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Abstract: This paper discusses the impact of the existing truck ban on Metro Manila's urban transport system and evaluates the effectiveness of the truck ban by comparing traffic patterns in the form of loaded traffic flows in the road network for different truck ban schemes. Five schemes are examined, namely; existing truck ban, without truck ban, peak-hour truck ban only, all-day truck ban at the primary road, and all day truck ban at the primary road and other major arteries. The paper also estimates the vehicle emissions of each alternative truck ban scheme and compares them with the existing truck ban measure. General findings indicate that additional restrictions significantly increase total vehicle-kilometers, total vehicle-hours, and total pollutant emissions.

Key Words: freight transport, urban logistics, traffic assignment, truck ban

1. INTRODUCTION

As traffic congestion continues to worsen in most cities throughout the world, increasing attention has been directed towards policies designed to improve the operational efficiency of urban streets. Among the several alternatives available, restricting large trucks has been one of the most popular in the motoring public's view. Large trucks are often perceived as slow moving and occupy a large amount of road space, thus hampering the smooth flow of traffic, especially during peak-periods.

The truck ban scheme in Metro Manila has become a very feasible form of rationing scarce road space because of the city's insufficient road capacities. And because Metro Manila relies on road-based public transport due to the lack of an efficient rail-based public transport system, the government enforces restraints on large trucks with the intention that buses and other public transport modes will not have to compete for the limited road space. However, although large truck restrictions represent a rational solution to the problems of traffic congestion, such measures may present negative and harmful effects if not fully understood.

The truck ban was introduced in Metro Manila by the then Metropolitan Manila Authority (MMA) on 21 August 1978 as a measure to alleviate the worsening conditions of road traffic congestion. The ban applies to trucks with gross weights of more than 4.5 tons and prohibits truck movements along eleven specific routes, mostly primary arterial roads. There are presently two types of truck ban. One is the all-day truck ban, which prohibits trucks from using the circumferential road Epifanio delos Santos Avenue (EDSA), the most heavily used thoroughfare, from 6AM to 9 PM during weekdays. The other is the peak hour truck ban, which prohibits trucks from using 10 major thoroughfares from 6-9 AM and 5-9 PM except Saturdays, Sundays and holidays (Figure 1).

2. METHODOLOGY

An understanding of the transport characteristics of Metro Manila is essential in identifying possible changes and consequences of the truck ban measure, particularly the following: a) volume increase of truck ban-exempt trucks; b) reduction of truck loading factors; c) increase of truck traffic during the night; and d) changes in traffic distribution during the ban and no ban periods. The data from a comprehensive truck survey conducted under the Metro Manila Urban Transportation Integration Study (MMUTIS) provide a vital source of input to understand not only the city's freight transport conditions but also the changes brought about by the implementation of the truck ban.

Traffic assignment is performed to estimate the probable effects of the truck ban in terms of vehicle-kilometers and vehicle-hours. The shortest path method is utilized to achieve this purpose. It assumes that the goal of the driver is cost minimization that follows the minimum cost path between the origin and the destination. This is a reasonable assumption for truck drivers as their primary objective is to transport goods in the most efficient manner possible. A study of 100 truck drivers in Brisbane revealed that most drivers found the shortest route to be the most important factors affecting route choice (Bitzios and Ferreira, 1993). The shortest path approach results in the loading of all trips onto the single minimum cost route between nodes.

Environmental assessment is then carried out by synthesizing the results of traffic assignment which identifies truck volume, truck type, and average speed of vehicles at road links. The environmental emissions are computed by multiplying traffic volume by the respective emission factors for each environmental pollutant. Percentage changes in vehicle emissions are then calculated by comparing alternative truck ban schemes with the existing truck ban.

3. FREIGHT TRANSPORT CHARACTERISTICS IN METRO MANILA

In October 1996, MMUTIS conducted a truck survey to determine the flow of goods in Metro Manila. Cargo vehicles entering and leaving the metropolis were surveyed at selected cordon line stations (Figure 1). There were two types of surveys conducted, as follows: truck volume counts and truck driver roadside interviews, including origin and destination (OD) data. The surveys were conducted for 16 hours from 6 AM to 10 PM. A 24-hour survey count is ideally preferred but visual limitations and safety and health concerns of surveyors precluded a more thorough collection of data.

Truck traffic volume was counted by vehicle type and direction. The roadside interview survey was conducted on the same day as the truck traffic volume survey. This is important as the expansion factors will be computed from the ratio of truck traffic volumes and the number of samples taken during the driver interview survey. The expansion factors will differ according to vehicle type, direction, and time period. Information on the truck's origin and destination, truck type, loading capacity, commodity type, and loading factor were obtained through direct driver interviews and visual inspection. Driver interviews should be as many as possible to obtain a more realistic data set. The OD data will be used in the traffic assignment process.



Figure 1. Truck banned routes and location of survey stations

3.1 Truck traffic characteristics

Truck traffic characteristics at cordon stations are shown in Table 1. It reveals that the South Cordon stations have the highest volume of trucks entering and leaving the city during the 16-hour count survey period with 12,500 truck movements. This is not surprising as majority of freight traffic generators, such as factories, warehouses and industrial parks, are located in the southern periphery of Metro Manila. Additionally, products coming from the southern provinces are usually transported via the southern arteries, such as the South Superhighway (R3) and Manila-Cavite coastal road (R1). Compared to the South Cordon Stations, the North Cordon stations have relatively lower truck movements, with a total of 11,200 truck movements. Products from the northern regions are generally transported via McArthur Highway (R9) and the North Luzon Expressway (R8). Truck flows to and from Metro Manila via the East Cordon stations account for some 7,500 truck movements.

The overall share of truck traffic relative to the total vehicle traffic at cordon stations is around 10.2 percent. Light trucks form the majority of truck traffic with 26.7 percent for light cargo and 19.3 percent for cargo jeepneys and vans. This could imply the popular use of light trucks as a way to avoid restrictions of the truck ban.

The average loading weight for all commodities per vehicle is 2.0 tons per vehicle. The seemingly low average weight of commodities per vehicle may be due to either 1) small trucks with lower loading capacities are widely used for freight transport and delivery, or 2) majority of the vehicles are running empty.

Table 1 also shows that the volume of trucks entering Metro Manila is greater than those leaving the city for the 16-hour survey period. This is indicative of the fact that most of the freight facilities are located outside the city and that goods are generally delivered inside the city during daytime when majority of the freight receivers are open. A look at the percentage of inbound truck types substantiates this condition. Small trucks composed of cargo jeepneys, vans and light trucks, which are exempt from the ban, account for a high 50.5 percent share of inbound truck traffic. Thus, it can be inferred that majority of delivery operations inside the city are performed by small trucks.

		No	orth Cord	lon	E	ast Cord	on	So	uth Cord	lon	Co	ordon To	tal
		In	Out	2-dir	In	Out	2-dir	In	Out	2-dir	In	Out	2-dir
Truck Traffic	16hr (000 veh.)	6.1	5.1	11.2	4.5	3.1	7.5	7.2	5.3	12.5	17.7	13.5	31.2
Volume	% to total 16hr	10.1	10.8	10.5	9.6	9.1	9.3	10.7	9.9	10.3	10.3	10.0	10.2
	traffic volume												
Truck Type	Jeepney, van	14.8	6.3	11.0	48.6	45.6	47.4	10.1	9.6	9.8	21.4	16.5	19.3
% to total	Light cargo	29.1	5.8	18.5	25.4	26.6	25.9	31.4	38.5	34.4	29.1	23.5	26.7
volume	2-axle truck	28.4	48.7	37.6	10.8	11.0	10.9	21.6	24.2	22.7	21.2	30.4	25.2
	3-axle truck	10.2	23.1	16.1	4.0	4.7	4.3	15.8	9.4	13.1	10.9	13.5	12.0
	Dump truck	9.7	5.5	7.8	6.8	6.3	6.6	7.4	4.8	6.3	8.1	5.4	6.9
	Trailer/Contain	3.8	5.6	4.6	1.5	0.9	1.3	8.5	6.5	7.6	5.1	4.9	5.0
	Trailer Head	0.6	0.8	0.7	0.1	1.0	0.5	0.9	1.2	1.0	0.6	1.0	0.8
	Tank Lorry	3.1	3.8	3.4	1.6	2.7	2.1	3.9	5.1	4.4	3.0	4.1	3.5
	Mixer	0.3	0.4	0.3	1.0	1.0	1.0	0.5	0.7	0.6	0.5	0.7	0.6
Commodity	Agricultural	2.2	2.7	2.4	1.5	3.0	2.4	3.5	4.0	3.7	2.7	3.2	2.9
Туре	Manufacturing	1.6	2.3	2.0	1.6	2.2	1.8	3.5	3.0	3.2	2.0	2.4	2.2
weight/veh	Forest/Mining	1.9	4.0	2.6	1.1	4.3	2.7	4.3	2.5	3.2	1.8	3.9	2.8
	Construction	2.8	1.5	2.1	1.8	1.4	1.6	1.5	1.5	1.5	2.1	1.5	1.8
	Ave ton/veh	2.5	1.8	2.2	1.7	1.8	1.7	2.2	2.1	2.1	2.1	1.9	2.0

Table 1.	Truck	traffic	characteristics	at cordon	stations
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Notes: North Cordon includes survey stations CH04, CH05, and EX01, East Cordon includes CH08 and CH09, and South Cordon includes CH12 and EX02. Agricultural commodities include unprocessed cereals, agricultural foodstuff/crops, and processed crops/cereal products, Manufacturing commodities include foodstuff and manufactured goods, Forest/Mining commodities include forestry products, mining products, and mineral oil products, Construction/Other commodities include construction materials, producers goods and miscellaneous.

Trucking companies have apparently shifted to using small trucks not covered by the ban. A sudden increase in utility vehicle registration can be observed just before and after the implementation of the truck ban in 1978, as shown in Figure 2. Metro Manila, in fact, has been experiencing high annual growth increases of 14 percent in the registration of small freight vehicles in the last decade. Therefore, it may be that the effect of the truck ban has been to worsen congestion during peak hours due to the increase of small freight vehicles.

Furthermore, a survey of the trucking fleet used by 29 medium sized freight forwarders with average employment of about 52 workers and 12 large-sized freight shipping companies with average employment of about 1,100 workers in Metro Manila reveals that around one-third (32 to 36.6 percent) of the total truck fleet used for distribution belongs to four-wheel trucks (Table 2). This truck type is truck ban-exempt having gross weight of less than 4.5 tons. Thus, the effect of truck restrictions is to distort the size distribution of the fleet towards small trucks, such that the commercial trucking industry are not able to take advantage of the economies of scale of larger vehicles or the technology of detachable trailers and load consolidation.



Figure 2. Truck registration after the truck ban implementation

Table 2. Distribution of truck field

Truck type	Freight forwarders (%)	Freight shippers (%)
4-wheel truck (<4.5T)	36.6	32.0
2-axle 6-wheel truck (8-16T)	14.0	24.0
3-axle 10-wheel truck (25T)	8.0	24.0
3-axle semi-trailer truck (20T)	19.1	3.0
4-axle semi-trailer truck (20T)	2.0	3.0
5-axle semi-trailer truck (27T)	16.8	6.0
Truck-trailer (34T)	3.5	9.0
Total	100	100

3.3 Truck loading factors

The loading factors of trucks at cordon stations classified by direction are given in Table 3.

		Jeep/ Van	Lt Cargo	2-axle truck	3-axle truck	Dump truck	Trailer truck	Trailer head	Tank	Mixer	All veh
	In	32.6	22.7	27.6	23.8	44.2	16.6	0.0	44.0	57.1	22.5
Full	Out	41.0	22.7	29.3	40.9	29.2	55.6	0.0	27.3	50.0	35.7
	Both	36.6	22.7	28.5	32.8	37.7	34.4	0.0	38.9	53.3	28.9
	In	6.2	9.0	8.6	2.8	9.3	1.8	0.0	4.0	0.0	5.3
3/4 Full	Out	11.2	6.7	10.5	11.8	1.5	4.6	0.0	0.0	0.0	7.2
	Both	8.6	7.9	9.6	7.6	6.0	3.1	0.0	2.8	0.0	6.2
1/2 Full	In	12.9	14.8	13.0	6.6	9.3	1.7	0.0	8.0	14.3	8.4
	Out	12.4	11.2	14.1	10.3	6.2	8.9	0.0	18.2	12.5	10.4
	Both	12.7	13.0	13.6	8.6	7.9	5.0	0.0	11.1	13.3	9.3
	In	7.9	11.3	8.3	3.3	3.5	0.5	0.0	0.0	0.0	5.3
1/2 Full 1/4 Full	Out	12.4	18.4	10.8	6.4	1.5	1.4	0.0	0.0	0.0	8.7
	Both	10.0	14.8	9.6	4.9	2.6	0.9	0.0	0.0	0.0	6.9
	In	2.8	6.4	3.2	1.1	0.0	0.0	0.0	0.0	0.0	2.4
< 1/4 Full	Out	2.5	6.1	2.4	1.0	0.0	1.4	0.0	0.0	0.0	2.6
	Both	2.7	6.3	2.8	1.0	0.0	0.6	0.0	0.0	0.0	2.5
	In	37.6	35.8	39.4	62.4	33.7	79.4	100.0	44.0	28.6	56.1
Empty	Out	20.5	34.8	32.9	29.6	61.5	28.2	100.0	54.5	37.5	35.4
	Both	29.5	35.3	36.1	45.1	45.7	56.0	100.0	47.2	33.3	46.2

Table 3. Loading factor of trucks

In general, majority of the vehicles entering Metro Manila are running empty with a 56.1 percent overall share, while those leaving Metro Manila is only 35.4 percent. Inbound large trucks account for higher percentages of running empty, particularly 2-axle trucks with 39.4 percent, 3-axle trucks with 62.4 percent, and trailer trucks with 79.4 percent. This is reasonable because large trucks are mainly used for the collection of freight from the port and transport them to places outside Metro Manila. It is, thus, expected that outbound traffic will register high percentages from these three vehicle types running fully-loaded. This can be verified from Table 3, which shows that fully-loaded outbound 2-axle trucks account for 29.3 percent, 3-axle trucks for 40.9 percent, and trailer trucks for 55.6 percent.

There is, however, a surprising result in small inbound trucks such as cargo jeepneys, vans, and light cargo trucks because they likewise account for high percentages of running empty. This implies that small trucks may have also been utilized to collect freight from the port and then deliver them outside the city. The high percentages of fully-loaded outbound jeep and vans, and light cargo trucks support this argument. This, therefore, corroborates what was presented earlier, which claims that ban-exempt smaller trucks are now used in place of banned larger trucks in transporting freight from the ports.

3.4 Increase of truck traffic at night

Apart from the 16-hour truck volume count and roadside truck driver interview surveys, a continuous 24-hour classified volume count survey for all vehicles was also conducted in four cordon stations for one-week. These are: CH04 in the north, CH09 in the east, and CH012 and EX02 in the south. By calculating the ratio of the 24-hour count to the 16-hour count, the resulting ratio can be considered as some kind of an indicator to represent the rate of increase of truck traffic at night. Table 4 shows the increase of vehicle traffic for each cordon station.

Station	Period	Dir	Bus	Jeep	Car	Truck	Others	Total
CH04	24hr	Inbound	355	3211	5897	1156	1587	12206
		Outbound	400	3093	4723	979	1597	10793
	16hr	Inbound	287	2624	4816	830	1407	9965
		Outbound	284	2591	3893	723	1386	8876
	24/16hr	Inbound	1.2	1.2	1.2	1.4	1.1	1.2
		Outbound	1.4	1.2	1.2	1.4	1.2	1.2
CH09	24hr	Inbound	460	3088	13441	2246	1639	20874
		Outbound	440	3068	12767	2116	1641	20032
	16hr	Inbound	367	2334	10378	1576	1406	16061
		Outbound	384	2545	10338	1460	1424	16151
	24/16hr	Inbound	1.3	1.3	1.3	1.4	1.2	1.3
		Outbound	1.1	1.2	1.2	1.4	1.2	1.2
CH012	24hr	Inbound	1593	3748	20242	2593	1085	29260
		Outbound	1373	3768	16700	2343	856	25040
	16hr	Inbound	1399	3006	16945	1658	975	23983
		Outbound	1246	3253	13633	1272	775	20180
	24/16hr	Inbound	1.1	1.2	1.2	1.6	1.1	1.2
		Outbound	1.1	1.2	1.2	1.8	1.1	1.2
EX02	24hr	Inbound	2954	3393	28267	6159	27	40799
		Outbound	3501	3699	28197	6284	20	41703
	16hr	Inbound	2477	2903	25003	4652	17	35053
		Outbound	3125	3252	24130	4116	15	34637
	24/16hr	Inbound	1.2	1.2	1.1	1.3	1.6	1.2
		Outbound	1.1	1.1	1.2	1.5	1.4	1.2

Table 4. Increase of vehicle traffic at night

It is evident from the Table that the 24/16-hour count ratios for trucks are comparably higher than the other transport modes. On the average, trucks have a ratio of 1.4, as compared with the other modes with a ratio of 1.2. This verifies the proliferation of trucks at night. The highest ratios are found in the southern cordon station, CH012, wherein the inbound and outbound ratios are 1.6 and 1.8, respectively.

In addition, the volume of inbound trucks is generally greater than that of outbound trucks, as can be seen from the 16-hour truck counts. This situation, however, reverses at night when the

volume of outbound trucks becomes greater than that of inbound trucks for the 8-hour nighttime period (10PM-6AM), as manifested by the two south cordon stations CH012 and EX02. This finding is consistent with the previous sections that it may be possible that delivery trucks enter Metro Manila at daytime to perform deliveries and return back to their depot located outside the city at nighttime. Trucks may be forced to wait at the ports due to inefficient loading operations. It must be noted that loading operations of trucks are usually done during the day and that any delay will result in late truck departures. Truckers may also choose to travel at night to avoid the truck ban in Metro Manila.

3.5 Temporal distribution of traffic

To clarify the effect of the truck ban on traffic volumes, it is necessary to examine the temporal distribution of traffic at the cordon stations. Figure 3 presents the hourly distribution of traffic for all cordon stations. The upper chart shows vehicle volumes in each time period, while the lower chart shows the percentages of these volumes to the 16-hour traffic volume. The figures evidently confirm that the effect of the truck ban on truck traffic volume is significant. There is minimum truck movements observed during the AM and PM truck ban periods as shown in the lower chart.



Figure 3. Temporal distribution of traffic at cordon stations

3.6 Truck trips

Figure 4 represents the total origin-destination truck flows by time period, namely from 6 to 9 AM for the AM peak, 9 AM to 5 PM for the off-peak, and 5 to 9 PM for the PM peak. The figures were prepared using the Desired Line Viewer function of JICA STRADA (1997).



Figure 4. Desire lines of truck trips by truck type and time period

Most truck trips occur during the off-peak period when trucks can use the major roads except EDSA to conduct operations. Truck trips during peak-hours are significantly lower compared to the off-peak hours. The heaviest truck flows are those that emanate or end at Manila and Cavite. Truck flows are also significant throughout the Metro Manila area, especially in the radial direction and the north-south axis. As earlier said, small trucks account for the major truck flows.

4. TRAFFIC ASSIGNMENT

The required inputs for traffic assignment are the origins, destinations, quantity of movements, details of the road network, and rules for the selection of paths. It is usual to use a minimum path rule for selecting the route because of its wide applications in real-life large-scale network models. The link record contains length, or cost, or some other measure of movement impedance. A shortest path algorithm is used to build route trees from each origin to each destination. The tree lists the nodes in sequence that makes up the path.

Once the shortest paths are found, the trips between zones are loaded onto the links making up the shortest paths. This technique is referred to as all or nothing, since all trips between a given origin and destination is loaded on the links comprising the shortest path and nothing is loaded on the other links. The result is an estimate of volume on each link in the network. This method can cause some links to be assigned more travel volume than the link capacity. But this approach is useful in indicating where the major bottlenecks are likely to occur.

A program developed under the Visual Basic environment is utilized to perform shortest path assignment for the truck movements in Metro Manila. The program uses Dijkstra's algorithm to calculate for the shortest path. Studies suggest that when the goal is to obtain a one-to-one shortest path or one-to-some shortest paths, the Dijkstra algorithm offers some advantages because it can be terminated as soon as the shortest path distance to the destination node is obtained (Pallottino and Scutella, 1997). The algorithm offers fast implementation since one pass of the algorithm can produce the minimum path from one single node to another. This should be contrasted with other algorithms wherein for one pass, the minimum paths from a single node to all nodes of the network are produced, which obviously will take a longer time to process.

4.1 Data requirements

The major inputs are: 1) road network including link characteristics, such as coordinates of start and end nodes, distance, travel speed, and coordinates of zone centroid, and 2) truck OD classified by truck type and time period.

The node coordinates, including the characteristics of each link and node, were manually obtained from MapInfo maps of Metro Manila. In the preparation of the road network, small local streets were not included as freight trucks do not use them. Streets that are inside exclusive villages and subdivisions were also not considered. A list of street links that are affected by the truck ban in different time periods was also prepared. These links as well as changes in the road network due to alternative truck ban schemes were integrated in the final road networks.

OD tables were prepared from the actual truck driver roadside interview survey conducted after applying the necessary expansion factors. Truck OD tables were classified into small or large vehicles. Small vehicles include jeepneys, vans, and light cargo trucks, while large vehicles include 2-axle trucks, 3-axle trucks, and container trucks, among others. The OD Tables can be easily extracted using any database or spreadsheet application software.

There were only three time periods included for traffic analysis, which are the AM peak (6-9 AM), the daytime off-peak (9 AM-5 PM), and the PM peak (5-9 PM). This is because the truck driver roadside interview survey was only conducted for a period of 16-hours, and there was no information available for truck movements during nighttime off-peak period (9 PM- 6 AM). This may tend to underestimate the results but should a more comprehensive analysis is performed in the future, nighttime off-peak truck movements should be collected as well.

Ideally, passenger traffic flows should be included in the traffic assignment analysis. The lack of passenger traffic OD data for the three time periods and the unknown speed-flow relationship for each link, however, preclude a thorough assessment. Thus, only freight vehicles were considered for the traffic assignment procedure. The lack of speed-flow formula for each link compels the use of the simple shortest path assignment method. This means that only large trucks will be affected by changes in the truck ban implementation. This is because private vehicles and small trucks, which are ban-exempt, are motivated to use the shortest routes. Large trucks then are forced to use the available routes. However, if these data can be made available, it is recommended that a more advanced traffic assignment model, which also considers demand-capacity relationship, be used for a better traffic analysis.

4.2 Alternative truck ban schemes

Five truck ban schemes are examined to determine the probable effects of the truck ban in terms of vehicle-kilometers and vehicle hours, as follows:

- 1. *Existing truck ban scheme (base condition):* This alternative retains the existing truck ban in its present form. This also serves as the base case scenario from which comparisons are made. In this alternative, large trucks are prohibited to use major routes including EDSA during the morning (0600-0900 hrs) and the afternoon (1700-2100 hrs) peak periods.
- 2. *Without truck ban scheme:* This option is a total elimination of the ban, where large trucks freely use all routes anytime. This will be a reversion to the pre-1978 conditions. This would only be appropriate when there is compelling evidence that the truck ban produces minimal benefits or when there are too much economic costs involved.
- 3. *Peak-hour only truck ban at all major roads (EDSA and major routes):* This case is a compromise solution that relaxes the ban at the major roads during off-peak periods. This is based on the premise that the operating cost of trucks due to the ban is higher on the primary route than the other major routes. For this option, truck restrictions at EDSA during off-peak hours are lifted, thereby permitting large trucks to use the circumferential road from 0900-1700 hrs.
- 4. All day EDSA truck ban only scheme: This scheme is another compromise solution that relaxes the ban on some other major routes during certain time periods. This is based on the condition that operating costs of trucks due to the ban falls more heavily on some routes than on others. For this option, truck restrictions on the major routes except for EDSA are lifted so that large trucks are permitted to use these routes at all times. In EDSA, however, large trucks are not allowed during daytime from 0600-2100 hrs.
- 5. All day truck ban at EDSA and other major roads scheme: This scheme extends the truck ban period to routes presently not covered. If the truck ban proves to be effective along banned routes, then presumably the same benefit maybe achieved in adding other restricted routes. Large trucks will not be permitted at all major routes including EDSA from 0600 to 2100 hrs.

5. TRAFFIC ASSIGNMENT RESULTS

A summary of the results of the traffic assignment for the five cases is given in Table 5. To illustrate, routes that would be most frequently used by both large and small trucks for the existing and no truck ban schemes, are shown in Figures 5 and 6, respectively.

		AM Peak	Off-Peak	PM Peak	Total
		(6-9 HR)	(9-17 HR)	(17-21 HR)	(6-21 HR)
Existing truck ban scheme					
	VKM	27166	520250	74949	622365
	VHR	580	10478	1519	12577
	Ave. Km.	18.7	18.2	21.2	18.6
	Ave. Hr	0.39	0.37	0.43	0.38
No truck ban scheme					
	VKM	21861	512507	66338	600706
	VHR	480	10215	1324	12019
	Ave. Km.	15.1	18.0	18.8	17.9
	Ave. Hr	0.33	0.36	0.38	0.36
Peak-hour only truck ban so	cheme				
-	VKM	27166	512507	74949	614622
	VHR	580	10215	1519	12314
	Ave. Km.	18.7	18.0	21.2	18.3
	Ave. Hr	0.40	0.36	0.43	0.37
All-day truck ban at EDSA	only				
-	VKM	22193	520250	67105	609548
	VHR	484	10478	1348	12310
	Ave. Km.	15.3	18.2	19.0	18.2
	Ave. Hr	0.33	0.37	0.38	0.37
All-day truck ban at EDSA	and major routes				
	VKM	27166	591311	74949	693426
	VHR	580	11918	1519	14017
	Ave. Km.	18.7	20.7	21.2	20.7
	Ave. Hr	0.40	0.42	0.43	0.42

Table 5. Traffic impacts of alternative traffic control schemes

As expected, the "no truck ban" scheme has the least total vehicle kilometers and vehicle-hours among the five cases with 600,706 veh-kms and 12,019 veh-hrs for the 15-hour analysis period. Since trucks are allowed in all the major arterial roads, meaning both circumferential and radial roads, they do not have to use circuitous routes to get to their final destinations. Figure 5 shows that during off-peak period, large trucks mostly use the circumferential roads C2 and C4 (EDSA) and the southbound R1 and northbound R8 routes. During AM and PM peak-periods, however, large trucks are forced to take the circumferential road C2, the radial roads R1, R8, and the eastbound routes of R5 and R6. Small trucks mainly utilize C2, EDSA, southbound R1 and northbound R8 routes.

The second most optimal scheme is the "all-day truck ban at EDSA only" with 609,548 vehicle-kilometers and 12,310 vehicle-hours. Large trucks optimize transport operation by taking advantage of the radial roads where they are allowed to pass all day. Radial roads are popularly used by large trucks in the southbound routes of R1 and R3, eastbound routes of R5 and R6, and northbound route of R8. Small trucks still preferr to use EDSA during off-peak hours.

The "peak-hour only truck ban" scheme ranks third with 614,622 vehicle-kilometers and 12,314 vehicle-hours. As the truck ban is not in effect in EDSA during off-peak hours, large trucks are able to utilize the circumferential road. EDSA thus functions as the main distributor of traffic to the radial roads located outside the area bounded by EDSA. During off-peak hours, large trucks fully utilize the southbound R1 and northbound R8 routes. During peak hours, however, large trucks are forced to take the circuitous alternate truck routes set by government as they as they are not allowed to pass the major arterial roads.

The "existing truck ban" scheme only ranks fourth in terms of minimizing vehicle kilometers and vehicle-hours with 622,365 veh-kms and 12,577 veh-hrs. The present scheme shows that large trucks widely use the available alternate routes to transport freight during the morning and afternoon peak-hour ban. Except in EDSA, large trucks take advantage in passing through all radial and circumferential roads, as allowed during off-peak periods. Roads most commonly utilized by large trucks are the southbound R1 and R3, eastbound R6, the northbound R8, and the circumferential roads C2 and C5. Small trucks mainly use C2 and EDSA, and the southbound R1 and northbound R8 routes.



Figure 5. Assignment of trucks for the existing truck ban scheme



Figure 6. Assignment of trucks for the "no truck ban" scheme

Finally, as anticipated, the scheme with the highest vehicle-kilometers and vehicle-hours is the "all-day truck ban at EDSA and major routes" with 693,426 and 14,017, respectively. Since the truck ban is extended to cover all major roads, except those identified as alternate truck routes, large trucks are compelled to utilize the alternate truck routes at all times. This results in longer travel distances and travel times, and ultimately increases vehicle-kilometers and vehicle-hours.

6. ENVIRONMENTAL ASSESSMENT

Environmental assessment is performed by aggregating the results of the traffic assignment which identifies volume, type, and average speed of vehicles in each link. Environmental emissions are calculated by multiplying traffic volume by the respective emission factors for each environmental pollutant (i.e. CO, NOx, SOx, SPM). The changes in vehicle emissions are determined by comparing each truck ban scheme with the existing truck ban scheme. Pollutant emissions are assumed to be dependent on travel distance, travel speed, and emission factors for each vehicle type.

Emission factors depend on a variety of factors including speed, age of vehicle, altitude, temperature, operating conditions, and others (Campbell, 1995). It is very difficult, however, to find a single data source containing all the factors for all conditions. The emission factors calculated by MMUTIS are thus utilized for different vehicle classes. Given a table of emission factors in Table 6, pollutant emissions can be estimated as:

Pollutant (i) = travel distance × emission factor at average travel speed (veh-km) (g/veh-km)

Pollutant		Vehicle		Average Speed	
Type		Туре	< 10 km/h	10 - 20 km/h	> 20 km/h
СО	Gasoline	Car	27.57	23.5	18.7
		Small truck	47.58	52.2	41.14
	Diesel	Car	7.85	6.54	5.94
		Small truck	8.02	6.8	6.2
		Large truck	8.12	7.11	6.5
NOx	Gasoline	Car	2.75	2.76	2.78
		Small truck	4.7	3.59	3.53
	Diesel	Car	5.65	4.28	3.89
		Small truck	8.95	7.66	7.01
		Large truck	11.24	10.59	9.22
Sox	Gasoline	Car	0.013	0.011	0.011
		Small truck	0.015	0.011	0.01
	Diesel	Car	0.14	0.08	0.07
		Small truck	0.18	0.121	0.11
		Large truck	0.2	0.15	0.1
SPM	Gasoline	Car	0.07	0.05	0.05
		Small truck	0.07	0.06	0.05
	Diesel	Car	1.2	0.07	0.07
		Small truck	1.8	0.9	0.81
		Large truck	2.3	1.5	0.80

Table 6. Emission factors (unit: g/km)

The table of emission factors indicates that lower vehicle speeds yields higher amounts of emissions. Gasoline and diesel engines vary in emission profiles. Smaller vehicles typically have lower emission rates than the large ones. The largest amounts of emissions in terms of unit (i.e. grams per kilometer) are observed for carbon monoxide (CO), ranging from a minimum of 6.2 to a maximum of 52.2 g/km for both gasoline-powered and diesel-powered vehicles. Oxides of nitrogen (NOx) emissions vary from 2.75 to as high as 11.24 g/km. Gasoline-powered vehicles emit more CO than their diesel-powered counterparts.

Diesel-powered vehicles, though, emit more NOx than their gasoline-powered counterparts. It can then be inferred that more gasoline-powered vehicles, usually private cars, would result in higher CO emissions, or more diesel-powered vehicles, generally large trucks, would result in higher NOx emissions.

In the calculation of pollutant emissions, it is assumed that gasoline-powered small trucks comprise 50 percent and that diesel-powered small trucks comprise the other 50 percent of their total volume. Large trucks, on the other hand, are assumed to be 100 percent diesel-powered.

Figures 7a and 7b show the results of the computations for the amount of pollutant emissions for each scheme according to time period. Overall, the figures show that there is very little change in the amount of pollutant emissions for the four truck ban schemes, namely, existing truck ban, no truck ban, peak-hour only ban, and all-day ban at EDSA only. Considerable increases in pollutant emissions, though, are observed for the all-day truck ban scheme at all major routes including EDSA. The off-peak time period comprises the majority of amount of emissions as trucks have the freedom to use all the major roads except EDSA.







Figure 7. Amount of pollutant emissions in each time period



Figure 8. Amount of pollutant emission for each scheme

The results suggest that any switch to gasoline powered small trucks due to the truck ban will cause the following: a small effect in SOx and SPM, a moderate decrease in NOx emissions but a large increase in CO emissions. A decrease in NOx emissions from large trucks, especially heavy diesel, is beneficial because they account for a large percentage of the total NOx vehicle emissions. Increases in SPM and CO emissions are detrimental, although heavy truck emissions are a very small component of SPM and CO total vehicle emissions and total overall emissions. Increases in SPM emissions may be most hazardous as they react in the atmosphere to form smog, which in turn worsens air quality. The imposition of the truck ban, therefore, from the viewpoint of improving air quality is somewhat counterproductive.

7. COMPARISON OF ALTERNATIVE TRUCK BAN SCHEMES

The changes in performance measures are calculated by comparing alternative truck ban schemes with the existing truck ban scheme. For example, the percentage change in travel distance is calculated $\Delta D = D_a - D_b / D_b$, while the percentage change in pollutant emission *i* is computed $\Delta E_i = E_a - E_b / E_b$, where the subscripts *a* and *b* denote the two cases being compared (i.e. *a*: "after" or revised truck ban scheme, *b*: "before" or existing truck ban scheme).

A summary of the traffic and environmental impacts of the different traffic control schemes is presented in Table 7.

Traffic control scheme	Distance (km)	%	Time (hrs)	%	CO (kg)	%	NOx (kg)	%	SOx (kg)	%	SPM (kg)	%
Existing truck ban	622365	-	12577	-	9186	-	4489	-	50	-	387	-
No truck ban	600706	-3.5	12019	-4.4	9046	-1.5	4289	-4.5	48	-4.4	370	-4.5
Peak hour truck ban only at EDSA and major routes	614622	-1.2	12314	-2.1	9136	-0.5	4417	-1.6	49	-1.6	381	-1.6
All-day truck ban at EDSA only	609548	-2.1	12310	-2.1	9103	-0.9	4371	-2.6	49	-2.6	377	-2.6
All-day truck ban at EDSA and major routes	693426	11.4	14017	11.4	9648	5.0	5144	14.6	57	14.1	444	14.6

Table 7. Comparison of alternative traffic control schemes to the existing truck ban

When compared with the existing truck ban scheme, the alternative with the highest reduction is the "no truck ban scheme". The total travel distance is reduced by 3.5 percent, total travel time by 4.4 percent, CO by 1.5 percent, and NOx, SOx, and SPM by 4 to 5 percent. Shorter and direct routes as provided by the major radial and circumferential roads resulted in less total travel distances and travel times, which subsequently reduced pollutant emissions.

The "all day truck ban at EDSA only scheme" follows next with a reduction of 2.1 percent for both total travel distance and travel time, 0.9 percent for CO, and around 2.6 percent for NOx, SOx, and SPM. When this scheme is compared with the "no truck ban scheme", this may be more feasible since a fairly significant reduction in the amount of emissions can be obtained by merely restricting along EDSA during the day and lifting the ban at the major routes during peak-hours.

The "peak hour truck ban only at EDSA and major routes scheme" resulted into reductions of 1.2 percent for total distance, and 2.1 percent for total travel time. Minimal reductions were observed for CO with 0.5 percent, and about 1.6 percent for the remaining pollutant emissions. These results only indicate that this option offers very little reduction when compared with the existing truck ban.

Finally, the scheme with the worst performance is the "all-day truck ban at EDSA and major routes scheme". Total travel distance increased by 11.4 percent, total travel time also by 11.4 percent, CO by 5 percent, and NOx, SOx, and SPM by about 14 percent. These large increases in total travel distances, travel time, and pollutant emissions observed were due to the diversion of trucks in using the circuitous alternate routes.

8. CONCLUSION

The paper explained the impacts of the truck ban on the transportation system of Metro Manila. Aggregated results of the MMUTIS truck surveys indicated the following:

- Traffic volume of ban-exempt smaller cargo vehicles increased, which is attributable to the utilization of smaller trucks in place of larger trucks that are banned from using major roads in Metro Manila.
- Small inbound cargo trucks account for high percentages of empty vehicles, which indicates that perhaps they are likewise utilized to collect freight from the port and deliver them outside the city, an information complementing the preceding finding.
- Traffic volume of trucks at night is comparably higher than the other transport modes, which implies the proliferation of nighttime deliveries.
- Temporal traffic distribution trends confirmed that the effect of the truck ban on truck traffic volume is significant during the truck ban and the no truck ban periods. Minimum truck movements are observed during the peak-hour truck ban periods while peak volumes of trucks are observed during the middle hours of the off-peak period.

Switching to small trucks is an accidental by-product of the truck ban implementation in Metro Manila. The truck ban will be more successful if this switching is minimized or eliminated but companies may still need to use smaller trucks even if they could cause increases in the level of congestion and the amount of pollution. These companies do so in order to avoid the restrictions of the truck ban and also to fulfill quick response and just-in-time freight transportation.

The truck ban is designed to shift traffic out of the congested peak periods to the less congested daytime or nighttime off-peak periods. Although nighttime operations could be favorable for air quality, the operations of large trucks can be quite troublesome. Noise generated from shipping and receiving may be unpleasant near residential areas. Economic impacts may be significant to many businesses if forced to do nighttime operations.

Although traffic assignment results may indicate that the "no truck ban" scheme is the most favorable way of improving the traffic environment in terms of reducing total travel distances, travel times, and pollutant emissions, this scheme may encounter political resistance especially from private motorists and residents who will be definitely affected by its lifting. Add to this, the need to reduce emissions of NOx in local and sensitive areas, such as residential subdivisions, leisure parks, and shopping districts near the banned routes may warrant the implementation of the truck ban. Any call for improvement in the quality of air or traffic in these areas is enough reason to leave the truck ban in place. On the other hand, the "all day truck ban at EDSA only" scheme offers comparatively encouraging reductions without completely eliminating the truck ban. This scheme may thus be the most favorable option if only the government and the different freight transport actors will compromise into an agreement benefiting all sectors.

Additional analysis is needed to estimate the benefits of reduced congestion brought about by the truck ban scheme, such as its impact on passenger trips and the environment. For example, even if truck emissions and performance worsen due to truck restrictions, a large enough improvement in emissions from other vehicles, mainly private passenger cars, could result in a net improvement in air quality. However, the vague and poorly understood role of latent demand in canceling out any traffic congestion reductions brought about by the truck ban must be considered.

General findings indicate that additional restrictions significantly increase total vehicle-kilometers, total vehicle-hours, and total pollutant emissions. These translate into increased transportation costs as total distance and total travel time are directly proportional to costs. These increases may add to the cost of goods to producers and eventually to consumers. The additional fuel consumption caused by the inefficiencies could also be a significant factor. These negative effects must be balanced against many economic, environmental, and social benefits of truck restrictions. Additional analyses are needed to estimate these benefits.

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