THE EFFECTS OF PUBLIC TRUCK TERMINAL POLICIES ON AIR POLLUTION IN THE BANGKOK METROPOLITAN AREA

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ABSTRACT

The present study was undertaken to examine the potential effects on air pollution and traffic movement in the city of the three newly established public truck terminals in Bangkok. The findings of the study reveal that the patterns of freight movement differ from one distribution channel to another. These channels are categorized as traditional trade, wholesale and retail markets, and modern trading through chains of superstores and convenience stores. An estimation of the emission loads from truck transportation was made by using empirical models and the geographic information system. The findings show that oxides of nitrogen (NO_x) are the major emission load generated from trucks (61.73 tons per day), followed by carbon monoxide (CO) (37.72 tons per day). Emissions of NO_x from heavy-duty diesel vehicles (HDDV) are approximately twice as high as those from light-duty diesel trucks (LDDT), despite the fact that the vehicle kilometre travel (VKT) of LDDTs is 7.3 times higher than that of HDDVs. Finally, the potential effects of truck restriction policies on air pollution after the establishment of public truck terminals are assessed through simulation studies. The results of simulation show that such truck terminals could help decrease VKT of HDDVs, but would increase VKT of LDDTs. Consequently, the terminals could help reduce emission loads of NO_x by 825 per cent and Suspended Particulate Matter (SPM) by 860 per cent from their present levels. However, emission loads of CO and hydrocarbons (HC) would be higher owing to the increase in VKT of LDDTs. This increase in levels of CO and HC is not so important, since the number of LDDTs in Bangkok is much smaller than the number of cars, which generate much higher volumes of CO and HC. The current 24-hour truck restriction on the Outer Ring Road core is more effective in reducing NO_x and SPM than that on the Inner Ring Road core. Further policies need to be formulated to promote the usage of truck terminals, which can lead to further reductions of NO_x and SPM.

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I. OVERVIEW

Most of the freight traffic in Bangkok is generated by conventional wholesale and retail markets, private truck terminals, freight forwarders, factories and modern trade. The conventional wholesale markets are usually located inside the Inner Ring Road core. Most of the markets are categorized by type of goods: flower, vegetables, clothing, and so forth. These markets are under the management of either the Bangkok Metropolitan Administration (BMA) or the private sector. Recently, the construction of inner and outer ring road networks has made it possible to introduce large-scale, modern wholesale markets in suburban areas of Bangkok such as Simoom Muang and Talad Thai. At these markets agricultural products from other regions, are traded. The Government supports and promotes them because of their potentials to reduce the freight traffic volume in central areas of Bangkok. They provide more systematic and larger storage and handling areas for the massive volume of goods from the provinces.

Non-perishable goods such as clothing, groceries and processed foods are traded mainly inside the city. Commercial buildings are utilized as storehouses. Traffic volumes and the frequency of loading and unloading activities generated by these markets are less than those generated by markets of perishable goods, since non-perishable commodities can be kept in storage for longer periods. However, most of the trucks used in the wholesale markets are of medium and large types (6- and 10-wheeled trucks). The major problem of the wholesale markets is the lack of parking space. As a result, some loading and unloading activities take place at the roadside which obstructs the passage of other road users. The construction of multi-storey structures is one solution to the parking problem of these markets, for it could provide more space for parking and cargo storage. Other problems of the markets include poor accessibility and problems caused by truck ban regulations.

The conventional retail markets are scattered all over Bangkok, especially in residential and commercial areas. They are usually open from early morning until midday. Goods are transferred from these markets to vendors, hawkers, restaurants, hotels, hospitals, and supermarkets in small vehicles. Some markets are called "talad nud", where various commodities such as vegetables, fruits, clothes, plants, pets, and so forth are sold on specific days fixed by the market manager. Several foreign companies have introduced modern trading through chains of superstores and convenience stores. Freight forwarding and logistics systems play an important role in this type of trading. The transport operations serving this type of trading are more efficient than the two other types discussed earlier. Interested readers are referred to Sirikijpanichkul (2000) for more details about freight forwarding and logistics operations in Bangkok.

The rapid economic growth and urban sprawl of Bangkok have resulted in higher volumes of inner city freight transportation. The increased usage of trucks, especially heavy trucks, has a major impact on traffic conditions, road safety and the environment of the city. To address the negative effects of heavy truck movements, the Government has formulated a number of truck operation policies and taken other measures. Time-based truck restrictions, zonal restrictions, and three suburban truck terminals have been introduced in order to restrict heavy trucks from entering the inner city. However, these policies and measures have strengthened the role of smaller trucks and vans in transporting goods in inner Bangkok.

The main objective of this study was to examine the effects of the new public truck terminals on air pollution in Bangkok. The paper is organized as follows: the first section provides an overview of present freight transportation arrangements in Bangkok, a statement of the problem and the objectives of the study. The second section is a review of the literature concerning a freight transportation model, an emission model and previous studies. The freight transportation plans and policies for Bangkok are presented in the third section. The results of the estimation of emission loads from existing truck-based freight transportation are presented in the fourth section. The fifth section summarizes the possible effects on emission loads after the introduction of public truck terminals in Bangkok. Finally, conclusions are drawn and some recommendations are presented for consideration by the concerned authorities.

II. LITERATURE REVIEW

A. Freight transportation model

There are differences between the forecasting models used in urban freight transportation planning and the ones used in urban transportation planning, although the process of modelling may be similar. The major problem in developing an urban freight transport demand model is the lack of freight movement data at all spatial levels. The availability of appropriate data directly affects the choice of techniques (Memmott 1983). A number of actors are involved in freight transportion, such as industrial firms, shippers, carriers and logistics service providers, which is another factor that complicates freight transport demand modelling.

There are two basic types of model that can represent traffic flow on road networks: traffic assignment models and traffic simulation models. The traffic assignment models have a limited range of applications owing to their inherent theoretical properties. The simulation models are further classified into two types: micro-simulation models such as NETSIM (network simulator) (Lieberman 1981) and macro-simulation models such as CONTRAM (contiuous traffic assignment model) (Leonard and Gower 1982). Some other types of model were also developed to represent the relationship between performance of road systems and other factors: for example, congestion functions to indicate the relationship between demand and performance of a road system. In this type, link cost function and cost models provide information on the cost of transporting goods by alternative routes, and by using different terminals and different types of vehicle (Jara Diaz 1982).

Most of the freight demand models developed have followed the conventional four-step modelling process, with some adaptations specific to freight, such as the models developed by Van Es in 1982, Kim and Hinkle in 1982, Friesz, Tobin and Harker in 1983 and Harker in 1985 (Ortúzar and Willumsen 1996). The models can be either trip-based or goods-flow based. Boerkamps and Binsbergen (1999) suggest that the trip-based models are not able to evaluate new transport systems. For goods-flow based models, goods flows are modelled based on their production or distribution, or both, and consumption points (shops or consumers). A vehicle-loading model assigns goods flows from origin to comsumption points. Finally, the flows are assigned to the road network.

B. Emission model

The diesel engine is a major source of air pollution owing to exhaust emissions of oxides of nitrogen (NO_x), carbon monoxide (CO), Suspended Particulate Matter (SPM), sulphur dioxide (SO_2) and volatile organic compounds (VOCs). The high levels of NO_x emissions from heavy-duty vehicles are explained by the characteristics of diesel engines: they run at higher combustion chamber pressures and temperatures than petrol engines. The conditions of combustion are conducive to high levels of NO_x emissions. SPM in diesel exhaust originates mainly from unburned fuel and engine oil (Weaver and Klausmeier 1988 and Conte 1990).

Studies have been carried out to investigate the relationship between road traffic operating conditions and emission loads. Two main emission models developed in the United States of America are currently in use: the Enviromental Protection Agency Mobile Source Emission Factor Model (EPA MOBILE), which is the most widely used, and the California Air Resources Board Emission Factor Model (CARB EMFAC), which is used in California. The structures of both models are the same. Activity-specific emission rates estimated by the models are multiplied by vehicle activities to provide emission outputs by pollutant (that is, grams per vehicle-mile for MOBILE and grams per vehicle-hour and per vehicle trip for EMFAC) (Guensler 1993). Baseline emission rates are derived from a laboratory test procedure known as the federal test procedure (FTP). The FTP driving cycle consists of a sequence of accelerations, decelerations, cruise speeds and idling based on actual home-to-work commuter trips in the 1960s on Los Angeles freeways and surface arterials (EPA 1993).

C. Previous studies in Bangkok

Emissions from on-road vehicles can be determined from vehicle mileage travel (VMT) and the emission factors of pollutants. Hanson and Lopez (1992) estimated the emission factors of CO. Later, Boontherawara (1994) developed the emission factors of $NO_{x,}$ which depend on temperature, vapour pressure, speed, operating mode, altitude, age of vehicle, and so on. However, the most important determining factor of the emission rate is vehicle speed (EPA 1996). Chulalongkorn University conducted a study to develop an emission database as an input to the “Airviro” computer program. The database of Airviro can be updated and used to estimate the emission load and its dispersion. The road network and traffic data needed for the program include hourly volume, traffic composition, speed, and average daily traffic (ADT). The emission load is finally estimated by the program from data on fuel consumption, traffic characteristics and VKT (Pollution Control Department 1994).

Tanadtang (1999) conducted a study on the effects of traffic on air quality through driving cycle tests by measuring and evaluating the exhaust emissions of petrol vehicles on congested and uncongested roads, suburban roads and expressways in Bangkok. Muttamara and Leong (2000) measured exhaust emissions from petrol vehicles in Bangkok by chassis dynamometer. A fleet of 10 vehicles of different models, years and manufacturers was selected for the purpose of measuring air pollutants in exhaust fumes. They found that average CO and HC emissions from 1990-1992 cars were 32.3-64.2 and 1.82-2.98 gm per km respectively and decreased to 17.8-40.71 and 0.75-1.88 gm per km respectively for the newer 1994-1995 cars. The results also indicated that air pollutant emissions significantly increase with increases in mileage and the age of the car. The study also confirmed that there is a correlation between average air pollutant concentration and traffic speed.

III. FREIGHT TRANSPORTATION PLANS AND POLICIES IN BANGKOK

The restriction of truck movements was the first measure implemented to reduce the traffic load of heavy trucks in Bangkok. Restrictions have been in place since 1989. Four- and six-wheeled trucks are prohibited from entering the Bangkok metropolitan area at the peak hours of between 6 and 9 in the morning and 4 and 8 in the evening. Ten-wheeled and larger trucks have extended hours of restriction: they are banned between 6 and 10 in the morning and 3 and 9 in the evening. However, on-street parking of heavy trucks during the unrestricted hours continues to have adverse effects on other road users. To alleviate this problem, public truck terminals were proposed in 1969, and feasibility studies on truck terminals were subsequently carried out. These studies also considered land acquisition problems, the possibility of granting concessions to the private sector and the construction process. Finally, three public truck terminals were constructed and opened for operation in June 2000. These three public truck terminals are located in the north (Pathumthani), the east (Ladkrabang), and the west (Buddha Monthon) of Bangkok, as shown in figure 1. The truck terminals are aimed at reducing the number of heavy trucks and the enhancement of the air quality in the city area. Since the introduction of the three terminals there have been some significant changes in truck ban measures: in addition to the existing policy of restriction by hours of the day, new bans have been proposed based on spatial zones, defined by the Outer and Inner Ring Roads.

The zonal truck-ban policy is to be implemented in four phases. In the first phase, all trucks with 10 wheels or more were not allowed to park inside the 45-sq-km truck-free zone of Bangkok, as shown in figure 2. This was implemented in June 2000. This truck-free zone was extended up to the Inner Ring Road (113-sq-km) in September 2000 in the second phase. Finally, trucks with 10 wheels or more will be totally prohibited from entering the Inner and Outer Ring Road areas in the third and fourth phases respectively. However, as these bans could seriously affect the truck operators located inside the city, the Department of Land Transport has requested the Ministry of Industry to conduct a study on the movements of commodities in the inner areas, the location of truck operators and their fleets and other matters that could be adversely affected in the third and fourth phases of zonal truck bans. The study would, inter alia, identify the preventive measures to address the negative effects on freight operations caused by the proposed bans in the last two phases.

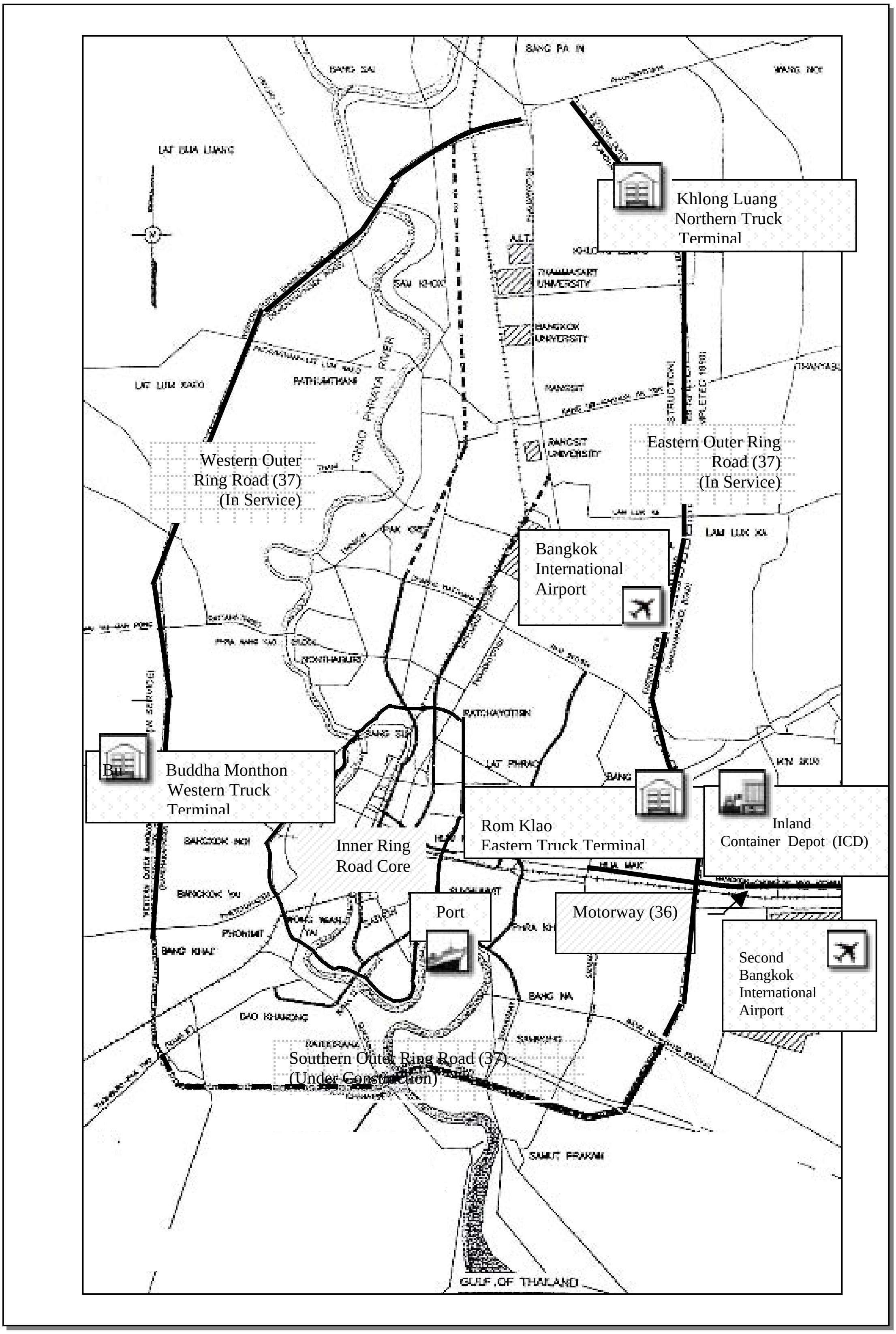


Figure 1. Inner and Outer Ring Roads, ports and freight terminals in Bangkok

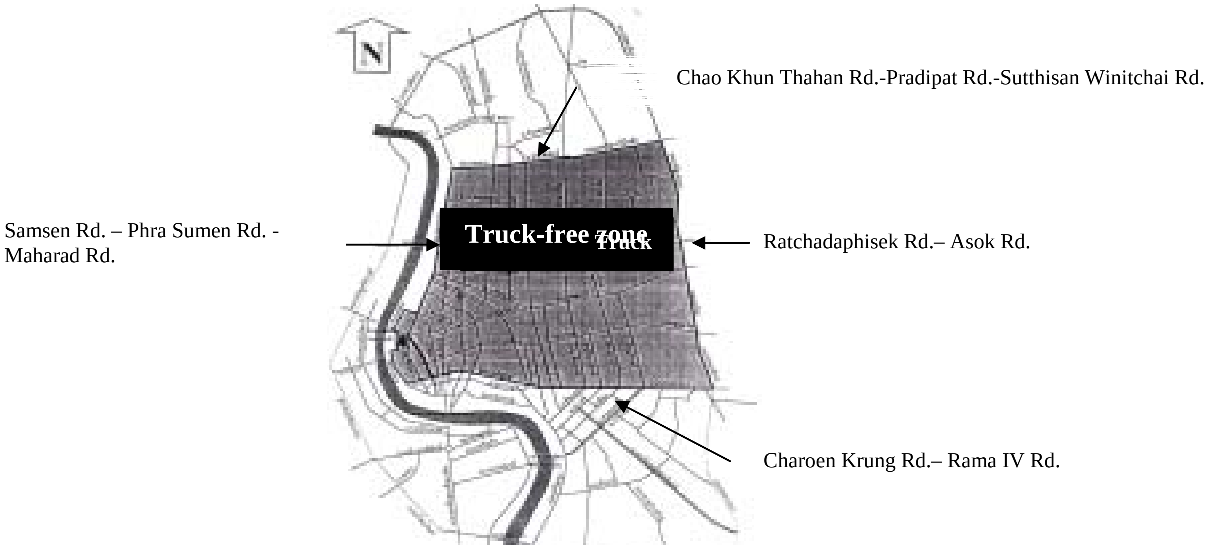


Figure 2. Truck-free zone implemented in June 2000

Besides zonal restrictions, some truck routes have been designated to enable truck access to ports and freight terminals located within the restricted area. Such routes include the Outer Ring Road and all links between ports and expressway access roads (Department of Land Transport 1999a).

IV. ESTIMATION OF EMISSION LOADS FROM TRUCK-BASED FREIGHT TRANSPORTATION IN BANGKOK

A. Data collection

In order to estimate emission loads from truck-based freight transportation, a study was carried out, including all 50 administrative districts of Bangkok. They were encoded to simplify the origin-destination (O-D) study. Twelve major markets and two private truck terminals were selected as survey locations for the collection of data on freight movement and other related information through a questionnaire. The selection of the survey locations was based on size, location and type of market, as shown in table 1.

After defining the survey locations, a questionnaire was designed. General questions and those on freight transportation data and freight transportation problems were incorporated. The general questions related to the type of business (retail, wholesale, factory, farm and garden, freight forwarder, or other); the type of commodity (vegetables, clothes and leather, fresh food, fruits, processed foods, meat and fish, flowers, rice, sugar and flour, manufactured products, or other); and the type of vehicle (pick-up, 4-, 6- or 10-wheeled truck, or van). Freight transportation data included distance travelled per day and per week, origin and destination, number of trips per day, age of vehicle, trip frequency per week, refuelling, load factor, loading and unloading time, and travel time.

Table 1. Emission load survey locations by type of market

No	Location *		Size of market		
	Outer Ring Road Core	Inner Ring Road Core	Large (over 20,000 sq. m)	Medium (5,001 – 20,000 sq. m)	Small (less than 5,000 sq. m)
1	Inside	Inside	-	4 (3 wholesale, 1 weekend)	2 (1wholesale, 1 private truck terminal)
2	Inside	On	-	1 (wholesale)	-
3	Inside	Outside	1 (wholesale)	-	3 (weekend)
4	On	Outside	-	1 (retail market)	-
5	Outside	Outside	-	-	2 (1 weekend market, 1 private truck terminal)
Total			**14**		

Notes: * See locations of Outer and Inner Ring Road in figure 1.

One thousand two hundred (1200) questionnaires were distributed and collected from truck users at 14 survey locations in November and December 1999. After screening, 910 valid questionnaires were accepted for analysis.

Data collected from secondary sources included truck registration numbers from 1981 to 1999, emission factors of LDDTs and HDDVs, and the estimated number of trucks using the public truck terminals. These data were obtained from the Department of Land Transport (1999b), the Pollution Control Department (1994), and the Japan International Cooperation Agency (1992) respectively. Geographic information on Bangkok from SmartMap™ (a GIS-based program) was applied to estimate VKT. There are two methods to estimate VKT: the average daily traffic (ADT) method and the method based on a distance-travelled analysis. The second was selected for this study because of the lack of the necessary traffic data for the first method. For travel time, the interview technique was applied. The whole process of data analysis is shown in figure 3.

B. Some general characteristics of freight traffic

It was found that the small pick-up truck was the major type of vehicle used in freight transportation (93.8 per cent), followed by 6-wheeled trucks (4.2 per cent). Other types formed the rest. Most of the trucks carried goods from factories, wholesalers, and warehouses and truck terminals to vendors, fresh markets and retail or grocery shops. The load factor of trucks carrying manufactured products was highest (88.3 per cent), followed by fruits (85.9 per cent), and clothes and leather (82.8 per cent). In terms of origin, trucks from factories had the highest load factor (88.4 per cent), followed by trucks from warehouses or truck terminals (88.1 per cent) and wholesalers (86.8 per cent).

The peak hours for truck movements to and from fresh markets were between 5 and 8 in the morning. For processed food and clothes markets as well as private truck terminals, the peak hours were between 10 and 12 in the morning.

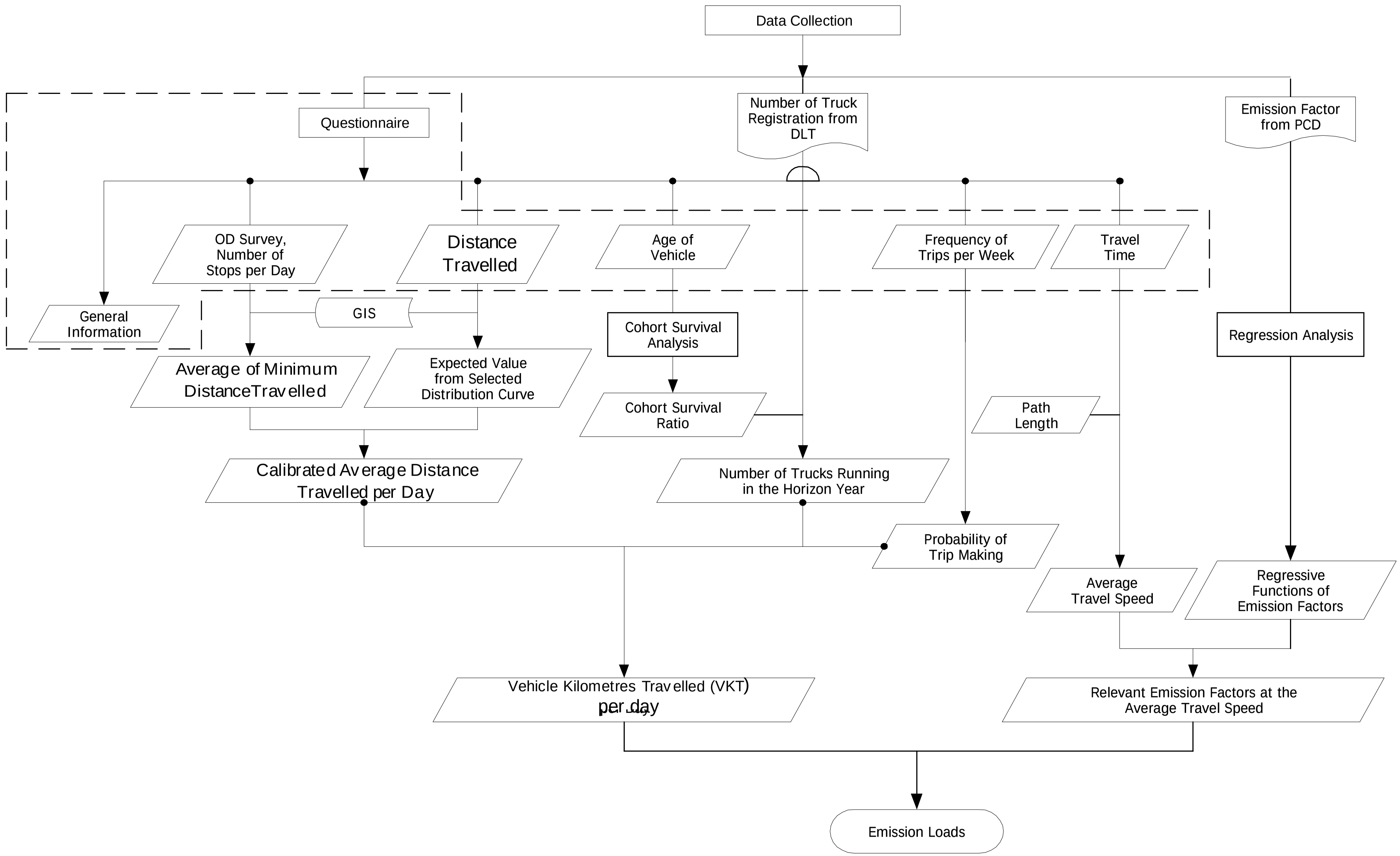


Figure 3. The process of data analysis in emission load survey

Note: DLT: Department of Land Transport; GIS: geographic information system: OD: origin-destination; PCD: Pollution Control Department

C. Estimation of vehicle kilometer travel

VKT and travel speed are the two important parameters for the estimation of emission loads. In this study, data on distance travelled per day was validated by Chi-square ($\chi 2$) goodness-of-fit test. A logarithmic normal distribution model best fitted the collected data. Reference is made to Sirikijpanichkul (2000) for details on the model. The average value was 74.761 kilometres at 0.05 significance level. It was verified later by using GIS. A distance matrix of Bangkok was established using SmartMap. This matrix was developed to provide distances between each pair of the 50 administrative areas in Bangkok based on their assumed central reference positions. An O-D table developed from the survey was then overlapped on the matrix. Consequently, the average shortest distance per trip was obtained. The average shortest distance travelled per day was calculated from the average number of trips per day multiplied by the average shortest distance per trip. The analysis shows that the average shortest distance of travel per day is 33.504 kilometres. When disaggregated by type of vehicle, the modelled average travel distances of LDDTs and HDDVs were found to be 53.700 and 63.119 kilometres respectively.

The age of vehicle and trip frequency per week were used as inputs for estimating the number of trucks running in the base year (1999). A survival rate matrix for different age groups of trucks was developed by using the cohort survival technique (Ortúzar and Willumsen 1996). The matrix of truck population by age and for each category was developed from the vehicle registration data. To get the estimated number of trucks by category in the base year, the survival rate matrix was multiplied by the truck population matrix. Summation of the numbers of truck in both the categories gave the estimated total number of trucks running in 1999.

The data on trip frequency per week were used for the calculation of probability of trip-making by a truck. Finally, VKT per day for HDDVs and LDDTs were calculated by multiplying the modelled average distance travelled per day for each category by the corresponding number of trucks running in the base year and their probability of trip-making as shown in table 3.

Table 2. Number of truck registrations from 1983 to 1999

Year	Number of truck registrations	Number of heavy-duty diesel vehicles	Number of light-duty diesel trucks	Increase in number of heavy-duty diesel vehicles	Increase in number of light-duty diesel trucks
1999	788,493	118,656	669,837	14,112	75,220
1998	699,161	104,544	594,617	-5,910	41,782
1997	663,289	110,454	552,835	3,657	98,595
1996	561,037	106,797	454,240	15,370	51,560
1995	494,107	91,427	402,680	8,177	78,778
1994	407,152	83,250	323,902	-7,099	51,712
1993	362,539	90,349	272,190	5,401	80,282
1992	276,856	84,948	191,908	2,938	41,977
1991	231,941	82,010	149,931	-26,096	63,725
1990	194,312	108,106	86,206	22,716	8,807
1989	162,789	85,390	77,399	5,544	20,866
1988	136,379	79,846	56,533	11,835	10,290
1987	114,254	68,011	46,243	2,433	16,103
1986	95,718	65,578	30,140	1,663	13,865
1985	80,190	63,915	16,275	9,721	3,289
1984	67,180	54,194	12,986	2,354	8,545
1983	56,281	51,840	4,441	-	-

Source: Department of Land Transport (1999).

Table 3. Calculation of vehicle kilometres travelled per day by the estimated number of trucks running in 1999

Vehicle type	Number of trucks running in 1999 (1)	Probability of trip-making (2)	Average distance travelled per day (kilometres per day) (3)	Vehicle kilometres travel per day (vehicle–kilometres per day) (4) = (1) x (2) x (3)
LDDT	342,194	0.7761	53.700	14,261,472
HDDV	40,755	0.7594	63.119	1,953,492

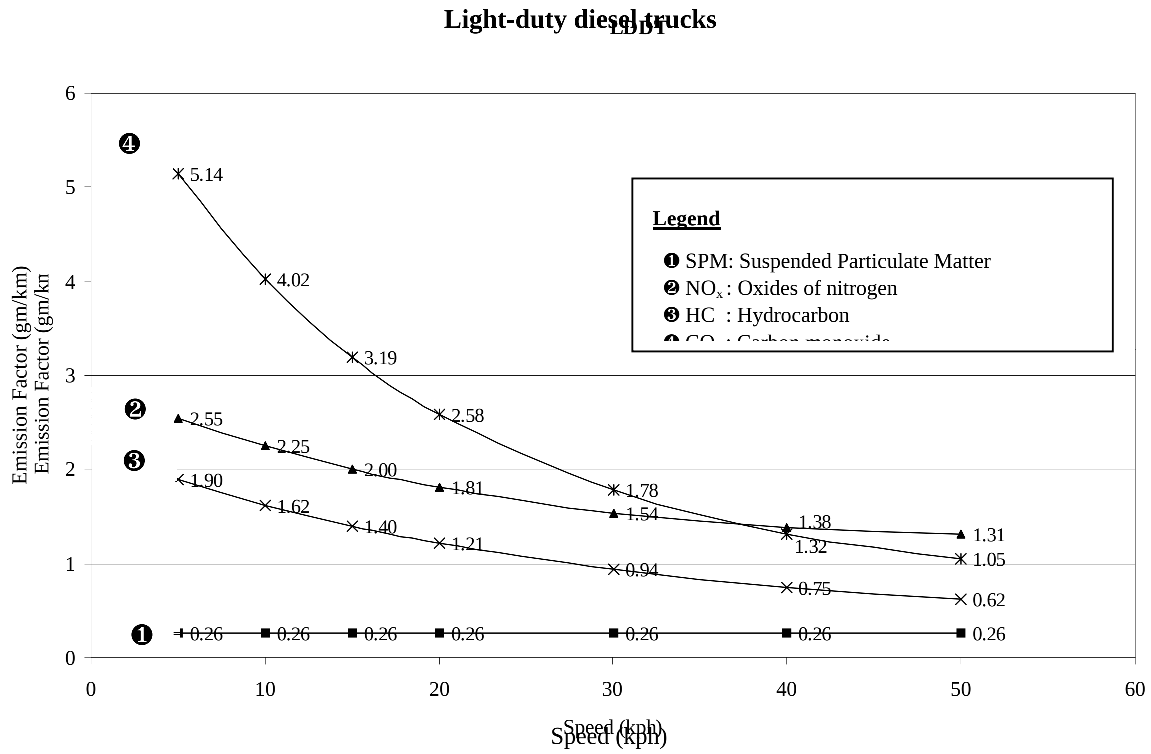
D. Estimation of emission loads

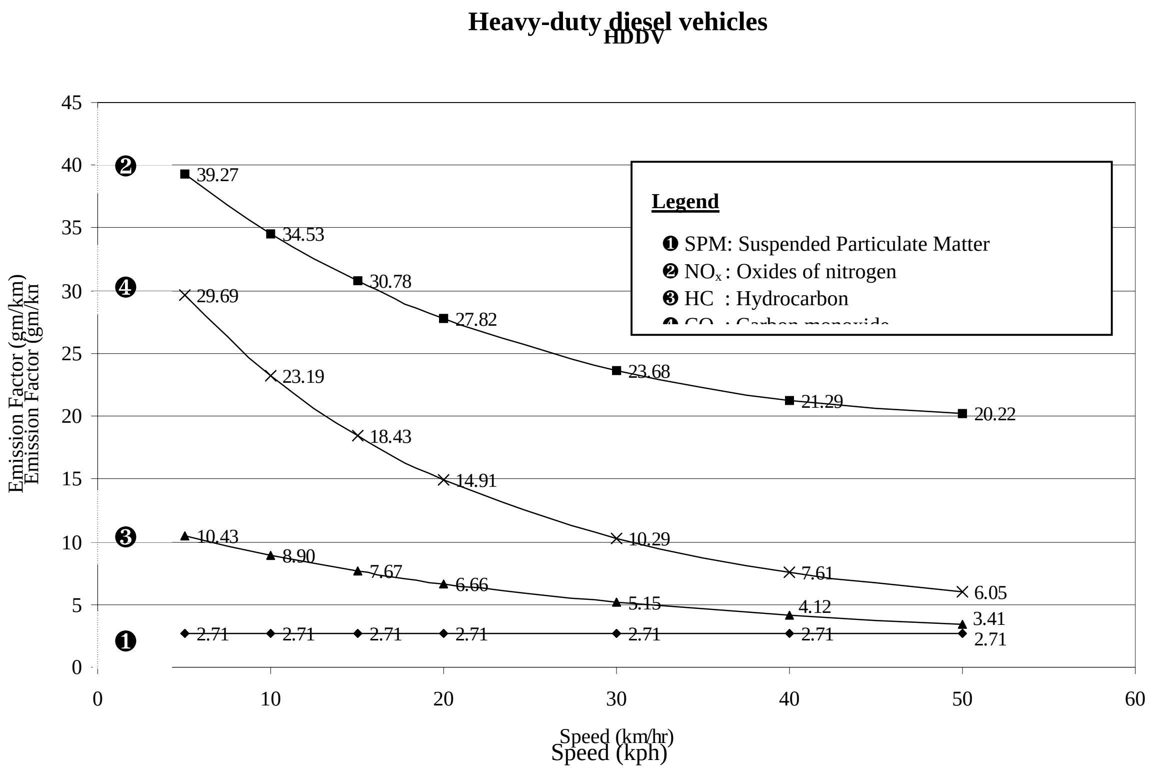
The emission factor (in grams per kilometre) of each pollutant depends on the type of vehicle and the travel speed. Sources of emission were broadly categorized into LDDT (pick-up truck and van) and HDDV (6- and 10-wheeled trucks). In this study, travel speed was calculated from distance travelled and travel time. Distance travelled was obtained by tracing the route of O-D survey data on a GIS database. Data on travel time was collected from the questionnaire. A logarithmic normal distribution model was fitted to the estimated travel speed. The model was validated by Chi-square ($\chi 2$) goodness-of-fit test. The average value was 36.22 kilometres per hour at 0.05 significance level. The average travel speeds of LDDTs and HDDVs were 36.07 and 39.37 kilometres per hour respectively. The average speed of HDDVs was higher than that of LDDTs owing to the fact that HDDVs could enter the city only during off-peak hours.

The emission factor of each pollutant was obtained from emission factor charts developed by the Pollution Control Department (1994) as shown in figure 4. It was assumed that emission factors would be similar to those based on the driving conditions as used in the above mentioned study by the Pollution Control Department. The emission loads were finally calculated by multiplying VKT per day by the corresponding emission factors at the average travel speed. The results of emission load estimation are shown in table 4.

As shown in table 4, NO_x is the major emission load generated by HDDVs, followed by CO, HC and SPM, in that order. On the other hand, LDDTs emit CO at the highest level, followed by NO_x, HC and SPM.

HDDVs generate very high levels of NO_x. It is noteworthy that the total NO_x generated by HDDVs is approximately double that of LDDTs, despite the fact that the mileage of LDDTs is 7.3 times higher than HDDVs. Total SPM from HDDVs is also much higher than that from LDDTs.





Source: Pollution Control Department, Thailand (1994).

Figure 4. Emission factors of light-duty diesel trucks and heavy-duty diesel vehicles

Table 4. Emission load generated by trucks running in the Bangkok Metropolitan Area

Vehicle class	VKT per day	Average travel speed (kph)	Emission factor (grams per vehicle kilometre)		Emission load (kilograms per day)
Light-duty diesel trucks (pick-up truck and van)	14,261,472	36.07	CO	1.5481	22,078
			NO_x	1.4416	20,559
			HC	0.7583	10,814
			SPM	0.2600	3,708
Heavy-duty diesel vehicle (6- and 10-wheeled trucks)	1,953,492	39.37	NO_x	21.0747	41,169
			CO	8.0073	15,642
			HC	4.0497	7,911
			SPM	2.7100	5,294

V. THE POTENTIAL EFFECTS OF PUBLIC TRUCK TERMINALS ON EMISSION LOADS

The estimated number of truck trips from the three public truck terminals in the year 2000 was used for the calculation of emission loads. The Japan International Cooperation Agency (1992) simulated five scenarios based on the proposed truck ban measures after the opening of the truck terminals. The scenarios were as follows:

Case 1: existing condition with 2.8 per cent use ratio.
Case 2a: 24-hour heavy truck restriction in the inner area with 100 per cent use ratio.
Case 2b: 24-hour heavy truck restriction in the inner area with 2.8 per cent use ratio.
Case 3a: 24-hour heavy truck restriction in the outer area with 100 per cent use ratio.
Case 3b: 24-hour heavy truck restriction in the outer area with 2.8 per cent use ratio.

The predicted number of truck trips using each public truck terminal in the year 2000 is shown in table 5 (JICA 1992). Four commodity types were considered in the study: processed food, clothes and leather, manufacturing products and miscellaneous goods. After the opening of the truck terminals, the number of heavy trucks running inside Bangkok would reduce. However, the number of delivery trucks (LDDTs) transporting goods from truck terminals to destinations inside Bangkok would increase. In addition, the distance travelled by LDDTs would also increase, owing to the longer average distances between the truck terminals and destinations inside the metropolitan area than before.

The three public truck terminals are located in the Don Muang, Thavee Watthana and Ladkrabang areas respectively. From the distance matrix, distance ratios were calculated by dividing the average distance between Don Muang, Thavee Watthana and Ladkrabang and the other administrative areas by the average distance between all administrative areas. For example, the ratio of distance for the northern public truck terminal North is $\frac{21.752}{16.234} = 1.3399$. The average distance travelled per day for 1.6 ton delivery trucks and the distance ratio at each terminal are shown in table 5.

Table 5. Distance travelled per day of delivery trucks using three public truck terminals

Scenario (1)	Truck terminal (2)	Number of 1.6 ton delivery trucks (vehicle trips per day) (3)	Percentage of 1.6 ton delivery trucks using each terminal (4)	Distance ratio (5)	Existing distance travelled per day (km/day) (6)	Adjusted distance travelled per day (km/day) (7) = (5) x (6)
Case 1	North	1,454	40.45	1.3399	57.789	77.432
	West	1,054	29.32	1.4004		80.928
	East	1,087	30.23	1.6399		94.766
	Total	3,596	100.00		Average	83.697
Case 2a	North	7,181	37.08	1.3399	57.789	77.432
	West	4,828	24.93	1.4004		80.928
	East	7,357	37.99	1.6399		94.766
	Total	19,367	100.00		Average	84.886
Case 2b	North	5,956	36.74	1.3399	57.789	77.432
	West	4,073	25.13	1.4004		80.928
	East	6,182	38.13	1.6399		94.766
	Total	16,211	100.00		Average	84.920
Case 3a	North	14,049	42.35	1.3399	57.789	77.432
	West	9,336	28.14	1.4004		80.928
	East	9,791	29.51	1.6399		94.766
	Total	33,176	100.00		Average	83.532
Case 3b	North	11,529	42.30	1.3399	57.789	77.432
	West	7,679	28.17	1.4004		80.928
	East	8,049	29.53	1.6399		94.766
	Total	27,258	100.00		Average	83.536

Source: Japan International Cooperation Agency 1992.

The possible effects of truck terminals on vehicle mileage and emission loads are presented in tables 6 and 7. It is observed that after the implementation of public truck terminals, the mileage of HDDVs would slightly decrease, while the mileage of LDDTs would greatly increase. The results also show that the truck terminals could reduce emission loads of NO_x and SPM in Bangkok owing to the lower mileage of HDDVs. However, emission loads of CO and HC would significantly increase, owing to the increased mileage of smaller delivery trucks.

The results also indicate that a 24-hour truck restriction on the Outer Ring Road core would be more effective in reducing NO_x and SPM emissions than a restriction on the Inner Ring Road. The percentage of emission reduction, however, depends on truck terminal usage. The higher the usage of the truck terminal, the larger is the potential emission reduction.

Table 6. Estimation of increased vehicle-kilometres travelled per day of delivery trucks and heavy trucks for each truck ban scenario

Vehicle type/ scenario	Estimated number of truck trips using public truck terminals	Average distance travelled per day (kilometres per day)	Increased vehicle kilometres per day
Delivery Truck (1.6 Tons per vehicle)			
Case 1	3,596	83.697	300,942
Case 2a	19,367	84.886	1,643,971
Case 2b	16,211	84.920	1,376,666
Case 3a	33,176	83.532	2,771,265
Case 3b	27,258	83.536	2,276,978
Heavy Truck (10.5 tons per vehicle)			
Case 1	548	63.119	-34,583
Case 2a	2,951	63.119	-186,273
Case 2b	2,470	63.119	-155,922
Case 3a	5,055	63.119	-319,094
Case 3b	4,154	63.119	-262,166

Source: Japan International Cooperation Agency 1992.

Table 7. Net increment of NO_x, CO, HC and SPM (in kilograms per day) after the introduction of public truck terminals in Bangkok

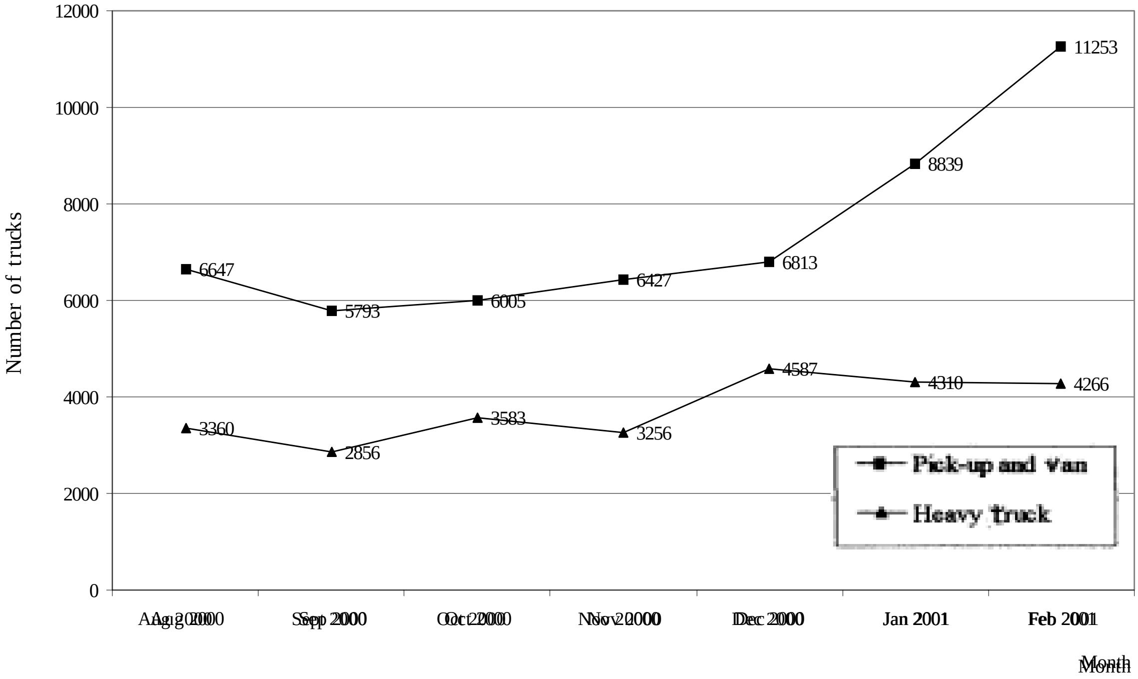
Scenario	NO_x	CO	HC	SPM
Case 1	-295	189	88	-15
Case 2b	-1,301 (-341)	883 (+367)	412 (+368)	-65 (-333)
Case 2a	-1,556 (-427)	1,053 (+457)	492 (+459)	-77 (-413)
Case 3b	-2,243 (-660)	1,426 (+654)	665 (+656)	-118 (-687)
Case 3a	-2,730 (-825)	1,735 (+818)	809 (+819)	-144 (-860)

Note: The figures in parentheses indicate the change in emission load compared with the case 1 scenario.

CONCLUSIONS AND RECOMMENDATIONS

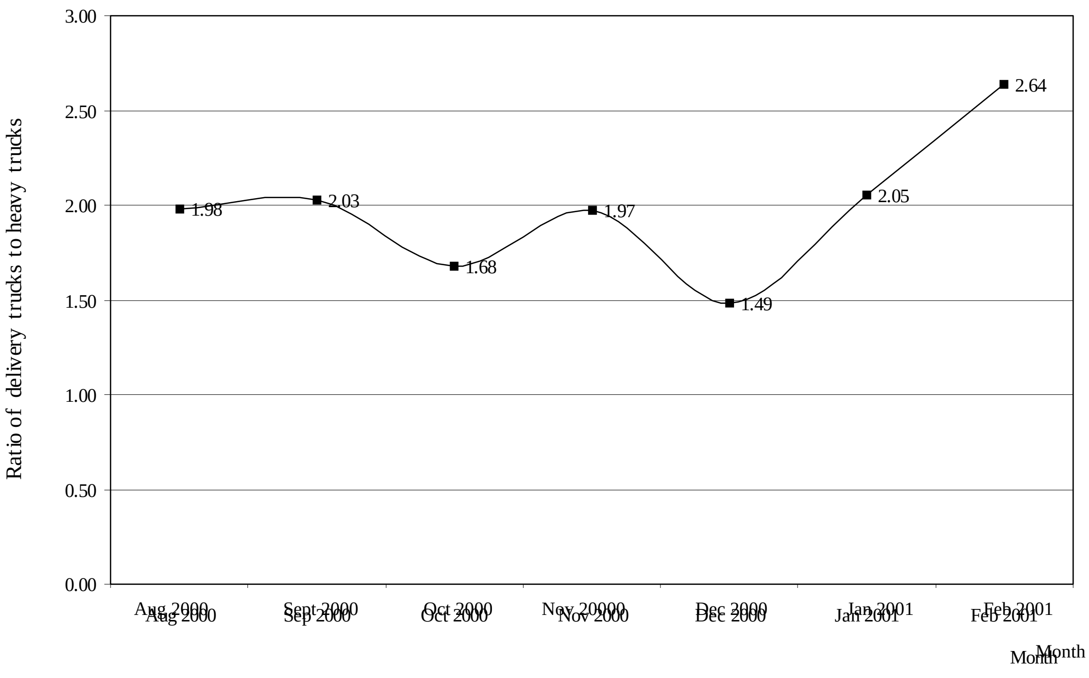
This study was conducted to examine the possible effects of public truck terminals on traffic movement and the environment of Bangkok. An estimation of the emission loads from truck transportation was made by using empirical models and the geographic information system.

The findings of the study show that NO_x are the major emission load generated by trucks (61.73 tons per day), followed by CO (37.72 tons per day). NO_x emissions from heavy-duty diesel vehicles are approximately double those from light-duty diesel trucks, despite the mileage of LDDTs being 7.3 times higher than the mileage of HDDVs. The public truck terminals could have a considerable impact on the air quality of Bangkok. They would slightly decrease the mileage of HDDVs, but increase the mileage of LDDTs. This could help reduce emission loads of NO_x by as much as 825 per cent and SPM by 860 per cent from their respective base levels. However, emission loads of CO and HC would become much higher, owing to the increased mileage of smaller delivery trucks. However, the overall impact of increases in emission loads of CO and HC is not expected to be very significant as there are fewer diesel pick-up trucks in Bangkok than cars, which generate much higher volumes of CO and HC (Department of Land Transport 1999b). The 24-hour truck restriction on the Outer Ring Road core is more effective in reducing NO_x and SPM than the restriction on the Inner Ring Road.



Source: Department of Land Transport, Thailand (2001).

Figure 5. Number of delivery trucks and heavy trucks using the western public truck terminal from August 2000 to February 2001



Source: Department of Land Transport, Thailand (2001)

Figure 6. Ratio of delivery trucks to heavy trucks using the western public truck terminal from August 2000 to February 2001

In addition, the higher the usage of the truck terminal, the greater is the reduction in NO_x and SPM.

The study reveals some promising positive effects of the truck terminals. However, some problems are challenging the success of this policy. Terminal usage is not as high as was originally predicted. The most serious problem faced by the truck operators is the increase in operating costs. They claim that additional costs include terminal rental cost, parking fees, the purchasing of new delivery trucks, and so forth. The number of delivery trucks using the western public truck terminal in December 2000 was 220 vehicles per day, which was only 5.4 per cent of the predicted volume for Case 2b of table 6. Nevertheless, the number of delivery trucks using the terminals increased sharply in the following months. It is observed that the ratio of delivery trucks to heavy trucks using the truck terminals also rose, as shown in figure 6. This trend indicates the consolidation of cargo handling. Since greater usage of the truck terminals could contribute to significant improvements in air quality in Bangkok, actions need to be considered to promote their usage. To enhance the usage of public truck terminals further, some measures may be considered as follows:

(a) The Government could encourage factories in inner areas to move out to industrial zones established near the public truck terminals. If needed, new zones could be established by the Government to ensure a reasonable land price and the availability of all the necessary physical infrastructure;

(b) Logistics facilities for chilled and frozen goods could be developed in public truck terminals;

(c) The road network and other infrastructure facilities linking the truck terminals and industrial zones could be improved to provide greater accessibility, wider coverage and faster movement.

The lessons learned should be useful for the proposed regional truck terminals in different parts of the country, which include truck terminals in the north at Chiang Mai, in central Thailand at Nakhon Sawan, in the north-east at Khon Kaen and Nakhon Ratchasima, and in the south at Had Yai and Songkhla.

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