Technical Note

a. Calculation Model

The dispersion of emission gas is influenced by many conditions, such as wind condition, stability of atmosphere, volume and temperature of gas, and shape of stack.

For forecasting the expected maximum concentration of emission gas on the ground surface and distance from the source, the Plume Model for windy condition and the Puff Model for calm condition are adapted.

Plume Model (windy condition)

$$C(R) = \sqrt{\frac{2}{\pi}} \frac{q}{\frac{\pi}{8}\sigma_z RU} \exp\left(-\frac{H_e^2}{2\sigma_z^2}\right)$$

C(R) : Concentration of R for under the wind (g/m^3)

R : Distance of under the wind (m)
$\sqrt{x^2+y^2}$

Z : Height of forecast (m)

q : Indensity of emission gas (g/s)

σ_z : Width of gas or vertical

U : Wind speed (m/s)

H_e : Effective stack height (m)

Puff Model (Calm condition)

$$C(R) = \sqrt{\frac{2}{\pi}} \cdot \frac{q}{\frac{\pi}{8} \cdot \beta} \cdot \frac{1}{R^2 + \frac{\alpha^2}{\beta^2} \cdot H_e^2} \cdot \exp\left\{-\frac{U^2 \cdot H_e^2}{2\beta^2(R^2 + \frac{\alpha^2}{\beta^2} H_e^2)}\right\}$$

C(R) : Concentration of R for under the wind (g/m^3)

R : Distance of under the wind (m)

α, β : Coefficient

α, β is calculated by the following formula:

$\sigma_y = \alpha t$

$\sigma_z = \beta t$

t : Continues period of calm

σ_y : Horizontal diffusion width for y (m)

σ_z : Vertical diffusion width (m)

Here, H_e is calculated by the following formula:

$H_e = H_o + \Delta H$

H_o : Height of stack

ΔH : Height of gas ascent

ΔH is calculated by the following conditions:

i) Windy condition

Under windy condition, ΔH is applied with the CONCAW Model. The CONCAW Model is as follows:

$\Delta H = 0.175 \cdot Q_H^{1/2} \cdot U^{-3/4}$

Q_H : Calory of emission gas

U : Wind speed at height of Stack (m/s)

Q_H is calculated by the following formula:

$Q_H = \rho \cdot Q \cdot C^P \cdot \Delta T$

ρ : Density of emission gas at 28°C,
1.173×10^3 (g/m^3)

Q : Emission gas volume (Nm^3/s)

C^P : Specific heat at constant pressure 0.24 (Cal/k.g)

ΔT : Temperature of gas at the outlet of stack
- temperature of Atmosphere 28 (°C)

U is calculated by the following formula:

$U = Us \left(\frac{Z}{Z_s}\right)^p$

Us : Ground wind speed (m/s)

Z : Height of stack (m)

Zs : Height of ground wind (m)

P : Number of Pasquill

ii) Calm condition

Under calm condition, ΔH is used by the Briggs Model. The Briggs Model is as follows:

$\Delta H = 1.4 \cdot Q_H^{1/4} (d\theta/dz)^{-3/8}$

Q_H	:	Calory of emission gas	(Cal/s)
$d\theta/dz$	:	Temperature gradient	(°C/m)

b. Conditions for Forecast

Conditions for Calculation are set as follows:

Table 10.2-3 Conditions for Forecast of Air Pollution

Item	Conditions			
Pollutant	NO_X	SO_X	SPM	HCl
Emission Rate	250mg/Nm^3	50 ppm	0.15g/Nm^3	200 mg/Nm^3
Emission volume:	53000 Nm^3/h x 3			
Stack:	Height : 60 m			
	Diameter : 1.08 m			
	Number of stack : 3			
	Temperature of gas : 200°C			
Climate:	Temperature : 28°C (0.0033 °C/m)			
	Wind speed : 1.74 m/s			
	Wind direction : refer to Chapter 2			
	Stability of atmosphere : windy condition D (Pasquill)			
	calm condition D (Pasquill)			

2) Water Pollution

The planned incineration plant will not affect the surrounding public water as the plant will have a closed system whereby all the leachate generated in the waste reception pit will be put into a furnace, and sewage generated as a result of cleaning the floors and equipment will be used as cooling water.

3) Noise

(1) Collection Vehicle

The planned incineration plant will not worsen the current noise conditions around the site because it will not increase the total number of vehicles going to the On Nut site where there will a new compost plant and transfer stations as well.

(2) Equipment

Among the various noise sources in the incineration plant, fans for blowing air and electrostatic precipitators are major ones. Impact of the equipments to the adnacent area is predicted on site boundary.

However, it is considered that those equipment will not cause a significant change in noise level at the site boundary, which is 45 m away from the noise source. Those equipment will cause the noise level at the boundary to increase only by 3 dB(A) from 55 dB(A) to 58 dB(A). A wall will be helpful in decreasing the noise. Refer to Technical Note which explains noise calculation model used, and conditions of forecast.

Technical Note

a. Calculation Model

Noise level is calculated by the following formula:

This formula is supposed the source of noise is surface of a cubic.

$$L = Lwi\text{-}10 \log\{1+\frac{2\pi r(H+r)+r\pi(A+B)}{A\cdot B+2H(A+B)}\}$$

L	:	Noise level at r meters away from the source of the noise	(dB(A))
Lwi:		Noise level at surface of the building	
r	:	Distance from the source of the noise to receiving point	(m)
A,B:		Length and width of the building	(m)
H	:	Height of the building	(m)

Here, Lwi is calculated by the following formula:

Lw:		Powe level of noise sources	(dB(A))
R	:	Coefficient of the building	(m^2)
TL :		Transmission loss by the wall	(dB(A))

R is calculated by the following formula:

$$R = \frac{\alpha \Sigma Sn}{1-\alpha}$$

$$\alpha = \frac{\Sigma \alpha n Sn}{\Sigma Sn}$$

a : Average absorbency ratio of inner materials

an : Absorbency ratio of each inner materials

Sn : Area of surface of each inner materials

b. Condition of Forecast

Conditions for calculation of the noise level of the funs and the electrostatic precipitators are show in Table 10.2-4.

Size of building of the incinerator is supposed 55m of length, 28.5m width and 30.5m height. Wall of the building is made of concrete block with mortar and floor of building is made of concrete. The wall and the floor are same material, and this building is completely sealed.

Table 10.2-4 Condition for Forecast of Noise Level from Incineration Plant

ITEM	CONDITIONS
Powe Level	Fan 107 dB(A) x 3 = 112 dB(A)
	Electrostatic Precipitator
	88 dB(A) x 3 = 93 dB(A)
	Total amount = 112 dB(A)
Building Size	Length = 55 m, Width = 28.5 m
	Height = 30.5 m
Transmission loss by the wall	28 dB(A)
Absorbency ratio	Wall and roof = 0.02
	Floor = 0.02
Distance from the source of the noise to receiving point	45 m

4) Transportation

Collection vehicles enter the On-Nut Site from Sukhumvit Road 77. At present, the collection vehicles go into the dumping site and the compost plant. The number of the collection vehicles was estimated at 318 a day in August, 1990.

It is judged that the planned incineration plant will not worsen the current traffic conditions around the site because it will not increase the total number of vehicles going to the On Nut site where there will be a new compost plant and transfer stations as well.

5) Fauna and Flora

There will be no special consideration required regarding fauna and flora because there are no endangered species of animals or plants in and around the site.

10.3 Economic and Financial Evaluation

The construction and operation of the planned incineration plant will cost 2,061 million Baht (Construction 1,842 million Baht + Operation 219 million Baht) during the master plan period 1991 - 2000. The estimated total SWM cost with the incineration plant is 12 % higher than that without the plant as shown in Table 10.3-1. The corresponding percentage will be 23 % if focussing on the treatment and disposal cost alone as shown in Table 10.3-2.

Table 10.3-1 Future Cash Expenditures for SWM With and Without the Planned Incineration Plant (1991 - 2000)

	SWM COSTS WITHOUT THE INCINERATOR	SWM COST WITH THE INCINERATOR	DIFFERENCE
	A	B	C = B – A
1. Amounts	17,145 M.B.	19,206 M.B.	2,061 M.B.
2. Cost Index	100 %	112 %	12 %
3. Share to BMA's Gross Budget	13.5 %	15.1 %	1.6 %

M.B.: Million Baht

Table 10.3-2 Future Cash Expenditures for Treatment and Disposal With and Without the Planned Incineration Plant (1991 - 2000)

	TREATMENT & DISPOSAL COST WITHOUT THE INCINERATOR	TREATMENT & DISPOSAL COST WITH THE INCINERATOR	DIFFERENCE
	A	B	C = B – A
1. Amounts	8,771 M.B.	10,832 M.B.	2,061 M.B.
2. Cost Index	100 %	123 %	23 %

M.B.: Million Baht

The current master plan takes a view that the BMA should construct the planned incineration plant only if its financial conditions allow. If a choice has to be made between the sanitary landfill project and the incineration project due to a financial

constraint, the BMA should give a higher priority to the realization of the sanitary landfill than the other.

In the case that the BMA construct the planned incineration plant, it would be advisable for the BMA to acquire a loan from an international lending agency because it is very likely that the BMA can obtain a loan for the project with a very soft conditions if the BMA wishes.

A case study has been made where it is assumed that about 74 percent of the project cost is financed by a loan and the remaining portion is financed by the BMA's own budget. The loan conditions are assumed as follows:

1. Interest Rate:	2.7 % per year
2. Repayment Period:	20 years, of which the first 10 years is a grace period
3. Loan Amounts:	1370 million Baht in total (900 million Baht for the first construction phase, and 470 million Baht for the second construction phase)

Table 10.3-3 shows a repayment schedule under the above-shown loan conditions. With the above conditions, the net cash expenditure for the project during the master plan period will be reduced to 667 million Baht from 1,842 million Baht in cash that has to be spent for the project if no loan was used. This will certainly helpful in alleviating the financial conditions during the master plan period.

Table 10.3-3 Loan Repayment Schedule

Unit: Million Baht

YEAR	CONSTRUC-TION COST	FINANCIAL SOURCES		LOAN INTEREST & REPAYMENT			TOTAL CASH EXPENITITURE
		BMA	A LOAN	FOR FIRST PHASE CONSTRUCTION	FOR SECOND PHASE CONSTRUCTION	TOTAL	
	A	B	C	D	E	F=D+E	G=B+F
1993	490		900	-	-	-	-
1994	490	80	-	24.30	-	24.30	104.3
1995	229	229	-	24.30	-	24.30	253.3
1996	-	-	-	24.30	-	24.30	24.3
1997	-	-	-	24.30	-	24.30	24.3
1998	280	-	470	24.30	-	24.30	24.3
1999	280	90	-	24.30	12.69	36.99	126.99
2000	73	73	-	24.30	12.69	36.99	109.99
2001	-	-	-	24.30	12.69	36.99	36.99
2002	-	-	-	24.30	12.69	36.99	36.99
2003	-	-	-	95.66	12.69	108.35	108.35
2004	-	-	-	95.66	12.69	108.35	108.35
2005	-	-	-	95.66	12.69	108.35	108.35
2006	-	-	-	95.66	12.69	108.35	108.35
2007	-	-	-	95.66	12.69	108.35	108.35
2008	-	-	-	95.66	49.96	145.62	145.62
2009	-	-	-	95.66	49.96	145.62	145.62
2010	-	-	-	95.66	49.96	145.62	145.62
2011	-	-	-	95.66	49.96	145.62	145.62
2012	-	-	-	95.66	49.96	145.62	145.62
2013	-	-	-	95.66	49.96	145.62	145.62
2014	-	-	-	-	49.96	49.96	49.96
2015	-	-	-	-	49.96	49.96	49.96
2016	-	-	-	-	49.96	49.96	49.96
2017	-	-	-	-	49.96	49.96	49.96
2018	-	-	-	-	49.96	49.96	49.96
Total	1,842	472	1,370	1,270.96	663.77	1,934.73	2,406.73

If a government subsidy is available for the project, the BMA's financial burden will be further reduced. For example, if a quarter of the project cost is covered by the subsidy, the BMA's expenditure would be reduced by 460 million Baht. It can said that the planned incineration project would be financially less feasible if no subsidies are available.

10.4 Overall Evaluation

As has been already discussed, the planned incineration plant is feasible from technical and environmental viewpoints.

Although the incineration system is very costly, its earlier introduction will be helpful for the BMA in the sense that it could enable the BMA to acquire the incineration know-

how and experience, and to prepare itself for the future situation where substantial amount of waste would have to be incinerated due to the difficulty in the acquisition of land for sanitary landfill.

As a conclusion, the BMA should implement the incineration project if its financial conditions allow. It would be more appropriate to consider the issue of incineration as a question of a timing for implementation rather than a question of "yes" or "no" in view of the situation where the necessity for incinerators will increase in the future.

Part III

Waste Collection Improvement Projects

Chapter 1. Pilot Project for the Introduction of Plastic Bins for the Collection of Market Waste in Huai Khwang

1.1 Background

1.1.1 Character of Market

In Bangkok there are 204 markets, of which 190 are private markets, the remaining 14 markets are owned by the BMA as shown in Table 1.1-1.

The Department of Public Cleansing (DPC) collects waste from the 7 BMA markets, while the Districts collect waste from the other 7 BMA markets and all the private markets.

Table 1.1-1 Number of Markets in Bangkok. (as of Jan 20, 1989)

	Districts	Number of Market	
		Private	BMA
1	Phra Khnong	30	1
2	Bangkok Noi	13	1
3	Thon Buri	13	1
4	Yannnawa	12	0
5	Bang Khen	12	0
6	Bang Gapi	12	1
7	Dusit	11	2
8	Phaya Thai	11	0
9	Pra Nakho	8	0
10	Huai Khwang	8	2
11	Phatum Wan	7	0
12	Pom Prab	7	0
13	Khlong San	7	1
14	Bang Khun Tien	8	0
15	Bangkok Yai	6	0
16	Sam Phantha Wong	6	1
17	Phasi Charoen	5	0
18	Bang Ruk	4	0
19	Rat Burana	4	1
20	Nong Khaem	3	0
21	Meen Bui	2	1
22	Lad Krabang	1	0
23	Jomtong	0	1
24	Non Chok	0	1
	Total	190	14

Source: BMA

1.1.2 Volume of Market Waste

As shown in Table 1.1-2, it is estimated that the DPC collects market waste averaging about 40 tons/day, 12% approximately of total market waste amount (331 tons/day) collected by both the DPC and Districts. Market waste collected by the Districts is estimated at 291 tons/day based on the survey conducted by the JICA Study Team in 1990.

Table 1.1-2 The amount of waste collected by the BMA

	Name of Market	District	Amount of Waste
1	Karuna	Huai Khwang	0.5 ton/day
2	Huai Khwang	Huai Khwang	8 ton/day
3	Keatthongchai	Huai Khwang	5 ton/day
4	Banggapi I	Banggapi	4 ton/day
5	Banggapi II	Banggapi	4 ton/day
6	Chatruchak	Banggapi	7 ton/day
7	Tewarat	Dusit	10-12 ton/day
	Total		38.5-40.5 ton/day

Source: BMA

1.1.3 Market Waste Storage and Its problems

Market workers are responsible for collecting waste from each stall in a market. Until a collection vehicle come to the market , its waste is kept in or around the market. There are mainly three ways to store waste discharged from stall; 1) open dumping at a waste depot site, 2) use of container(s) placed by the District or the DPC near the market, and 3) use of bamboo baskets. In some markets where there is no room for waste storage around a market, its waste is just collected and carried to a truck as soon as the collection trucks come. In most cases bamboo baskets and handcarts are used as receptacles and transport means in markets.

1) Open dumping

After collecting waste from each shop in a market, market workers dump the waste at a depot site. Until a collection truck comes, market waste is pilled up. So there are many flies, cockroaches,and rodents found at the depot.

2) Container

The use of containers is beneficial for market workers because they can collect market waste at any time convenient to them, and it is more sanitary than the open dumping method. However, it is a tough work for workers to load market waste into containers by bamboo baskets because containers are high; more than 2m. (see Photo 1.1-1) In addition, opening areas of containers from which market waste is dumped are narrow so that waste in containers should be levelled inside the containers so that those containers can receive waste as much as possible.

Photo 1.1-1 Typical Container

3) Bamboo baskets

Bamboo baskets are commonly used to collect waste in markets. However, in case that there are no waste depots and no containers, bamboo baskets filled with market waste are placed in a vacant lot. Although a piece of bamboo basket is cheap, around 35 to 40 Bahts, the cost of using bamboo baskets is very large due to its short life time; around 10 days. Therefore, use of more durable and inexpensive receptacles for bamboo baskets is recommended.

Photo 1.1-2 Bamboo Baskets Placed Near a Market

1.2 Purpose and Outline of the Pilot Project

1.2.1 Purpose of the Project

The objectives of the pilot project are as follows:

Through the introduction of plastic baskets and reduction of double handling of waste:

a. to improve the working conditions of workers
b. to improve the collection and loading efficiency
c. to reduce cost of receptacles

1.2.2 Selection of the Project Site (Market)

1) Site Selection

Huai Khwang market in Huai Khwang District was chosen as a project site from the following reasons.

- Huai Khwan market is one of the BMA markets.
- It is of the biggest size among the BMA markets in Huai Khwang district.

- Market waste is stored at the depot site by open dumping method.
- Bamboo baskets are used for discharging solid waste

The district has an area of 22.7 km^2 and is located at the center of Bangkok (Fig. 1.2-1)

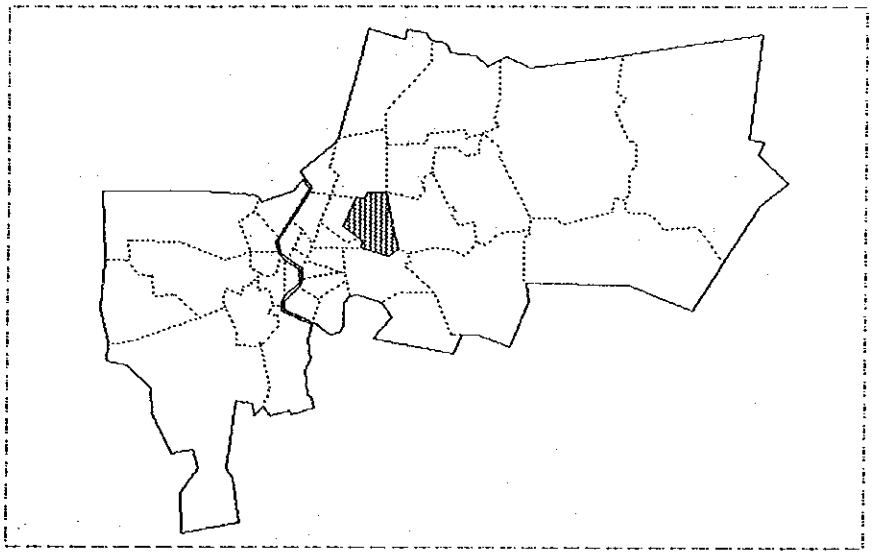


Fig. 1.2-1 The Location of Huai Khwang District

2) Outline of Huai Khwang Market

The outline of the Huai Khwang market in Huai Khwang district is as follows:

- Area: 7 Rai
- Number of stalls: 1,098
- Management of the market: The market office of BMA
- Number of market workers: 7
- Business hours: about 5:00 to 22:00

3) Waste Collection

Seven workers from the market office of the BMA collect waste from each stall and carry it to the waste depot inside the market by using bamboo baskets and carts during the business hours. Waste is generally piled up in the waste depot between 16:00 to 22:00. In addition, some store workers or street sweepers dump their waste to the waste depot.

Waste collection services are provided by the DPC by using a compactor (6m^3). The collection vehicle visits the market twice a day to collect market waste. The working time for the market waste collection is as follows.

First trip: 6 am - 9 am
Second trip: 11 am - 2 pm

The waste amount collected in the market is around 8 ton/day. The waste amount of the first trip is about 5 tons (15-20 m^3). About 3 tons(6 m^3) is collected in the second trip.

The current situation of the Huai Khwang market is shown in Photo 1.2-1.

Photo 1.2-1 The Current Situation of Huai Khwang Market

1.2.2 Outline of the Pilot Project

1) Type and Capacity of Plastic Bins

Box type plastic bins were selected in view of easy handling and drainage of rainfall. The capacity of a box-type plastic bin is 90 liter (0.09 m^3). Therefore, on the basis of

market waste volume collected in the first trip, it was estimated that 178 plastic bins would be necessary for the project as shown in the following equation:

$$16\ m^3 \div 0.09\ m^3 = 178$$

For the experiment level, however, one hundred (100) plastic bins were judged sufficient for the pilot test.

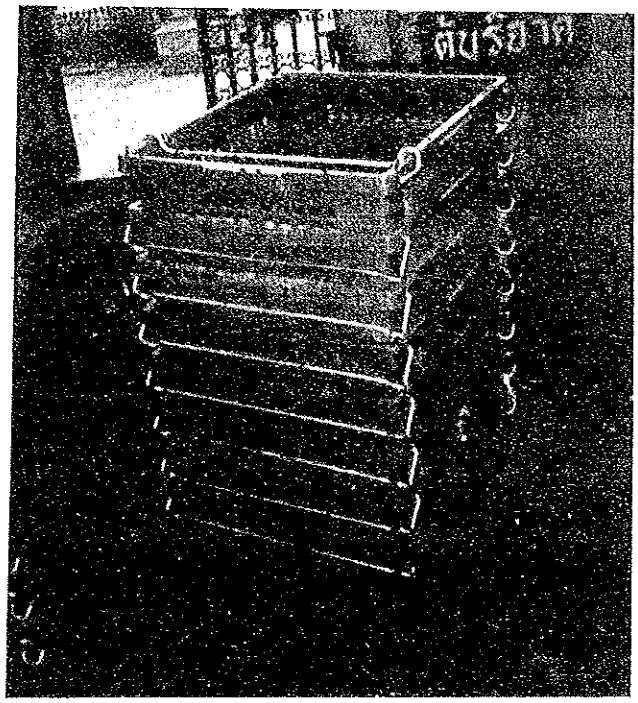


Photo 1.2-2 Plastic Bins Used for the Pilot Project

2) Collection System

The following system was recommended to collect market waste from each stall :

- Market workers collect waste from each stall in the market using carts and two plastic bins.
- After the two plastic bins was filled with waste, a worker carries them to the waste depot and put them to the depot space A in orderly manner.
- Then workers bring other two empty plastic bins, and they continue their work.

- In the case there is a shortage of bins, the waste collected should be put to the space B in the waste depot in orderly manner.
- When street sweepers and stall keepers carry their own waste to the depot, they should put them into empty plastic bins placed inside the waste depot.
- Empty plastic bins should be piled up inside the waste depot, while the collection activities of the market workers finish.

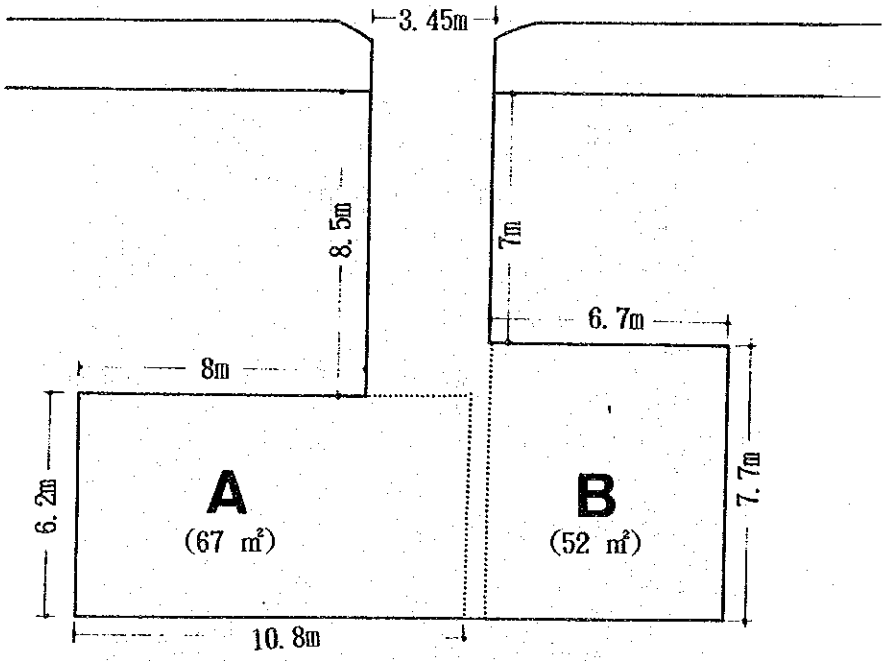


Fig. 1.2-1 Waste Depot Site in Huai Khwang Market

1.2.3 Pilot Project Period

The project was implemented for about one month starting on 24 September 1990. Before and after implementing the project, the Time and Motion study was executed to evaluate the efficiency of using plastic bins. In addition, interviews with the market workers, the market manager and collection workers of the DPC were carried out.

1.3. Results and Evaluation of the Project

1) Time and Motion Study

The result of Time & Motion study is shown in Table 1.3-1. Amount of waste collected per worker per minute decreased after the implementation of the project. This is attributed to the situation that all collection crews of the DPC working in the Huai

Khwang market were replaced by new crew from 1 October 1990. The new crew engaged themselves in the useful material picking activity. Therefore, it is judged, through the observation, that the efficiency of waste loading would have increased after the implementation of the project, if there was no change in the crew.

Table 1.3-1 Result of Time and Motion Study at the Huai Khwang Market

DAY	COLLECTION TIME SPENT (Min)	NO OF WORKER (Person)	GARBAVE COLLECTED (kg)	GARBAGE COLLECTED PER MIN. (kg/min)	GARBAGE COLLECTED PER MIN. PER WORKER (kg/min/person)
	A	B	C	D=C/A	E=D/B
1. Before the Project					
Sept. 27th	177	3	6,400	36.2	12.1
	50	3	5,200	104.0	34.7
28th	140	3	5,770	41.2	13.7
	35	3	4,400	125.7	41.9
2. After the Project					
Oct. 18th	148	4	4,740	32.0	8.0
	68	4	3,630	53.4	13.4
19th	155	4	4,550	29.4	7.3
	81	4	3,460	42.7	10.7

2) Results of Interview

(1) Collection Workers of the DPC

Workers said they felt the project was very helpful to collect market waste because the workload for collection of waste spreading on the depot site was tremendously reduced. They wished to continue the project.

(2) The Market Manager and the Market Workers.

There is no advantage for the workers. Constantly, collection time increased since the capacity of plastic bins is so small; 1/2 or 1/3 of the big bamboo basket. Therefore they prefer bamboo baskets to plastic bins. Moreover, plastic bins may be stolen if left in the depot since they are expensive.

Photo 1.3-1 shows the improved waste depot site by plastic bins at the Huai Khwang market.

Photo 1.3-1 Improved Situation by Plastic Bins at the Waste Depot Site

1.4 Conclusion

The use of plastic bins in the Huai Khwang Market has proved to be effective in the sense that:

a. The sanitary condition of the collection area has remarkably improved for collection workers of the DPC.

b. The loading of waste into a collection track can be made by single handling instead of double handling. Therefore, waste loading job is now much easier for the DPC's collection workers.

Although it was anticipated that plastic bins would be easily stolen, it turned out that only three (3) plastic bins have been missing out of 100 during one month. With this condition, the use of plastic bins is considered still much more economical than the use of bamboo baskets as the former would last much longer time than the latter. This project should be continued to examine the significant advantages.

The use of plastic bins on the other hand was not advantageous to waste collection workers employed by the Market who collect waste from each stall, and carry to the depot. A disadvantage is that they have to make more number of trips to carry waste to the waste depot because the capacity of plastic bins is smaller than that of bamboo baskets. Although this problem could be solved by using larger plastic bins, they cannot easily be found in Bangkok.

A more radical solution is to introduce a hauled-in-container in the market, which however can be made possible only if the structures of the entrance and the depot area of the market is modified accordingly.

Chapter 2. The Pilot Project for the Introduction of the Bell Collection in Huai Khwang

2.1 Background

The door-to-door collection is the most common collection system applied in Bangkok. The door-to-door collection is convenient to the local people as little work is required on the part of the people. However, it is a costly and inefficient system for BMA because it requires a longer collection time than some other systems do. Main reasons explaining the inefficiency in the current collection system include the following:

- There are many places that collection workers have to enter yards of houses where waste receptacles are placed.
- There are many houses which are not accessible with collection vehicles. (Some of such houses, however, can be reached with small trucks (1 ton). Therefore, the use of small vehicles in Sois will contribute to the efficiency increase in waste collection.)

However, the present collection system is rational in the following sense:

- It provides jobs for many people (workers).
- This system provides an extra income (tips) to collection workers.

Yet the improvement of waste collection system is imperative for the BMA in the future for the sound waste management; the increasing personnel expenses will cause costs to increase further. The bell collection system is the one of the measures to be taken to improve the current waste collection system.

The bell collection requires residents to bring their waste by themselves to a collection vehicle when it visits them. Residents will know the coming of the trucks by hearing some sound such as bell or music. The following areas will be appropriate to apply bell collection system.

- Areas where it is difficult to apply station collection with the use of plastic bags or plastic bins
- Areas where communal containers cannot be placed

- Areas with houses which are always occupied in the daytime. (If there is no one staying in a house, waste cannot be brought out when a collection vehicle visits the area.)

In general, the bell collection may be suitably applied to low income residential areas where 1) residents may not afford to buy plastic bags and 2) streets are narrow and there is not enough space for waste station.

2.2 Purpose of the Project

The objective of the pilot project is to study feasibility of introduction of the bell collection system in residential area of Bangkok. The study focused on the following four points.

1. Can waste collection time be reduced?
2. Do residents in the study area cooperate for the project, and comply with the waste discharge manner requested?
3. Is it acceptable to the collection workers?
4. Are there any applicable areas in Bangkok?

2.3 Outline of the Project

2.3.1 Selection of Project Area

The DPC selected the Huai Khwang District for the project. (Refer to Chapter 1, Fig. 1.2-1) Since there is no areas which satisfy the above conditions in the District, the typical residential area which partly satisfies such conditions was selected as the project area This site is served with one middle-sized compactor (6 m^3). The project site is shown in Fig. 2.3-1.

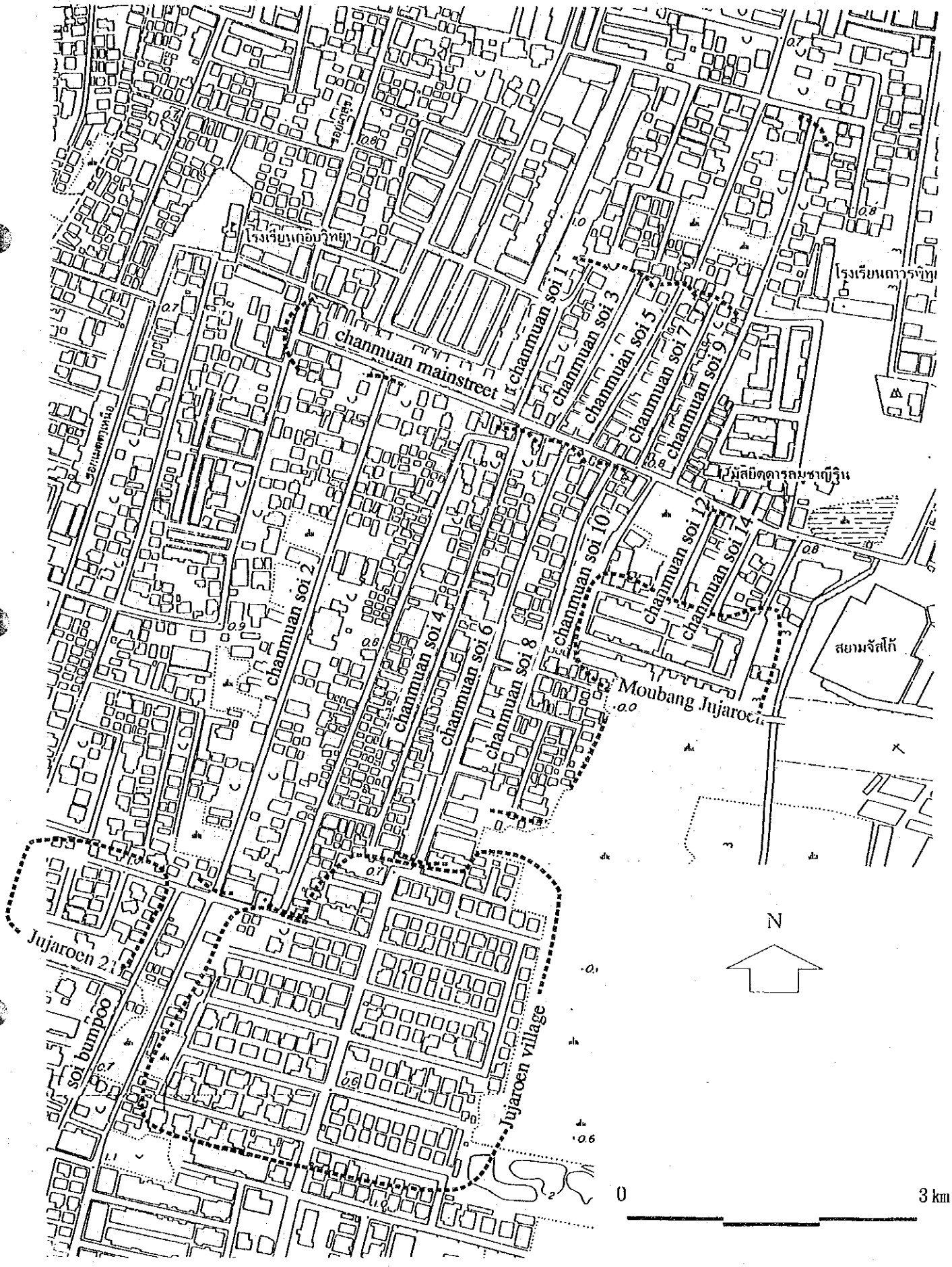


Fig 2.3-1 The project site

2.3.2 Implementation

1) Introduction to Residents

a. Residents are requested to put garbage receptacles (plastic bag, or plastic bin or bamboo basket) just outside the house when the music coming from the collection track was heard, if they live in houses located on the side of roads where a garbage track can pass.
b. Residents are requested to bring garbage up to collection trucks if they live in houses located in places which are not accessible by the truck.

2) Time and Motion Study for the Project Evaluation

Time and motion study was conducted twice, before and after the project, to examine the improvement of efficiency.

3) Interview

Interviews were made to know the opinion of the residents about the pilot project.

2.4. Results of the Time and Motion Study and Interviews

1) Time and Motion Study

The result of the time and motion study is shown in Table 2.4-1. It clearly shows that the number of basket collected per time increased

Table 2.4-1 Results of Time & Motion Study Conducted at the Chanmuan Area in Huai Khwang District

Headings:
A: Collection time (minutes) spent per soi or apartment building
B: Number of baskets collected
C: B/A=Number of baskets collected per minute
D: Number of houses of which residents put garbage baskets outside the house
E: Total number of houses visited by crew
F: Number of houses to which crew walked more than 30 m from the collection vehicle

NAME OF SOIS	BEFORE THE PROTECT (27-30 Sept.)					AFTER THE PROJECT (27-30 Oct.)				
	A	B	C	D/E	F/E	A	B	C	D/E	F/E
Soi 1	5.5	6	1.09	3/8 (37.50	8/8 (100)	-	-	-	-	-
Soi 2	51.5	35	0.68	36/103 (35.0)	61/103 (59.2)	63	42	0.67	17/61 (27.8)	29/61 (47.5)
Soi 3	13.5	6.5	0.48	0/7 (0)	7/7 (100)	-	-	-	-	-
Soi 4	72	80.5	1.12	27/170 (15.9)	12/170 (7.1)	91	167	1.84	31/192 (16.1)	1/192 (0.5)
Soi 5	15	6	0.40	2/20 (10.0)	20/20 (100)	-	-	-	-	-
Soi 6	19.5	23	1.18	11/49 (22.4)	5/49 (10.2)	35	57	1.63	3/80 (3.75)	3/80 (3.75)
Soi 7	16.5	7	0.42	2/11 (18.2)	13/13 (100)	-	-	-	-	-
Soi 8	89	23	0.26	10/83 (12.0)	66/83 (79.5)	119	42	0.35	11/58 (20.0)	58/58 (100)
Soi 12	4	9	2.25	0/7 (0)	1/7 (14.3)	5	5	1.00	0/6 (0)	0/6 (0)
Soi 14	3	2	0.67	0/8 (0)	8/8 (100)	6	3	0.50	1/8 (12.5)	8/8 (100)
Sathaporn Apartment	28	11	0.39	1/1 (100)	1/1 (100)	11	5	0.46	1/2 (50.0)	2/2 (100)
Mou Bang Jujaroen	21.5	39	1.81	10/70 (14.3)	1/70 (1.43)	18	35	1.94	6/71 (8.5)	0/71 (0)
Jujaroen 21	21.5	20	0.93	1/27 (3.7)	0/27 (0)	14	15	1.07	0/19 (0)	0/19 (0)
Bunpoo	28	12.5	0.45	1/32 (3.1)	2/32 (6.3)	21	21	1.00	4/24 (16.7)	3/24 (12.5)
Jujaroen Village	80.5	81	1.01	22/169 (13.0)	4/169 (2.4)	92	120	1.30	8/178 (4.5)	4/178 (0.8)
Total	469	361.5	0.77	126/767 (16.4)	207/767 (27.2)	475	512	1.08	82/699 (11.7)	108/699 (15.5)

Note: The figures in parenthesis shows the percentages.

2) Interview with the Collection Workers and the Huai Khwang District Officer

(1) Collection Workers' Opinion

Their opinion is as follows:
It is boring to hear the same music every day so that music should be changed from time to time. However, because the residents' cooperation is much more than before, the project should be continued.

(2) Huai Khwang District Officer

The officer said it is unconvenient from the following points:

a. This project requires money for purchasing a speaker, amplifier, cassette-recorder, and for maintenance of the equipment.
b. Workers have to bring this equipment back to home from the fear that the equipment may be stolen.
c. Workers may dislike hearing the same loud music during the collection time.
d. If local people bring their garbage by themselves, collection workers will lose the chance to get extra-money (tips).

3)Interview to the Residents

According to the result of interview to the 125 interviewees selected, 68% are satisfied and 12% are answered "it is OK," and only 20% expressed dissatisfaction to the project.

2.5 Conclusion

1) It was initially planned that;

A. Residents living along the streets where a garbage collection vehicle can pass, will put their garage-filled receptacles just outside the houses.

B. Residents living along soi (narrow streets) where a garbage collection vehicle cannot pass, will bring garbage up the collection vehicle.

With respect to the above item B, the pilot project was not successful. Almost nobody cooperated to the extent as planned. However, with respect to the item A the pilot project has resulted in a limited success as explained below:

a. On the basis of the time and motion study carried out, it is roughly estimated that only 5 % of the households in the project has actually changed their waste discharge manner, and put waste at the entrance of their houses by hearing the music. (Majority of the remaining residents put their waste in front of their houses even before the commencement of the pilot project)

b. Consequently, the collection efficiency has improved in a sense that the number of waste baskets carried and emptied per worker per hour has increased.

c. It has been found that there are some other important things (other than using music) for improvement on the waste collection efficiency as explained in Item 3).

2) This pilot project should be continued due to the reasons given below:

a. It was found through the interview with the residents in the project area that the majority of the residents support the project: only 20% of the interviewees did not support the project.

b. The collection workers and driver also support the project.
Notes: The driver complained that he is tired of hearing the same music again and again. However, this may be solved by using different music.

c. It always takes time for the people to change their old practice and get accustomed to a new system. It is too early to make a final judgement on this project.

3) For the improvement of the waste collection efficiency, it would be necessary to take the following measures:

a. Regular collection - Collection at Regular Time in Regular Days

This will make possible for the residents to expect the timing of collection, and therefore residents would discharge waste some time before the arrival of collection vehicles without hearing the music.

b. Discouragement of the Residents to Use Heavy Drum Cans

c. To Request Residents living in Apartments to Discharge Waste at Fixed Places by Using Baskets (plastic bags preferably) without Littering

d. Discouragement of the Use of Dust-Chutes

Items c & d will be increasingly important in the future because the number of apartments is likely to increase in Bangkok.

Chapter 3. Pilot Project for the Improvement on the Maintenance of Waste Collection Vehicles

3.1 Background

The current BMA's vehicle maintenance is not adequate. There have not been many improvements on the vehicle maintenance though the number of collection vehicles has been more than doubled during the past five years. Insufficient maintenance has then lead to a lower vehicle utilization and higher repair costs.

A case study shows that typical repair costs incurred after the 4th year from purchase are large, and the cumulative costs incurred during the first 10 years exceeds the purchase price, while such cumulative costs are normally 50%-70% of the purchase price if an appropriate preventive maintenance is provided. Therefore it is necessary for the BMA to strengthen the maintenance systems for waste collection vehicles in view of using vehicles more effectively, and reducing repair costs.

The vehicle maintenance comprises of the two major activities, i.e. 1) to check vehicles to know their conditions, and 2) to repair troubles. In view of the fact that the BMA is particularly week in the former (to check vehicles), the daily checking of vehicles and related program as shown in Section 3.2 have been carried out on a pilot project basis.

3.2 Purpose and Outline of the Project

3.2.1 Purpose of the Project

The purpose of the project was to improve vehicle conditions and to increase the reliability of the vehicles through the implementation of the daily checking of vehicles and knowing accurately the vehicle conditions.

3.2.2 Outline of the Project Executed

1) Executing Bodies

Both the Public Cleansing Division of the DPC and Huai Khwang District have implemented the pilot project. The project involved drivers, supervisors and section managers.

2) Programs Implemented

The following programs have been implemented:

RESPONSIBLE PERSON	ACTIONS TAKEN
Drivers	- Daily checking of own vehicles and keeping the records in the daily check sheet as shown in Fig. 3.2-1, and giving the sheets to Supervisors at the end of daily work
Super visors	- Checking of the daily check sheet filled by the drivers to know vehicle conditions - To record any reported troubles in the sheet "History of Vehicle" as shown in Fig. 3.2-2 - To place repair orders as required

Although all the drivers were expected to follow the above program (daily checking of vehicle), about a half of the drivers actually participated in it.

3.3 Evaluation of the Project

1) The pilot project contributed much to the increases in drivers' and supervisors' awareness of the importance of the daily checking.

2) The pilot project enabled the drivers and supervisors to understand troubles of each vehicle more specifically than before.

ใบรายการตรวจเช็ครถยนต์ประจำวัน

วันที่ _____

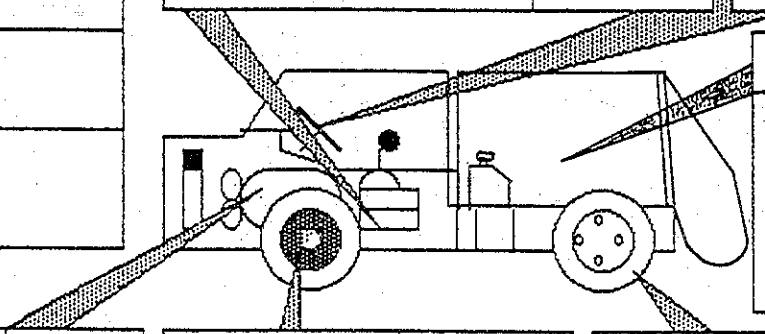
รถบรรทุกหมายเลข _____ เลขไมล์ที่ _____ กม. คนขับ _____ หัวหน้า _____

✓ ทำการตรวจปรับ
✗ ทำการตรวจซ่อม
○ อยู่ในสภาพที่ดี

คลัชและระบบส่งกำลัง	เครื่องหมาย
1. ระดับน้ำมันไฮโดรลิคคลัช	
2. ระยะเลื่อนของคันเหยียบคลัช	
3. มีเสียงในเสื้อคลัช	
4. การเข้าเกียร์เป็นปกติ	
5. เสียงในกระปุกเกียร์	
หมายเหตุ	

อุปกรณ์ที่ติดกับรถและพ่วงมาลัย	เครื่องหมาย
1. สภาพของเกลแต่ละตัว เกลความเร็ว เชื้อเพลิง, อุณหภูมิน้ำ, เกลแรงดันน้ำมันเครื่อง, แอมมิเตอร์	
2. สภาพของไฟต่าง ๆ	
3. ระยะขยับตัวของพวงมาลัย	
หมายเหตุ	

ชิสซี่และตัวถัง	เครื่องหมาย
1. สภาพภายนอกและภายใน	
2. ตัวน็อต	
3. ตรวจการรั่วซึมของน้ำมันเครื่องและน้ำ	
หมายเหตุ	



อุปกรณ์การทำงาน	เครื่องหมาย
1. ระดับน้ำไฮโดรลิก (ขณะทำงาน)	
2. สภาพของอุปกรณ์ขณะทำงาน	
หมายเหตุ	

ระบบเครื่องยนต์	เครื่องหมาย
1. ระดับน้ำหล่อเย็น	
2. ความตึงหย่อนของสายพาน	
3. ระดับน้ำมันเครื่อง	
4. การสตาร์ทของเครื่องยนต์	
5. สีของควันไอเสีย	
หมายเหตุ	

ระบบเบรค	เครื่องหมาย
1. ระดับน้ำมันไฮโดรลิคเบรค	
2. เบรคมือ	
3. เบรคเท้า	
4. ระยะเลื่อนของการเหยียบเบรค	
หมายเหตุ	

ยาง	เครื่องหมาย
1. แรงดันลม	
2. การสึกหรอดำหนิ	
3. ตัวน็อต	
หมายเหตุ	

ระบบไฟฟ้า	เครื่องหมาย
1. ไฟสูง, ไฟต่ำ	
2. ไฟเบรค, ไฟท้าย	
3. ไฟกระพริบ	
4. แตร	
5. ที่ปัดน้ำฝน	
หมายเหตุ	

Fig. 3.2-1 Daily Check Sheet

Daily Check Sheet for Vehicle.

Date. ____ (D) ____ (M) ____ (Y)

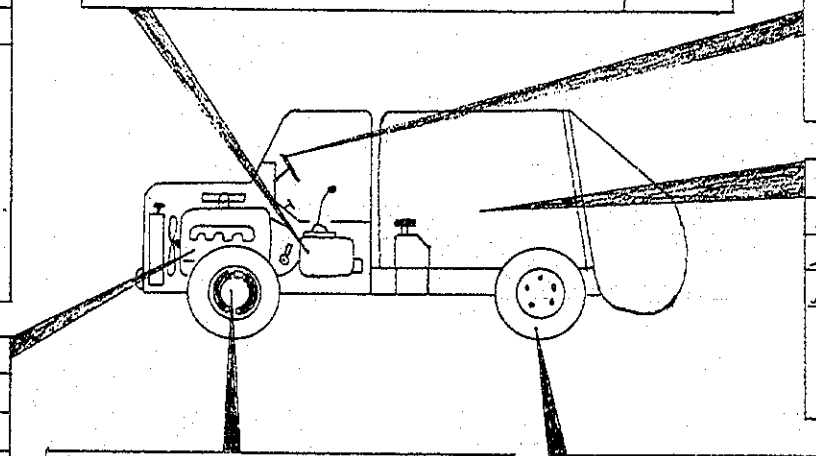
Truck No, _____ Odometor. _____ (Km) Inspector Name. _____

Inspection mark.
V = Adjustment required
× = Repairs required
○ = Good condition

Chassis & Body	Check
1. Visible damage exterior interior.	
2. Lost · Loosen bolts & nuts.	
3. Leakage oil & water.	
Remakes.	

Main Clutch & Transmission	Check
1. Hydraulic clutch oil level.	
2. Free travel dimension of clutch pedal.	
3. Make a noisy in the main clutch housing.	
4. Shifter-Control lever will shifting normally.	
5. Make a noisy in the transmission case.	
Remakes.	

Instrument Panel & Steering.	Check
1. Condition of each gauges. • Speed • Fuel • Water teniperature. • Engine oil pressure • Ammeter	
2. Condition of each lamps	
3. Normally free play of steering wheel.	
Remakes.	



Work Equipment.	Check.
1. Hydraulic oil level (for work equipment)	
2. Condition of work equipment.	
Remakes.	

Engine System.	Check
1. Cooling water level.	
2. Flaw · Tension of the fan belt	
3. Engine oil level.	
4. Engine will start normally	
5. Color of exhaust smoke	
Remakes.	

Brake system.	Check
1. Hydrulic brake oil level.	
2. Condition of the hand brake.	
3. Condition of the foot brake.	
4. Normally travel dimension of brake pedal	
Remakes.	

Tires	Check
1. Air Pressure	
2. Wear · flaw	
3. Loosen bolts & nuts	
Remakes.	

Electrical SYSTEM	Check
1. Head lamps · Small lamps	
2. Stop lamps · tail lamps	
3. winker lamps	
4. Horn	
5. Wipers	
Remakes.	

History of the Vehicle

District Name _____

Truck No, (side No,) _____ Plate No, _____ Type of Truck _____

Receiving Date _____ (D) _____ (M) _____ (Y) Capacity _____ (m^3)

No.	Date	Fault	Remedy	TOTAL Repair time	TOTAL Repair cost	Remarks
	/					
	/					
	/					
	/					
	/					
	/					
	/					
	/					
	/					
	/					
	/					
	/					
	/					
	/					

Fig. 3.2-2 Format "History of Vehicle"

3.4 Conclusions

1) The Pilot Projects (the daily checking of vehicles and recording of troubles in the vehicle history sheets) are essential for knowing accurately the vehicle conditions. To know the vehicle conditions is an important first step for always keeping vehicles in good conditions.

2) It is possible for the drivers and supervisors to obtain not only phenomenal understanding of the vehicle troubles but also structural understanding of troubles through the execution of the daily checking of vehicles and recording troubles in the vehicle history sheets.

3) With structural understanding of vehicle troubles, it is possible to forecast when and what troubles may occur in the future. With this forecast, it is then possible to take timely actions such as:

    1) To repair troubles before getting worse
    2) To place orders for necessary spare parts well in advance

   The above actions would be helpful in minimizing repair costs and time.

4) This project therefore should be implemented by all the Districts and DPC.

5) Daily checking of vehicles would be useful only if the BMA has a system where necessary repairs can be done quickly after the checking. However, it often takes a long time for the Central Workshop to repair vehicles due to lack of spare parts or some other reasons.

6) Therefore, it is equally important for the BMA to establish a system where necessary repairs can ben done quickly.