as shown by reductions in both traffic and emissions. Total travel distance is reduced by 4.2 percent, total travel time by 8.2 percent, CO by 1.7 percent, NOx by 5.4 percent, and SPM by 5.5 percent. Scenario 1 is the best in terms of overall performance.

Scenario 2 has mixed results. In terms of traffic impacts, this scenario performs very well when compared with the existing scenario with total travel distance reduction of 0.8 percent and total travel time reduction of 3.5 percent. In terms of environmental impacts, however, this scenario performed rather poorly with increases of 1.4 percent for CO, 4.6 percent for NOx, and 4.7 percent for SPM.

Scenario 3 is essentially better than the existing scenario with reductions in traffic impacts and environmental emissions. Total travel distance is reduced by 3.0 percent and total travel time is reduced by 3.1 percent. Emissions are also reduced by 0.9 percent for CO, by 2.8 percent for NOx, and by 2.9 percent for SPM. Overall, Scenario 3 has the second-best performance of all the scenarios.

The worst performance is exhibited by Scenario 4 with increases in both total travel distance (+6.7 percent) and total travel time (+6.9 percent), in addition to increases in pollutant emissions; CO (+4.1), NOx (+13.0), and SPM (+13.3).

In summary, Scenario 1 or abolishing the large truck restriction would lead to lower traffic and environmental impacts mainly because large trucks would be utilizing the shorter direct routes and would not be using the longer alternate routes to get to their final destinations. This result is consistent with the study of Bitzios *et al.* (1993) which found out that truck drivers in Brisbane select the shortest route to be the most important factor affecting route choice. The implementation of additional restrictions on other arterial roads during peak hours (Scenario 4), on the other hand, would result in severe traffic impacts and environmental pollution. The additional restrictions would limit the choice of truckers to optimize their operations by limiting their movements to tortuous alternate routes resulting in additional travel distances and longer travel times.

5.2 Area-specific analysis

An area-specific analysis is necessary to determine and examine the impacts of the various alternatives to local traffic and environmental conditions which are not possible in a region-wide analysis. For the area-specific analysis, Metro Manila is subdivided into 3 smaller zones: Zone 1 (inner zone), Zone 2 (middle zone), and Zone 3 (outside zone) (Figure 6). Zone 1 is made up of the Manila city area (or old Manila), Zone 2 is composed of seven cities directly adjoining the old Manila area, and Zone 3 is composed of the remaining cities located at a distance from the old Manila area.

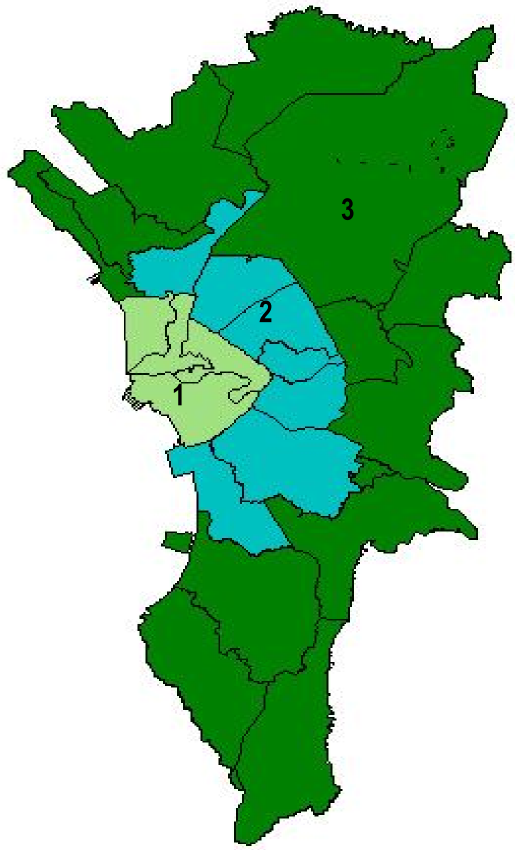


Figure 6 - Classification into 3 zones for area-specific analysis

5.2.1 Traffic impact

As indicator of traffic impact, the percentage change of vehicle-kilometers for each zone, as compared with the existing scenario (base condition), is presented in Table 3. The Table shows remarkable results that are not apparent in the region-wide analysis presented earlier. The different scenarios experience mixed traffic impacts which vary depending on the area.

Table 3 - Percentage change of veh-kms for each zone in each scenario

Alternative Scenarios	Zone 1	Zone 2	Zone 3
Scenario 1	-4.1	+20.1	+0.2
Scenario 2	-0.7	-4.4	+3.3
Scenario 3	+4.3	-14.0	-8.0
Scenario 4	-2.3	+4.0	+16.5

Under Scenario 1, Zone 1 experiences a reduction of 4.1 percent, although both Zone 2 and Zone 3 experience increases of 20.1 percent and 0.2 percent, respectively. This result is mainly caused by the re-distribution or loading of flows to the circumferential road C4 which has become available for truck drivers to use due to the total abolition of the large truck restriction. Most of the C4 road network is located within Zone 2.

Under Scenario 2, Zone 1 and Zone 2 experience minor traffic impact reductions of 0.7 percent and 4.4 percent, respectively. However, Zone 3 experiences a minor increase of 3.3 percent. The small percentage change is due to the lifting of truck restrictions at C4 during off peak hours which causes minor re-distribution of freight traffic to C4.

Scenario 3 experiences the exact opposite of Scenario 1, wherein Zone 1 experiences an increase in traffic impacts of 4.3 percent while Zone 2 and Zone 3 experience reductions of 14.0 percent and 8.0 percent, respectively. This ensues because large trucks would use the direct radial routes and the shorter C2 route which are located within Zone 1.

Scenario 4 has essentially the same trend as Scenario 1, in which Zone 1 experiences reduced traffic impacts of 2.3 percent, while Zones 2 and 3 experience increases of 4.0 percent and 16.5 percent, respectively. This result occurs because in the absence of shorter radial and circumferential routes, large trucks would utilize the alternative route C5, which is mostly located within Zone 3.

In terms of minimizing total travel distance, the best alternative is Scenario 3 or abolishing the truck ban at ten major arterial roads, which results in significant percentage reductions in Zones 2 and 3, and with minimal increase in Zone 1. The second-best alternative is Scenario 2 or abolishing the truck ban at the major circumferential road during off peak hours with reduced total travel distances in Zones 1 and 2, and minimal increase in Zone 3.

5.2.2 Environmental impacts

With respect to the three pollutant emissions, the percentage changes are indicated in Table 4.

Table 4 - Percentage change of amount of emissions for the alternative scenarios

	Zone 1			Zone 2			Zone 3		
Alternative Scenarios	CO	NOx	SPM	CO	NOx	SPM	CO	NOx	SPM
Scenario 1	-2.3	-5.5	-5.6	+7.3	+28.1	+29.0	+0.1	+0.3	+0.3
Scenario 2	-1.4	-4.4	-4.5	+5.4	+20.7	+21.4	+1.4	+4.6	+4.7
Scenario 3	+0.3	+1.0	+1.0	-0.4	-1.7	-1.7	-2.0	-6.3	-6.5
Scenario 4	-0.7	-2.1	-2.1	+1.0	+3.9	+4.0	+4.4	+14.3	+14.7

The above result supports the previous finding that the impacts vary depending on the area. For instance, in the case of CO emission, Scenario 1 experiences a 2.3 percent reduction in Zone 1 but causes increased emissions to Zone 2 with 7.3 percent and Zone 3 with 0.1 percent. Similar trends can be observed for NOx and SPM, in which Scenario 1 has a positive impact to Zone 1, but negative impacts to Zones 2 and 3.

The trend for Scenario 1 is similar to Scenarios 2 and 4, wherein benefits are experienced in Zone 1 but negative impacts are experienced in the other zones. The impact for Scenario 3 is the opposite of the three Scenarios, in which higher emissions are generated in Zone 1 but lower emissions are produced in Zones 2 and 3.

In terms of minimizing the overall emissions of CO, NOx, and SPM, the best alternative is Scenario 3 or abolishing the truck ban at the ten major arterial roads. This scenario leads to significant percentage reductions of CO, NOx and SPM emissions in Zones 2 and 3, with minor increases in Zone 1. The scenarios that are extremely unfavorable to Zone 2 are Scenarios 1 and 2. These alternatives would result in huge increases in NOx and SPM and substantial increase in CO emissions because of the loading of large freight vehicles to C4. Scenario 4, on the other hand, is highly unfavorable to Zone 3 as large freight vehicles are shifted to the alternate circumferential road C5, which could cause additional traffic and emissions along the route.

Summarizing the results for area-specific analysis, the impacts of the alternatives differ depending upon the area. It seems that the best alternative is a compromise solution that results in substantial amount of traffic and environmental benefits to two out of three areas, and a slight negative impact to one of the areas. This trade-off relationship must be clarified and recognized by the different stakeholders, including the policy makers, in order that an acceptable traffic demand management solution can be implemented.

6. CONCLUSIONS

This paper tried to assess the existing and other potential large freight vehicle restriction schemes in Metro Manila in terms of its impact to traffic and the environment.

From a region-wide perspective, abolishing the current policy on large freight vehicle restrictions would result in lower traffic impacts and emissions because large trucks would have the liberty to use the shorter direct routes. However, this scheme would be difficult to implement as there would be, without doubt, resistance from different stakeholders such as the government, private motorists, pedestrians, shop owners, residents, as well as some freight distribution companies. Therefore, the second-best alternative of abolishing the truck ban at the ten major arterial roads offers a compromise solution without totally abolishing the ban, and presents a feasible alternative that could reconcile the different stakeholder needs.

The area-specific analysis was able to identify the impacts of the various truck restriction schemes to local traffic and environmental conditions. It revealed that the different schemes experience mixed and varied traffic impacts and emissions depending on the area. Yet, the best restriction scheme in terms of minimizing travel distance and pollutant emissions is the abolition of the truck ban at the ten major arterial roads. This alternative leads to reductions in pollutant emissions in two of the three zones, with only a minor increase in the other zone.

As an application to transport policy making, the above results might be useful for decision-makers to determine how travel demand management measures can affect and improve traffic flow and reduce environmental impacts. Useful information on vehicle emissions is imperative to the design of effective pollution control plans and strategies consistent with the pertinent provisions of the Clean Air Act of the Philippines (RA 8749).

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