4. REVIEW OF DAILY OPERATION AND MAINTENANCE RECORDS OF NCC COLLECTION VEHICLES

4.1 General

All NCC collection vehicles park and start from the Kaloleni Cleansing Section Office to collect solid waste. Staff of the office keep records of the daily operation and maintenance of collection vehicles everyday. This section describes some major findings through a review of those records. The inventory of collection vehicles and plants in the Department of Environment (DoE) is tabulated in **Subsection 5.3.1** of **Data Book (1)**. The year-round summary of NCC vehicles is presented in **Subsection 5.3.2**, and the daily operation records from May 1996 to May 1997 are compiled in **Subsection 5.3.3** of **Data Book (1)**.

4.2 Major Findings

4.2.1 Average Amount of Vehicles Working Daily

Figure E.4-1 shows the monthly variation of average number of vehicles working everyday. The vehicles consist of NCC trucks, NCC tractors and government trucks. The daily average number of vehicles is 15.5 for NCC trucks and 2.2 for NCC tractors. Due to the five new trucks (T77 to T81) added in February and March 1997, these figures are kept rather constant throughout the year, although the number of NCC trucks declined slightly. The number of government trucks, on the other hand, varies from month to month due to support from the Central Government. The total number of vehicles working in July, August and September 1996 exceeded 30, and that worked efficiently to clean the city. Ever since the Government withdrew its support to the NCC to some extent in 1997, however, the total number of trucks collecting solid waste in the city seemed to be insufficient.

4.2.2 Monthly Operation Ratio of NCC and Government Trucks

No support was given to NCC in May 1996 but since the next month, i.e., June 1996, the Government has been supporting NCC in terms of collecting solid waste in the city, as shown in **Figure E.4-2**. The ratio of trucks provided by the Government varies from month to month.

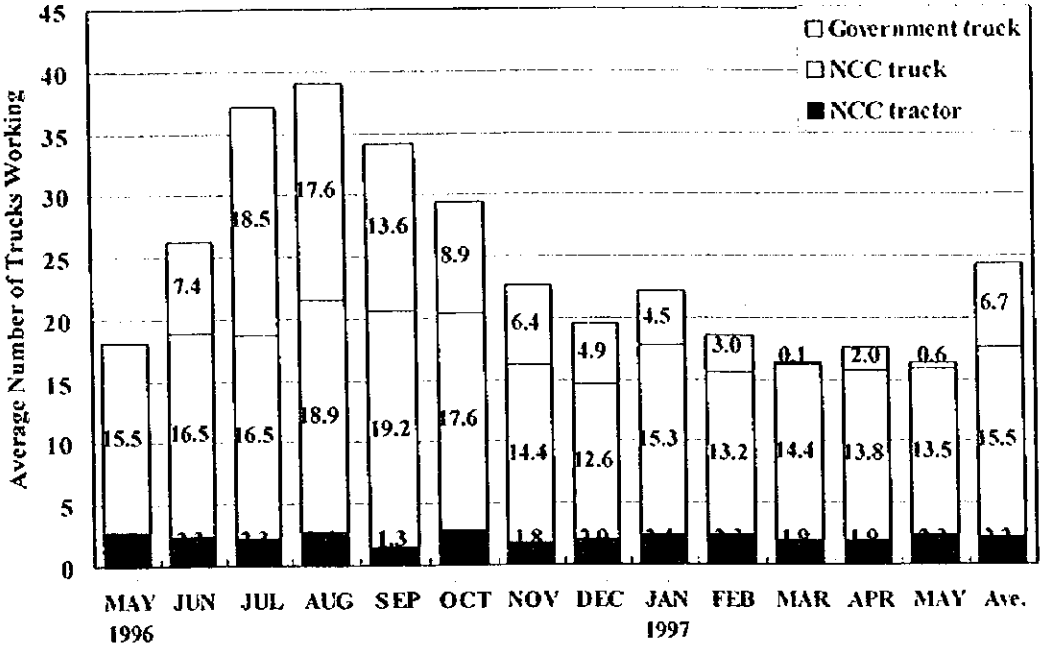


Figure E.4-1 Average Number of Vehicles Working Daily
(Source: NCC)

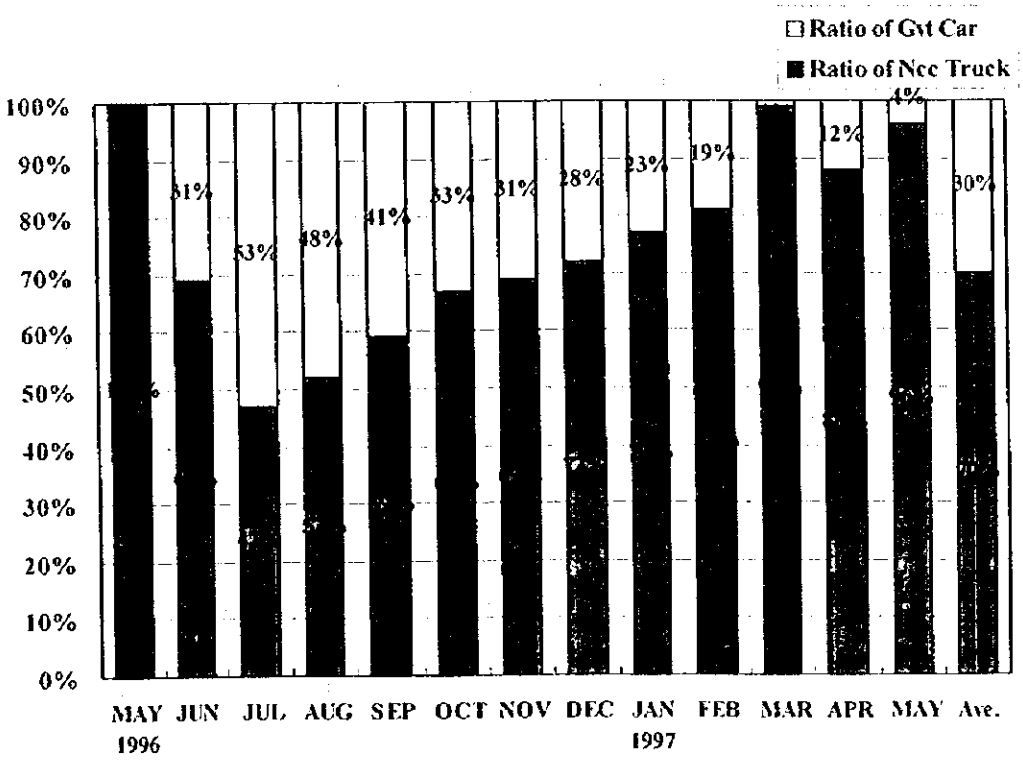
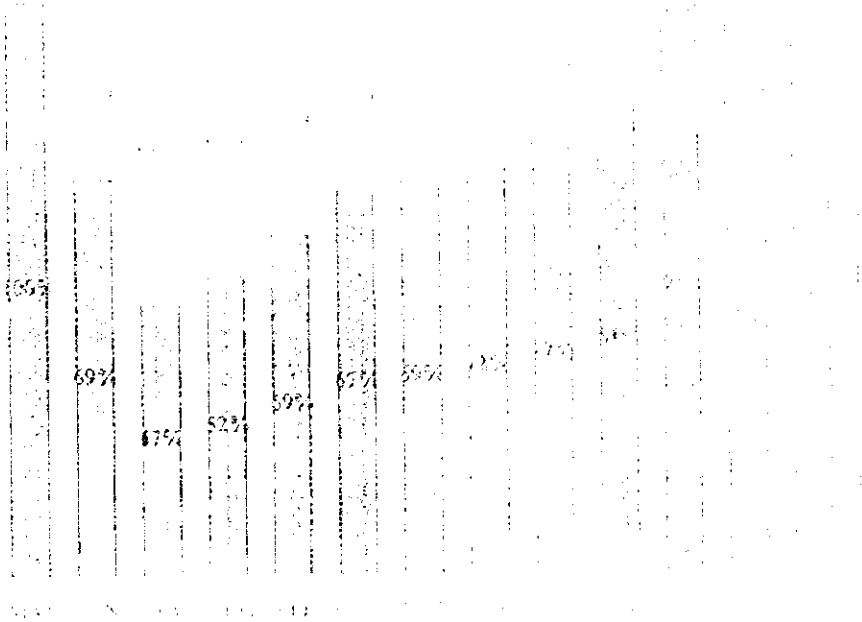


Figure E.4-2 Monthly Operation Ratio of NCC and Government Trucks
(Source: NCC)



4.2.3 Comparison between the Number of Working and Not Working Vehicles

Figures E.4-3 and E.4-4 show the comparison of the number of NCC trucks which are working and which are not. Specifically, **Figure E.4-3** is plotted by using the average number and **Figure E.4-4** by using the ratio of trucks in operation and in the workshop. The number of trucks in operation slightly exceeds 50% compared to the number of those in the workshop for the months of August and September, 1996, but since then the ratio has been declining. Currently, more than two-thirds of all NCC trucks are in the workshop. Some of the trucks have stayed in the workshop for many months, keeping the ratio of trucks in the workshop at high levels.

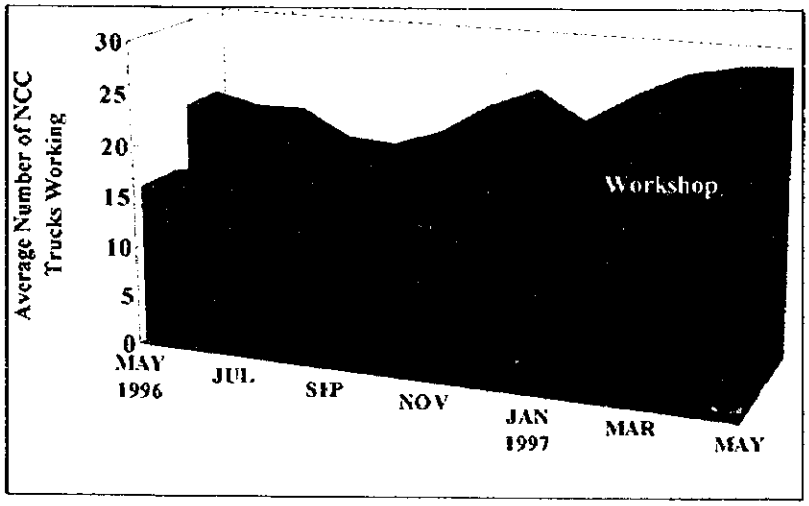


Figure E.4-3 Monthly Average Number of NCC Trucks in Operation
(Source: NCC)

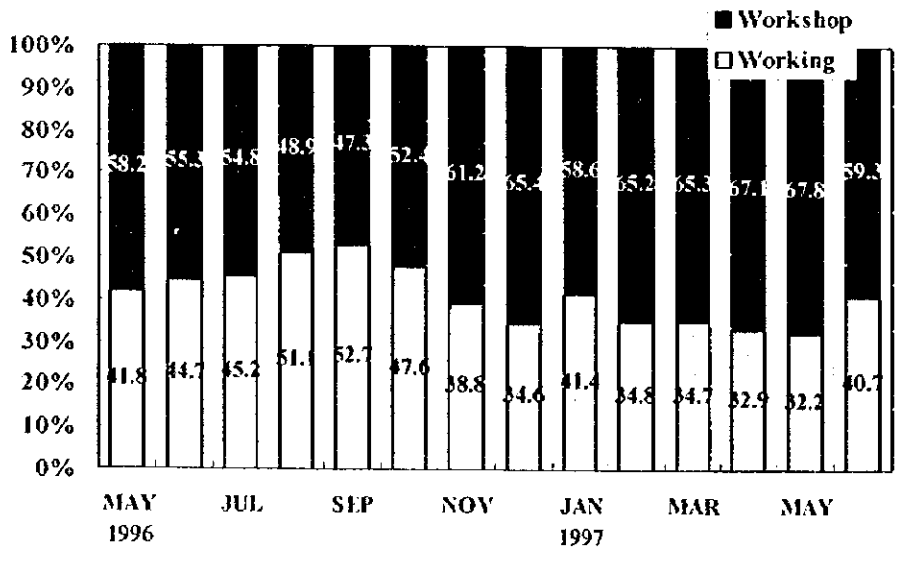


Figure E.4-4 Ratio of NCC Trucks in Operation and in Workshop
(Source: NCC)

4.2.4 Collection Area

NCC trucks in principle visit six districts everyday to collect waste, as shown in **Figure E.4-5.** The trucks have been collecting waste from each district since last May. The largest collection area is the central business district and its proportion to the total operation is about 30%.

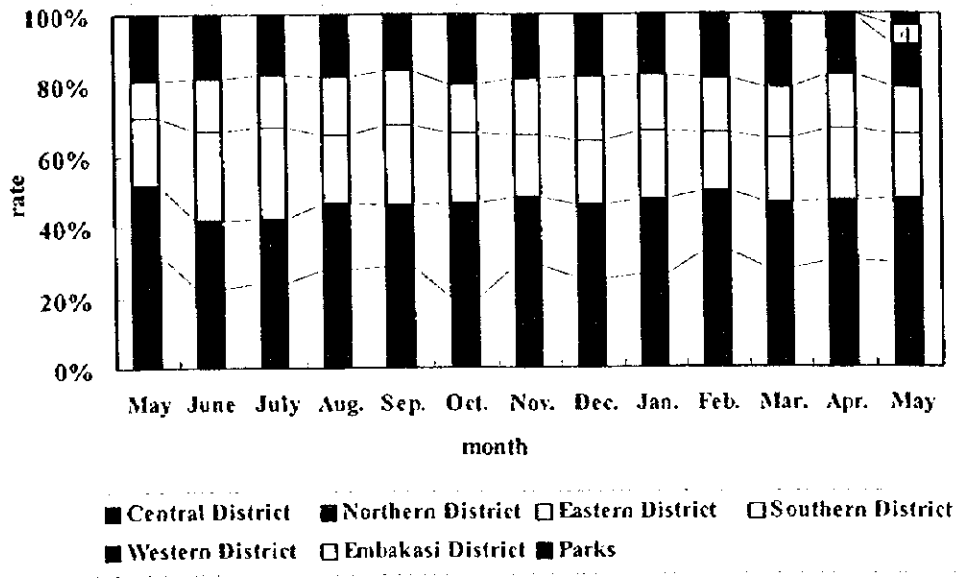


Figure E.4-5 Proportion of Collection Areas by NCC Trucks
(Source: NCC)

4.2.5 Causes of Failure of NCC Trucks

Figures E.4-6 and **E.4-7** show the types of failure caused on NCC trucks. The number of days used for repairs are counted and accumulated for each cause. The items of 'Service' and 'Financial' represent trucks which are under service or financial problems. Although these items are not related to mechanical failure, they contribute to the increase of non-working vehicles.

According to these figures, major failures resulted from 'Accident' which occupy about 20% of all failures. Other causes of failure are mainly due to mechanical problems, specifically coming from 'Engine,' 'Gear' and 'Brake' troubles. The proportion of these failures ranges between 15 and 20%.

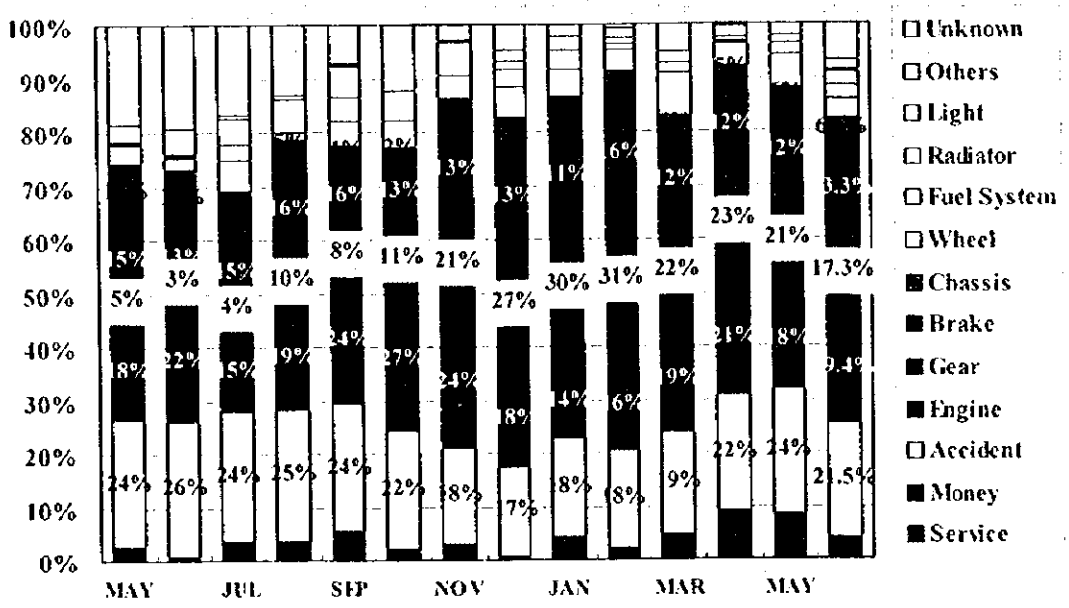


Figure E.4-6 Proportion of Causes of Failure of NCC Trucks
(Source: NCC)

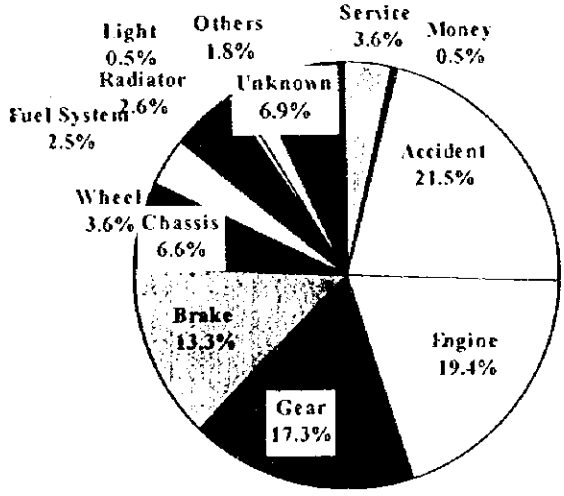


Figure E.4-7 Averaged Proportion of Causes of Failure of NCC Trucks (May 1996 - May 1997)
(Source: NCC)

4.2.6 Duration for Recovery from Failures

Causes of failure classified into the required duration for recovery are presented in **Figure E.4-8**. The items of 'Gear' and 'Accident' are the major causes which require more than 90 days in the workshop. In the duration between 20 to 90 days, 'Engine' and 'Brake' problems are added to the major causes of failure. It seems to be difficult

to recover from 'Accident' and 'Engine' troubles for less than 20 days. The items of 'Gear,' 'Chassis' and 'Brake' share a large portion of the required duration from 6 to 20 days. In a short term of less than 5 days, the items of 'Brake,' 'Wheel' and 'Gear' are main causes of trouble to stay in the workshop.

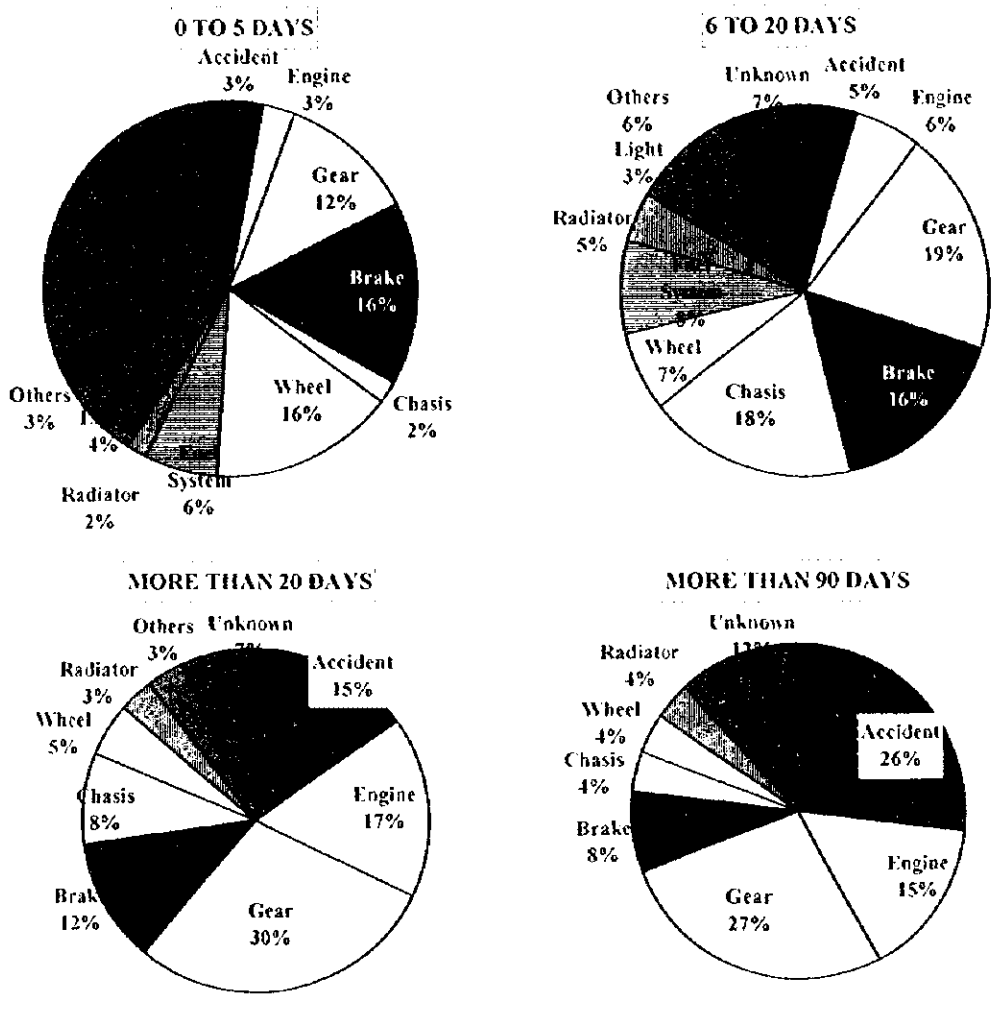
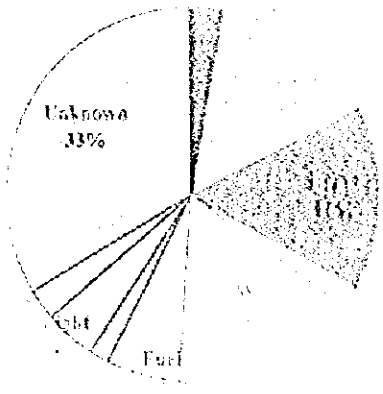


Figure E.4-8 Causes of Failure Classified into Duration for Recovery
(Source: NCC)

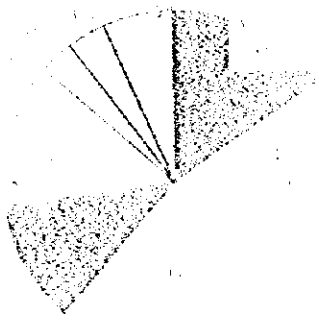
5. EXPERIMENTAL COLLECTION WORK

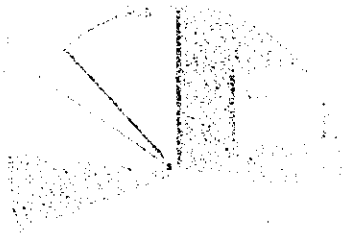
5.1 Objective of the Work

The objective of this work is to grasp and promote residents' participation for discharge and collection/transportation of solid waste in middle and low income, and slum areas in the city. It is also to monitor the actual costs incurred, and manpower and equipment required for the collection/haulage work.


Unknown
33%
Oil
Fuel


Fuel





5.2 Outline of the Work

Preliminary interview surveys were conducted to explain the outline of the work and to examine residents' awareness for solid waste discharge and disposal. Explanation meetings were also held to the residents particularly in a slum area for smooth implementation of the work in cooperation with NGOs. The collection work was done by renting a 7-ton ($10m^3$) dump truck to avoid confusions with the existing NCC vehicles. The existing waste was removed and the operation was tested in the first week. Before the operation, wheelbarrows, rakes, brooms and other equipment which will support the work were distributed to the residents in the slum area. In middle and low income areas, the residents discharged the waste as usual by the middle of the second week while plastic bags were distributed to each household and used for discharging the waste from the end of the second week.

5.3 Project Area

The following three areas were selected from the areas where an educational video programme was recorded since the residents in these areas already noticed our study contents so that it might be easy to get a consent with the implementation of the work:

(a) Madaraka from middle income areas;
(b) Dandora Phase I from low income areas; and
(c) Kayaba from slum areas.

Location of each area is shown in **Figure E.5-1** and description of each area is briefly presented as follows.

(1) Madaraka (Middle Income Area)

The Madaraka Estate is located 2 km southwest, outside of the central business district (CBD), passing through the Nyayo National Stadium along the Langata Road. The estate was established in 1971 and has been managed by the NCC.

There are 46 buildings of two types: 12 blocks comprising 2-bedroom type flats, called B type, and 34 blocks comprising 3-bedroom type flats, called C type. The monthly rent is Kshs 2,800 for B type and Kshs 3,200 for C type. The total population in the estate is estimated at about 3,600.

Figure E.5-2 shows the project area in the Madaraka Estate.

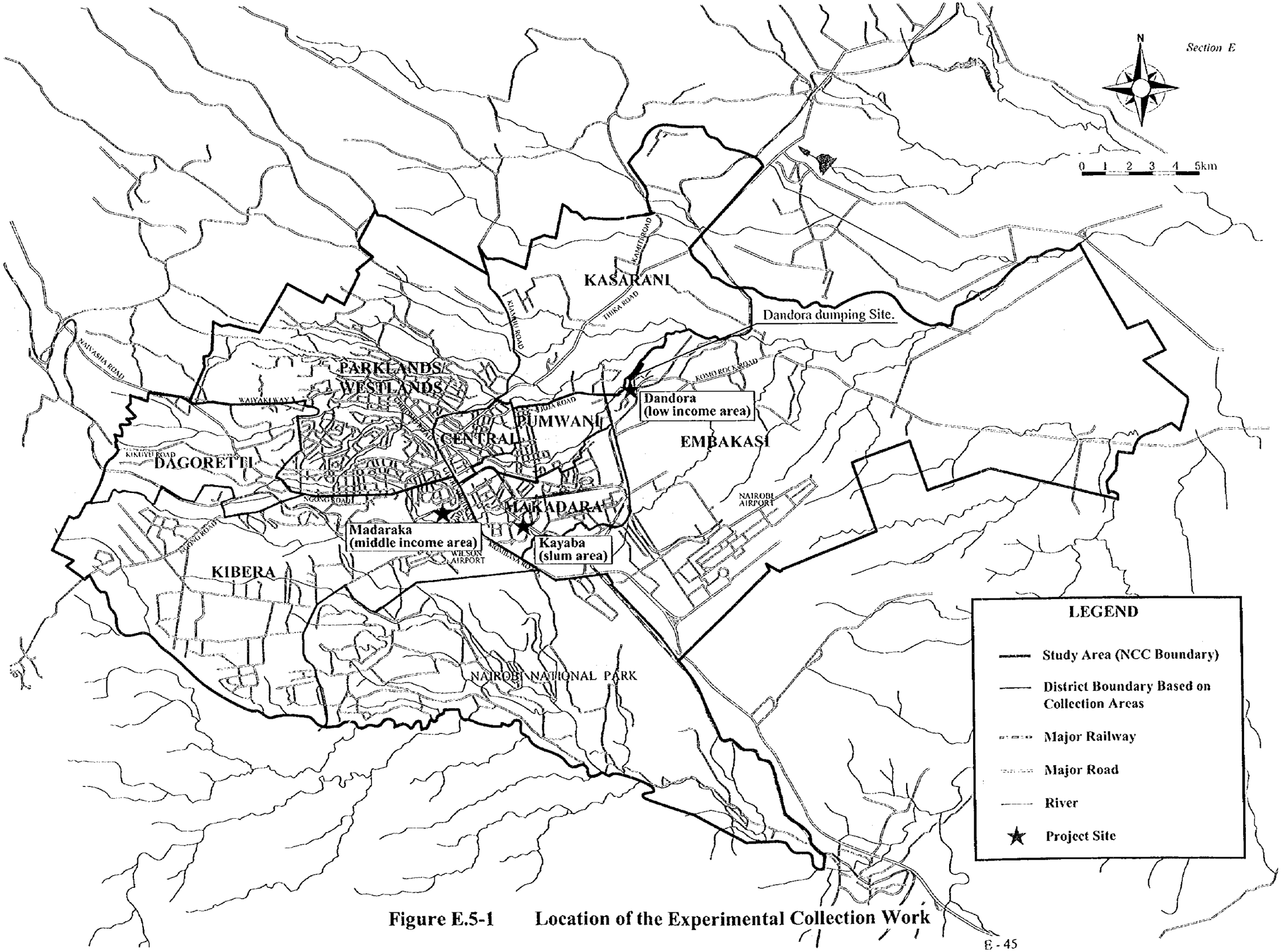
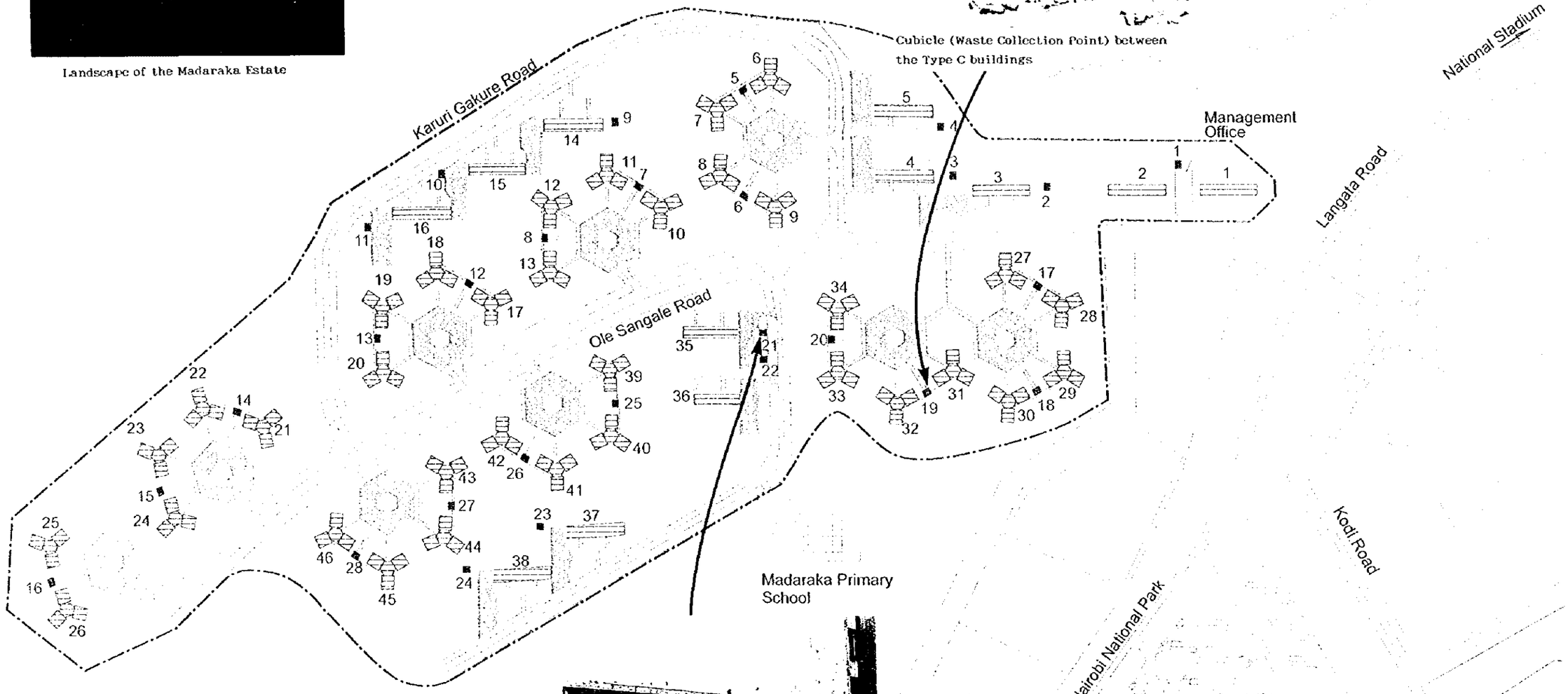


Figure E.5-1 Location of the Experimental Collection Work

Landscape of the Madaraka Estate

Cubicle (Waste Collection Point) between the Type C buildings



Cubicle in front of the Type B building

Figure E.5-2 Project Area for the Experimental Collection Work in Madaraka

Although the estate is well designed with wide open spaces, many plants and trees, the infrastructure such as wastewater pipes and drainage system has deteriorated. The Cleansing Section of DoE had sent one (1) senior headman, two (2) headmen and 14 sweepers to clean the estate. However, waste collection and transportation service has not been made on a regular basis. To discharge and store the waste, concrete box shaped cubicles built near each block are consequently always contain old garbage.

(2) Dandora-I (Low Income Area)

The Dandora Estate has been developed in stages under the Dandora Community Development Project of NCC. The estate is located in the eastern part of the city and approximately 8 km far from the city centre.

Phase I area was selected as the project area from the whole project components. The Dandora-I (Phase I) which lies along the Komo Rock Road was constructed in 1975. There are 1,026 plots in the project area, and one plot has five (5) to seven (7) families. The total population in the project area is estimated at about 13,000.

Waste collection and transportation services as well as street cleansing is not sufficient in the area and, especially, a large amount of uncollected garbage can be seen along the Komo Rock Road. This road is on the way to the existing dumping site at Dandora, so that some collection vehicles sometimes throw their collected waste along the roadside and not inside the dumpsite.

The project area in Dandora-I is shown in **Figure E.5-3**.

(3) Kayaba (Slum Area)

Kayaba is one of the typical informal settlements located in the southern part of Nairobi City. It has been reported that between 70,000 to 100,000 people live here (AMREF, 1990). A medium sized river called Ngong River, whose water has been coloured by pollution, forms the southernmost boundary of this extensive slum area, as shown in **Figure E.5-4.**

Most of the residents in Kayaba work in the nearby industries while others operate small scale businesses. In the case of those who are unemployed, majority are women, especially housewives, children and young people. Social services in Kayaba are limited and illiteracy is high due to poverty. Only one Catholic sponsored school serves the area. Water supply is also limited to a few selling points and contamination is common because of frequent breakage of the plastic pipes. Poor sanitation and drainage is a common feature in this area.

Any activity that involves the whole community has to take into account the eight clusters or zones into which the village is divided. These clusters are coded from A to H and were originally defined during an earlier community health project. The area and population vary from cluster to cluster.

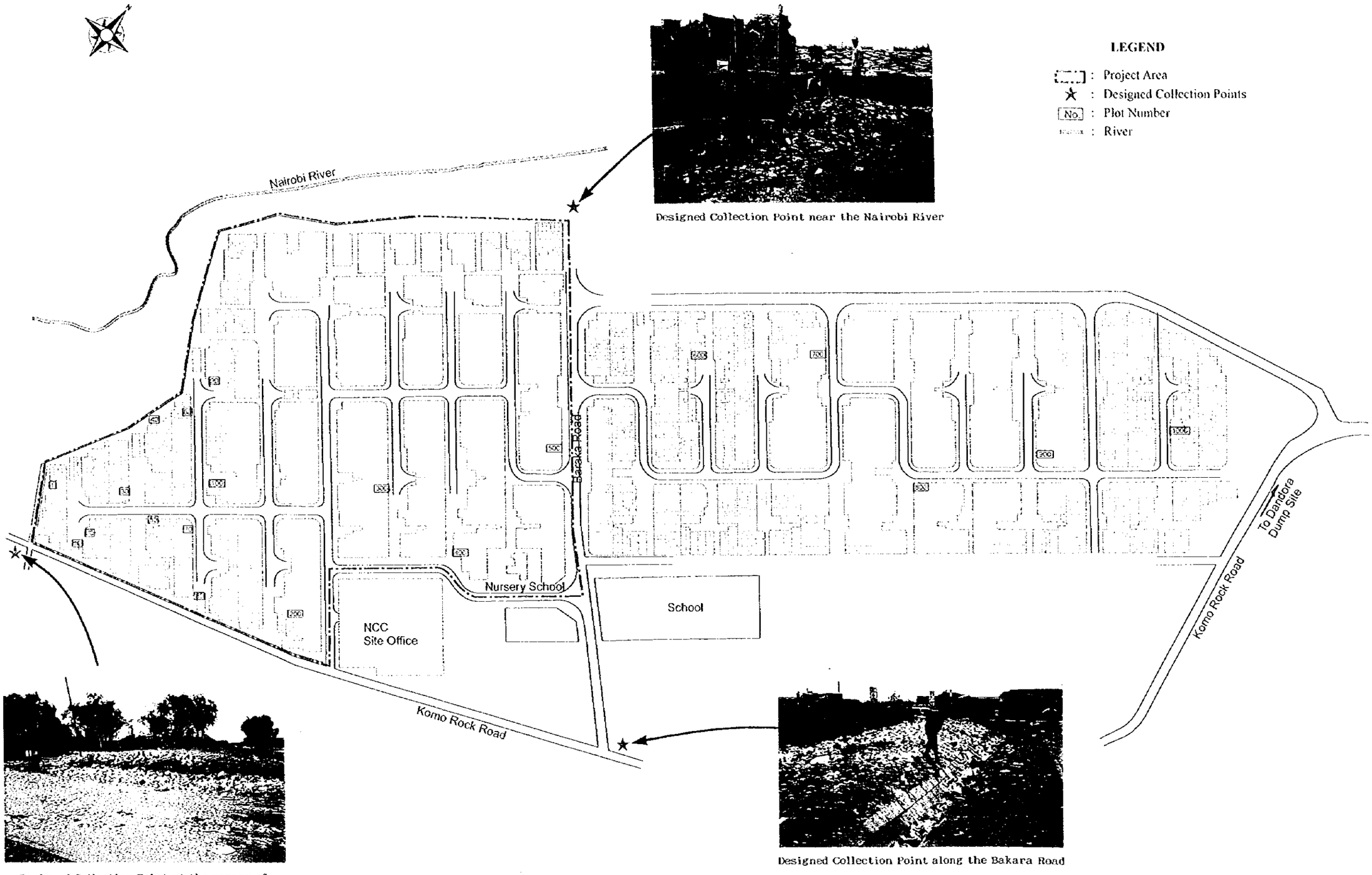
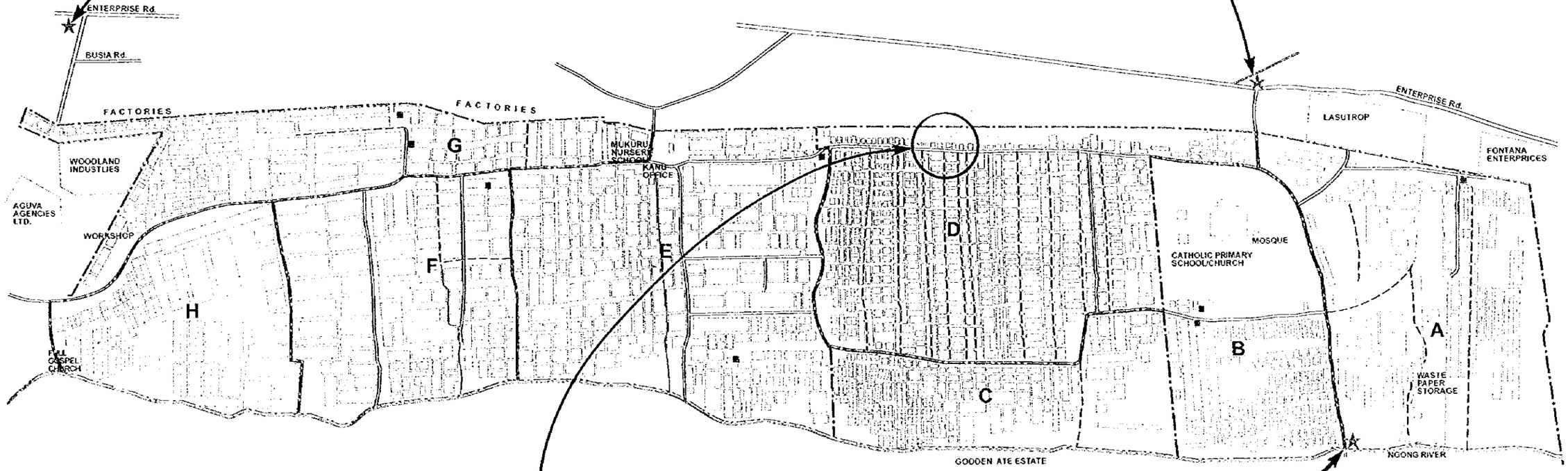


Figure E.5-3 Project Area for the Experimental Collection Work in Dandora (I)

Designed Collection Point along the Busia Road

Designed Collection Point along the Enterprise Road



Inside Kayaba area

Designed Collection Point near the Ngong River

LEGEND

- : Project Area
- : Cluster Boundary
- ☆ : Designed Collection Points
- A-H : Name of Cluster
- ✱ : Water Tap
- : River

Figure E.5-4 Project Area for the Experimental Collection Work in Kayaba

5.4 Limitations of the Work

This experimental work is restricted to a very small proportion of the whole population in the area except Madaraka. Nonetheless, the issues under investigation bear a common thread throughout and significant deviations are not expected because the options for solid waste collection and transportation in these areas are very limited. Moreover, these options can be shared among the whole population.

In addition, the prevailing high level of political activities at the time of the work deserves mention. During the period, many residents of the project areas, i.e., Madaraka, Dandora and Kayaba, like in other parts of the city were drawn into political events and campaigns because of the coming presidential and general election. This meant that some residents who would have taken part in interviews and questionnaires were not available. Young men and the middle aged people including women's groups, were mostly involved in these political activities.

5.5 Work Procedure

Main tasks of the Work proceeded as follows:

(1) Selection of sites

(2) Planning of collection and transportation work

- (a) existing operation (discharge method, frequency of collection)
- (b) coverage areas by a single dump truck
- (c) collection routes
- (d) collection points
- (e) scheduling (operation date and time for a specific area)
- (f) recording system for daily operation

(3) Orientation on the operation

- (a) explanation of the objective of the work
- (b) explanation of the contents of the work (confirmation of the collection date and points)
- (c) interview/questionnaire survey

(4) Preparatory work

- (a) removal of the existing waste in the site
- (b) checking the condition of the collection vehicle
- (c) document preparation (operation records, vehicle conditions, etc.)

(5) Implementation

- (a) recording by video and photos
- (b) inspection of the daily operation of the collection vehicle
- (c) checking the documents (operation records, vehicle conditions, etc.)

(6) Review

(a) interview/questionnaire survey
(b) compiling the documents (operation records, vehicle conditions, etc.)
(c) estimation of the actual costs and manpower

5.6 Collection and Transportation Plan for the Work

(1) Collection Plan for Madaraka (Middle Income Area)

(a) Collection Frequency

2 days a week (Monday and Thursday)
3 trips per day

(b) Design Collection Amount of Waste

Dump truck capacity: 10 $m^3 \times 0.3 = 3$ t
Total amounts collected per day: 3 t × 3 = 9 t

(c) Number of Households

There are a total of 46 blocks in the Madaraka Estate as mentioned before: 12 two bedroom type and 34 three bedroom type. The two bedroom type has 16 households in one block and the three bedroom type has 12 households in one block. Therefore, the total number of households in the estate is calculated as follows:

12 blocks × 16 + 34 blocks × 12 = 600 households

(d) Amounts of Waste Generated

Each household is assumed to be 6 people on average, thus;

600 households × 6 = 3,600 persons
3,600 × 0.67 kg/day = 2,412 kg/day = 2.4 t/day

Amounts generated on each collection day are the following:

2.4 × 3.5 (twice a week) = 8.4 t/day < 9 t OK

(e) Collection Method

At present there are 28 concrete cubicles in the estate for use as waste collection points, as shown in **Figure E.5-2**. Accordingly, the existing collection method which is to collect discharged waste from the collection point was planned to be applied. In addition, plastic bags were distributed in the last three collection days to examine the utilisation of plastic bags while residents were instructed to discharge their waste in the same usual way in the first three collection days.

(f) Required Number of Plastic Bags

In view of amount of waste generated in one household, one plastic bag per household should be able to cover one time collection.

Thus, 600 households × 3 = 1,800 bags

(2) Collection Plan for Dandora Phase I (Low Income Area)

(a) Collection Frequency

3 days a week (Tuesday, Friday and Sunday)
4 trips per day

(b) Design Collection Amount of Waste

Dump truck capacity: 10 m^3 × 0.3 = 3 t
Total amounts collected per day: 3 t × 4 = 12 t

(c) Number of Households to be Covered

12 t/day ÷ (0.61 kg/day × 3 days) = 6,560 persons

Considering housing allocation, the work should cover Plot No. 1 to No. 512. Therefore, 6,560 ÷ 512 = 12.8 persons/plot. This average number of persons per plot was considered to be understandable from our observation in the site.

(d) Collection Method

There were some dumping sites along the Komo Rock Road and the Baraka Road. It seemed quite difficult to allocate collection points inside the estate because most residents carry their wastes to the roadside. Therefore, three collection points were selected from the existing dumping sites; two along the two roads and the other was set up near the pond of a former quarry site. The location of the designed collection points is presented in **Figure E.5-3.**

In addition, plastic bags were distributed in the last three collection days to examine the utilisation of plastic bags while the residents were instructed to discharge their waste in the same usual way in the six collection days in the first and second weeks.

(e) Required Number of Plastic Bags

3 plastic bag per plot were given for 1 time collection.

Thus, 512 plots × 3 × 3 = 4,608 bags

(3) Collection Plan for Kayaba (Slum Area)

(a) Collection Frequency

2 days a week (Wednesday and Saturday)
3 trips per day

(b) Design Collection Amount of Waste

Dump truck capacity: 10 m^3 × 0.3 = 3 t
Total amounts collected per day: 3 t × 3 = 9 t

(c) Number of Population to be Covered

9 t/day ÷ (0.57 kg/day × 4 days) = 3,950 persons

(d) Collection Method

There is a well organised community group in Kayaba slum. The organisation carried out primary collection and transportation of the waste generated in the slum; in other words, the organisation collected the waste inside the slum and transported it to the designated points. The collection work included street sweeping by using handcarts and other equipment which were provided by the Study. The hired truck came to the designated collection points, namely, the roadsides in Enterprise Road and Busia Road and the point near the bridge inside the slum, which are selected from the existing dumping points. The two collection points, i.e., Enterprise Road and Busia Road have been a source of conflict between the adjacent industries; however, the NCC explained that these were temporary collection points which kept appearing in the area due to lack of permanent sites at this moment. The location of the designed collection points is presented in **Figure E.5-4**.

(e) Required Number of Equipment

The following equipment were provided for the residents to facilitate the collection work. Every representative of the clusters has the responsibility of supervising the use of these equipment and makes them available to all residents in the clusters.

Wheelbarrow	:	4 per cluster; 8 clusters × 4 = 32
Rake	:	4 per cluster; 8 clusters × 4 = 32
Broom	:	4 per cluster; 8 clusters × 4 = 32
Shovel	:	4 per cluster; 8 clusters × 4 = 32
Manure fork	:	4 per cluster; 8 clusters × 4 = 32
Gumboot	:	4 per cluster; 8 clusters × 4 = 32
Glove	:	12 per cluster; 8 clusters × 12 = 96

5.7 Operation Schedule

According to the above plan, the collection and transportation work has been scheduled weekly, as shown below.

Table E.5-1 Weekly Operation Schedule for Experimental Collection Work

	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
Madaraka		♠			♠		
Dandora (I)	♠		♠			♠	
Kayaba				♠			♠

Note: Symbol ♠ indicates the operation date.

In fact, the presidential and general elections were planned to be held on the 29th of December 1997. The actual operation date was therefore set up as follows:

Table E.5-2 Operation Schedule for Experimental Collection Work

Date	Day	Designation	Remarks
8 - 14/12/97	-	Removal of existing waste from three sites	
15/12/97	Mon	Madaraka	
16/12/97	Tue	Dandora (I)	
17/12/97	Wed	Kayaba	
18/12/97	Thu	Madaraka	
19/12/97	Fri	Dandora (I)	
20/12/97	Sat	Kayaba	
21/12/97	Sun	Dandora (I)	
22/12/97	Mon	Madaraka	
23/12/97	Tue	Dandora (I)	
24/12/97	Wed	Kayaba	
25/12/97	Thu	Madaraka	using plastic bags
26/12/97	Fri	Dandora (I)	using plastic bags
27/12/97	Sat	Kayaba	
28/12/97	Sun	Dandora (I)	using plastic bags
29/12/97	Mon	OFF	Election day
30/12/97	Tue	Madaraka	using plastic bags
31/12/97	Wed	Kayaba	
1/1/98	Thu	Dandora (I)	using plastic bags
2/1/98	Fri	Madaraka	using plastic bags
3/1/98	Sat	Kayaba	
4/1/98	Sun	Dandora (I)	
5/1/98	Mon	Madaraka	
6/1/98	Tue	Dandora (I)	
7/1/98	Wed	Kayaba	

5.8 Organisation of the Work

5.8.1 Organisation for the Collection from Communal Collection Points

The daily collection work of picking up the waste from communal collection points took place under an inspection team comprising staff of the Cleansing Section, NCC

and the JICA Study Team. The team monitored and reviewed the daily operation and revised the collection plan if the plan did not work well. The organisation of the team is shown as follows.

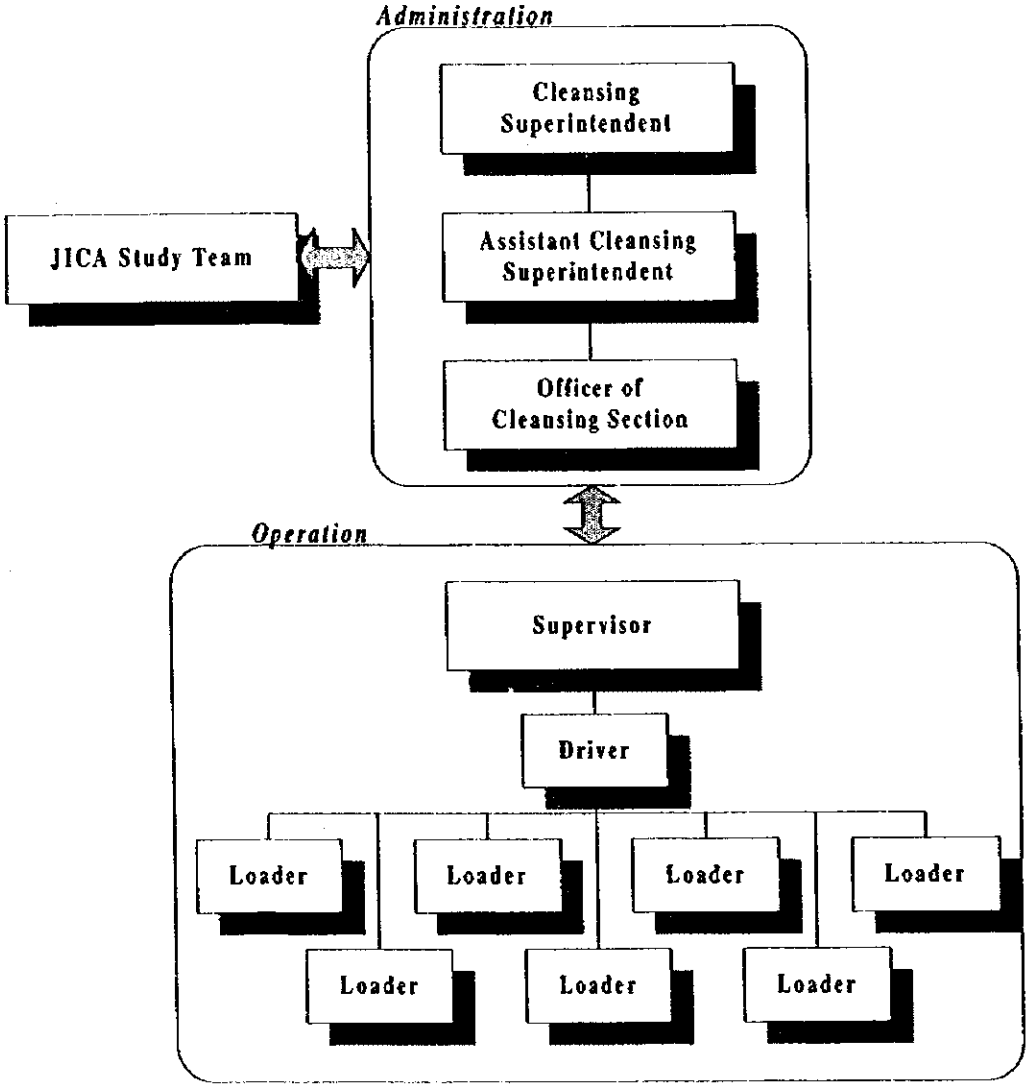


Figure E.5-5 Organisation Chart of the Experimental Collection Work

5.8.2 Organisation for the Collection inside the Informal Settlement

It might be very difficult for the NCC to collect solid waste inside the slum area because of the dense population and the inadequate road conditions. To facilitate the collection work inside the slum area, local community groups have to be established to make the residents understand that the work will depend on their own effort and commitment.

One of the Non-Governmental Organisations (NGOs), named SPEK (Society for Protection of Environment in Kenya) assisted the NCC and the JICA Study Team to organise the group in this collection work. There are some community groups existing in Kayaba, and SPEK had established a project working group comprising

members of the two existing groups, namely, Kayaba Community Health Workers and Mwangaza Health Workers. The project working group was organised as illustrated in **Figure E.5-6.**

Through this project working group the collection team and SPEK had been able to discuss, plan, evaluate and identify problems on a daily basis. The working group, on the other hand, has developed a schedule where its members are involved in systematic weekly cleanups of the clusters in order to sensitise individual residents.

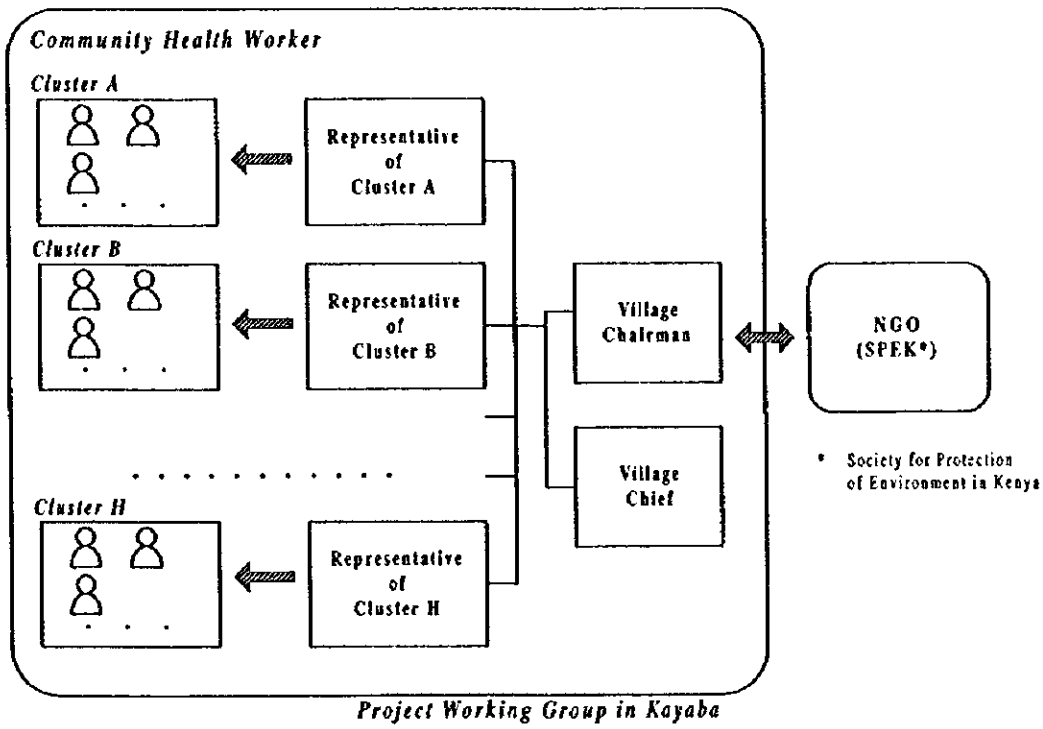


Figure E.5-6 Organisation Chart of the Project Working Group in Kayaba

5.9 Monitoring and Reviewing System

The inspection team monitored the following items daily by submission of a daily log and a vehicle inspection form put in by the supervisor and driver, respectively. The original forms are attached in **Subsection 5.4.1** of **Data Book (1)**.

Items of Daily Log

1. Day
2. Date
3. Vehicle Registration Number
4. Driver's Name
5. Mileage Reading (start and close)
6. Fuel Consumption (Diesel and oil)
7. Time Out and In
8. Collection Area
9. Number of Trips
10. Tipping Time

11. Remarks
12. Supervisor's Name, Signature, Date and Time

Items of Vehicle Inspection Form

1. Day
2. Date
3. Vehicle Registration Number
4. Inspection Items (Fuel, Oil, Battery, Tyres, Water, Lights/Indicators, Body structure and others)
5. Driver's Name, Signature, Date and Time

The inspection team also reviewed the daily performance and the collection plan after finishing the operation every one week.

5.10 Questionnaire Survey

5.10.1 Objectives of the Survey

As a part of the experimental work, members of the public were interviewed in Madaraka, Dandora and Kayaba, where the experimental collection work was carried out. The objectives of this survey are to provide basic information on general aspects on solid waste management before the start of the experimental collection work in order to assess its status, and to evaluate the work through a comparison of the survey results between before and after the work.

5.10.2 Survey Methodology

The main method of data collection involved direct primary sources, i.e., questionnairing and personal interviews. This method proved useful in the absence of related previous studies in the area. In view of ease of getting response, two types of questionnaire were developed depending on different income levels in the project areas to be used as a guide to conduct the interviews among the residents. One is for residents of Kayaba who are supposed to be living in a considerably low income situation, and the other is to cover Madaraka and Dandora residents, ranging from middle to low income levels.

Simultaneously, the JICA Study Team prepared posters to announce the implementation of the collection work and distributed them to the residents at the time of the questionnaire survey. The design of the poster is illustrated in **Figure E.5-7**, and the original questionnaire forms are presented in **Subsection 5.4.2** of **Data Book (1)**. To facilitate the interviews, NCC staff supervising the project area and local volunteers joined the survey team.

For the purpose of sampling, the survey adopted the existing maps for each area which clearly show the dwellings or building blocks. Based on the maps, random sampling was carried out; for example, although Kayaba is divided into eight clusters of varying sizes and population, these clusters formed the basis for random sampling of 25 respondents from each cluster.

Figure E.5-7 Illustration of Poster Distributed to Residents in Project Areas

5.10.3 Major Results of the Survey

(1) Madaraka

All answers of the questionnaire are summarised in tables in **Subsection 5.4.3** of **Data Book (1)**. The following items are major results of the survey.

(a) Respondent Profile

The number of samples, sex composition, age, marital status, etc., of the respondents are summarised as follows:

Table E.5-3 Profile of Respondents in Madaraka

Item	Before the Work	After the Work
Total Number of Samples	95	112
Sex Composition*1 (A2) *2		
- Female	52 (56%)	82 (74%)
- Male	41 (44%)	28 (26%)
Age (A3)	28.1*3	19.2*4
Occupation*5 (A4)	Student (23%)	Student (41%)
	Business person (15%)	Housegirl or wife (10%)
	Secretary (8%)	Businessman (9%)
Marital Status*6 (A5)		
- Married	34 (42%)	33 (31%)
- Single	47 (58%)	74 (69%)
No. of Family Size (A6)	4.9*7	5.2*8

*1 The proportion of sex composition is calculated based on the number of response which is not necessarily the same as the total number of samples due to no response.
*2 Figures in parenthesis indicate the original question number, e.g., A2 means a question in Part A, number 2. The following tables are shown in the same manner.
*3 This age is calculated by an average of 79 answers (83%).
*4 This age is calculated by an average of 55 answers (49%).
*5 The total number of respondents is 65 (68%) before the Work and 98 (88%) after the Work.
*6 The proportion of marital status composition is calculated based on the number of response which is not necessarily the same as the total number of samples due to no response.
*7 This family size is calculated by an average of 83 answers (87 %).
*8 This family size is calculated by an average of 110 answers (98 %).

(b) Interest in Solid Waste Management

Public interest in solid waste management (SWM) are evaluated from answers to the questionnaire and summarised, as shown in **Table E.5-4.**

(c) Discharge of Solid Waste

Discharge methods of solid waste, e.g., where, how many, how often, are summarised in **Table E.5-5.**

Table E.5-4 Interest in Solid Waste Management in Madaraka

Question	Answer (Before the Work)
Interested in SWM? (B1)	
- Yes	87 (92%)
- No	7 (7%)
- Others*1	1 (1%)
Heard the News of SWM? (B2)	
- Yes	68 (73%)
- No	19 (26%)
- Others*1	8 (1%)
Know the SWM problem? (B3)	
- Yes	81 (85%)
- No	4 (4%)
- Others*1	10 (11%)
Know the final disposal site? (B4)	
- Yes	31 (33%)
- No	59 (62%)
- Others*1	5 (5%)
Know the private collection? (B5)	
Yes	74 (78%)
No	16 (17%)
Others*1	5 (5%)

*1 Others include answers of 'not applicable'.

Table E.5-5 Discharge Method of Solid Waste in Madaraka

Question	Answer (Before the Work)
Where are wastes discharged? (B6)	
- Collection points	73 (77%)
- Road side	5 (5%)
- Others*1	16 (17%)
How many times discharged? (B7)	
- Everyday	46 (48%)
- Once 2 days	25 (26%)
- Once 3 days	7 (7%)
- Once a week	13 (14%)
- Others*1	4 (4%)
How do you store in your house? (B8)	
- Dust bins	31 (33%)
- Plastic bags	21 (22%)
- Bucket	42 (44%)
- Others*1	2 (2%)

*1 Others include answers of 'not applicable'.

(d) Collection of Solid Waste

Collection methods of solid waste are summarised in **Table E.5-6.**

Table E.5-6 Collection Method of Solid Waste in Madaraka

Question	Answer (Before the Work)
Who pick up the waste? (B12)	
- NCC	70 (74%)
- NGO	2 (2%)
- Nobody	15 (16%)
- Others*1	8 (8%)
How often picked up? (B13)	
- Once a week	5 (5%)
- Twice a month	8 (8%)
- Once a month	28 (29%)
- Others*1	54 (57%)

*1 Others include answers of 'not applicable'.

(e) Recycling/Reuse of Solid Waste

Recycling/reuse of solid waste is summarised in **Table E.5-7.**

Table E.5-7 Recycling/Reuse of Solid Waste in Madaraka

Question	Answer (Before the Work)
Sorting recycle materials? (B9)	
- Yes	13 (14%)
- No	82 (86%)
Effort to reduce waste? (B10)	
- Yes	52 (55%)
- No	36 (38%)
- Others*1	7 (7%)

*1 Others include answers of 'not applicable'.

(f) Willingness to Pay, etc.

Willingness to pay (WTP) for periodical collection service and how many times collection is required are summarised in **Table E.5-8.**

Table E.5-8 Willingness to Pay in Madaraka

Question	Answer (Before the Work)	Answer (After the Work)
How many times required?	(B16)*2	(B7)
- Twice a month	4 (4%)	2 (2%)
- Once a week	36 (38%)	35 (31%)
- Twice a week	39 (41%)	61 (54%)
- Others*1	16 (17%)	14 (13%)
Pay the waste charge?	(B17)	(B8)
- Yes	66 (69%)	97 (87%)
- No	22 (23%)	7 (6%)
- Others*1	7 (7%)	8 (7%)
Willingness to pay? *3	(B18)	(B9)
- Average	Kshs.179	Kshs.164
- Median	Kshs.100	Kshs.100
- Mode	Kshs.100	Kshs.100
- Maximum	Kshs. 0	Kshs.10
- Minimum	Kshs.1500	Kshs.800

*1 Others include answers of 'not applicable'.
*2 Figures in parenthesis indicate the original question number, e.g., B16 means a question in Part B, number 16.
*3 The total number of respondents are 69 (73%) before the Work and 87 (78%) after the Work.

(g) Awareness to the Experimental Collection Work

Residents' awareness regarding the experimental collection work are summarised in **Table E.5-9.**

Table E.5-9 Awareness to the Work in Madaraka

Question	Answer (After the Work)
Know the Work? (B1)	
- Yes	102 (91%)
- No	10 (9%)
Know the collection day? (B2)	
- Yes	99 (88%)
- No	13 (12%)
Know the collection point? (B3)	
- Yes	103 (92%)
- No	9 (8%)
Discharge to the collection point? (B4)	
- Yes	100 (89%)
- No	12 (11%)
The Work contributed to clean up? (B5)	
- Yes	110 (98%)
- No	1 (1%)
- Others*1	1 (1%)

*1 Others include answers of 'not applicable'.

(h) Ideas for the Improvement of Waste Collection

Residents' ideas to improve waste collection work are summarised in **Table E.5-10.**

Table E.5-10 Ideas for the Improvement of Waste Collection in Madaraka

Question	Answer (Before the Work)	Answer (After the Work)
What should be done to improve waste collection?	(B15) *1	(B6)
	Privatise	Provision of plastic bags
	32 (34%)	49 (44%)
	Regular collection	Regular collection
	15 (16%)	36 (32%)
	More equipment	Continue the same collection work
	15 (16%)	30 (27%)
	Make awareness	Educate the residents
	9 (9%)	12 (11%)
	Collection more often	Collection more often
	4 (4%)	11 (10%)

*1 Figures in parenthesis indicate the original question number, e.g., B15 means a question in Part B, number 15.

(2) Dandora

All answers of the questionnaire are summarised in tables in **Subsection 5.4.3** of **Data Book (1)**. The following items are major results of the survey.

(a) Respondent Profile

The number of samples, sex composition, age, marital status, etc., of the respondents are summarised as follows:

Table E.5-11 Profile of Respondents in Dandora

Item	Before the Work	After the Work
Total Number of Samples	83	100
Sex Composition*1 (Q2) *2		
- Female	48 (59%)	43 (43%)
- Male	35 (41%)	57 (57%)
Age (Q3)	27.8*3	35.0*4
Occupation*5 (Q4)	Businessperson (25%)	Businessperson (26%)
	Housewife (21%)	Student (19%)
	Student (14%)	Landlady (7%)
Marital Status*6 (Q5)		
- Married	39 (48%)	58 (58%)
- Single	43 (52%)	42 (42%)
No. of Family Size (Q6)	3.9*7	4.4*8

*1 The proportion of sex composition is calculated based on the number of response which is not necessarily the same as the total number of samples due to no response.
*2 Figures in parenthesis indicate the original question number, e.g., A2 means a question in Part A, number 2. The following tables are shown in the same manner.
*3: This age is calculated by an average of 61 answers (73%).
*4: This age is calculated by an average of 74 answers (74%).
*5: The total number of respondents is 57 (69%) before the Work and 95 (95%) after the Work.
*6: The proportion of marital status composition is calculated based on the number of response which is not necessarily the same as the total number of samples due to no response.
*7: This family size is calculated by an average of 76 answers (92%).
*8: This family size is calculated by an average of 97 answers (97%).

(b) Interest in Solid Waste Management

Public interest in solid waste management (SWM) is evaluated from answers of the questionnaire and summarised in **Table E.5-12**.

Table E.5-12 Interest in Solid Waste Management in Dandora

Question	Answer (Before the Work)
Interested in SWM? (B1)	
- Yes	78 (94%)
- No	5 (6%)
Heard the News of SWM? (B2)	
- Yes	67 (81%)
- No	15 (18%)
- Others*1	1 (1%)
Know the SWM problem? (B3)	
- Yes	76 (92%)
- No	5 (6%)
- Others*1	2 (2%)
Know the final disposal site? (B4)	
- Yes	49 (59%)
- No	33 (40%)
- Others*1	1 (1%)
Know the private collection? (B5)	
- Yes	54 (65%)
- No	27 (33%)
- Others*1	2 (2%)

*1 Others include answers of 'not applicable'.

(c) Discharge of Solid Waste

Discharge methods of solid waste, e.g., where, how many, how often, are summarised in **Table E.5-13.**

Table E.5-13 Discharge Method of Solid Waste in Dandora

Question	Answer (Before the Work)
Where waste discharge? (B6)	
- Collection points	24 (29%)
- Roadside	51 (61%)
- Others*1	8 (10%)
How many times discharge? (B7)	
- Everyday	26 (31%)
- Once in 2 days	15 (18%)
- Once in 3 days	6 (7%)
- Once a week	33 (40%)
- Others*1	3 (4%)
How store in your house? (B8)	
- Dust bins	18 (22%)
- Plastic bags	30 (36%)
- Bucket	33 (40%)
- Others*1	2 (2%)

*1 Others include answers of 'not applicable'.

(d) Collection of Solid Waste

Collection methods of solid waste are summarised in **Table E.5-14.**

Table E.5-14 Collection Method of Solid Waste in Dandora

Question	Answer (Before the Work)
Who pick up the waste? (B12)	
- NCC	68 (82%)
- NGO	0 (0%)
- Nobody	12 (14%)
- Others*1	3 (4%)
How often picked up? (B13)	
- Once a week	7 (8%)
- Twice a month	6 (7%)
- Once a month	36 (43%)
- Others*1	34 (41%)

*1 Others include answers of 'not applicable'.

(e) Recycling/Reuse of Solid Waste

Recycling/reuse of solid waste are summarised in **Table E.5-15.**

Table E.5-15 Recycling/Reuse of Solid Waste in Dandora

Question	Answer (Before the Work)
Sorting recycle materials? (B9)	
- Yes	17 (20%)
- No	66 (80%)
Effort to reduce waste? (B10)	
- Yes	45 (54%)
- No	38 (46%)

(f) Willingness to Pay, etc.

Willingness to pay (WTP) for periodical collection service and how many times of collection are required are summarised in **Table E.5-16.**

Table E.5-16 Willingness to Pay in Dandora

Question	Answer (Before the Work)	Answer (After the Work)
How many times required?	(B16) *2	(B7)
- Twice a month	6 (7%)	0 (0%)
- Once a month	36 (43%)	0 (0%)
- Once a week	7 (8%)	18 (18%)
- Twice a week	0 (0%)	79 (79%)
- Others*1	34 (41%)	1 (1%)
Pay the waste charge?	(B17)	(B8)
- Yes	5 (6%)	95 (95%)
- No	77 (93%)	5 (5%)
- Others*1	1 (1%)	0 (0%)
Willingness to pay? *3	(B18)	(B9)
- Average	Kshs.62	Kshs.200
- Median	Kshs.50	Kshs.200
- Mode	Kshs.100	Kshs.200
- Maximum	Kshs. 0	Kshs.50
- Minimum	Kshs.200	Kshs.400

*1 Others include answers of 'not applicable'.
*2 Figures in parenthesis indicate the original question number, e.g., B16 means a question in Part B, number 16.
*3 The total number of respondents are 69 (73%) before the Work and 87 (78%) after the Work.

(g) Awareness to the Experimental Collection Work

Residents' awareness regarding the experimental collection work is summarised in **Table E.5-17.**

Table E.5-17 Awareness to the Work in Dandora

Question	Answer (After the Work)
Know the Work? (B1)	
- Yes	81 (81%)
- No	19 (19%)
Know the collection day? (B2)	
- Yes	11 (11%)
- No	89 (89%)
Know the collection point? (B3)	
- Yes	95 (95%)
- No	5 (5%)
Discharge to the collection point? (B4)	
- Yes	97 (97%)
- No	3 (3%)
The Work contributed to clean up? (B5)	
- Yes	97 (97%)
- No	3 (3%)

[1] Others include answers of 'not applicable'.

(h) Ideas for Improvement of Waste Collection

Residents' ideas to improve waste collection work are summarised in **Table E.5-18**.

Table E.5-18 Ideas for Improvement of Waste Collection in Dandora

Question	Answer (Before the Work)	Answer (After the Work)
What should be done for improvement of waste collection?	(B15) [1]	(B6)
	Privatise	Privatisation/Decentralisation
	17 (20%)	26 (26%)
	Regular collection	Improve NCC
	11 (13%)	11 (11%)
	Employ more people	Regular collection
	8 (10%)	7 (7%)
	Public awareness	Transfer dump site from Dandora
	8 (10%)	5 (5%)
	Supply dustbins	Continue the same collection work
	7 (8%)	5 (5%)
	Provide vehicles	Educate the residents
	7 (8%)	5 (5%)

[1] Figures in parenthesis indicate the original question number, e.g., B15 means a question in Part B, number 15.

(3) Kayaba

The contents of the questionnaire used in Kayaba were slightly different from those in Madaraka and Dandora (I). Major answers to the questionnaire are summarised in tables in **Subsection 5.4.3** of **Data Book (1)**. The following items are major results of the survey.

(a) Respondents Profile

The number of samples, sex composition, age, marital status, etc., of the respondents are summarised as follows:

Table E.5-19 Profile of Respondents in Kayaba

Item	Before the Work	After the Work
Total Number of Samples	200	100
Sex Composition (A5)		
- Female	122 (61%)	60 (60%)
- Male	78 (39%)	40 (40%)
Age (A3)	29.8*1	31.8*2
Marital Status*3 (A5)		
- Married	80 (58%)	28 (49%)
- Single	57 (42%)	29 (51%)
No. of Family Size (A6)	4*4	-

*1 This age is calculated by an average of 200 answers (100%).
*2 This age is calculated by an average of 100 answers (100%).
*3 The proportion of marital status composition is calculated based on the number of response which is not necessarily the same as the total number of samples due to no response.
*4 This number may not indicate the real size of the family since it was hard to distinguish between extended members of the family and those families with some of the members living in rural areas.

(b) Interest in Solid Waste Management

Public interest in solid waste management (SWM) is evaluated from answers to the questionnaire and summarised in **Table E.5-20**.

Table E.5-20 Interest in Solid Waste Management in Kayaba

Question	Answer (Before the Work)
Waste affects the environment? (B12)	
- Yes	186 (93%)
- No	14 (7%)
Have been taking part in clean ups? (B13)	
- Yes	165 (83%)
- No	35 (17%)

(c) Discharge of Solid Waste

Discharge methods of solid waste, e.g., where and how, are summarised in **Table E.5-21**.

Table E.5-21 Discharge Method of Solid Waste in Kayaba

Question	Answer (Before the Work)
Where is waste discharged? (B9)	
- Outside the house	10 (5%)
- Busia Road	7 (4%)
- Enterprise Road	6 (3%)
- Along the River	169 (85%)
- Others*1	8 (4%)
What kind of container is used? (B8)	
- Paper bag	28 (14%)
- Plastic bag	32 (16%)
- Plastic bucket	64 (32%)
- Metal tin	40 (20%)
- Others*1	36 (18%)

*1 Others include answers of 'not applicable'.

(d) Awareness to the Experimental Collection Work

Residents' awareness regarding the experimental collection work are summarised in **Table E.5-22**.

Table E.5-22 Awareness to the Work in Kayaba

Question	Answer (After the Work)
Participated in the Work? (B9)	
- Yes	45 (45%)
- No	55 (55%)
Used the implements? (B7)	
- Yes	32 (32%)
- No	68 (68%)

5.10.4 Summary of Survey Findings

(1) Respondents Profile

While a wide range of people were surveyed ranging from youth to adults, unemployed to professionals, women outnumbered men to the ratio of about 6:4 in the survey. One of the reasons why the number of females were larger seems to be that a significant number of male residents went out to work during the daytime leaving behind women and children. What students were dominant in the proportion of respondents and the averaged age of respondents were relatively young particularly in Madaraka support this reason.

(2) Interest in Solid Waste Management

Public interest in solid waste management (SWM) in the project area is remarkably high. More than 90% of respondents are interested in solid waste management and/or know the waste problems and influences by the waste to the environment. However, the present final disposal site is not familiar to the citizens. Only 33% of the residents in Madaraka know the place, even in Dandora where the existing dump site is located 40% of residents are not aware of the nearby place. Private waste collection is relatively known by the residents; specifically, the percentage of people who know the private collection is 78% in Madaraka and 65% in Dandora (I).

(3) Discharge of Solid Waste

Majority of the people in Madaraka (77%) discharge their waste into communal collection points while only 29% of the residents in Dandora (I) do the same. This is because the Madaraka Estate has many cubicles as communal collection points to store the waste temporarily as well. Dandora (I) does not have communal collection points inside the estate and therefore 61% of the people discharge their waste on the roadside. In Kayaba, the data shows that the river is the most preferred (85%) for indiscriminate disposal of all kinds of waste.

The residents in Madaraka discharge the waste mainly everyday (48%) although 40% of the residents in the Dandora (I) discharge once a week.

Buckets are the most commonly used for storing the waste in all project areas. Dust bins and plastic or paper bags are also in prevalent use.

(4) Collection of Solid Waste

In both Madaraka and Dandora (I), NCC is the major collector of solid waste. There is no operation by private collectors in these areas.

Frequency of waste collection is very rare; in other words, 80 to 90% of respondents answered that waste collection is made once or less in a month.

(5) Recycling/Reuse of Solid Waste

More than 80% of the people have never tried sorting waste for recycling and/or reuse. However, almost half of the respondents in both Madaraka and Kayaba have tried to make an effort to reduce waste.

(6) Willingness to Pay, etc.

In general, most positive responses (50-80%) were received for a collection service that would be twice a week. In Madaraka and Dandora (I), more than 90% of the people are prepared to pay for a regular and reliable collection service. In the Madaraka Estate, median and mode of the samples are Kshs.100, and the experimental work did not contribute to the change of the amount of willingness to pay. In Dandora (I), more people seemed to be prepared to pay between Kshs.100 and 200 for the collection service, median and mode are Kshs.200. In Dandora (I), accountability for the charge was a point often made. People's willingness was significantly increased from Kshs.62 before the work to Kshs.200 after the work.

(7) Awareness to the Experimental Collection Work

Most people (80-90%) in Madaraka and Dandora (I) knew that JICA and NCC were carrying out the experimental collection service twice a week. In Kayaba, 45% of the residents had participated in the collection work, and 32% of people had used the implements given in the experiment.

Details about the collection day were not well known in Dandora (I). However, in Madaraka and Dandora (I), most people (92-95%) knew about the collection points before the experiment started, and most people (89-97%) discharged their solid waste to the appointed collection points on the day. There was an almost unanimous response (97-98%) that the experimental collection did contribute to clean up in both areas.

(8) Ideas for Improvement of Waste Collection

Many suggestions were made about improvement to waste collection; for example, provision of plastic bags (Madaraka, 44%), regular collection [Madaraka, 32%; Dandora (I), 7%], continuation of the experimental collection [Madaraka, 27% ; Dandora (I), 5%]. In particular 26% of the people in Dandora (I) suggested to introduce privatisation and/or decentralisation of the collection services.

5.11 Results of the Work

The scheduled work was finished on 7th January 1998 although two breaks were made due to the presidential and general election days held on 29th and 30th December 1997. The time and motion study of the work was executed on randomly selected several operation days. The result of the study are complied in **Subsections 5.4.4** and **5.4.5 of Data Book (1)**. On the other hand, the work had been supervised based on the daily log records, and the records are complied in **Subsection 5.4.6 of Data Book (1)**. The collection operation and cleansing work in the project areas are presented in **Subsection 5.4.7 of Data Book (1)**. The major findings through these survey results are summarised basically in comparison with the ordinary work as discussed below.

5.11.1 Vehicle Operation

(1) Operation Distance

The averaged daily mileage for the experimental collection work is about 37 km while that of the ordinary work is 56 km as shown in **Figure E.5-8**. Since the project sites for the experimental collection work were located in the city centre and just next to the dumpsite, the mileage of the experiment was less recorded than that of the ordinary one. The same tendency is observed in terms of operating distance per trip as shown in **Figure E.5-9**. The ordinary work tripped more than 30 km per trip although only about 10 km were recorded in the experimental work.

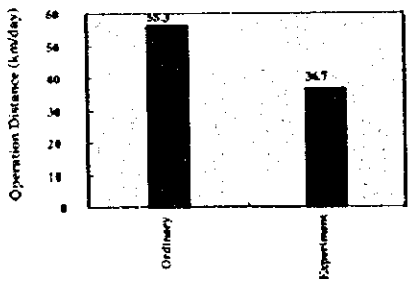


Figure E.5-8 Comparison of Daily Operation Distance between the Experimental and Ordinary Collection Works
(Note: Data of the ordinary work indicate the results of the time and motion study in the second field survey.)

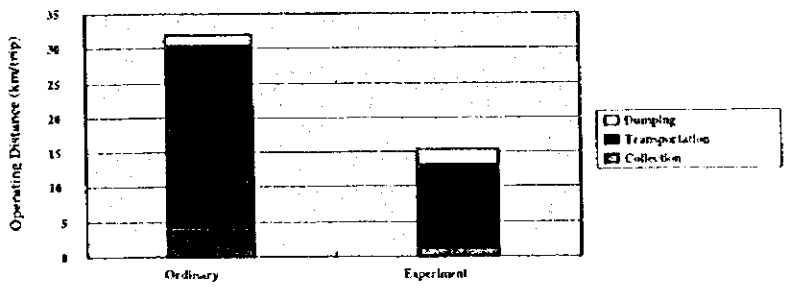


Figure E.5-9 Comparison of Operation Distance per Trip between the Experimental and Ordinary Collection Works
(Note: Data of the ordinary work indicate the results of the time and motion study in the second field survey.)

(2) Operation Time

The operating time for the experimental collection work was about 485 minutes (approximately 8 hours) while that of the ordinary work was 330 minutes (6.5 hours). According to the daily logs covering the whole project period checked daily by a supervisor of the work, the experimental work spent nine (9) hours daily on average. These facts clearly show that the experimental work was operating longer than the ordinary work. The longer working hours seems to be due to strict instructions and daily management by the administration team. The comparison of the operating time between the experimental and ordinary work is as shown in **Figure E.5-10.**

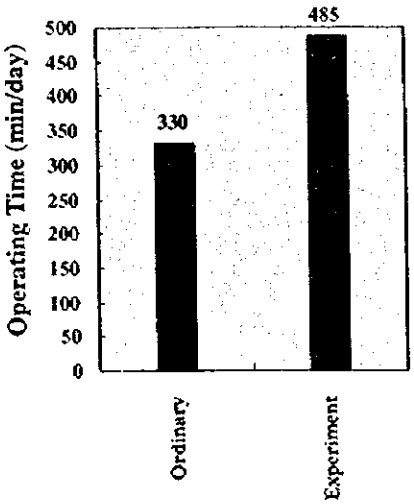


Figure E.5-10 Comparison of Daily Operation Time between the Experimental and Ordinary Collection Works
(Note: Data of the ordinary work indicate the results of the time and motion study in the second field survey.)

5.11.2 Manpower Performance

(1) Proportion of Each Activity

Collection was the main activity in the experimental work, and it spent nearly 70% of the total operation time in a trip. On the other hand, collection and transportation are almost of the same portion in the operation in the ordinary work. The comparison between the two works is presented in **Figure E.5-11.** The experimental work was conducted solely by a combination of a dump truck and manual loading. This mode of work resulted in much more time spent for the collection rather than the transportation.

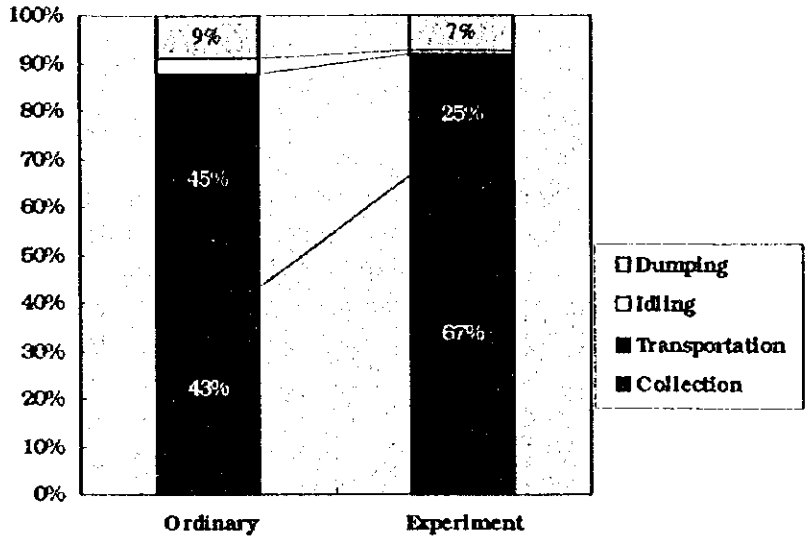


Figure E.5-11 Comparison of Proportion of Time Spent for Each Activity to Total Operation Time between the Experimental and Ordinary Collection Works
(Note: Data of the ordinary work indicate the results of the time and motion study in the second field survey.)

(2) Number of Trips

The number of trips in the experimental collection work was 2.4 which is 1.5 times as much as that of the ordinary one as shown in **Figure E.5-12**. The longer working hours in the experiment may have contributed to the more number of trips recorded.

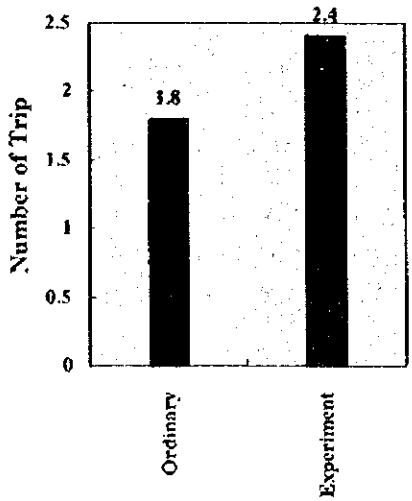


Figure E.5-12 Comparison of the Number of Trips between the Experimental and Ordinary Collection Works
(Note: Data of the ordinary work indicate the results of the time and motion study in the second field survey.)

(2) Number of Crew

The number of crew in the experimental collection work was quite higher than that of the ordinary; 9.0 persons for the experiment and 5.1 for the ordinary, as shown in **Figure E.5-13**.

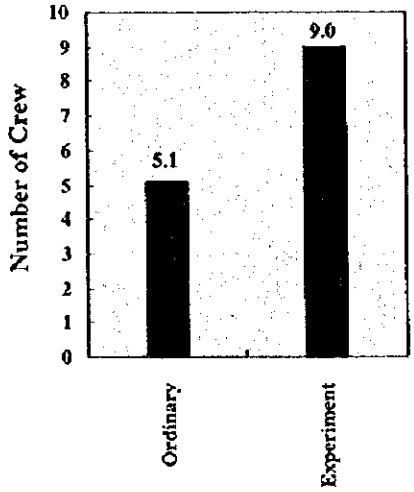


Figure E.5-13 Comparison of the Number of Crew between the Experimental and Ordinary Collection Works
(Note: Data of the ordinary work indicate the results of the time and motion study in the second field survey.)

5.11.3 Differences among Locations of Experimental Work

The experimental collection work was carried out in three (3) different locations: Madaraka, Dandora (I) and Kayaba. These areas were classified into three different income levels, i.e., middle and low income, and slum area. The differences among the three in terms of vehicle operation and manpower performence are analysed as discussed below.

(1) Vehicle Operation

The daily operating time and mileage are shown in **Figures E.5-14** and **E.5-15**. There were no big differences among them; the daily operating time was between 8.5 and 9 hours.

On the other hand, daily mileage had some differences; namely, mileage in the Dandora operation was recorded at 27 km per day which was almost half of the mileage recorded in the operation of Madaraka and Kayaba which were 58 km and 69 km, respectively. This may be understandable because the work site at Dandora was just next to the dumpsite.

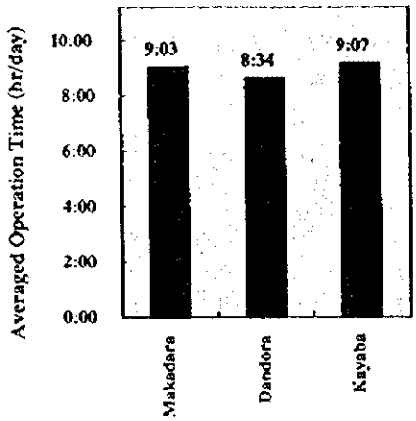


Figure E.5-14 Comparison of Daily Operation Time among the Different Locations of the Experimental Work

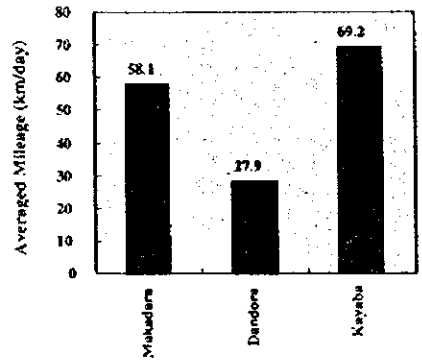


Figure E.5-15 Comparison of Daily Mileage among the Different Locations of the Experimental Work

In addition, fuel consumption was about 1.8 km per litre for the operation of Madaraka and Kayaba while that of Dandora was worse, 1.5 km per litre. This may have also resulted from the fact that the project location of Dandora was very close to the dumpsite and no long drive was required in the operation.

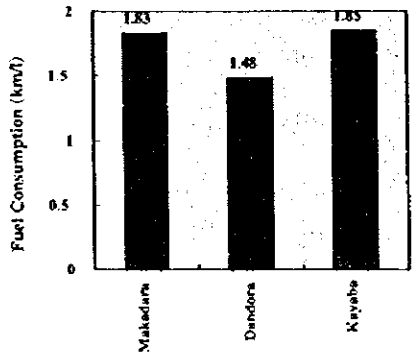


Figure E.5-16 Comparison of Fuel Consumption among the Different Locations of the Experimental Work

(2) Manpower Performance

As shown in **Figure E.5-17,** the number of trips in the three locations was approximately between two and three. The operation in Madaraka made two trips a day since there were 28 collection points and it required a lot of time to clean all of them. In Dandora, three trips were usually made a day, while the operation in Kayaba varied from two to three trips depending on the waste volume to be collected on the designated day. Except Kayaba, the collection work was executed according to the original schedule.

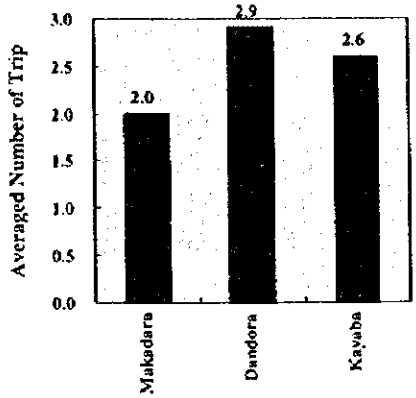


Figure E.5-17 Comparison of Number of Trips among the Different Locations of the Experimental Work

5.11.4 Effects of the Distribution of Plastic Bags

Six (6) days were selected to conduct the experimental collection work with the use of plastic bags distributed to each household. There were no big differences between with and without plastic bags for the residents and the effect of distribution of plastic bags could not be observed during the experimental work.

Table E.5-23 Comparison of the Effects of Distribution of Plastic Bags

Location	Plastic Bag	Mileage (km/day)	Fuel (l/day)	Fuel Consumption (km/l)	Operation Time (hr./day)	No. of Trips
Madaraka	With	55.3	32.3	1.88	8:52	2.0
	Without	59.3	31.6	1.71	9:07	2.0
Dandora	With	30.0	14.3	1.33	8:41	2.7
	Without	27.1	20.6	2.10	8:31	3.0

5.12 Economic Aspects of the Work

5.12.1 Total Amount of Waste to be Collected

The total number of trips recorded in the work is 73 from data of the daily logs. Each trip is assumed to carry four (4) tons on average based on the other survey records. Therefore, the total amount of waste to be collected in the Work is estimated at $4 \times 73 = 292$ tons.

5.12.2 Actual Expenditure

(1) Personnel Cost

The planned organisation of the Work comprises three (3) administrative staff, one (1) supervisor, one (1) driver and seven (7) loaders. During the Work period, this number of staff was consistent. The actual expenditure is thus estimated based on the salaries of employees for collection services as follows:

Administrative	:	Kshs.11,055/month
Driver	:	Kshs. 7,610/month
Supervisor	:	Kshs. 5,750/month
Loader	:	Kshs. 4,940/month

The actual operation were carried out for 29 days including Saturday and Sunday which are normal day-offs for employees in NCC. Since the averaged monthly working days are assumed to be 22, the above monthly payment is converted to the following daily basis:

Administrative	:	Kshs.503/day (11,055 ÷ 22)
Driver	:	Kshs.346/day (7,610 ÷ 22)
Supervisor	:	Kshs.261/day (5,750 ÷ 22)
Loader	:	Kshs.225/day (4,940 ÷ 22)

For estimation of the expenditure for the Work, benefits work which are 30% of the above salaries are to be considered. Therefore, the personnel cost for the regular work is calculated as follows:

$$(503 \times 3 + 346 + 261 + 225 \times 7) \times 22 \times 1.30 = \text{Kshs.}105{,}563$$

For overtime job, additional payment which are 30% of the above salaries are also to be considered. Therefore, the personnel cost for the overtime work is calculated as follows:

$$(503 \times 3 + 346 + 261 + 225 \times 7) \times 7 \times 1.30 \times 1.30 = \text{Kshs.}43{,}665$$

The total personnel cost is calculated as follows:

$$105{,}563 + 43{,}665 = \text{Kshs.}149{,}228$$

(2) Overhead Cost

The overhead cost is assumed at ranging from 60% to 100% of the total personnel cost based on the other projects. The overhead cost is calculated as follows:

$$149{,}228 \times 0.60 \sim 1.00 = \text{Kshs.}89{,}537 \sim 149{,}228$$

(3) Vehicle Operation Cost

The vehicle operation cost is composed of fuel and oil cost and maintenance cost. The fuel and oil cost is calculated based on the actual consumption during the Work, and the annual maintenance cost is assumed to be estimated at 3% of the capital cost. The actual consumption is as follows:

Fuel consumption : 28.1 littre/day
Oil consumption : 0.08 littre/day

Price of fuel and oil is assumed to be Kshs.34/littre and Kshs.250/littre, respectively. Thus;

$$28.1 \times 29 \times 34 + 0.08 \times 29 \times 250 = \text{Kshs.}28,287$$

Purchasing a new dump truck whose capacity is 8 ton is assumed to be paid for the capital cost of the Work. Price of the dump truck is assumed at Kshs.3,250,000. The maintenance cost is therefore calculated as follows:

$$3,250,000 \times 0.03 \times 29/365 = \text{Kshs.}7,747$$

(4) Total Cost

The total cost of the above items is calculated as follows:

$$149,228 + (89,537 \sim 149,228) + 28,287 + 7,747 = \text{Kshs.}274,799 \sim 334,490$$

5.12.3 Unit Cost

The unit cost of the experimental collection work is estimated based on the above expenditure as follows:

$$\text{Kshs.}274,799 \sim 334,490 \div 292 = \text{Kshs.}941 \sim 1,146 \cong \text{US\$}16 \sim 20$$

Focusing on operation cost, the unit cost of the proposed collection and transportation system options is about US$20~30. The unit cost of the experimental work is slightly less than those of the proposed one because the proposed options include not only for collection vehicles but also other auxiliary vehicles and facilities, such as inspection cars, recovery trucks, workshop and parking lots. The operation cost of these additional vehicles and facilities results in higher amounts of the unit cost. Apart from these additional operation costs, the unit cost of the experimental work is almost the same as that of the proposed system.

6. DEVELOPMENT OF COLLECTION AND TRANSPORTATION TECHNICAL OPTIONS

6.1 Quantities Required for Each Collection System Option

6.1.1 Container System with Side Loaders, Tippers and Wheel Loaders (Option A-1)

(1) Container Arrangement

The results of the field survey and analysis reveal that there are many locations in the city without waste collection sites so that wastes are thrown away on the roads or in open derelict spaces. These scattered dumping points are to be basically replaced by containers, however, some of the dumping sites cannot be containerized because they either lack the space for installing containers or are inaccessible to container vehicles.

Since the installation of containers is considered to be a key principle of the implementation of the solid waste management (SWM) programme in Nairobi, the Nairobi City Council (NCC) shall have to conduct a more detailed site investigation to check in each of the scheduled container installation sites whether there is space for accommodating the container, whether the road is sufficiently wide for container vehicle access and what the present situation is in terms of waste dumping and collection.

To establish the Master Plan, the number of required containers are determined on the assumption that daily generated amount of solid waste are once stored in installed containers throughout the city.

(2) Vehicle Fleet Composition

Based on the above assumption, the vehicle fleet for waste collection and transportation should have the composition described below. Essentially, waste collection and transportation will take place using containers and for those parts of the waste collection and transportation service which cannot be met by containerization, side loaders and dump trucks (tippers) should be introduced.

The proportion of the three types of vehicles to be used for collection is designed taking into consideration local road conditions as follows:

Container trucks	: 50%
Side loaders	: 30%
Dump trucks (tippers)	: 20%

(a) Detachable Container Trucks

These trucks collect the containers installed in waste dumping locations on roads or on vacant derelict plots. Detachable container trucks can be classified into two categories based on differences in the release mechanism: the arm (or arm roll) and the horizontally moving types.

Although the arm type system has generally a lower unit price than the horizontal detachment system the field survey and analysis has shown that it would be difficult to load the container onto the truck with the arm type system because the roads in the city are very bumpy due to inadequate maintenance. It has also been found that when the existing dumping points are replaced by containers it would be difficult to position the container in such a way as to allow for the loading of the containers onto the truck. For these reasons a horizontally moving container type will be selected. The vehicle specifications will be for a 6-ton ($8m^3$) capacity type in view of the local road width and the spaces available for container installation.

(b) Side Loaders

Side loading type of trucks will be introduced for the collection and transportation of wastes that cannot be collected by container trucks or by station-type collection. Considering the existing dump trucks operated by NCC, medium-type (6-ton) side loaders will be used. These have the same vehicle length and width as the existing dump trucks so that they can negotiate a number of narrow roads that are accessible to the existing dump trucks or unsuitable for the installation of containers.

(c) Dump Trucks (Tippers)

Dump trucks combining use of wheel loaders also will be recommended to cover the areas whose space is not enough for the installation of containers and to clear the heaps of waste along the roadside or open spaces. Considering the existing dump trucks operated by NCC, medium-type (6-ton) dump trucks will be used from the same reason of the above side loaders.

(d) Wheel Loaders

In combination with the above dump trucks, wheel loaders will be employed for loading the waste from the dumping points on the roadside or open spaces. In view of the existing road width and accessibility to the dumping points, medium-type with bucket capacity of 2 cubic meters wheel loaders will be used.

(e) Water Sprinklers

Water sprinkler vehicles will be used for cleaning the dumping points after waste collection and for sprinkling roads in dry conditions when the roads are covered with a large amount of sand and soil. Considering the local road width and spaces as well as ease of procurement, a 8,000 litre capacity sprinkler vehicle is planned.

(f) Inspection Cars

To monitor the daily operation and transport information, tools and equipment for the operation, inspection cars are necessary. As a result of the experimental collection work, a proper and continuous inspection leads to better operation and management of the vehicles and personnel. In view of the present road condition in Nairobi, four-wheel-drive cars are required to go through the area to be inspected. Additionally, some pick-ups for carrying stuff of the work and sedans for administrative job are needed for the inspection.

(g) Recovery Trucks

Currently, some of the collection vehicles are stuck on the roads due to accidents or mechanical problems. These damaged vehicles block the roads and seriously cause heavy traffic. Once those failures occur, there is no way to remove the vehicle from the road at present. Recovery trucks are thus planned to tow the vehicles to a workshop for repair.

(3) Other Necessary Materials and Facilities

To reduce frequent intervals for vehicle maintenance and repair, a small workshop should be constructed in the present depot at Kaloleni. Also, the increase of the number of vehicles requires much more space for parking in the city.

(4) Determination of the Basic Conditions

To roughly estimate the required number of the above vehicles, the basic conditions have been fixed as follows:

(a) Operating Time

The time and motion study were made to establish the standard working hours for the NCC. The findings are that the personnel working in the collection and transportation of waste work an average of approximately 6 hours a day (excluding break for lunch and/or any idling time caused by some trouble). While it has been realised that it might be difficult to change this, the major private collector's performance shows about 8 hours assignment in a day. In addition, the experimental collection work showed that the staff of the collection and transportation operation could work more than 8 hours a day under proper inspection. Therefore, it is recommendable for NCC to assign the collection services for 8 hours a day.

(b) Number of Collection/Transportation Trips

With the introduction of containerization, the working time required for collection would be significantly reduced from the present 1.2 hours to about 10~20 minutes (0.2~0.3 hours) per trip. Since the candidate

disposal site at Ruai area is located 15 km further from the existing dump site at Dandora, the transportation time will be calculated on the assumption that the average transportation speed in suburban areas is 30 km/hr. The additional transportation time is therefore as follows:

$$15 \times 2 \times 60 \div 30 = 60 \text{ minutes} = 1.0 \text{ hours}$$

The present transportation time in making a round-trip to Dandora is from 84 to 91 minutes, i.e., 1.4~1.5 hours on average. As a result, the trip time in case of containerization would be 1.4~1.5 + 1.0 + 0.2~0.3 = 2.6~2.8 hours instead of the current 183~188 minutes, i.e., approximately 3.1 hours. Since there will be 8 working hours in a day, it would be possible to make 8 ÷ 2.6~2.8 = 2.9~3.1, or 3 trips a day on average. For the side loaders, however, it would not be possible to achieve greater efficiency (time saving) for the collection work because the present system will continue to take place. Therefore, the number of trips possible in a day would be the same as the present 2.2 ; that is, 2 trips a day. Finally, the use of dump trucks (tippers) could make the same improvement as much as the container trucks because of assistance of wheel loaders. The number of trips by dump trucks can thus be expected to be 3 trips a day on average.

(c) Container Capacity and Performance

In view of the width of the local roads and the space available for container installation the capacity per container should be 8 m^3. Given that the bulk density (apparent specific gravity) of the waste as determined by site measurements is 0.3 t/m^3, it is possible to calculate the transportation performance per container as follows:

$$8 \times 0.3 = 2.4 \text{ t/each}$$

(d) Side Loader and Dump Truck Capacity and Performance

Site measurements have shown that the existing side loaders and dump trucks have a load-carrying performance of 4 t/each. On the other hand, the maximum load capacity of the proposed new dump trucks is 6 t/each and ordinary performance is assumed at 70% of the maximum, i.e., about 4 t/each, the same as that of the existing one.

(e) Availability

In view of the need for repair in case of breakdowns and maintenance/management and in view of the breaktime for drivers, vehicles and containers could not be operated at 100% of their capacity all the time. Based on the study results for similar projects, the availability factor for vehicles and containers have been set as follows:

Vehicles	: 90%
Containers	: 95%

For the personnel involved in the collection and transportation work, a total of 6-day breaks in a month can be considered because of their holidays and leaves. Thus, the avilability is:

Personnel : 80% (24 ÷ 30 = 0.8; 80%)

(f) Proportion of Waste Amount Collected by Types of Vehicles

NCC collection services would be mainly in middle and low income areas since private collectors cover collection in high income areas. Concerning types of housing in middle and low income areas, flats and housing complex types dominantly exist, and it would be more suitable for those areas to adopt the station collection than door-to-door collection. While it is difficult to estimate accurately how much portion is occupied by each income level in Nairobi, as described in the **Supporting Report Section A** a public health survey shows the following population ratios:

High income	: 23.3%
Middle income	: 26.7%
Low income	: 50.0%

According to the above ratio, middle and low income residents are occupying about 80% of the total population. However, high income people have generally larger lots than middle and low ones and demarcation of different collection systems should be determined based on the areas with whom each income level occupies. Therefore, in the Master Plan the proportion of waste amount collected mainly by station type collection is assumed at 70% of the total amount collected by NCC. The ratio of container trucks and dump trucks with wheel loaders is assumed at 50% and 20%, respectively. The remaining 30% of the total is handled by side loaders.

(g) Design Waste Amount to be Collected

To provide a minimum level of service throughout Nairobi, increased solid waste collection is urgently required. On the assumption that NCC can collect all the solid wastes generated in the city, the target amount of waste can be estimated, considering the effects of the waste reduction plan as described in the **Supporting Report Section G** and the expected private sector involvement (PSI) in **Supporting Report Section D.**

(i) Waste Amount by Reduction

From the waste reduction point of view, the total amount of solid waste by the reduction plan is assumed to gradually increase from 0% at present to 5% in the year 2008. **Table E.6-1** shows the projected ratio of total reduction amount to total generated waste.

Table E.6-1 Projection of Waste Reduction Ratio for SWM in Nairobi

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Ratio (%)	0	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0

(ii) Waste Collected by PSI

The private collection companies are at present collecting about 20% of the total amount of generated solid waste, and it is expected that they will continuously keep up with the existing level of their involvement. As mentioned in **Section D**, therefore, the total collection coverage by private companies which is assumed to be 20% in 2008, would be constant.

(iii) Total Waste Collected by NCC

Considering the above two factors, the total amount of waste collected by NCC is estimated as follows:

Table E.6-2 Projection of Total Waste Amount Collected by NCC

(Unit: ton/day)

Year	Total generation* (1)	Total amount by reduction (2)	Total amount by PSI (3)	Total amount collected by NCC (4) = (1)-(2)-(3)
1998	1,509	0	302	1,207
1999	1,595	8	319	1,268
2000	1,684	17	337	1,330
2001	1,785	27	357	1,401
2002	1,893	38	379	1,477
2003	2,009	50	402	1,557
2004	2,141	64	428	1,649
2005	2,269	79	454	1,736
2006	2,413	97	483	1,834
2007	2,566	115	513	1,937
2008	2,730	137	546	2,048

* Total generation is shown in Table 1.2.3 of the Data Book 1

Based on the above conditions, design waste amount collected by container trucks and dump trucks are calculated as shown in **Table E.6-3**.

Table E.6-3 Waste Amount Designed to be Collected (Option A-1)

(Unit: ton/day)

Year	Total amount collected by NCC (1)	Total amount collected by container trucks (2) = (1)×50%	Total amount collected by side loaders (s) = (1)×30%	Total amount collected by dump trucks (4) = (1)×20%
1998	1,207	604	362	241
1999	1,268	634	380	254
2000	1,330	665	399	266
2001	1,401	701	420	280
2002	1,477	738	443	295
2003	1,557	778	467	311
2004	1,649	824	495	330
2005	1,736	868	521	347
2006	1,834	917	550	367
2007	1,937	969	581	387
2008	2,048	1,024	614	410

(h) Crew Size

Not only the daily waste collection and transportation work but other construction or field operation in Nairobi also necessitates at least one supervisor for smooth implementation. A result of the experimental collection work supports this. In consideration of this matter, composition of crew members depending on the collection vehicle is formulated as follows:

Table E.6-4 Crew Size of the Collection Vehicle

Collection Vehicle	Crew Size
Container truck	1 driver, 2 loaders, 6 sweepers, 1 supervisor and 1 headman for every 15 sweepers
Side loader	1 driver, 6 loaders, 18 sweepers, 1 supervisor and 1 headman for every 15 sweepers
Compactor	1 driver, 6 loaders, 18 sweepers, 1 supervisor and 1 headman for every 15 sweepers
Dump truck (tipper) with manual loading	1 driver, 6 loaders, 18 sweepers, 1 supervisor and 1 headman for every 15 sweepers
Dump truck (tipper) with wheel loader	1 driver and 1 supervisor
Wheel loader	1 driver, 2 loaders, 6 sweepers, 1 supervisor and 1 headman for every 15 sweepers

(5) Calculation of the Required Quantities of Vehicles and Other Facilities

(a) Containers

Under the container arrangement policy and the design waste amount mentioned previously, as of 1998 it will be necessary to provide the following container quantities:

- Total amount of solid waste collected by NCC : 1,207 t/day (refer to **Table E.6-3**)
- Total amount of waste collected by containers : 604 t/day (1,207 t/day × 0.5)
- Total amount of waste collected by side loaders : 362 t/day (1,207 t/day × 0.3)
- Total amount of waste collected by dump trucks : 241 t/day (1,207 t/day × 0.2)

All the containers have to store the above total amount, i.e., 604 t/day. On the other hand, the waste collection is planned to be carried out once a week from the designated communal collection point. Thus,

$$604 \times 7 \div 2.4 = 1{,}761 \text{ containers}$$

are to be installed. If an availability factor of 95% is assumed, the container number required will be 1,761 ÷ 0.95 = 1,853.

(b) Detachable Container Trucks

The frequency of collecting and transporting installed containers depends on how much waste is generated in an area. On average, it is assumed that the NCC has to pick up the containers once a week to provide a minimum level of services throughout the city. Thus,

$$1{,}853 \times 1/7 \text{ (collected once a week)} = 264$$

To transport these on a route of three trips a day, it will be necessary to have:

$$264 \div 3 = 88 \text{ trucks}$$

Assuming an availability factor of 90%, the value would be:

$$88 \div 0.90 = 97.8; \text{ say, } 98$$

(c) Side Loaders

Side loaders will be working 2 trips a day to carry 4 tons per trip. For the handling of the 362 tons of waste generated in a day, it will be necessary to have 362 ÷ (4 × 2) ÷ 0.90 = 50.2; thus, 50 loaders will be required (availability 90%).

(d) Dump Trucks (Tippers)

For the handling of the 241 tons of waste generated in a day, it will be necessary to have 241 ÷ (4 × 3) ÷ 0.90 = 22.3; thus, 22 trucks will be required (availability 90%).

(e) Wheel Loaders

The plan is to use a wheel loader to collect those wastes that cannot be handled by the above container trucks and side loaders when a large amount of waste are dumped on open spaces or street corners. Consequently, the number of wheel loaders is as the same as that of dump trucks: 22 loaders.

(f) Water Sprinklers

Sprinkler vehicles will be required for cleaning collection points after loading waste as well as sprinkling water on the road. This machine portion is assumed to be one water sprinkler for every six wheel loaders. Therefore, the number of water sprinklers is: 22 ÷ 6 = 3.7; say 4. This number already included 90% availability.

(g) Inspection Cars

To monitor the total six districts under the Cleansing Section, 10 four-wheel-drive cars are planned since some of the districts are too large to be covered by only one vehicle. Another 10 pick-ups are employed for transporting some stuff of the work. For administrative work, 2 sedans are additionally planned, and the total number of inspection cars would be 22.

(h) Recovery Trucks

In the initial stage of the Master Plan, the collection and transportation system will be working by using new, procured vehicles. Therefore, it is foreseeable that the breakdown ratio will not be high at least for 5 to 6 years or so. Hence, from the beginning to the year 2003, one recovery truck is planned and one will be added in 2004.

(i) Parking Lots

Collection services in principle will cover all of the city. Therefore, the existing six districts basically are responsible for the whole area in terms of daily collection and transportation work. From operation and maintenance of the vehicles, it is preferable that a parking space for the collection vehicles is to be secured in one location in every district, i.e., 6 parking lots are to be prepared.

(6) Calculation of the Required Manpower

(a) Drivers

The total number of planned vehicles in the year 1998 are:

$$98 + 50 + 22 + 22 + 4 + 22 + 1 = 219$$

This number already included 90% availability. Therefore, the number of actual operating vehicles are to be 219 × 0.9 = 197. Considering 80% availability for the personnel arrangement, the required number of drivers are: 197 ÷ 0.8 = 246.2; say 246.

(b) Loaders

The number of actual operating vehicles required for loaders with 90% of availability are:

Container truck	98.042 × 0.9 = 88.24
Side loader	50.278 × 0.9 = 45.25
Wheel loader	22.315 × 0.9 = 20.08

Based on the crew size as previously shown in **Table E.6-4**, the required number of loaders are calculated depending on the type of vehicles. Thus:

Container truck	88.24 × 2 = 176.48
Side loader	45.25 × 6 = 271.5
Wheel loader	20.08 × 2 = 40.16

The above total have 176.48 + 271.5 +40.16 = 488.14. Therefore, the required number of loaders are: 488.14 ÷ 0.8 = 610.2; say 610 (80% availability).

(c) Sweepers

As in the number of drivers and loaders, the required number of sweepers are calculated depending on the type of vehicles. Thus:

Container truck	88.24 × 6 = 529.44
Side loader	45.25 × 18 = 814.5
Wheel loader	20.08 × 6 = 120.48

The above total have 529.44 + 814.5 +120.48 = 1,464.42. Therefore, the required number of loaders are: 1,464.42 ÷ 0.8 = 1,830.5; say 1,831 (80% availability).

(d) Supervisors

Each crew needs one supervisor. The number of actual operating vehicles required for supervisors with 90% of availability are:

Container truck	98.042 × 0.9 = 88.24
Side loader	50.278 × 0.9 = 45.25
Dump truck	22.315 × 0.9 = 20.08
Wheel loader	22.315 × 0.9 = 20.08

The above total have 88.24 + 45.25 + 20.08 + 20.08 = 173.65. Therefore, the required number of loaders are: 173.65 ÷ 0.8 = 217.1; say 217 (80% availability).

(e) Headman

A headman is appointed every 15 sweepers. The total number of sweepers are 1,831, and therefore the required number of headman is 1,831 ÷ 15 = 122.1; say 122. This number already included 80% availability.

For the other year's cases, the same procedures above result in the required quantities, and the results are given in **Table E.6-5** below.

Table E.6-5 Vehicles, Equipment and Manpower Required for Option A-1

No	Items	Quantity										
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1	Detachable-container truck	98	103	108	114	120	126	134	141	149	157	166
2	Container	1853	1947	2042	2151	2267	2390	2531	2665	2815	2974	3143
3	Side loader	50	53	55	58	62	65	69	72	76	81	85
4	Dump truck	22	23	25	26	27	29	31	32	34	36	38
5	Wheel loader	22	23	25	26	27	29	31	32	34	36	38
6	Water sprinkler	4	4	4	4	5	5	5	5	6	6	6
7	Inspection car	22	22	22	22	22	22	22	22	22	22	22
8	Recovery truck	1	1	1	1	1	1	2	2	2	2	2
9	Parking lots	6	6	6	6	6	6	6	6	6	6	6
10	Driver	246	257	269	282	296	310	327	343	361	380	400
11	Loader	610	641	673	709	747	787	834	878	927	980	1035
12	Sweeper	1831	1924	2018	2126	2240	2362	2501	2633	2782	2939	3106
13	Supervisor	217	228	239	252	266	280	297	312	330	349	368
14	Headman	122	128	135	142	149	157	167	176	185	196	207

6.1.2 Dump Truck (Tipper) System with Wheel Loaders (Option A-2)

(1) Vehicle Fleet Composition

Dump trucks or tippers with wheel loaders would be the main system in this option to collect the waste from the communal points. Side loader type of vehicles are also employed for the areas that cannot be covered by the dump trucks, and combination of the two kinds of vehicles can effectively work well.

The same specifications of the vehicles, namely, dump trucks, side loaders, wheel loaders, water sprinklers, inspection cars and recovery trucks in **Option A-1** will be adopted.

(2) Other Necessary Materials and Facilities

As in **Option A-1**, it is necessary to build a new small workshop for the acceleration of maintenance and repair work. Also, additional parking lots are required to cope with the increase of number of vehicles.

(3) Determination of the Basic Conditions

The following describes the basic conditions to determine the required number of the above vehicles. However, the description is made only for new items, i.e., proportion of waste amount collected by the above vehicles.

(a) Proportion of Waste Amount Collected by Types of Vehicles

Since a dump truck can be easily loaded with almost any size and type of waste and applicable for any road and location, 70% of the total waste amount, which is equivalent to the amount collected by both container trucks and dump trucks in the previous option, would be suitable for collection by using dump trucks only instead of container trucks. The remaining 30% is the portion for side loaders.

(b) Designed Waste Amount to be Collected

Based on the above conditions, design waste amount collected by dump trucks and side loaders is calculated as shown in **Table E.6-6.**

Table E.6-6 Waste Amount Designed to be Collected (Option A-2)

(Unit: ton/day)

Year	Total amount collected by NCC (1)	Total amount collected by dump trucks (2) = (1)×70%	Total amount collected by side loaders (3) = (1)×30%
1998	1,207	845	362
1999	1,268	888	380
2000	1,330	931	399
2001	1,401	981	420
2002	1,477	1,034	443
2003	1,557	1,090	467
2004	1,649	1,154	495
2005	1,736	1,215	521
2006	1,834	1,284	550
2007	1,937	1,356	581
2008	2,048	1,433	614

(4) Calculation of the Required Quantities of Vehicles and Other Facilities

(a) Dump Trucks (Tippers)

From the preceding **Table E.6-6**, as of 1998 it will be necessary to provide the following vehicle quantities.

- Total amount of solid waste collected by NCC : 1,207 t/day (refer to **Table E.6-6**)
- Total amount of waste collected by dump trucks : 845 t/day (1,207 t/day × 0.7)
- Total amount of waste collected by dump trucks : 362 t/day (1,207 t/day × 0.3)

All the dump trucks are required to collect and transport the above total amount, i.e., 845 t/day. Thus,

$$845 \div (4 \times 3) = 70 \text{ trucks}$$

are to be procured. If an availability factor of 90% is assumed, the dump truck number required will be $70 \div 0.90 = 77.7$; say 78.

(b) Side Loaders

For the handling of the 362 tons of waste generated in a day, it will be necessary to have $362 \div (4 \times 2) \div 0.90 = 50.3$; thus, 50 loaders will be required (availability 90%).

(c) Wheel Loaders

As described previously, wheel loaders are used for handling a large amount of waste dumped on open spaces or street corners and loading into the dump trucks for transport. Thus, the number of required wheel loaders is the same as the number of dump trucks; that is 78.

(d) Water Sprinklers

The same proportion to the number of wheel loaders is assumed to be planned, i.e., $78 \div 6 = 13$. 13 water sprinklers are to be procured.

(e) Inspection Cars

The same number of vehicles as the preceding option is assumed to be planned, i.e., 22 inspection cars are to be prepared.

(f) Recovery Trucks

The same number of vehicles as the preceding option is assumed to be planned, i.e., 1 recovery truck is to be prepared from 1998 to 2003, and one will be added from 2004.

(g) Parking Lots

Although the total number of required vehicles is increased about 110% as much as the previous option, the existing six districts basically are responsible for all collection and transportation vehicles. In this sense, a parking space for the collection vehicles will be required to be secured in one location for every district, i.e., 6 parking lots are to be prepared.

(5) Calculation of the Required Manpower

Basic conditions to estimate the required personnel for collection and transportation are the same as **Option A-1**.

For other years, the same procedure as above would result in required quantities as given in **Table E.6-7**.

Table E.6-7 Vehicles, Equipment and Manpower Required for Option A-2

No	Items	Quantity										
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1	Dump truck	78	82	86	91	96	101	107	113	119	126	133
2	Wheel loader	78	82	86	91	96	101	107	113	119	126	133
3	Side loader	50	53	55	58	62	65	69	72	76	81	85
4	Water sprinkler	13	14	14	15	16	17	18	19	20	21	22
5	Inspection car	22	22	22	22	22	22	22	22	22	22	22
6	Recovery truck	1	1	1	1	1	1	2	2	2	2	2
7	Parking lots	6	6	6	6	6	6	6	6	6	6	6
8	Driver	272	285	297	312	327	344	362	380	400	422	444
9	Loader	516	542	568	598	631	665	704	741	783	827	874
10	Sweeper	1547	1625	1705	1795	1892	1995	2112	2224	2350	2482	2623
11	Supervisor	233	244	256	270	285	300	318	335	353	373	395
12	Headman	103	108	114	120	126	133	141	148	157	165	175

6.1.3 Dump Truck (Tipper) System with Manual Loading (Option A-3)

(1) Vehicle Fleet Composition

Main system of this option is worked out by using dump trucks (tippers) but collection workers, specifically loaders collect household waste on door-to-door basis and load the waste into the dump truck manually. This collection method is very common in Nairobi at present. The dump truck collection with wheel loaders and side loader collection are also used to supplement the main system. Other subsystem vehicles, i.e., sprinklers, inspection cars and recovery trucks are required as in **Options A-1** and **A-2.**

The same specifications as the vehicles in **Options A-1** and **A-2**, namely, dump trucks, side loaders, wheel loaders, water sprinklers, inspection cars and recovery trucks, are adopted.

(2) Other Necessary Materials and Facilities

The new small workshop at Kaloleni and parking lots for increase of the number of vehicles are required as in **Options A-1** and **A-2.**

(3) Determination of the Basic Conditions

(a) Number of Collection/Transportation Trips

As the experimental collection work and the ordinary work clearly show, it takes a quite long time to load wastes manually. The number of trips possible in a day would be the same as the present level, i.e., 2 trips a day when the system of dump trucks with manual loading is applied.

(b) Proportion of Waste Amount Collected by Vehicle Type

The system of dump trucks with manual loading is adopted instead of containers in this option. This means that 50% of the total waste amount which is equivalent to the amount collected by container trucks in **Option A-1** would be suitable for collection by dump trucks with manual loading. As for 20% of the total, the dump trucks with wheel

loaders is employed for loading waste from dumping points on the roadside or open spaces as well. The remaining 30% is the portion for side loaders.

(c) Waste Amount Designed to be Collected

Based on the above conditions, waste amount designed to be collected by compactors and dump trucks is calculated as shown in **Table E.6-8**.

Table E.6-8 Waste Amount Designed to be Collected (Option A-3)

(Unit: ton/day)

Year	Total amount collected by NCC (1)	Total amount collected by dump trucks with manual loading (2) = (1)×50%	Total amount collected by dump trucks with wheel loaders (3) = (1)×20%	Total amount collected by side loaders (4) = (1)×30%
1998	1,207	604	241	362
1999	1,268	634	254	380
2000	1,330	665	266	399
2001	1,401	701	280	420
2002	1,477	738	295	443
2003	1,557	778	311	467
2004	1,649	824	330	495
2005	1,736	868	347	521
2006	1,834	917	367	550
2007	1,937	969	387	581
2008	2,048	1,024	410	614

(4) Calculation of the Required Quantities of Vehicles and Other Facilities

(a) Dump Trucks (Tippers)

From the preceding **Table E.6-8**, as of 1998 it will be necessary to provide the following vehicle quantities:

- Total amount of solid waste collected by NCC : 1,207 t/day (refer to **Table E.6-8**)
- Total amount of waste collected by dump trucks with manual loading : 604 t/day (1,207 t/day × 0.5)
- Total amount of waste collected by dump trucks with wheel loaders : 241 t/day (1,207 t/day × 0.2)
- Total amount of waste collected by side loaders : 362 t/day (1,207 t/day × 0.3)

The dump trucks with manual loading are required to collect and transport the above total amount, i.e., 604 t/day. Thus,

$$604 \div (4 \times 2) = 76 \text{ trucks}$$

are to be procured. If an availability factor of 90% is assumed, the dump truck number required will be $76 \div 0.90 = 84.4$; say 84.

On the other hand, the waste amount for the dump truck with wheel loaders is 241 t/day. The required number of trucks are calculated, considering 90% availability, at $241 \div (4 \times 3) \div 0.90 = 22.3$; say 22.

In conclusion, the total number of dump trucks is $84 + 22 = 106$.

(b) Side Loaders

The same number of loaders as required in the previous options is assumed to be planned, i.e., 50 loaders will be prepared (availability 90%).

(c) Wheel Loaders

Excluding the number of dump trucks with manual loading, the number of required wheel loaders is estimated to be the same as the number of dump trucks which are used with wheel loaders; that is 22.

(d) Water Sprinklers

The same proportion to the number of wheel loaders is assumed to be planned, i.e., $22 \div 6 = 3.6$; thus, 4 water sprinklers are to be procured.

(e) Inspection Cars

The same number of vehicles as the preceding options is assumed to be planned, i.e., 22 inspection cars are to be prepared.

(f) Recovery Trucks

The same number of vehicles as the preceding options is assumed to be planned, i.e., 1 recovery truck is to be prepared from 1998 to 2003, and one will be added from 2004.

(g) Parking Lots

The same number of parking lots as the preceding options is assumed to be planned, i.e., 6 parking lots are to be prepared.

(5) Calculation of the Required Manpower

Basic conditions to estimate the required personnel for collection and transportation are the same as **Options A-1** and **A-2**.

For other years, the same procedure as above would result in required quantities as given in **Table E.6-9**.

Table E.6-9 Vehicles, Equipment and Manpower Required for Option A-3

No	Items	Quantity										
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1	Dump truck	106	112	117	123	130	137	145	153	161	170	180
2	Wheel loader	22	23	25	26	27	29	31	32	34	36	38
3	Side loader	50	53	55	58	62	65	69	72	76	81	85
4	Water sprinkler	4	4	4	4	5	5	5	5	6	6	6
5	Inspection car	22	22	22	22	22	22	22	22	22	22	22
6	Recovery truck	1	1	1	1	1	1	2	2	2	2	2
7	Parking lots	6	6	6	6	6	6	6	6	6	6	6
8	Driver	230	240	251	263	276	290	305	320	337	354	373
9	Loader	1326	1346	1367	1390	1415	1442	1472	1500	1533	1566	1602
10	Sweeper	2867	3012	3160	3328	3507	3698	3915	4122	4355	4601	4863
11	Supervisor	201	211	222	234	246	259	275	289	306	323	341
12	Headman	191	201	211	222	234	247	261	275	290	307	324

6.1.4 Compactor System with Side Loaders, Tippers and Wheel Loaders (Option A-4)

(1) Vehicle Fleet Composition

Dump trucks or compaction-type vehicles (compactor trucks) can be employed for the door-to-door collection system. Although some difficulties exist to introduce compaction-type vehicles due to many bumps and dents on the roads in Nairobi, compactor trucks are one of the options for the door-to-door collection system. Side loaders will be used additionally for areas that cannot be covered by dump trucks and compactors. In view of efficiency of operation depending on housing type, the combination of the three kinds of vehicles may effectively work well.

(a) Compactor Trucks

Taking into account present road width and the spaces, a vehicle of 6-ton ($8m^3$) capacity is recommended.

(b) Dump Trucks (Tippers)

The same specifications as the previous options are adopted.

(c) Side Loaders

The same specifications as in the previous options will be adopted.

(d) Wheel Loaders

The same specifications as in the previous options are adopted.

(e) Water Sprinklers

The same specifications as in the previous options are adopted.

(f) Inspection Cars

The same specifications as in the previous options are adopted.

(2) Other Necessary Materials and Facilities

The new small workshop at Kaloleni and parking lots for increase of the number of vehicles are also required as in the preceding options.

(3) Determination of the Basic Conditions

The following describes the basic conditions to determine the required number of the above vehicles. However, the description is made only for new items, such as compactors.

(a) Number of Collection/Transportation Trips

Compared with the introduction of containerization, it would not be possible to achieve greater efficiency (time saving) for the door-to-door collection work so that the number of trips possible in a day would be the same as the present 2.2 ; that is, 2 trips a day.

(b) Compactor Capacity and Performance

The maximum load capacity of the proposed new compactor trucks is 6 t/each and ordinary performance is assumed at 70% of the maximum, i.e., about 4 t/each, the same as that of the existing and proposed dump truck.

(c) Proportion of Waste Amount Collected by Types of Vehicles

Based on the introduction of the door-to-door collection, main collection vehicles would be compactors. Instead of the use of the containers, 50% of total waste amount is proposed to be handled by compactors. The remaining 30% and 20% is the portion for side loaders and dump trucks, respectively.

(d) Waste Amount Designed to be Collected

Based on the above conditions, design waste amount collected by compactors and dump trucks is calculated as shown in **Table E.6-10.**

Table E.6-10 Waste Amount Designed to be Collected (Option A-4)

(Unit: ton/day)

Year	Total amount collected by NCC (1)	Total amount collected by compactors (2) = (1)×50%	Total amount collected by dump trucks (3) = (1)×20%	Total amount collected by side loaders (4) = (1)×30%
1998	1,207	604	241	362
1999	1,268	634	254	380
2000	1,330	665	266	399
2001	1,401	701	280	420
2002	1,477	738	295	443
2003	1,557	778	311	467
2004	1,649	824	330	495
2005	1,736	868	347	521
2006	1,834	917	367	550
2007	1,937	969	387	581
2008	2,048	1,024	410	614

(4) Calculation of the Required Quantities of Vehicles and Other Facilities

(a) Compactor Trucks

From the preceding **Table E.6-10**, as of 1998 it will be necessary to provide the following vehicle quantities.

- Total amount of solid waste collected by NCC : 1,207 t/day (refer to **Table E.6-10**)
- Total amount of waste collected by compactors : 604 t/day (1,207 t/day × 0.5)
- Total amount of waste collected by dump trucks : 241 t/day (1,207 t/day × 0.2)
- Total amount of waste collected by side loaders : 362 t/day (1,207 t/day × 0.3)

The compactors are required to collect and transport the above total amount, i.e., 604 t/day. Thus,

$$604 \div (4 \times 2) = 76 \text{ trucks}$$

are to be procured. If an availability factor of 90% is assumed, the compactor number required will be 76 ÷ 0.90 = 84.4; say 84.

(b) Dump Trucks (Tippers)

For the handling of the 241 tons of waste generated in a day, it will be necessary to have 241 ÷ (4 × 3) ÷ 0.90 = 22.3; thus, 22 trucks will be required (availability 90%).

(c) Side Loaders

The same number of loaders required as the previous options is assumed to be planned, i.e., 50 loaders will be prepared (availability 90%).

(d) Wheel Loaders

The number of required wheel loaders is estimated to be the same as the number of dump trucks; that is 22.

(e) Water Sprinklers

The same proportion to the number of wheel loaders is assumed to be planned, i.e., 22 ÷ 6 = 3.6; thus, 4 water sprinklers are to be procured.

(f) Inspection Cars

The same number of vehicles as the preceding options is assumed to be planned, i.e., 22 inspection cars are to be prepared.

(g) Recovery Trucks

The same number of vehicles as the preceding options is assumed to be planned, i.e., 1 recovery truck is to be prepared from 1998 to 2003, and one will be added from 2004.

(h) Parking Lots

The same number of parking lots as the preceding options is assumed to be planned, i.e., 6 parking lots are to be prepared.

(5) Calculation of the Required Manpower

Basic conditions to estimate the required personnel for collection and transportation are the same as the preceding options.

For other years, the same procedures above would result in required quantities as given in **Table E.6-11**.

Table E.6-11 Vehicles, Equipment and Manpower Required for Option A-4

No	Items	Quantity										
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1	Compactor	84	88	92	97	103	108	114	121	127	135	142
2	Dump truck	22	23	25	26	27	29	31	32	34	36	38
3	Wheel loader	22	23	25	26	27	29	31	32	34	36	38
4	Side loader	50	53	55	58	62	65	69	72	76	81	85
5	Water sprinkler	4	4	4	4	5	5	5	5	6	6	6
6	Inspection car	22	22	22	22	22	22	22	22	22	22	22
7	Recovery truck	1	1	1	1	1	1	2	2	2	2	2
8	Parking lots	6	6	6	6	6	6	6	6	6	6	6
9	Driver	230	240	251	263	276	290	305	320	337	354	373
10	Loader	1326	1346	1367	1390	1415	1442	1472	1500	1533	1566	1602
11	Sweeper	2867	3012	3160	3328	3507	3698	3915	4122	4355	4601	4863
12	Supervisor	201	211	222	234	246	259	275	289	306	323	341
13	Headman	191	201	211	222	234	247	261	275	290	307	324

6.2 Quantities Required for Each Transportation System Option

6.2.1 Final Disposal Site at Ruai and Ngong Road Forest Area (Option B-1)

(1) Vehicle Fleet Composition

If the final disposal site is constructed in the two areas, i.e., Ruai and Ngong Road Forest, collected solid waste will be transported to the two sites separately. Since the two areas lie in both east and west side of the city, the average transportation distance from collection points on the one side to the disposal site of the same side is less than 20 km. This indicates that transfer stations are not necessary in this option because construction of a transfer station, in general, is feasible only when the distance is over 20 km. Based on the location boundary and distance to the disposal site, the collection area for the two candidate final disposal sites is designed as shown in **Figure E.6-1**.

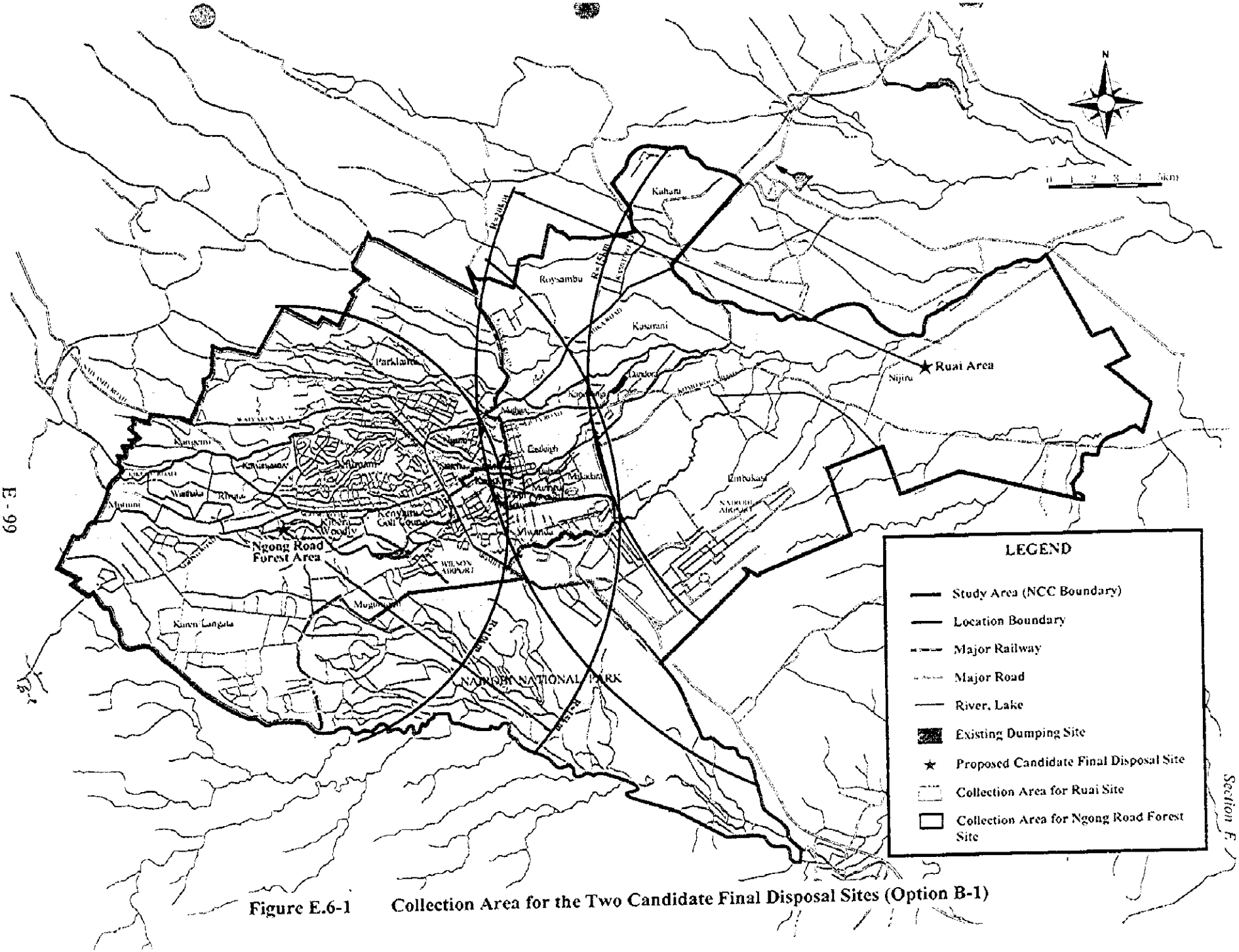


Figure E.6-1 Collection Area for the Two Candidate Final Disposal Sites (Option B-1)

Vehicle fleet composition for transporting waste in **Option B-1** is the same as in **Option A-1** of the collection system; that is, container trucks are used for the main system and the subsystem comprises side loaders, dump trucks and wheel loaders.

(a) Detachable Container Trucks

Same as **Option A-1**: a 6-ton ($8m^3$) capacity type.

(b) Dump Trucks (Tippers)

Same as the preceding options: a 6-ton ($8\ m^3$) capacity type.

(c) Wheel Loaders

Same as the preceding options: a medium-type with bucket capacity of 2 m3.

(d) Water Sprinklers

Same as the preceding options: 8,000 litre capacity of water tank.

(e) Inspection Cars

Same as the preceding options: three types, specifically 4-wheel drive, pick-ups and sedans.

(2) Other Necessary Materials and Facilities

Same as the preceding options: a small workshop and parking lots.

(3) Determination of the Basic Conditions

The following describes the basic conditions to determine the required number of the above vehicles.

(a) Number of Collection/Transportation Trips

The two disposal sites, east and west, can make the number of trips for the waste collection greatly increased. The number of trips for collection and transportation is estimated as follows:

As estimated for the working time with the introduction of containerization in **Option A-1**, the time for collection would be 10 to 20 minutes (0.2~0.3 hours) per trip. As shown in **Figure E.6-1**, the candidate final disposal sites at the Ngong Road Forest area is assumed to be located at the centre of a circle whose radius is about 10 km. Considering 50% additional distance due to a detour and/or runabout by the vehicle, the average transportation distance per trip to the Ngong site would be (10×2) × 1.5 = 30 km. According to the time and motion study, the average transportation speed is at about 20 km/hour.

Therefore, the transportation time in making a round-trip to the Ngong site is 30 ÷ 20 = 1.5 hours. As a result, the trip time for container trucks would be 1.5 + 0.2~0.3 = 1.7~1.8 hours. Since the daily working hours are assumed to be 8 hours, it would be possible to make 8 ÷ 1.7~1.8 = 4.7~4.4, or 4.5 trips a day on average. Since almost the same efficiency will be expected to use the dump trucks with wheel loaders, the average trip time for dump trucks could be 4.5 trips.

The results of the time and motion study shows that the present average transportation distance is approximately 40 km. If the final disposal site is constructed in the Ngong, the transportation distance would be 30 km which is 10 km less than that at present. This will reduce the time for transportation of 10 ÷ 20 = 0.5 hour. Accordingly, the total trip time for side loaders will thus reduce from the existing 3 hours to 2.5 hours; if the the daily working hours are 8 hours, 3.5 trips will be made on average.

On the other hand, if the final disposal site is constructed in the Ruai area, most collection areas to be covered by Ruai lies between 15 and 20 km form the site. Therefore, the average transportation distance per trip would be (15~20 × 2) × 1.5 = 45~60 km considering 50% additional distance due to a detour and/or runabout by the vehicle. Consequently, the transportation time in making a round-trip to Ruai site is 45~60 ÷ 20 = 2.3~3.0 hours. As a result, the trip time for container trucks would be 2.3~3.0 + 0.2~0.3 = 2.5~3.3 hours. Since the daily working hours are assumed to be 8 hours, it would be possible to make 8 ÷ 2.5~3.3 = 2.4~3.2, or 3 trips a day on average. Since almost the same efficiency will be expected to use the dump trucks with wheel loaders, the average trip time for dump trucks could be 3 trips.

As a result of the time and motion study, the average collection time was recorded at about 1.3 hours. The transportation time is estimated at 2.3~3.0 hours; therefore, the trip time for side loaders would be 2.3~3.0 + 1.3 = 3.6~4.3 hours. Thus, it would be possible to make 8 ÷ 3.6~4.3 = 1.8~2.2, or 2 trips a day on average.

(b) Container Capacity and Performance

Same as **Option A-1**: 2.4 t/each

(c) Proportion of Waste Amount Collected by Types of Vehicles

The proportion of waste amount to be collected by each type of trucks does not depend on the location of final disposal sites so that the distribution is the same as **Option A-1** as follows:

Container trucks	: 50%
Side loaders	: 30%
Dump trucks (tippers)	: 20%

(d) Proportion of Waste Amount Transported to Ruai and Ngong Road Forest Sites

Based on the demarcation as shown in **Figure E.6-1**, the proportion of waste amount to be transported to Ruai area and Ngong Road Forest area is estimated as presented below. Details are shown in **Section 5.5** of **Data Book (1).**

Table E.6-12 Proportion of Waste Amount Transported to Ruai and Ngong Road Forest Sites (Option B-1)

(Unit: ton/day)

Year	Total amount collected by NCC (1)= (2)+(3)	Total amount transported to Ruai (2)	Total amount transported to Ngong (3)
1998	1,207	622	585
1999	1,268	657	611
2000	1,330	693	638
2001	1,401	728	673
2002	1,477	764	713
2003	1,557	801	756
2004	1,649	849	800
2005	1,736	889	847
2006	1,834	939	895
2007	1,937	988	949
2008	2,048	1,042	1,006

(e) Design Waste Amount to be Collected

Based on the above conditions, design waste amount collected by container trucks, side loaders and dump trucks is calculated as shown in **Tables E.6-13** and **E.6-14.**

Table E.6-13 Waste Amount Designed to be Collected (To Ruai, Option B-1)

(Unit: ton/day)

Year	Total amount transported to Ruai (1)	Total amount collected by compactors (2) = (1)×50%	Total amount collected by side loaders (3) = (1)×30%	Total amount collected by dump trucks (4) = (1)×20%
1998	622	311	187	124
1999	657	328	197	131
2000	693	346	208	139
2001	728	364	219	146
2002	764	382	229	153
2003	801	401	240	160
2004	849	424	255	170
2005	889	444	267	178
2006	939	469	282	188
2007	988	494	296	198
2008	1,042	521	313	208

Table E.6-14 Waste Amount Designed to be Collected (To Ngong, Option B-1)

(Unit: ton/day)

Year	Total amount transported to Ngong (1)	Total amount collected by compactors (2) = (1)×50%	Total amount collected by side loaders (3) = (1)×30%	Total amount collected by dump trucks (4) = (1)×20%
1998	585	292	175	117
1999	611	306	183	122
2000	638	319	191	128
2001	673	336	202	135
2002	713	356	214	143
2003	756	378	227	151
2004	800	400	240	160
2005	847	423	254	169
2006	895	448	269	179
2007	949	475	285	190
2008	1,006	503	302	201

(4) Calculation of the Required Quantities of Vehicles and Other Facilities

(a) Containers

Under the container arrangement policy and the design waste amount mentioned previously, as of 1998 it will be necessary to provide the following container quantities:

(i) Ruai Site

- Total amount of solid waste transported to Ruai (refer to **Table E.6-13**) : 622 t/day
- Total amount of waste collected by containers (622 t/day × 0.5) : 311 t/day
- Total amount of waste collected by side loaders (622 t/day × 0.3) : 187 t/day
- Total amount of waste collected by dump trucks (622 t/day × 0.2) : 124 t/day

All the containers have to store the above total amount, i.e., 311 t/day. On the other hand, the waste collection is planned to be carried out once a week from the designated communal collection point. Thus,

$$311 \times 7 \div 2.4 = 907 \text{ containers}$$

are to be installed. If an availability factor of 95% is assumed, the container number required will be 907 ÷ 0.95 = 955.

(ii) **Ngong Road Forest Site**

- Total amount of solid waste transported to Ngong (refer to **Table E.6-14**) : 585 t/day
- Total amount of waste collected by containers (585 t/day × 0.5) : 292 t/day
- Total amount of waste collected by side loaders (585 t/day × 0.3) : 175 t/day
- Total amount of waste collected by dump trucks (585 t/day × 0.2) : 117 t/day

The same calculation is adopted; that is, 292.5 × 7 ÷ 2.4 = 853 containers. Consequently, If an availability factor of 95% is assumed, the container number required will be 853 ÷ 0.95 = 898.

(b) Detachable Container Trucks

It is assumed that the NCC has to pick up the containers once a week to provide a minimum level of services throughout the city, and the number of trips is planned to be 3 for Ruai and 4.5 for Ngong in a day. Thus,

for Ruai site:

$$955 \times 1/7 \text{ (collected once a week)} \div 3 \text{ (three trips a day)} = 45.5$$

for Ngong site:

$$898 \times 1/7 \text{ (collected once a week)} \div 4.5 \text{ (four point five trips a day)} = 28.5$$

In addition, it will be necessary to have the following on the assumption of an availability factor of 90%.

Ruai site: 45.5 ÷ 0.90 = 51 trucks
Ngong site: 28.5 ÷ 0.90 = 32 trucks

The total required number of trucks for collection is therefore:

$$51 + 32 = 83$$

(c) Side Loaders

Side loaders will be working 2 trips a day for Ruai and 3.5 trips a day for Ngong to carry 4 tons per trip. For the handling of the 187 tons of waste generated in a day for Ruai and 175 tons per day for Ngong, it will be necessary to have:

Ruai site: 187 ÷ (2.0 × 4) ÷ 0.90 = 26 loaders
Ngong site: 175 ÷ (3.5 × 4) ÷ 0.90 = 14 loaders

The above considered an availability factor of 90%. The total required number of trucks is therefore:

$$26 + 14 = 40$$

(d) Dump Trucks (Tippers)

For the handling of the 124 tons of waste for Ruai and 117 tons for Ngong in a day, it will be necessary to have the following:

Ruai site: $124 \div (3 \times 4) \div 0.90 = 11.5$; thus, 12 trucks will be required (availability 90%).

Ngong site: $117 \div (4.5 \times 4) \div 0.90 = 7.2$; thus, 7 trucks will be required (availability 90%).

The total required number of trucks is therefore:

$$12 + 7 = 19$$

(e) Wheel Loaders

As in the preceding collection system options, this machine portion is assumed to be of the same number as the dump trucks because a combination of a truck and a loader will enhance to a great extent the efficiency of carrying the waste. Consequently, the number of wheel loaders is 19. This number already includes 90% availability.

(f) Water Sprinklers

The same proportion to the number of wheel loaders is assumed to be planned, i.e., $19 \div 6 = 3.2$. Three (3) water sprinklers are to be procured.

(g) Inspection Cars

The same number of vehicles as the preceding option is assumed to be planned, i.e., 22 inspection cars are to be prepared.

(h) Recovery Trucks

The same number of vehicles as the preceding option is assumed to be planned, i.e., 1 recovery truck is to be prepared from 1998 to 2003, and one will be added from 2004.

(i) Parking Lots

A parking space for the collection vehicles will be required to be secured in one location for every district, i.e., 6 parking lots are to be prepared.

(5) Calculation of the Required Manpower

Basic conditions to estimate the required personnel for collection and transportation are the same as **Option A-1**.

For other year, the same procedures above would result in required quantities as given in **Table E.6-15**.

Table E.6-15 Vehicles, Equipment and Manpower Required for Option B-1

No	Items	Quantity										
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1	Detachable-container truck	83	86	91	95	101	106	112	118	124	131	139
	(Ruai)	(51)	(53)	(56)	(59)	(62)	(65)	(69)	(72)	(76)	(80)	(85)
	(Ngong)	(32)	(33)	(35)	(36)	(39)	(41)	(43)	(46)	(48)	(51)	(54)
2	Container	1853	1946	2043	2151	2266	2390	2531	2665	2815	2974	3143
	(Ruai)	(955)	(1008)	(1064)	(1118)	(1172)	(1230)	(1303)	(1365)	(1441)	(1517)	(1599)
	(Ngong)	(898)	(938)	(979)	(1033)	(1094)	(1160)	(1228)	(1300)	(1374)	(1457)	(1544)
3	Side loader	40	42	44	46	49	51	54	57	60	64	67
	(Ruai)	(26)	(27)	(29)	(30)	(32)	(33)	(35)	(37)	(39)	(41)	(43)
	(Ngong)	(14)	(15)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(23)	(24)
4	Dump truck	19	20	21	21	23	24	26	26	28	30	31
	(Ruai)	(12)	(12)	(13)	(13)	(14)	(15)	(16)	(16)	(17)	(18)	(19)
	(Ngong)	(7)	(8)	(8)	(8)	(9)	(9)	(10)	(10)	(11)	(12)	(12)
5	Wheel loader	19	20	21	21	23	24	26	26	28	30	31
	(Ruai)	(12)	(12)	(13)	(13)	(14)	(15)	(16)	(16)	(17)	(18)	(19)
	(Ngong)	(7)	(8)	(8)	(8)	(9)	(9)	(10)	(10)	(11)	(12)	(12)
6	Water sprinkler	3	3	3	3	3	4	5	5	5	5	5
	(Ruai)	(2)	(2)	(2)	(2)	(2)	(2)	(3)	(3)	(3)	(3)	(3)
	(Ngong)	(1)	(1)	(1)	(1)	(1)	(2)	(2)	(2)	(2)	(2)	(2)
7	Inspection car	22	22	22	22	22	22	22	22	22	22	22
	(Ruai)	(11)	(11)	(11)	(11)	(11)	(11)	(11)	(11)	(11)	(11)	(11)
	(Ngong)	(11)	(11)	(11)	(11)	(11)	(11)	(11)	(11)	(11)	(11)	(11)
8	Recovery truck	1	1	1	1	1	1	2	2	2	2	2
	(Ruai)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
	(Ngong)	(0)	(0)	(0)	(0)	(0)	(0)	(1)	(1)	(1)	(1)	(1)
9	Parking lots	6	6	6	6	6	6	6	6	6	6	6
	(Ruai)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
	(Ngong)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
10	Driver	208	217	226	238	248	260	275	287	303	318	334
	(Ruai)	(127)	(133)	(139)	(146)	(152)	(159)	(168)	(175)	(185)	(194)	(203)
	(Ngong)	(81)	(84)	(87)	(92)	(96)	(101)	(107)	(112)	(118)	(124)	(131)
11	Loader	496	522	548	577	607	639	677	713	753	795	839
	(Ruai)	(315)	(332)	(350)	(368)	(386)	(405)	(429)	(450)	(475)	(500)	(527)
	(Ngong)	(181)	(190)	(198)	(209)	(221)	(234)	(248)	(263)	(278)	(295)	(312)
12	Sweeper	624	651	680	713	746	782	824	862	908	953	1003
	(Ruai)	(380)	(398)	(418)	(438)	(457)	(478)	(504)	(526)	(554)	(581)	(610)
	(Ngong)	(244)	(253)	(262)	(275)	(289)	(304)	(320)	(336)	(354)	(372)	(393)
13	Supervisor	180	189	199	209	219	231	245	258	272	288	303
	(Ruai)	(112)	(118)	(125)	(131)	(137)	(144)	(153)	(160)	(169)	(178)	(187)
	(Ngong)	(68)	(71)	(74)	(78)	(82)	(87)	(92)	(98)	(103)	(110)	(116)
14	Headman	41	44	45	47	49	52	55	57	61	64	67
	(Ruai)	(25)	(27)	(28)	(29)	(30)	(32)	(34)	(35)	(37)	(39)	(41)
	(Ngong)	(16)	(17)	(17)	(18)	(19)	(20)	(21)	(22)	(24)	(25)	(26)

6.2.2 Final Disposal Site at Ruai Area Only with a Transfer Station (Option B-2)

(1) Location of Transfer Station

It is preferred that transfer stations are located in the most convenient places of access from anywhere in the city and haul the waste to the disposal site. The city centre is recommendable from this perspective; however, it might be extremely difficult to secure land for the transfer station in this area due to rapid urbanization. In addition, much more careful consideration on the surrounding environment will be required if the station is near the city centre.

Since Madaraka or Kariobangi area is thought to be a candidate transfer station in the city by NCC, indirect transportation options will be developed based on these areas for the transfer station.

For planning purposes, the site for the transfer station will be considered to be an area which is shown in **Figure E.6-2**. Although the specific site has not been decided yet, the proposed site within the area would be the same conditions to construct the transfer station.

(2) Vehicle Fleet Composition

In terms of vehicle fleet composition, the only difference between direct and indirect transportation systems exists in kinds of vehicles used to transport waste from a transfer station to a final disposal site. This option is basically to collect the waste from communal containers. Apart from the transportation vehicles from the transfer station, the vehicle fleet is thus composed of container trucks, side loaders, dump trucks, wheel loaders and water sprinklers, etc., exactly the same as the previous **Option A-1**.

(a) Detachable Container Trucks

Collection

Same as **Option A-1**: a 6-ton ($8m^3$) capacity type.

Transportation

In view of efficiency and ease of procurement, large-scale arm type container trucks with a 10-ton (20 m^3) capacity are widely used for the secondary transport.

(b) Side Loaders

Same as the preceding options: a 6-ton (8 m^3) capacity type.

(c) Dump Trucks (Tippers)

Same as the preceding options: a 6-ton (8 m^3) capacity type.

(d) Wheel Loaders

Same as the preceding options: a medium-type with bucket capacity of 2 m3.

(e) Water Sprinklers

Same as the preceding options: 8,000 litre capacity of water tank.

(f) Inspection Cars

Same as the preceding options: three types, specifically 4-wheel drive, pick-ups and sedans.

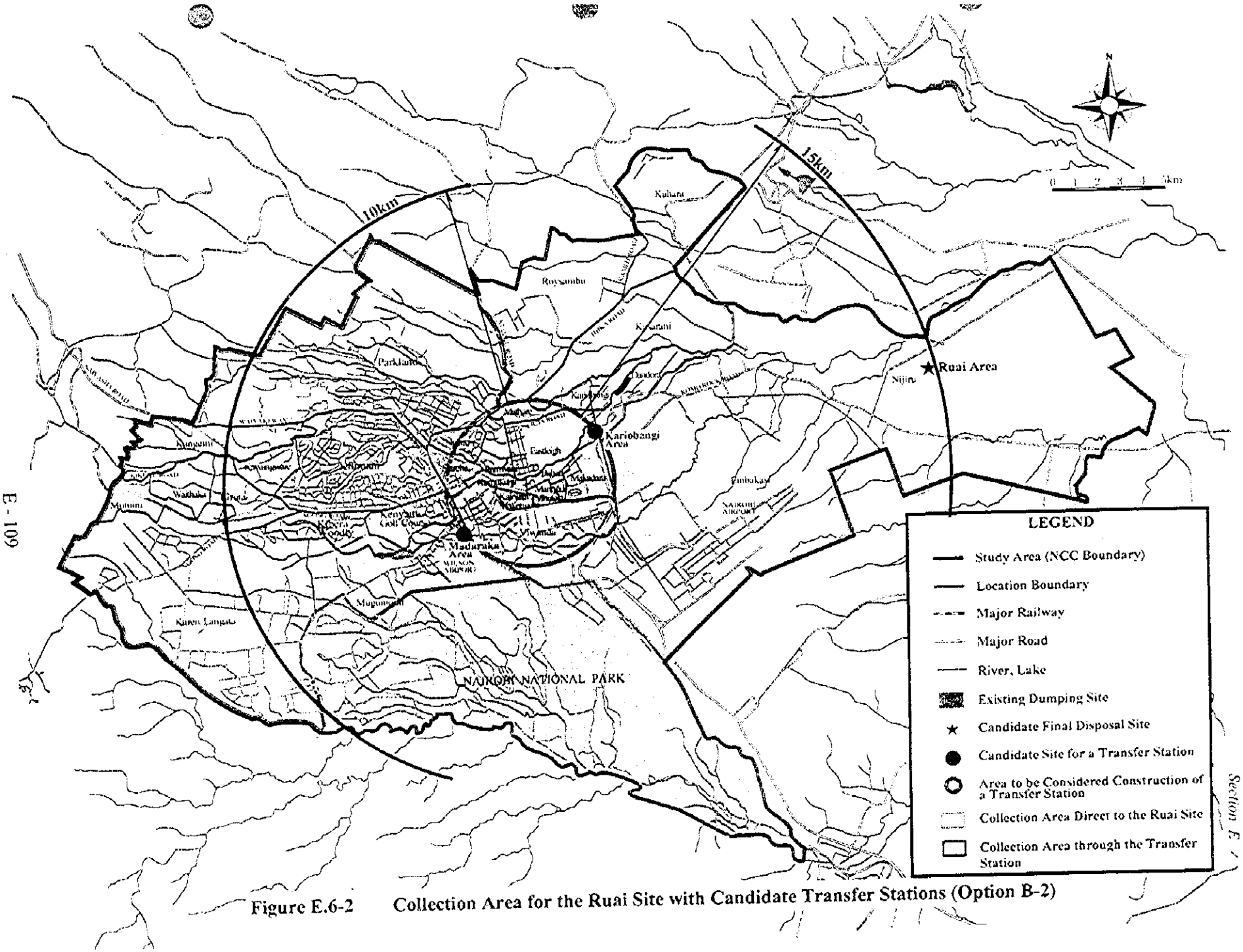


Figure E.6-2 Collection Area for the Ruai Site with Candidate Transfer Stations (Option B-2)

(2) Other Necessary Materials and Facilities

Same as the preceding options: a small workshop and parking lots.

(3) Determination of the Basic Conditions

The following describes the basic conditions to determine the required number of the above vehicles.

(a) Proportion of Waste Amount Collected by Direct and Indirect Transport Systems

The proportion of waste amount to be collected depending on the transport system is estimated on the following assumptions:

- Waste from locations close to the candidate disposal site at Ruai, which are far from the Ruai site (15 to 20 km), are hauled directly to the disposal site to minimize the required dimensions of the transfer station and reduce the investment cost. Those locations are:

  Mathare, Kahara, Roysambu, Makadara, Kaloleni/Makongeni, Maringo/Mibotela, Bahati, Pumwani, Eastleigh, Kamukunji, Embakasi, Dandora, Kasarani, Kairobangi and Njiru.

- Waste from the other locations, which are located in the western side of the city, are hauled to the transfer station to increase the number of trips and reduce the transportation cost. Those locations are:

  Viwanda, Mugumoini, Kibera/Woodley, Waithaka, Kangemi, Ruita, Kawangware, Mutuini, Ngara, Starehe, Kenyatta/Golf Course, Karen/Langata, Kilimani, and Parklands.

The area where the waste amount is to be transported directly to the Ruai site and through the transfer station is illustrated in **Figure E.6-2**, and the waste amount collected by direct and indirect transport is estimated as shown in **Table E.6-16.**

Table E.6-16 Proportion of Waste Amount to be Collected by Direct and Indirect Transport (Option B-2)

(Unit: ton/day)

Year	Total amount collected by NCC (1)	Total amount collected by direct transport (2)	Total amount collected by indirect transport (3)	Total amount transported from transfer station (4) *
1998	1,207	622	585	731
1999	1,268	657	611	765
2000	1,330	693	638	799
2001	1,401	728	673	844
2002	1,477	764	713	896
2003	1,557	801	756	951
2004	1,649	849	800	1,068
2005	1,736	889	847	1,008
2006	1,834	939	895	1,131
2007	1,937	988	949	1,200
2008	2,048	1,042	1,006	1,274

*Total amount of waste transported from the transfer station is shown in *Section 5.5, Data Book (1).*

(b) Number of Collection/Transportation Trips

The primary objective for the introduction of the indirect transportation system is to reduce the transportation time and increase the number of trips per day. As presented in **Figure E.6-2**, there are two areas to be considered where the area is covered by direct transport and the other is the indirect transport area because it would be better to haul the waste directly to the disposal site if the waste is collected in locations close to the candidate disposal site. Therefore, the number of trips for collection and transportation is estimated depending on the collection area as follows:

(i) Direct Transport Area

The number of collection trips by transport directly to the candidate disposal site is assumed to be the same as the case of construction of the final disposal site at Ruai in **Option B-1**; that is, 3 trips for container trucks and dump trucks, and 2 trips for side loaders.

(ii) Indirect Transport Area (collection)

If the transfer station is built in the city centre area, as especially shown in **Figure E.6-2**, the transportation time designed in **Option B-1** will not significantly be changed, because the transportation distance is estimated at around 10 to 15 km on average in this case, which is almost the same distance as the case of construction of the final disposal site at Ngong in **Option B-1**. Therefore, 4.5 trips in a day is expected for container trucks and

dump trucks. For the side loaders, the same trip as the previous option would be possibly made on 3.5 trips a day.

(iii) Indirect Transport Area (transportation)

Carried waste to the transfer station is transported to the disposal site. Between the transfer station and the disposal site it is assumed that the average transportation speed is 40 km/hr because of the suburban area. Since the candidate disposal site at Ruai area is located 15 to 20 km further from the area considered for construction of a transfer station, the transportation time is calculated as follows:

$$15\text{~}20 \times 2 \times 60 \div 40 = 45\text{~}60 \text{ minutes} = 0.75\text{~}1.0 \text{ hours}$$

Loading and unloading time is additionally required in the transfer station and the disposal site. The time for this is assumed to be 45 minutes or 0.75 hours; thus, the total trip time is 0.75~1.0 + 0.75 = 1.5~1.75 hours. Consequently, the required number of trips is: 8 ÷ 1.5~1.75 = 4.6~5.3, say 5 trips a day.

(c) Container Capacity and Performance

Collection

Same as **Option A-1**: 2.4 t/each

Transport

The capacity per container for transport will be 10 tons. Assuming that 70% of the total container capacity corresponds to the "full" condition during transportation, it is possible to calculate the transportation performance per container as follows:

$$10 \times 0.70 = 7 \text{ t/each}$$

(d) Proportion of Waste Amount Collected by Types of Vehicles

The proportion of waste amount to be collected by each type of truck does not depend on the location of final disposal sites so that the distribution is the same as **Option A-1,** as follows:

Container trucks	: 50%
Side loaders	: 30%
Dump trucks (tippers)	: 20%

(e) Design Waste Amount to be Collected

Based on the above conditions, design waste amount collected by container trucks and dump trucks for each transport system is calculated as shown in **Tables E.6-17** and **E.6-18.**

Table E.6-17 Waste Amount Designed to be Collected by Direct Transport (Option B-2)

(Unit: ton/day)

Year	Total amount collected by direct (1)	Total amount collected by compactors (2) = (1)×50%	Total amount collected by side loaders (3) = (1)×30%	Total amount collected by dump trucks (4) = (1)×20%
1998	622	311	187	124
1999	657	328	197	131
2000	693	346	208	139
2001	728	364	219	146
2002	764	382	229	153
2003	801	401	240	160
2004	849	424	255	170
2005	889	444	267	178
2006	939	469	282	188
2007	988	494	296	198
2008	1042	521	313	208

Table E.6-18 Waste Amount Designed to be Collected by Indirect Transport (Option B-2)

(Unit: ton/day)

Year	Total amount collected by indirect (1)	Total amount collected by compactors (2) = (1)×50%	Total amount collected by side loaders (3) = (1)×30%	Total amount collected by dump trucks (4) = (1)×20%
1998	585	292	175	117
1999	611	306	183	122
2000	638	319	191	128
2001	673	336	202	135
2002	713	356	214	143
2003	756	378	227	151
2004	800	400	240	160
2005	847	423	254	169
2006	895	448	269	179
2007	949	475	285	190
2008	1006	503	302	201

(4) Calculation of the Required Quantities of Vehicles and Other Facilities

(a) Containers (collection)

From the preceding **Tables E.6-17** and **E.6-18**, as of 1998 it will be necessary to provide the following container quantities.

- Total amount of waste collected by containers : 604 t/day
  (311 t/day + 292 t/day)

All the containers have to store the above total amount for a week since the waste collection is planned to be carried out once a week, i.e., 604 t/day. Thus,

$$604 \times 7 \div 2.4 = 1{,}761 \text{ containers}$$

are to be installed. If an availability factor of 95% is assumed, the container number required will be 1,761 ÷ 0.95 = 1,853. This is the same quantity as **Option A-1** because of the same waste amount to be collected. The proportion of the number of containers subject to the transport system is as follows:

Direct transport	: 311 × 7 ÷ 2.4 ÷ 0.95 ≈ 956 containers
Indirect transport	: 292 × 7 ÷ 2.4 ÷ 0.95 ≈ 897 containers

(b) Detachable Container Trucks

Although the number of containers is the same as **Option A-1**, the number of required container trucks for collection purpose only is not necessarily the same due to the different number of trips between direct and indirect transport. On average, it is assumed that the NCC has to pick up the containers once a week to provide a minimum level of services throughout the city. Thus,

for direct transport:

956 × 1/7 (collected once a week) = 136.5

for indirect transport:

897 × 1/7 (collected once a week) = 128.1

To transport these on a route of 3 trips a day for the direct transport and 4.5 trips a day for indirect transport, it will be necessary to have the following on the assumption of an availability factor of 90%.

Direct transport : 136.5 ÷ 3.0 ÷ 0.90 = 50 trucks
Indirect transport: 128.1 ÷ 4.5 ÷ 0.90 = 32 trucks

The total required number of trucks for collection is therefore:

50 + 32 = 82

On the other hand, for waste transport from the transfer station to the disposal site 20 m^3 capacity container trucks are adopted. The waste amount for the secondary transport is estimated by the waste amount carried to the transfer station. The number of trips between the transfer station and the disposal site is five. This design waste amount is thus 731 t/day, and the required number of trucks is:

731 ÷ (7 × 5) ÷ 0.90 = 23.2; thus, 23 trucks will be required (availability 90%).

(c) Side Loaders

Side loaders will be working 2 trips a day for direct transport and 3.5 trips a day for indirect to carry 4 tons per trip. For the handling of the

187 tons of waste generated in a day for direct transport and 175 tons per day for indirect, it will be necessary to have:

Direct transport	: $187 \div (2 \times 4) \div 0.90 = 26$ loaders
Indirect transport	: $175 \div (3.5 \times 4) \div 0.90 = 14$ loaders

The above considers an availability factor of 90%. The total required number of trucks is therefore:

$$26 + 14 = 40$$

(d) Dump Trucks (Tippers)

For the handling of 124 tons of waste for direct transport and 117 tons for indirect in a day, it will be necessary to have the following:

Direct Transport: $124 \div (3 \times 4) \div 0.90 = 11.5$; thus, 12 trucks will be required (availability 90%).

Indirect Transport: $117 \div (4.5 \times 4) \div 0.90 = 7.2$; thus, 7 trucks will be required (availability 90%).

The total required number of trucks is therefore:

$$12 + 7 = 19$$

(e) Wheel Loaders

As in the preceding collection system options, this equipment portion is assumed to be of the same number as the dump trucks because the combination of a truck and a loader will enhance to a great extent the efficiency of carrying the waste. Consequently, the number of wheel loaders is 19. This number already includes 90% availability.

(f) Water Sprinklers

The same proportion to the number of wheel loaders is assumed to be planned, i.e., $19 \div 6 = 3.2$. Three (3) water sprinklers are to be procured.

(g) Inspection Cars

The same number of vehicles as the preceding option is assumed to be planned, i.e., 22 inspection cars are to be prepared.

(h) Recovery Trucks

The same number of vehicles as the preceding option is assumed to be planned, i.e., one recovery truck is to be prepared from 1998 to 2003, and one will be added from 2004.

(i) **Parking Lots**

A parking space for the collection vehicles is required to be secured in one location for every district, i.e., 6 parking lots are to be prepared.

(5) Calculation of the Required Manpower

Basic conditions to estimate the required personnel for collection and transportation are the same as **Option A-1**.

For the other years, the same procedures above would result in required quantities as given in **Table E.6-19**.

Table E.6-19 Vehicles, Equipment and Manpower Required for Option B-2

No	Items	Quantity										
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1	Detachable-container truck	82	86	91	96	101	106	112	118	125	132	139
2	Container	1853	1947	2042	2151	2267	2390	2531	2665	2815	2974	3143
3	Trailer truck	23	24	25	27	28	30	32	34	36	38	40
4	Side loader	40	42	44	46	49	51	54	57	60	64	67
5	Dump truck	19	20	21	22	23	24	26	27	28	30	32
6	Wheel loader	19	20	21	22	23	24	26	27	28	30	32
7	Water sprinkler	4	4	4	4	5	5	5	5	6	6	6
8	Inspection car	22	22	22	22	22	22	22	22	22	22	22
9	Tow truck	1	1	1	1	1	1	2	2	2	2	2
10	Parking lots	6	6	6	6	6	6	6	6	6	6	6
11	Driver	212	221	231	242	253	265	279	292	307	322	339
12	Loader	413	433	454	478	505	533	564	595	629	665	703
13	Sweeper	1239	1300	1361	1435	1514	1599	1693	1785	1886	1995	2110
14	Supervisor	182	191	200	211	222	233	247	260	274	289	306
15	Headman	83	87	91	96	101	107	113	119	126	133	141

6.2.3 Final Disposal Site at Ruai Area Only without a Transfer Station (Option B-3)

Without a transfer station, all the waste should be carried directly to the final disposal site. Therefore, this option is exactly the same as **Option A-1**.

6.3 Quantities Required for Collection and Transportation System of the Master Plan

6.3.1 Case of the Target Collection Ratio of 60-80-100%

(1) Planning Strategy

The option that is the introduction of container system and construction of one final disposal site at Ruai with a transfer station is to be considered for the collection and transportation system of the Master Plan. The construction of the transfer station is to be planned in the year 2004.

Since the current waste collection rate is estimated at approximately 25%, a stepwise increase in collection rate is to be made every year as follows to

attain the goal of 100%. In the initial stage of the project, the collection rate is to be proposed at more than half of the generated waste, i.e., 60% to realise the environmental improvement level. Accordingly, the collection rate will go up to 100% in the year of 2008 through a milestone of 80% in 2004.

(2) Design Basis

All the design basis, such as location of the transfer station, vehicle fleet composition and other necessary materials and facilities would be the same as **Option B-2.** The only difference is the target collection ratio.

(3) Determination of the Basic Conditions

The following describes the basic conditions to determine the required number of the above vehicles.

(a) Proportion of Waste Amount Collected by Direct and Indirect Transport Systems

The proportion of waste amount to be collected by direct and indirect transport system is the same as **Option B-2.** However, between 1998 and 2003 direct transport would be applied since the transfer station will start to operate from the year 2004.

The waste amount collected by direct and indirect transport is estimated as shown in **Table E.6-20.**

Table E.6-20 Proportion of Waste Amount to be Collected by Direct and Indirect Transport (Master Plan: Collection Ratio 60-80-100%)

(Unit: ton/day)

Year	Total amount collected by NCC (1)*	Total amount collected by direct transport (2)	Total amount collected by indirect transport (3)	Total amount transported from transfer station (4)*
1998	604	604	0	0
1999	630	630	0	0
2000	657	657	0	0
2001	687	687	0	0
2002	719	719	0	0
2003	753	753	0	0
2004	1,220	628	592	800
2005	1,282	657	625	847
2006	1,351	692	660	895
2007	1,424	726	698	949
2008	2,048	1,042	1,006	1,274

* The details are shown in *Section 5.5, Data Book (1).*

(b) Number of Collection/Transportation Trips

The number of trips for collection and transportation is also exactly the same as **Options B-1** and **B-2** depending on the collection area as follows:

(i) Direct Transport Area

Three (3) trips for container trucks and dump trucks, and two (2) trips for side loaders.

(ii) Indirect Transport Area (collection)

4.5 trips in a day is expected for container trucks and dump trucks. For the side loaders, it would be possibly made on 3.5 trips a day.

(iii) Indirect Transport Area (transportation)

Five (5) trips a day could be made between the transfer station and the final disposal site at Ruai.

(c) Container Capacity and Performance

Collection

Same as **Option B-2**: 2.4 t/each

Transport

Same as **Option B-2**: 7 t/each

(d) Proportion of Waste Amount Collected by Types of Vehicles

The proportion of waste amount to be collected by each type of truck does not depend on the location of final disposal sites so that the distribution is the same as **Option B-2,** as follows:

Container trucks	: 50%
Side loaders	: 30%
Dump trucks (tippers)	: 20%

(e) Design Waste Amount to be Collected

Based on the above conditions, design waste amount collected by container trucks and dump trucks for each transport system is calculated as shown in **Tables E.6-21** and **E.6-22.**

Table E.6-21 Waste Amount Designed to be Collected by Direct Transport (Master Plan: Collection Ratio 60-80-100%)

(Unit: ton/day)

Year	Total amount collected by direct (1)	Total amount collected by compactors (2) = (1)×50%	Total amount collected by side loaders (3) = (1)×30%	Total amount collected by dump trucks (4) = (1)×20%
1998	604	302	181	121
1999	630	315	189	126
2000	657	329	197	131
2001	687	344	206	137
2002	719	359	216	144
2003	753	376	226	151
2004	628	314	188	126
2005	657	329	197	131
2006	692	346	208	138
2007	726	363	218	145
2008	1,042	521	313	208

Table E.6-22 Waste Amount Designed to be Collected by Indirect Transport (Master Plan: Collection Ratio 60-80-100%)

(Unit: ton/day)

Year	Total amount collected by indirect (1)	Total amount collected by compactors (2) = (1)×50%	Total amount collected by side loaders (3) = (1)×30%	Total amount collected by dump trucks (4) = (1)×20%
1998	0	0	0	0
1999	0	0	0	0
2000	0	0	0	0
2001	0	0	0	0
2002	0	0	0	0
2003	0	0	0	0
2004	592	296	178	118
2005	625	312	188	125
2006	660	330	198	132
2007	698	349	209	140
2008	1,006	503	302	201

(4) Calculation of the Required Quantities of Vehicles and Other Facilities

(a) Containers (collection)

From the preceding **Tables E.6-21** and **E.6-22**, as of 1998 and 2004 it will be necessary to provide the following container quantities.

- Total amount of waste collected by containers (as of 1998) :302 t/day
- Total amount of waste collected by containers (as of 2004) :610 t/day (314 + 296 = 610 t/day)

All the containers have to store the above total amount for a week since the waste collection is planned to be carried out once a week, i.e., 302 t/day in 1998 and 610 t/day in 2004. Thus,

$302 \times 7 \div 2.4 = 881$ containers (as of 1998); and

$610 \times 7 \div 2.4 = 1{,}779$ containers (as of 2004, direct transport; $314 \times 7 \div 2.4 = 916$, and indirect transport; $296 \times 7 \div 2.4 = 863$)

are to be installed. If an availability factor of 95% is assumed, the container number required will be $881 \div 0.95 = 927$ (as of 1998), and $1{,}779 \div 0.95 = 1{,}873$ (as of 2004, direct transport; 964, and indirect transport; 909).

(b) Detachable Container Trucks

On average, it is assumed that the NCC has to pick up the containers once a week to provide a minimum level of services throughout the city. Thus,

$927 \times 1/7$ (collected once a week) = 132.4 (as of 1998)

$964 \times 1/7$ (collected once a week) = 137.7 (as of 2004, direct transport)

$909 \times 1/7$ (collected once a week) = 129.9 (as of 2004, indirect transport)

To transport these on a route of 3 trips a day for the direct transport and 4.5 trips a day for the indirect transport, it will be necessary to have the following on the assumption of an availability factor of 90%.

Direct transport: $132.4 \div 3.0 \div 0.90 = 49$ trucks (as of 1998)
Direct transport: $137.7 \div 3.0 \div 0.90 = 51$ trucks (as of 2004)
Indirect transport: $129.9 \div 4.5 \div 0.90 = 32$ trucks (as of 2004)

The total required number of trucks as is therefore:

49 (as of 1998)
51 + 32 = 83 (as of 2004)

On the other hand, for waste transport from the transfer station to the disposal site 20 m^3 capacity container trucks are adopted from the year of 2004. The waste amount for the secondary transport is estimated by the waste amount carried to the transfer station. The number of trips between the transfer station and the disposal site is five. This design waste amount is thus 800 t/day as of 2004, and the required number of trucks is:

$800 \div (7 \times 5) \div 0.90 = 25.3$; thus, 25 trucks will be required (availability 90%).

(c) Side Loaders

Side loaders will be working 2 trips a day for direct transport and 3.5 trips a day for indirect to carry 4 tons per trip. For the handling of the 181 tons of waste generated in a day for direct transport as of 1998, and 188 tons per day for direct transport and 178 tons per day for indirect as of 2004, it will be necessary to have:

Direct transport : $181 \div (2 \times 4) \div 0.90 = 25$ loaders (as of 1998)
Direct transport : $188 \div (2 \times 4) \div 0.90 = 26$ loaders (as of 2004)
Indirect transport : $178 \div (3.5 \times 4) \div 0.90 = 14$ loaders (as of 2004)

The above considers an availability factor of 90%. The total required number of trucks as is therefore:

25 (as of 1998)
26 + 14 = 40 (as of 2004)

(d) Dump Trucks (Tippers)

For the handling of the 121 tons of waste generated in a day for direct transport as of 1998, and 126 tons per day for direct transport and 118 tons per day for indirect as of 2004, it will be necessary to have:

Direct Transport: $121 \div (3 \times 4) \div 0.90 = 11.2$; thus, 11 trucks will be required (availability 90%) (as of 1998).

Direct Transport: $126 \div (3 \times 4) \div 0.90 = 11.6$; thus, 12 trucks will be required (availability 90%) (as of 2004).

Indirect Transport: $118 \div (4.5 \times 4) \div 0.90 = 7.3$; thus, 7 trucks will be required (availability 90%) (as of 2004).

The total required number of trucks is therefore:

11 (as of 1998)
12 + 7 = 19 (as of 2004)

(e) Wheel Loaders

This equipment portion is assumed to be of the same number as the dump trucks because the combination of a truck and a loader will enhance to a great extent the efficiency of carrying the waste. Consequently, the number of wheel loaders is 11 as of 1998 and 19 as of 2004. This number already includes 90% availability.

(f) Water Sprinklers

The same proportion to the number of wheel loaders is assumed to be planned, i.e., in 1998 $11 \div 6 = 1.8$, and in 2004 $19 \div 6 = 3.2$. Two (2)

and three (3) water sprinklers are to be procured in 1998 and 2004, respectively.

(g) Inspection Cars

The same number of vehicles as the preceding option is assumed to be planned, i.e., 22 inspection cars are to be prepared.

(h) Recovery Trucks

The same number of vehicles as the preceding option is assumed to be planned, i.e., one recovery truck is to be prepared from 1998 to 2003, and one will be added from 2004.

(i) Parking Lots

A parking space for the collection vehicles is required to be secured in one location for every district, i.e., 6 parking lots are to be prepared.

(5) Calculation of the Required Manpower

Basic conditions to estimate the required personnel for collection and transportation are the same as **Option B-2**.

For the other years, the same procedures above would result in required quantities as given in **Table E.6-23**.

Table E.6-23 Vehicles, Equipment and Manpower Required for the Master Plan (Collection Ratio 60-80-100%)

No	Items	Quantity										
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1	Detachable-container truck	49	51	53	56	58	61	83	87	92	97	139
2	Container	927	967	1008	1055	1104	1156	1873	1968	2074	2186	3143
3	Trailer truck	0	0	0	0	0	0	25	27	28	30	40
4	Side loader	25	26	27	29	30	31	40	42	45	47	67
5	Dump truck	11	12	12	13	13	14	19	20	21	22	32
6	Wheel loader	11	12	12	13	13	14	19	20	21	22	32
7	Water sprinkler	2	2	2	2	2	2	3	3	3	4	6
8	Inspection car	22	22	22	22	22	22	22	22	22	22	22
9	Tow truck	1	1	1	1	1	1	2	2	2	2	2
10	Parking lots	6	6	6	6	6	6	6	6	6	6	6
11	Driver	138	143	148	154	160	166	214	223	233	244	339
12	Loader	149	155	162	170	177	186	418	439	463	489	703
13	Sweeper	447	466	486	509	532	558	1253	1318	1390	1466	2110
14	Supervisor	111	115	120	126	131	138	183	192	203	213	306
15	Headman	30	31	32	34	35	37	84	88	93	98	141