Estimating Traffic and Emissions for Various Scenarios of Freight Vehicle Restrictions in Metro Manila

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Introduction

Transportation demand management (TDM) through the application of strategies to reduce vehicle travel demand or redistribute demand in space or in time, have been suggested to deal with traffic and environmental problems.

In Metro Manila, one of the TDMs applied in freight transport is the implementation of large truck restrictions.

However, the impacts of large truck restrictions have not been fully understood.
Objectives

- To examine the traffic and environmental impacts of large truck restrictions in Metro Manila.

- To determine and recommend suitable alternative truck restriction schemes to reduce vehicle traffic and emissions.
Truck restrictions in Metro Manila

<table>
<thead>
<tr>
<th>Truck Ban 1 (EDSA only)</th>
<th>6 AM to 9 PM everyday except Saturdays, Sundays and Holidays. No cargo truck shall be allowed to travel or pass along EDSA.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck Ban 2 (10 major routes)</td>
<td>6 AM to 9 AM and 5 PM to 9 PM everyday except Saturdays, Sundays and Holidays. No cargo truck shall be allowed to travel or pass along these routes.</td>
</tr>
<tr>
<td>Definition of Cargo Truck</td>
<td>“Cargo truck” as used in the ordinance refers to motor vehicles, whether loaded or empty, having a gross vehicle weight of 4,500 kgs or more, principally intended for carrying cargo.</td>
</tr>
<tr>
<td>Violation and Penalty</td>
<td>Any person who violates the provisions of this ordinance shall be punished by a fine of not less than 500 pesos but not more than 2000 pesos or by imprisonment of not less than 7 days but not more than 30 days or both, at the discretion of the court.</td>
</tr>
</tbody>
</table>

Legend:
- Red: 6AM – 9PM
- Red Dashed: 6-9 AM, 5-9 PM
- Blue: Alternate truck routes

Truck Ban Hours:
- Red: 6 AM - 9 PM
- Red Dashed: 6 AM - 9 AM; 5 PM - 9 PM
- Blue: Truck alternate routes from Port Area to Outside and vice versa
Freight transport in Metro Manila

- 10% share of truck traffic vs. total vehicle traffic
- Major commodity is agricultural products
- 2 tons average loading weight per vehicle
- Majority of trucks (56%) entering Metro Manila are running empty
- 70% of trucks circulating around Metro Manila are small trucks (i.e. vans, 2-axle trucks, etc.)
- Increased small truck volumes due to the truck ban (small trucks utilized to replace large trucks)
- Higher truck traffic volumes at night (due to nighttime deliveries)
- Minimum truck movements during peak-hours, but high truck volumes during off-peak periods.
Freight transport in Metro Manila

- Trucking industry heavily regulated at present.

- Large truck restrictions force truckers to use circuitous alternate routes and shift their delivery times during non-restricted times such as early and/or nighttime deliveries.

- These may have considerable impacts to traffic and the environment in the form of increased travel distances, travel times, and emissions.
Methodology: Estimation of flow

- Flows in the road network were approximated through a User Equilibrium (UE) Traffic Assignment Model.

- Model assumes that each user tries to minimize travel time without considering its impact to other users in the network. Stable condition is attained when no user can improve its travel time by changing its route.

- 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).

- Model allows the estimation of traffic patterns, i.e. volumes, speeds, etc. on each link of the road network as well as the share of total travel demand serviced by each mode.
Methodology: Estimation of flow

- UE model requires transportation data to provide input for executing the traffic assignment model.
- To facilitate manipulation and checking, these data were stored in a Geographic Information System (GIS).

**Transport data in GIS**

<table>
<thead>
<tr>
<th>Information</th>
<th>GIS type</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network links</td>
<td>Polyline</td>
<td>Link ID&lt;br&gt;Link type (i.e. expressway, arterial, collector, centroid connector)&lt;br&gt;Link length&lt;br&gt;Link free-flow speed&lt;br&gt;Link capacity&lt;br&gt;Link volumes by periods (i.e. AM peak, PM peak, off-peak)&lt;br&gt;Link speeds by periods</td>
</tr>
<tr>
<td>Node</td>
<td>Point</td>
<td>Node ID&lt;br&gt;Node type (i.e. link end, centroid)&lt;br&gt;Node coordinates</td>
</tr>
<tr>
<td>Traffic Analysis Zone (TAZ)</td>
<td>Polygon</td>
<td>TAZ ID&lt;br&gt;Number of trip productions&lt;br&gt;Number of trip attractions&lt;br&gt;Demographic information (i.e. population, land use, etc.)</td>
</tr>
</tbody>
</table>
Methodology: Estimation of emissions

Three types of emissions were estimated: CO, NOx, & SPM.

Vehicles on the road are modeled as a line source (Nagendra et al., 2002), emitting a defined amount of pollution, per unit of time, along its length.

Therefore, emissions can be determined by multiplying the number of vehicles by a per-vehicle emission factor. The emissions were generated on each link of the road network for the different time periods.

\[ E_{ai} = \frac{F_a L_a EF_{ai}}{1 \times 10^3} \quad \text{where} \]

- \( E_{ai} \): Estimated pollutant \( i \) on link \( a \) (kg)
- \( F_a \): Number of vehicles on link \( a \) (veh)
- \( L_a \): Length of link \( a \) (km)
- \( EF_{ai} \): Emission factor of pollutant \( i \) (g/km/veh)
Alternative Scenarios

- **Existing scenario**: Ban at 10 major arterials during AM and PM peak-hours and total ban at main circumferential road at daytime.

- **Scenario 1**: Abolition of truck ban regulation.

- **Scenario 2**: Abolition of truck ban during off-peak period at the major circumferential road.

- **Scenario 3**: Abolition of truck ban at 10 major roads.

- **Scenario 4**: Implementation of additional ban at 10 major arterials.

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

- Region-wide analysis: Area of analysis is whole of Metro Manila

- Area-specific analysis: Metro Manila divided into 3 smaller areas
Region-wide analysis

- The alternative scenarios showed changes in the transport network, in terms of redistribution of flows.

- Without the restriction, heavy vehicles mostly 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, large trucks use R1, R3, R8, and the circumferential roads C2 and C5. C5 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, heavy vehicles utilize R3, R8, and C5.
Pattern of traffic flow for large freight vehicles at different restriction conditions

(a) No restriction
(b) Restriction at main circumferential road C4
(c) Restriction at main circumferential road C4 and ten arterial roads
### Traffic impacts for the existing and alternative scenarios

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Veh–km</th>
<th>Veh–hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Scenario</td>
<td>681,708</td>
<td>28,810</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>653,342</td>
<td>26,449</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>676,092</td>
<td>27,789</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>661,482</td>
<td>27,924</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>727,358</td>
<td>30,811</td>
</tr>
</tbody>
</table>

- Scenario 1 has the least total travel distance and total travel time.
- Scenario 4 has the highest total travelled distance and highest total travel time.
Scenario 4 has the highest amount of emissions out of the five scenarios, while Scenario 1 has the least.
# Percentage changes by the application of alternative scenarios

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

- Overall, scenario 1 has the best performance of all the scenarios, followed by scenario 3.
- Scenario 2 has mixed results; compared to the existing scenario, this performs very well in terms of traffic impacts but performed poorly in terms of environmental impacts.
- Scenario 4 has the worst performance.
In general, Scenario 1 (abolishing the large truck restriction) would lead to lower traffic and environmental impacts, because large trucks would be allowed to use the direct and shorter routes.

On the other hand, Scenario 4 (implementing additional restrictions on other arterial roads during peak hours) would lead to higher traffic impacts and environmental pollution, because the additional restrictions limit truckers to use meandering alternate routes which only adds to total travel distance and total travel time.
The disadvantage of region-wide analysis is that local traffic and environmental impacts are not captured. Hence, an area-specific analysis is performed.

For the area-specific analysis, Metro Manila was divided into 3 distinct zones:
- inner zone (Zone 1): composed of the Manila city area, traditionally known as the “old Manila”
- middle zone (Zone 2): made up of seven cities directly adjoining the old Manila area
- outside zone (Zone 3): composed of the remaining cities which are located at a distance from the old Manila area
**Percentage change of veh-kms for each zone in each scenario**

<table>
<thead>
<tr>
<th>Alternative Scenarios</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>-4.1</td>
<td>+20.1</td>
<td>+0.2</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>-0.7</td>
<td>-4.4</td>
<td>+3.3</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>+4.3</td>
<td>-14.0</td>
<td>-8.0</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>-2.3</td>
<td>+4.0</td>
<td>+16.5</td>
</tr>
</tbody>
</table>

The different scenarios experience varied and mixed traffic impacts depending on the area.
Area-specific analysis: Traffic impacts

- In terms of minimizing total travel distance, the best alternative is Scenario 3 (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 (abolishing the truck ban at major circumferential road during off peak hours) with reduced total travel distances in Zones 1 and 2, and minimal increase in Zone 3.
**Percentage changes of amount of emissions for the alternative scenarios**

<table>
<thead>
<tr>
<th>Alternative Scenarios</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO</td>
<td>NOx</td>
<td>SPM</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>-1.8</td>
<td>-5.5</td>
<td>-5.6</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>-1.4</td>
<td>-4.4</td>
<td>-4.5</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>+0.3</td>
<td>+1.0</td>
<td>+1.0</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>-0.7</td>
<td>-2.1</td>
<td>-2.1</td>
</tr>
</tbody>
</table>

- Impacts on emission are varied and depend on area.
- Scenarios 1, 2 and 4 have the same trend, in which reductions in emissions are experienced in Zone 1, but higher emissions in Zones 2 and 3.
- Impact of Scenario 3 is the opposite, in which higher emissions are experienced in Zone 1 but lower emissions in Zones 2 and 3.
Area-specific analysis: Emissions

In terms of minimizing emissions, the best alternative is again Scenario 3 (abolishing the truck ban at the ten major arterial roads).
- This leads to percentage reductions on the three pollutant emissions in Zones 2 and 3, with insignificant increases in Zone 1.

Alternatives which are unfavorable to Zone 2 are Scenario 1 (abolishing the truck restrictions) and Scenario 2 (abolishing the truck restriction at the major circumferential road during off peak hours).
- These alternatives would result in considerable increases in NOx and SPM and substantial rise in CO emissions due to the distribution of freight trucks into C4.

Alternative which is unfavorable to Zone 3 is Scenario 4 (implementing additional restrictions on other arterial roads during peak hours).
- Freight trucks are rerouted to the alternate circumferential road C5, thereby causing more emissions along the route.
Specific-area analysis: Results summary

For area-specific analysis, the impacts of the scenarios vary depending on the area.

Apparently, the best alternative for Metro Manila is a compromise solution which results in substantial amount of traffic and environmental benefits to two out of three analysis areas, and a slight negative impact to one of the areas.

A trade-off relationship between benefits and scope is therefore observed.
Conclusion

Results show that the existing large truck restriction policy in Metro Manila is not very effective from a regional point of view. If viewed from an area-specific scale, the policy may be effective in reducing traffic & environmental impacts.

From a region-wide perspective, abolishing the existing truck restriction would lead to lower traffic and environmental impacts because large trucks would be free to use the direct and shorter routes. This alternative, however, will encounter resistance from various stakeholders. Hence, the second-best scenario of abolishing the truck ban at ten major arterial roads offers a compromise alternative without totally abolishing the ban.

From the area-specific analysis, the analysis revealed that the effectiveness of a scenario is dependent upon the area, and that different scenarios experience varied and mixed traffic and environmental impacts. Nevertheless, the best alternative, in terms of minimizing total travel distance and environmental emissions, is abolishing the truck ban at the ten major arterial roads (Scenario 3). This alternative leads to reductions in pollutant emissions in two of the three zones, and minor increases in the other zone.
Implications

As an application to policy making, the results could be useful for decision-makers to determine how certain TDM measures can impact and improve traffic flow and reduce emissions.

Information on emissions is important to the design of effective pollution control plans and strategies consistent with pertinent environmental laws.
Thank you!