JAPAN INTERNATIONAL COOPERATION AGENCY

THE REPUBLIC OF YEMEN
SANA'A CAPITAL SECRETARIAT

BASIC DESIGN STUDY REPORT ON SANA'A MUNICIPAL SOLID WASTE MANAGEMENT IMPROVEMENT PROJECT IN THE REPUBLIC OF YEMEN

MARCH 1993

KOKUSAI KOGYO CO.,LTD.

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PREFACE

In response to a request from the Government of the Republic of Yemen, the Government of Japan decided to conduct a basic design study on Sana'a Municipal Solid Waste Management Improvement Project and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Yemen a study team headed by Mr. Junji Ishizuka, Deputy Director, Consultant Contract Division, Procurement Department, JICA, and constituted by members of KOKUSAI KOGYO CO., LTD., from November 14th to December 4th, 1992.

The team held discussions with the officials concerned of the Government of Yemen, and conducted a field study at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Yemen for their close cooperation extended to the team.

March, 1993

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

March, 1993

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

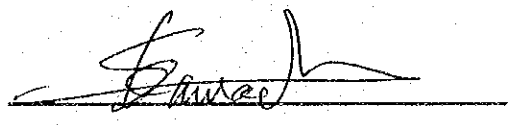
We are pleased to submit to you the basic design study report on Sana'a Municipal Solid Waste Management Improvement Project in the Republic of Yemen.

This study has been made by KOKUSAI KOGYO CO.,LTD., based on a contract with JICA, from November 9th, 1992 to March 26th, 1993. Throughout the study, We have taken into full consideration of the present situation in the Republic of Yemen, and have planned the most appropriate project in the scheme of Japan's grant aid.

We wish to take this opportunity to express our sincere gratitude to the officials concerned of JICA, the Ministry of Foreign Affairs, the Ministry of Health and Welfare and Embassy of the republic of Yemen in Tokyo. We also wish to express our deep gratitude to the officials concerned of Sana'a Capital Secretariat, Embassy of Japan in Yemen for their close cooperation and assistance during our study.

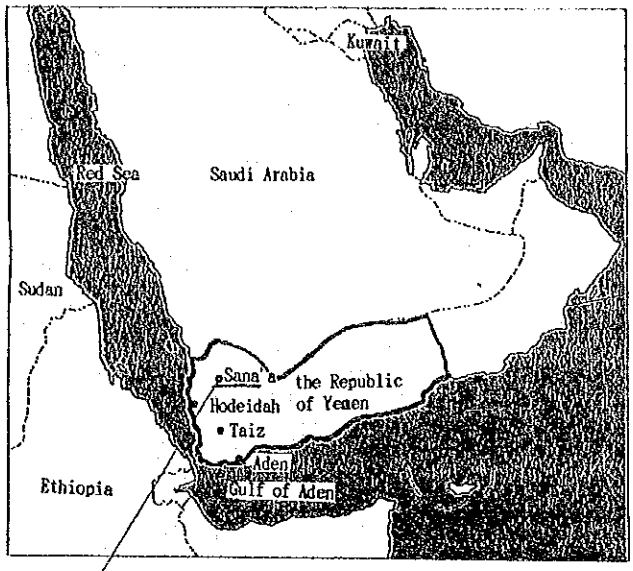
At last, we hope that this report will be effectively used for the promotion of the project.

Very truly yours,



Shinya Kawada
Project manager
Basic design study team on
Sana'a Municipal Solid Waste
Management Improvement Project
KOKUSAI KOGYO CO.,LTD.

Location Map



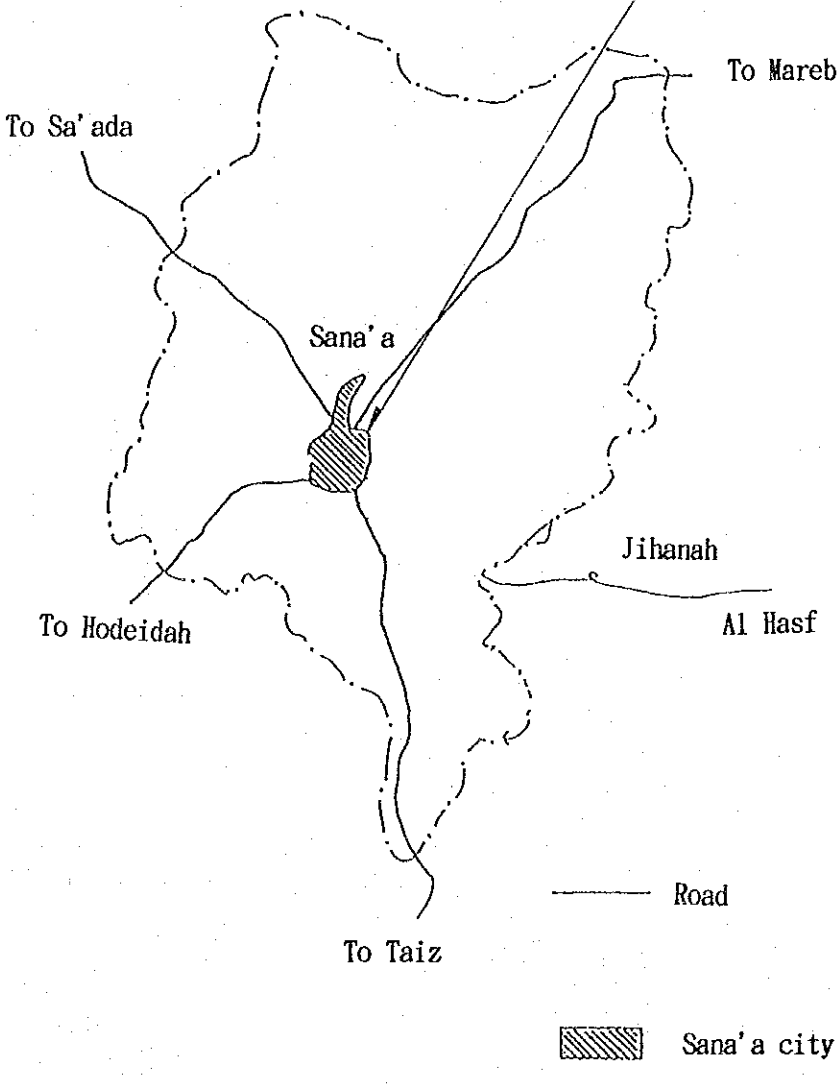
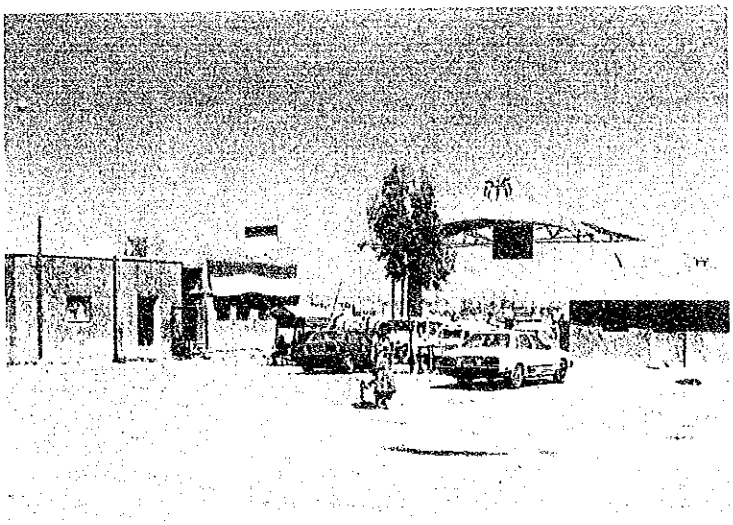


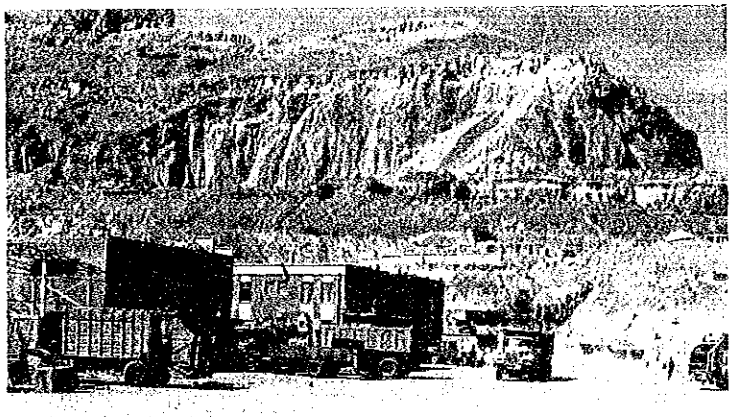
Photo 1 Central area of Sana'a City

Photo 2 Sana'a Cleaning Project (SCP)



The front gate faced ASSETTEEN Road.

Photo 3 Sana'a Cleaning Project (SCP)



The view of the SCP office from the transfer station.

Photo 4 New resident area in the south suburbs

This area receives no waste collection service and uncontrolled waste is scattered on the road.

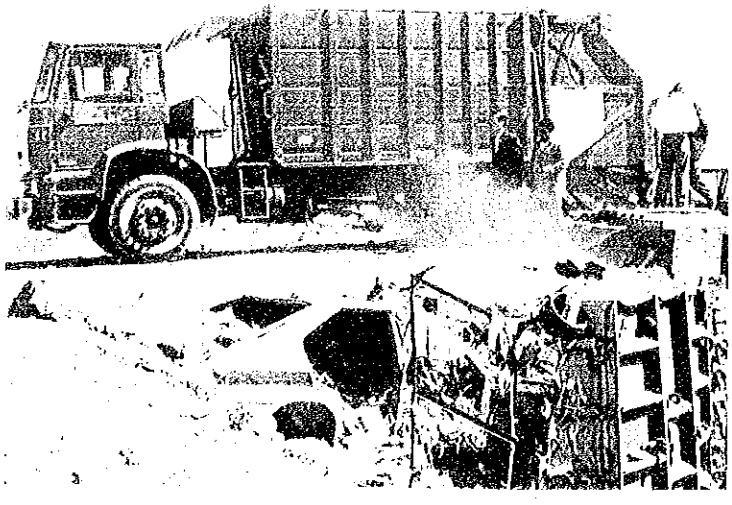
Photo 5 The circumferential condition of the container

As shown in photo, there are many people who go from one container to another and take out garbage from container to feed goats.

Photo 6 Cleaning around the container

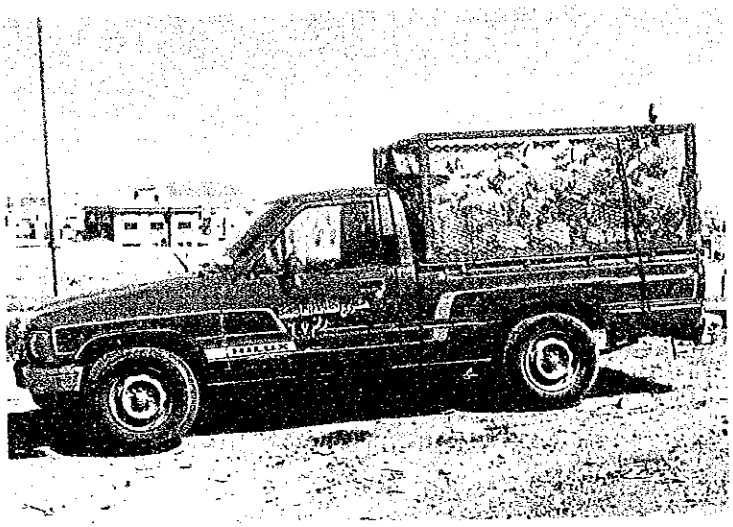
Because of wastes scattered around the container, workers must clean these wastes before loading to the compactor. This is one of factors deteriorating the efficiency of collection.

Photo 7 Transfer station



Garbage in the compactor is transferred to the trailer.

Photo 8 Pick up truck



These trucks are used for the supplementary collection and road cleaning.

Photo 9 The outside of the workshop

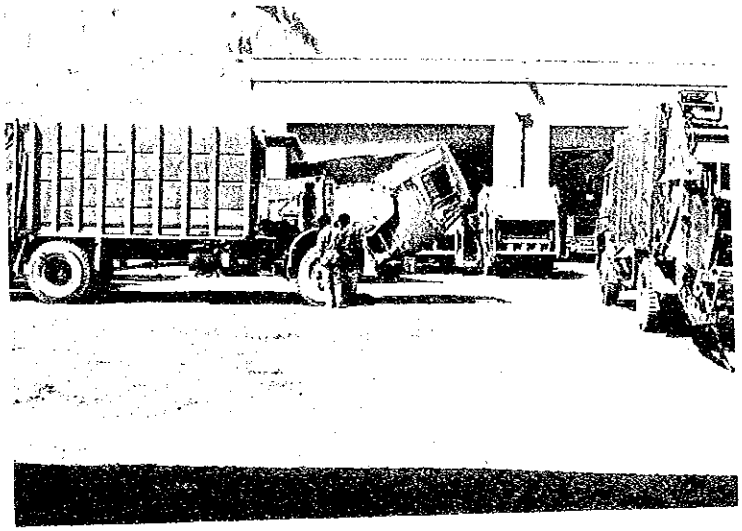


Photo 10 Inside of the workshop

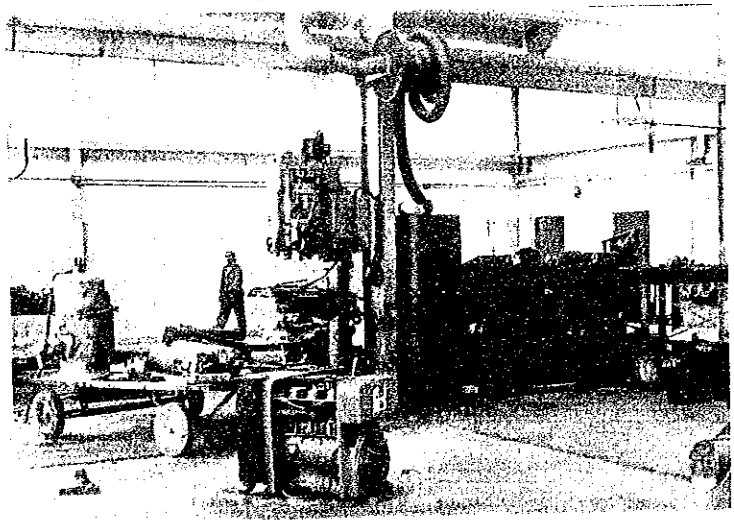
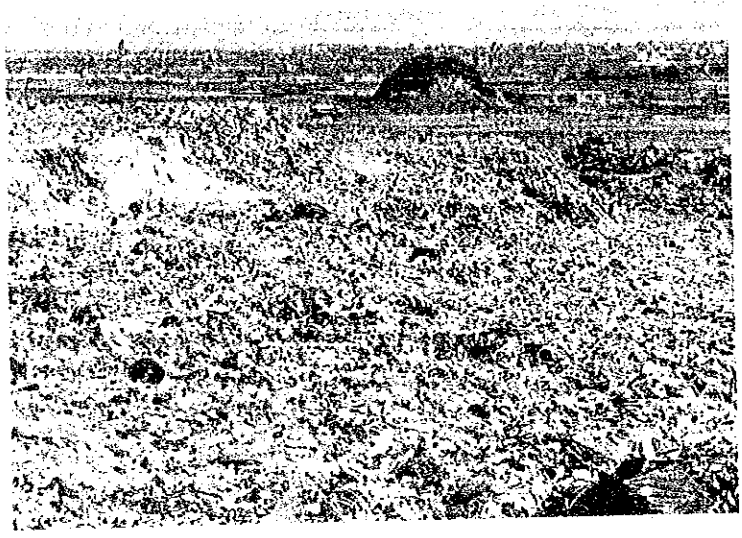


Photo 11 Custody of spare parts

The stock of spare parts are supervised by computer.

Photo 12 Final disposal site



Sanitary treatment is not carried out in major part of the site.

Photo 13 Final disposal site

Covering soil is conducted patially.

SUMMARY

The Republic of Yemen (referred to as "Yemen") is situated in the southwest of the Arabian Peninsula; it shares a border with Saudi Arabia to the north and Oman to the east with the Red Sea to the west and the Arabian Sea to the south. Its area is approximately 52.8 km^2 (1.5 times more than that of Japan), and a population of approximately 11.61 million (1990). Yemen differs from other countries in the peninsula in that it is a mountainous region, and the highest mountain in the peninsula, Nabi Shoaib (3,760m above sea level), is situated 35km west of Sana'a City. It also has a rainy season and a mean annual rainfall of 400mm (2,000mm in some areas), an amount considered to be comparatively large in the Middle and Near East.

Yemen can be considered as one of the LLDC (Least Less-Developed Countries) and one of the most economically underdeveloped countries in the Middle and Near East. It is an agricultural country and 27% of the 1987 GDP and approximately 70% of the labour force are covered by the agricultural, forestry and fisheries sectors.

The main crops cultivated in Yemen are sorghum, millet, grain, vegetables, fruits, coffee and raw cotton. Because agricultural production is largely affected by rainfall and due to the absence of valuable exports, the trade balance has been sharply in the red. Formerly, the deficit was compensated through the remittance of overseas workers in the Gulf Coast region and the economic aid from OPEC and DAC. However, after effects of the Gulf War has altered the situation, prompting the further acceleration of the trade balance deficits.

Sana'a City was the former capital of North Yemen, and even after the unification of the north and south in May 1990, it has still remained as the administrative and economic centre of Yemen. Directly after the unification, the Gulf War broke out, and Saudi Arabia, the largest economic sponsor of Yemen and where many Yemeni overseas workers were acquiring large foreign currency holdings, enforced the repatriation of 800,000 Yemeni overseas workers because of the Yemeni diplomatic policy supporting Iraq. Furthermore, with the fall of communism, the inflow of people from the former South Yemen and of refugees from neighbouring countries like Somalia and Ethiopia has raised the population of Sana'a City. Consequently, the population of the city has reached 1,080,000 in 1992 from the 427,000 of the 1986 census, and is further expected to increase.

This phenomena puts pressure on the social foundation of Sana'a City, particularly in view of the increase in waste generation amount which largely affects solid

waste management (referred to as "SWM"). The peculiar customs and traditions of the country, namely Cart party, cooking in excess, and the minimum awareness of the residents concerning SWM, etc., further aggravate the situation.

The SWM of Sana'a City is the responsibility of the Sana'a Cleaning Project (hereinafter referred to as "SCP"). SCP effectively uses its equipment and works on improving their treatment capacities. However, shortage in equipment has led to the daily collection of only 50% of the generative waste amount (800 tons/day), and its capability remains (400tons/day) as it was in 1989.

Accordingly, the Government of Yemen requested Grant Aid to the Japanese Government mainly concerning the supply of equipment required for the improvement of SWM in Sana'a City.

In response to the request, the Government of Japan decided to conduct the Basic Design Study on the Project for Sana'a Municipal Solid Waste Management Improvement in the Republic of Yemen (herein after referred to as "the Project") and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA dispatched the Basic Design Study Team (hereinafter referred to as "the Team") to Yemen.

The Team held discussions with SCP and officials concerned and conducted a field survey on the following items:

1) To confirm the background of the plan and details of the request;
2) To understand the details of the plan;
3) To grasp the appropriateness and effects of the plan;
4) To understand the operation and maintenance plan;
5) To collect related data on prices and after-services concerning the equipment procured from some foreign countries other than Japan and Yemen.

The Team first conducted the study on the present condition of SWM in Sana'a City.

Waste collection is conducted under three methods; collection by containers, door to door collection, and collection along roads. In the majority of the areas the first collection method is adopted, while in some parts the second is enforced. On the other hand, the third collection method is mainly used for the beautification of the roads.

In the first method the containers are basically collected by compactor trucks twice a day. In the 3rd method the wastes discharged along the roads are collected by small pick-up trucks twice in the daytime, and by compactors once at night.

The compactors basically transport the collected wastes to the final disposal site. In case collection is conducted more than twice, wastes are transported to the transfer station established by SCP. On the other hand, pick up trucks transfer wastes to a trailer installed with a compressor at the transfer station. After being compressed, the trailers transport the waste to the final disposal site.

SCP has approximately 900 employees, 15 collection vehicles, about 2,300 containers, and tries to improve SWM. It only, however, gets to collect 50% (400 tons/day) of the waste generation amount of 800 tons/day because shortage in vehicles and equipment limits collection capacity. Consequently, wastes can be seen everywhere outside of the central city area, especially in new housing development sites at the suburbs of the city which is almost uncovered by the services. Although this is attributed to the shortage of equipment, emphasis should be focused on the fact that for a developing country, the residents discharge large amount of waste per day (800g/person/day). In accordance to this, the educational section of SCP conducts educational programs and propaganda that would heighten the awareness of the residents on SWM. There are no sufficient equipment, however, that would enable the effective execution of these propagandas during assemblies, etc..

The final disposal site is situated 25km north-northwest of the central city area. The site covers an area of 100 ha, has been used for the past 12 years and shall be used another 10 years. The site has 2 bulldozers and a landfill compactor. Although covering soil works are conducted partially, this can not be properly termed as sanitary landfill work due to shortage in equipment. Because of a dry climate, there are few environmentally devastating problems such as leachate problems.

With the inspection program, the maintenance of existing equipment is conducted effectively on a large scale. The computerized management of spare parts' stocks and the numerous repairmen for engines are also worth noticing. The final disposal site, however, is in need of maintenance and communication equipment.

The field survey results confirmed the necessity of collection equipment such as compactor trucks, containers, etc.. In addition, the final disposal site also requires heavy machinery for the covering soil. SCP will also require video projectors to aid the execution of educational programmes on SWM.

The equipment requested by the Government of Yemen, including the items in the 1st Request and 2nd phase request, are as follows:

Item	Required Equipment	Q'ty	1st	2nd
1	Compactor (15/11/4m^3)	15	13	2
2	Dump Truck (20m^3)	4	2	2
3	Small Tipper	6	–	6
4	Wheel Loader	2	–	2
5	Car Washing Unit	1	–	1
6	Telecommunication System	1	1	–
7	Four Wheel-Drive Vehicle	3	2	1
8	Medium Bus (26 Passengers)	2	–	2
9	Small Bus (7-8 Passengers)	4	–	4
10	Street Sweeper	3	2	1
11	Workshop Truck	2	2	–
12	Detachable Container Truck	3	–	3
13	Electrical Compactor	4	–	4
14	Garbage Container (1.6m^3)	250	–	250
15	Garbage Container (1.0m^3)	370	270	100
16	Garbage Container (5.0m^3)	30	–	30
17	Wheel Carrier	30	30	–
18	Spare parts for the above at 10% of cost	–		

These requested equipment can be largely classified into the following 4 categories:

(1) Equipment for covering soil in the final disposal site
(2) Equipment for waste collection and transportation
(3) Equipment for maintenance
(4) Equipment for operation

Although these are not included in the list of requests, a video projector and screen were also requested during the conference with SCP. These will be included above as the fifth category (Educational equipment).

Wastes in the final disposal site are flattened and compacted with a bulldozer or a landfill compactor. Soil coverage works are not effectively carried out due to the

absence of required equipment. Soil covering equipment are considered extremely important in the sanitation of the final disposal site and in the prevention of the scattering of wastes.

At present, only 50% of the waste generated is collected, therefore a lot of waste are seen scattered in many places in the city. Equipment for collection and transportation are indispensable to the improvement of collection and disposal capabilities.

The final disposal site also lacks a workshop and tools for repair works that would make immediate repair of old equipment or those to be supplied through this Project possible. A workshop truck, which shall be included in the list of maintenance equipment is extremely important for the repair of light damages.

Upon the operation and management of the SWM works, it is very important to monitor correction activities, to discern problems and to be able to cope with them. Four wheel-drive vehicles will be used for daily patrols. The request for a telecommunication system for emergency purposes and the effective use of collection vehicles is deemed appropriate due to the poor communication facilities of the city.

The most basic theme in the administration of SWM is the education of the residents on sanitation. SCP has just started its educational program and the forming of its foundations is extremely significant for the future development of SWM, therefore, equipment to support the educational activities are very important.

The equipment plan was conducted based on the basic policies shown below:

(1) Because it will be difficult to estimate the future population, the 1992 population estimate of 1,080,000 will be adopted as the base population of the plan.

(2) The specification of the containers for the new equipment will differ from the old throughout this Project. It is not favourable for the equipment to be used together during operation. For effective operation, the areas of collection will be divided into two parts: one for the existing equipment and the other for the new.

(3) The study area will be the southern part of the city divided by Zubairy Street. and the existing equipment will be transferred to the northern part of the city.

(4) The study area covers approximately 40 km^2 with a population of approximately 400,000.

The basic data gathered during the field survey on the area enabled the investigation on collection methods, area, generation waste amount, and the formulation of a very realistic and effective equipment plan. The outline of the planned equipment are as shown below:

(1) Equipment for covering soil in the final disposal site

Wheel loader (1.9m^3)	1 unit	to excavate covering soil and load it on Dump Truck
Dump truck (10m^3)	2 units	for the transportation of soil

(2) Equipment for collection and transportation

Compactor (15m^3)	4 units	for collection, using 1.0m^3 containers, and the transportation of wastes discharged by households, hotels, restaurants, etc.
Container (1m^3)	500 units	container for the compactor mentioned above
Compactor (10m^3)	8 units	for door to door collection and the transportation of household wastes
Detachable container truck	2 units	for collection, using 8m^3 containers, and the transportation of waste collected from markets, public institutions and households in the new residential area
Container (8m^3)	20 units	container for the truck mentioned above
Dump truck (10m^3)	1 unit	for the collection and transportation of heavy wastes, i.e construction waste
Wheel loader (1.9m^3)	1 unit	for loading heavy wastes on the dump truck

Small tipper ($1.5m^3$)	6 units	for additional collection and transportation of household wastes, and for road cleansing work

(3) Maintenance equipment

Workshop truck	1 unit	for immediate repair works in the final disposal site and collection area

(4) Operational equipment

Four wheel-drive vehicle	2 units	for field supervision of the operation section
Telecommunication system	lump sum	for communication between headquarters and collection vehicles

(5) Educational equipment

Video projectors	1 unit	to support educational programs conducted in assembly halls
Screen	1 unit	

(6) Spare Parts

Parts to be required 2 years after the implementation of the Project.

SCP plans to increase its number of employees from 900 to 1,300, along with the implementation of the Project. The operational budget steadily increases annually, and a budget suitable to the project is expected to be adopted for the year 1993. It is also considered that the implementation of the project will not have any hindrances operationally.

The equipment to be introduced are mainly vehicles and since no particularly difficult equipment will be used, technical cooperation will not be particularly required for OM.

The period required for procurement of equipment is 13.5 months after the Exchange of Notes (E/N), including the Detail Design if this project is implemented under the Japanese Grant Aid program.

The implementation of the Project will raise the actual collection service coverage rate of 57.3% to 85.5%. And this improvement will reduce the number of insanitary areas, and will largely contribute to the improvement of living conditions and will aid the promotion of the city's Tourist Industry. These results will show differences, especially concerning the improvement in the residents' concept on sanitation. Thus the implementation of the Project through the Grant Aid program of the Japanese Government is of extreme importance.

The Project is not aimed to drastically reform SCP but to provide the waste collection and treatment equipment it requires and to reinforce its foundation. Through the procurement of equipment, the services of SCP will be largely improved. To further ensure a smooth SWM, we would like to recommend the formulation of a Master Plan, implementation of personnel training and recruitment and a perfect educational program on environmental sanitation.

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CHAPTER 1 INTRODUCTION

CHAPTER 1 INTRODUCTION

The capital of the Republic of Yemen (referred to as "Yemen") is Sana'a City, the capital of north Yemen before the unification. Even after the unification of the north and south in May 1990, Sana'a still remains as the administrative and economic centre of Yemen. Directly after the unification, the Gulf War broke out, and Saudi Arabia, the largest economic sponsor of Yemen and where many Yemeni workers acquire large foreign currency holdings, enforced the repatriation of 800,000 Yemeni overseas workers because of the Yemeni diplomatic policy supporting Iraq. With the fall of communism, the inflow of people from the former south Yemen and of refugees from the neighbouring countries like Somalia and Ethiopia has raised the population of Sana'a City.

Consequently, the population of the city has grown to about 1,080,000 in 1992 from 427,000 in 1986, and further increase is expected.

The increase in population is a burden to the social foundation, especially the drastic increase of generated amount of waste which largely affects solid waste management (referred to as "SWM"). In addition, the peculiar customs and traditions of the country, such as Cart parties, cooking in excess, and the lack of awareness on SWM, further aggravates the situation.

The SWM in Sana'a City is conducted by the Sana'a Cleaning Project (referred to as SCP). SCP has approximately 900 employees and possesses 15 collection vehicles and about 2,300 containers, and reinforces the capability of SWM. However, SCP only gets to collect 50% (400 tons/day) of the generation waste amount of 800 tons/day because shortage in vehicles and equipment limits collection capacity, resulting in the increase in areas outside of the main city district which are not covered by collection services and scattered with wastes. This increase in insanitary areas has become a big social problem.

To improve the actual condition of SWM in Sana'a City, the Government of Yemen requested Grant Aid from the Japanese Government mainly in terms of supply of equipment. In response to the request, the Government of Japan decided to conduct the Basic Design Study on the Municipal Solid Waste Management Improvement Project of Sana'a in the Republic of Yemen (referred to as "the Project") and entrusted the Project to the Japan International Cooperation Agency (JICA). JICA dispatched the Basic Design Study Team (referred to as"the Team") headed by Mr.Junji ISHIZUKA, Deputy Director, Consultant Contract Division, Procurement Department, JICA. The Team stayed in Yemen from November 15th to December 3rd,1992. The Team held discussions with SCP and other related

agencies and conducted field surveys on the following items to assess the feasibility of the Grant Aid program:

1) To confirm the background of the plan and details of the request;
2) To understand the details of the plan;
3) To grasp the appropriateness and effects of the plan;
4) To understand the operation and maintenance plan;
5) To collect related data on prices and after-services concerning the equipment procured from some foreign countries other than Japan and Yemen.

After their return to Japan, the Team analyzed the records and data obtained from field surveys, and the results of the discussion with the Yemeni side to formulate the Basic Design Study for the project.

This report is a compilation of the results of the survey. Member List of Survey Team, Survey Schedule, Members List of concerning party in Yemen are enclosed in the Appendix.

CHAPTER 2 BACKGROUND OF THE PROJECT

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2.1 Background of the Project

Yemen is situated in the southwest of the Arabian Peninsula; it shares a border with Saudi Arabia to the north and Oman to the east with the Red Sea to the west and the Arabian Sea to the south. Its area is approximately 52.8 km^2 (1.5 times more than that of Japan), and has a population of approximately 11.61 million (1990). Yemen differs from other countries in the peninsula in that it is a mountainous region, and the highest mountain in the peninsula, Nabi Shoaib (3,760m above sea level), is situated 35km west of Sana'a City. It also has a rainy season and a mean annual rainfall of 400mm (2,000mm in some areas), an amount considered to be comparatively large in the Middle and Near East.

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The main crops cultivated in Yemen are sorghum, millet, grain, vegetables, fruits, coffee and raw cotton. Because agricultural production is largely affected by rainfall and due to the absence of valuable exports, the trade balance has been sharply in the red. Formerly, the deficit was compensated through the remittance of overseas workers in the Gulf Coast region and the economic aid from OPEC and DAC. However, after effects of the Gulf War has altered the situation, prompting the further acceleration of the trade balance deficits.

Sana'a City was the former capital of North Yemen, and even after the unification of the north and south in May 1990, it has still remained as the administrative and economic centre of Yemen. Directly after the unification, the Gulf War broke out, and Saudi Arabia, the largest economic sponsor of Yemen and where many Yemeni overseas workers acquire large foreign currency holdings, enforced the repatriation of 800,000 Yemeni overseas workers because of the Yemeni diplomatic policy supporting Iraq. Furthermore, with the fall of communism, the inflow of people from the former South Yemen and of refugees from neighbouring countries like Somalia and Ethiopia has raised the population of Sana'a. Consequently, the population of the city has reached 1,080,000 in 1992 from the 427,000 of the 1986 census, and is further expected to increase.

This phenomena puts pressure on the social foundation of Sana'a City, particularly in view of the increase in generation waste amount which largely affects SWM. The peculiar customs and traditions of the country, namely Cart party, cooking in excess, and the minimum awareness of the residents concerning SWM, etc., further aggravate the situation.

SCP is responsible for SWM in Sana'a City. It is made up of personnel from the Ministry of Housing and Urban Planning, and these people presently hold main positions in the organization. Three years after the unification (1993), however, it shall be decentralized in terms of finance and manpower.

The present upper organization of SCP is represented by the Sana'a Capital Secretariat, and the administrative organization of the city is shown below. The mayor of the city is appointed by the Prime Minister and holds positions similar to every Ministry head.

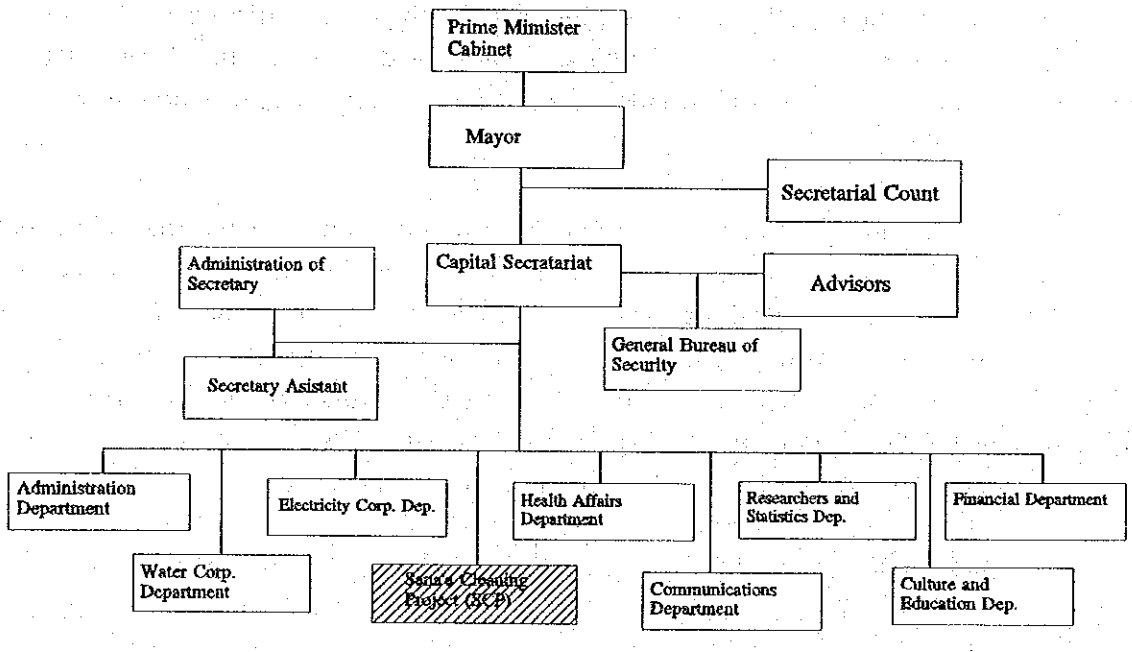

Fig.2.1 Organization Chart of Sana'a Sity

SCP has approximately 900 employees, 15 collection vehicles, about 2,300 containers, and tries to reinforce SWM. It only, however, gets to collect 50% (400 tons/day) of the generation waste amount of 800 tons/day because shortage in vehicles and equipment limits collection capacity, which has led to the increase in areas outside of the main city district which are not covered by collection services and scattered with wastes. This increase in insanitary areas has become a big social problem.

Accordingly, the Government of Yemen requested Grant Aid to the Japanese Government mainly concerning the supply of equipment required for the improvement of SWM in Sana'a City.

2.2 Outline of the Request

After the Gulf War in 1990, the Government of Yemen requested Grant Aid to the Japanese Government, mainly in terms of the supply of collection vehicles (shown in Table 2.1, 1st Phase Request).

In the following year, SWM in the city has deteriorated. Therefore, the Government of Yemen made the 2nd and 3rd phase requests, (shown in Table 2.2), which reinforce the 1st phase, before the Team's field survey. The equipment of the 2nd phase is what is desired to supply through this Grant Aid program, and the 3rd are the equipment required in the future.

Accordingly, the equipment of the 1st and 2nd request shall be dealt with in this Project.

Table 2.1 Equipment List of 1st Phase Request

No.	Items	Specification	Quantity
1	Compactor Truck	Loadage $15m^3$	5
2	Compactor Truck	Loadage $11m^3$	4
3	Compactor Truck	Loadage $4m^3$	4
4	Dump Truck	Loadage $20m^3$	2
5	Container	Loadage $1m^3$	270
6	Street Sweeper	Not less than 160HP	2
7	Four Wheel-Drive Vehicle	Not less than 100HP	2
8	Wheel Carrier	For the workers to push and tow	30
9	Workshop Truck		2
10	Telecommunication System		Lump Sum
11	Spare Parts	10% of equipment cost	Lump Sum

Table 2.2 Equipment List of 1st Phase, 2nd Phase and 3rd Phase Request

Item	Required Equipment	Q'ty (including 1st and 2nd phase)	1st phase	2nd phase	3rd phase
1	Compactor (15/11/4m^3)	15	13	2	–
2	Dump Truck (20m^3)	4	2	2	2
3	Small Tipper	6	–	6	6
4	Wheel Loader	2	–	2	–
5	Car Washing Unit	1	–	1	–
6	Telecommunication System	1	1	–	–
7	Four Wheel-Drive Vehicle	3	2	1	–
8	Medium Bus (26 Passenger)	2	–	2	–
9	Small Bus (7–8 Passenger)	4	–	4	–
10	Street Sweeper	3	2	1	–
11	Workshop Truck	2	2	–	–
12	Detachable Container Truck	3	–	3	2
13	Electrical Compactor	4	–	4	4
14	Garbage Container (1.6m^3)	250	–	250	250
15	Garbage Container (1.0m^3)	370	270	100	130
16	Garbage Container (5.0m^3)	30	–	30	50
17	Wheel Carrier	30	30	–	–
18	Spare parts for above at 10% of cost	–			

Note: 1st → 1st phase request
2nd → required at present
3rd → required in the future

2.3 Outline of the Project Area

Waste collection is conducted under three methods; collection by containers, door to door collection, and collection along roads. In the majority of the areas the first collection method is adopted, while in other places the second is enforced. On the other hand, the third collection method is mainly used for the beautification of the roads.

In the first method the containers are basically collected by compactor trucks twice a day. In the 3rd method wastes discharged along the roads are collected by small pick-up trucks twice in the daytime, and by compactors once at night.

The compactors basically transport the collected wastes to the final disposal site. In case collection is conducted more than twice, the wastes are transported to the transfer station established by SCP. On the other hand, pick up trucks transfer wastes to a trailer installed with a compressor at the transfer station. After being compressed, the trailer transports the wastes to the final disposal site.

SCP effectively uses its equipment and works on improving its treatment capacities. However, shortage in equipment has led to the daily collection of only 50% of the 800 tons of waste generated per day, and its capability remains as it was in 1989. Consequently, wastes can be seen everywhere outside of the central city area, especially in new housing development sites at the suburbs of the city which are almost uncovered by the services. Although this is attributed to the shortage of equipment, emphasis should be focused on the fact that for a developing country, the residents have large amount of waste discharges per day (800g/capita/day). In accordance to this, the educational section of SCP conducts educational programs and propaganda that would heighten the awareness of the residents on SWM. There are no sufficient equipment, however, that would enable the effective execution of propaganda during assemblies, etc..

The final disposal site is situated 25km north-northwest of the central city area. The site covers an area of 100 ha, has been used for the past 12 years and shall be used for another 10 years. The site has 2 bulldozers and a landfill compactor. Although covering soil works are conducted partially, this can not be properly termed as sanitary landfill due to shortage in equipment. Because of a dry climate, there are few environmentally devastating problems such as leachate problems.

With the inspection program, the maintenance of existing equipment is conducted effectively on a large scale. The computerized management of spare parts' stocks

and numerous repairmen employed are also worth noticing. The final disposal site, however, is in need of maintenance and communication equipment.

The field survey results confirmed the necessity of collection equipment such as compactor trucks, containers, etc.. In addition, the final disposal site also requires heavy machinery for the covering soil. SCP will also require video projectors to aid the execution of educational programmes on SWM.

CHAPTER 3 OUTLINE OF THE PROJECT

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3.1 Objective

The population of Sana'a City, which was approximately 427,000 in 1986, soared to an estimate of 1,080,000 in 1992 as a result of the population inflow from south Yemen caused by the unification and the forced repatriation of Yemen overseas workers due to the Gulf War. Consequently, the amount of waste discharged increased; current generation waste amount is approximately 800 tons/day (approximately 800 g/person/day). Unfortunately, the present equipment of SCP are only capable of accommodating approximately 400 tons of discharged waste per day, leaving the rest scattered thus leading to the increase in insanitary areas.

To improve waste management conditions, this project shall establish the foundation by mainly supplementing the equipment for waste collection, transportation work and for the final disposal site.

3.2 Study and Examination on the Request

3.2.1 Appropriateness and Necessity of the Project

Since 1989, Sana'a is only capable of disposing and treating approximately 400 tons of waste per day. The population and the generation waste amount in 1989 were approximately 600,000 and 470 tons per day respectively, and wastes then were comparatively dealt with immediately. Due to the influx of population from south Yemen and the forced repatriation of the Yemeni overseas workers, the population has exceeded the estimated amount as it soared to 1,080,000, which in turn effected an 800 tons/day discharge of waste. This in turn caused wastes, that can not be accommodated by SCP, to pollute the city.

The objectives of this project are to formulate the waste disposal equipment plan with the present population (1992). Consequently, through the provision of the collection and transportation equipment, the collection coverage rate of the city will rise from 57.3% to 85.5%. The implementation of this project is expected to sanitize the insanitary areas and thus improve the surrounding environment. Further, the requested equipment are judged to be highly important for the achievement of the expected results mentioned above.

The maintenance and operation of the vehicles, which are the main requested equipment, will influence the success of this project. Since SCP is fully equipped with a vehicular repair section and systematically manages its vehicles competently, including the spare parts, it is considered capable of dealing with the new vehicles to be introduced in this project.

3.2.2 Plan of Execution

(1) Operation System

SCP is presently made up of four sections, namely the financial, operational, technical and educational sections, and employs 908 people. Since SCP has accumulated a lot of experiences in its field, there are no operational problems observed. And no problems are expected to arise in the future, as SCP will reinforce the personnel and strengthen the present operation system in accordance with the implementation of the Project.

The items below are what SCP aims to strengthen and stabilize:

1) Elevation of collection coverage rate through the reinforcement of operational and technical divisions.
2) Phased employment in accordance with the operational plan.
3) Improvement of Final division to manage new equipment effectively.
4) Activation of educational conducts to raise the residents' consciousness on SWM and to decrease waste discharge.
5) Improvement of the equipment for final disposal site for sanitary landfill.
6) Expansion of workshop equipment to improve maintenance capabilities.

(2) Financial Plan

The city of Sana'a collects waste disposal fees, that is 5% of the electric bill, to cover the expenses of SCP. The average amount collected from one household i.e. only 10 Rial, does not suffice.

SCP is not solely or mainly reliant on the fees collected from the residents. Though its budget is subsidized by the national government and the municipality of Sana'a on an alternative basis, subsidization by the municipality is believed to be adopted in future.

Table 3.1. shows the SCP budgetary changes from 1989 to 1992 and Table 3.2 shows the budget required for 1993. The former clearly shows a steady increase in the annual budget of SCP, while the latter indicates a sharp increase of 50% in the 1993 budget, wherein 43% is appropriated for labour costs, as compared to the previous years' ratios. This 43% shall cover the costs for the hiring and the training of new drivers and workers.

Conclusively, with the experiences of SCP and the budget allocated for 1993, any hindrance can be overcome easily.

Table 3.1 Changes in the Budget of SCP

unit: Rial

Classification \ Year		1989	1990	1991	1992
Operation cost	from Government	2,978,676	4,000,000	4,360,000	8,400,000
	from City	1,767,996	1,529,193	2,630,310	3,240,000
	Subtotal	4,746,672	1,529,193	6,990,310	11,640,000
Labour cost	from Government	17,996,080	21,529,291	24,040,632	34,502,351
	from City	719,301	1,052,855	2,339,391	3,244,000
	Subtotal	18,715,381	22,582,146	26,380,023	37,746,351
Equipment cost	from Government	–	–	2,784,804	840,000
	from City	1,048,046	973,000	141,968	–
	Subtotal	1,048,046	973,000	2,926,772	840,000
Total		24,510,099	29,084,339 (+19%)	36,297,105 (+25%)	50,226,351 (+38%)

Notes: ( ) growth rate (%) from 1989–1992

Table 3.2 Requested Budget for 1993

Item	Requested Amount	Growth rate (%) from 1992
Operation cost	13,500,000	+16%
Labour cost	54,320,000	+44%
Equipment cost	7,580,000	+111%
Total	75,400,000	+50%

3.2.3 Relevance to Other International Assistance

SWM in Sana'a city was fully implemented in 1980. The equipment for collection and transportation are primarily those purchased from Geesink in Holland without international aid. Afterwards, other existing equipment (for collection, transportation and final disposal site) were also purchased and introduced without assistance. Therefore, there are no international assistance plans formulated on SWM and none are scheduled either.

3.2.4 Study on the Requested Equipment

The equipment requested by the Yemen Government are largely divided into the five following items:

1) Equipment for covering soil in final disposal site:

Dump Truck	Wheel Loader

2) Equipment for collection and transportation:

Compactor	Detachable Container Truck
Dump Truck	Electric Compactor Vehicle
Small Tipper	Container
Wheel Loader	Wheel Carrier
Road Sweeper	

3) Maintenance equipment:

Car Washing Unit	Workshop Truck

4) Operational equipment:

Telecommunication System	Medium Bus
Four Wheel-Drive Vehicle	Small Bus

5) Educational equipment:

Video Projector	Screen

The details concerning these equipment are elaborated herein.

(1) Final Disposal Site

The details of the requested equipment are shown below:

1)	Dump Trucks	($20m^3$)	2 units
2)	Wheel Loader	($1.9m^3$)	1 unit

SCP plans to use the landfill method for the future treatment of wastes at the final disposal site. The equipment for covering soil requested in this project are considered almost appropriate with due consideration of the topography of the area and operational conditions employed. Nevertheless, there is a need to estimate the number and capacity of these equipment in respect to the load of wastes disposed of at the site per day.

The dimension of the dump truck shall be altered to $10m^3$, as the manoeuvring capabilities of the $20m^3$ dump truck are inadequate for use on the disposal site.

(2) Equipment for Waste Collection and Transportation

The following equipment for waste collection and transportation were requested:

1)	Compactor ($15m^3$, $11m^3$, $4m^3$)	15 units
2)	Container ($1.6m^3$)	250 units
3)	Container ($1.0m^3$)	370 units
4)	Detachable Container Truck ($8m^3$)	3 units
5)	Container ($5m^3$)	50 units
6)	Dump Truck ($20m^3$)	2 units
7)	Wheel Loader ($1.9m^3$)	1 units
8)	Small Tipper ($1.5m^3$)	6 units
9)	Electric Compactor	4 units
10)	Street Sweeper	3 units
11)	Wheel Carrier	30 units

The use of these specified equipment will be determined in accordance with the collection methods adopted. The collection method is clarified herein and the details of the request will be studied. The required number of equipment are discussed in later sections.

a. Collection method

The present collection method mainly uses compactors for the collection of $1m^3$ containers [(3)] placed in many places in the city. $15m^3$ and $11m^3$ compactors [(1)] are requested to reinforce the present collection method. On the other hand, $1.6m^3$ containers [(2)] are not too suitable for the smooth operation of the loading system as they are too heavy to handle.

$4m^3$ compactors and an electric compactor were requested for door to door collection. This collection method is partly implemented and contributes to the efficient collection of wastes. SCP requested for further implementation of the method in other areas. The use of the electrical compactor [(9)], however, is not favourable due to the difficulty in body mechanisms and maintenance procedures.

Collection through the detachable container truck [(4)] will be intended for the market and housing areas uncovered by collection services. This collection method is proven appropriate in these areas, where waste discharge is dense, according to survey results.

Road sweepers [(10)] will be difficult to maintain due to the accumulation and clogging of sands which usually occur in dry places. Furthermore, the use of this equipment is not recommendable as the streets are effectively manually cleaned by foreign workers.

As a collection equipment, wheel carriers [(6)] are considered ineffective, therefore, SCP deletes them from the plan. Dump Truck [(6)] will be used to collect and transport heavy wastes such as construction wastes, which are scattered in the city. This countermeasure is considered effective to prevent illegal dumping observed around the containers designated areas.

Small tippers [(8)] will supplement the shortage of pick up trucks and will be used to collect the wastes scattered in the city or around containers.
Since there are many narrow roads, an agile small tipper is considered to be extremely effective than the compactor truck in supplementing collection by compactor.

The dimension of the dump truck shall be altered to $10m^3$, as the manoeuvring capabilities of the $20m^3$ dump truck are inadequate for waste collection.

The above stated that requested equipments(1)(3)(4)(5)(6)(7)(8) suit the conditions of the site.

(3) Maintenance Equipment

The maintenance equipment requested are:

1)	Workshop Truck	2 units
2)	Car Washing Unit	1 unit

The workshop truck is to be used for the maintenance of the equipment at the final disposal site and the repair of collection and transportation vehicles that break down during service hours.

The following are found essential to the repair of damaged equipment as the final disposal site has no repair equipment.

1) After discovering the factors behind the damages, repair tools and spare parts should be brought to the site from the workshop.

2) Malfunctioning or damaged equipment should be loaded on trailers and brought to the workshop.

There is a shortage of mechanical staff on the site, therefore, case (1) is not very effective due to the difficulty in looking for exact parts of chassis and tools, and errors in selection unavoidably lead to repeated journeys to have the parts changed. The absence of a trailer, on the other hand, makes case (2) impossible.

Given these conditions, repair on the site through the workshop truck is extremely effective and its request is considered very appropriate for the sound operation of the other required equipment. Further, damages in collection and transportation vehicles, i.e. suspension breakdown and flat tires during working hours usually caused by bad road surface condition, can be repaired by the workshop truck.

On the other hand a car washing unit, which essentially requires the securement of water, is not recommendable due to the bad water condition in the city.

(4) Operational Equipment

A patrol vehicle, telecommunications system and a bus are requested for the operation equipment.

1)	Four wheel-drive vehicle	3 units
2)	Telecommunication system	1 set

3) Medium Bus 2 units
4) Small Bus 4 units

Small four wheel drive vehicles used will enable passage in narrow alleys or streets. This vehicle will be intended for the following:

1) Regular patrol of the collection area in the city.
2) Guidance in collection work and to act as a lead car for effective collection work.

A timely understanding of the generation of waste and vehicular collection activities at the site is extremely important to achieve the above items (1) and (2).

The telecommunications system will be used to implement effective collection and transportation of waste. The popular means of communication at present in Sana'a city is the telephone. Due to unstable telephone conditions and the absence of public telephones, contacts in case of sudden vehicular breakdowns cannot be easily made to the workshop. Moreover, between headquarters and the final disposal site, there are no means of communication since telephone wires are not extended up to the latter.

The availability of telecommunications systems would enable an integrated management by establishing connections between the headquarters (operation section and workshop), final disposal site and every vehicle. In addition, collection and transportation vehicles on the road can relay their positions to the headquarters, and based on the data on waste collected during regular patrol rounds, the headquarters can in turn direct orders that would result in a more effective and efficient collection system. The request for a telecommunication system is indeed appropriate and necessary.

The requested buses, however, are of less importance in this project, as they have no direct effect on waste collection and is mainly requested for the transport of the workers.

(5) Educational Equipment

Although there are no educational equipment listed in the request, the additional items shown below were agreed upon after the discussion with SCP:

1) Video Projector 1 unit
2) Screen 1 unit

The most important matter of interest in the management of waste is the education of the residents concerning the reduction of waste amount and proper waste discharge manners. Educational programmes are being carried out at present in junior high schools to universities, in mosques and during women assemblies. SCP has also started the formulation of educational data. The equipment requested, i.e., video projector and screen, according to the following reasons, are considered to be appropriate and will come into full use in the propagation of educational activities.

1) One presentation can be viewed by a lot of residents;
2) The equipment are portable and make the execution of educational activities possible anywhere;
3) The details of the program should be made easy to understand by means of visual equipment, since the area has a mean illiteracy rate of approximately 55%.

3.2.5 Study on the Details of the Requested Equipment

(1) Policy of Equipment Plan

The project aims to improve the sanitary environment of Sana'a by compensating the present inadequate waste collection capacity. However, there is a need to divide the area of Sana'a City because problems may occur if loading systems for the container between the equipment implemented in this Project and those presently used are interchanged. By dividing the collection areas, the existing equipment will be moved to other areas to accommodate new ones. This will improve the collection capacity of other areas and the collection services in the city as a whole.

1) Scope of the Plan

This plan will not only involve waste collection and transportation equipment, but will also include equipment required for the operation and maintenance of the final disposal site and for the effective education of the residents on SWM, and will contribute to the improvement of public sanitation in Sana'a City.

2) Interchangeability of Containers

- The loading system of containers presently owned by SCP might be incompatible with this plan.

- The existing and new containers cannot be mixed and their area of designation must be clearly specified.

(2) Target Area

This plan will be focused on the southern part of Sana'a City divided by Zubairy Street (see Fig.3.1) as the population scale of the area corresponds to the scale of the equipment planned. Southern Sana'a has many new towns, a total area of 40 km^2 and a population of approximately 400,000. In this area the actual waste collection coverage rate is less than the northern.

(3) Proposed Collection Area and Method

In the southern area, which is very wide as shown in Fig.3.1, collection service is being carried out only in some parts of the densely populated area. The proposed area covered by this project are as follows:

- Current collection area
- New residential area

The above areas were selected because of their too insanitary current situations. On the other hand, self-disposal will be just fine for the proposed areas uncovered by this project because of its limited population. Fig. 3.2 illustrates the arrangement of these collection areas and the respective collection methods adopted.

The collection methods were determined based on the following:

Door to door collection – This method is presently being experimented in S2 collection area. However, SCP plans to positively adopt the method in the future. The results of the project discussion agreed upon the use of this method in residential areas S2, S4 and S5, where roads are considerably narrow.

Collection by container($1m^3$) – S2, S3 and S6 will be selected as the roads are considerably wide making the entrance or the passage of large compactors easy.

Collection by container($8m^3$) – This will be used in new residential areas presently not covered by the collection services. In addition, this collection will cover the point sources such as markets and public equipment in the southern part.

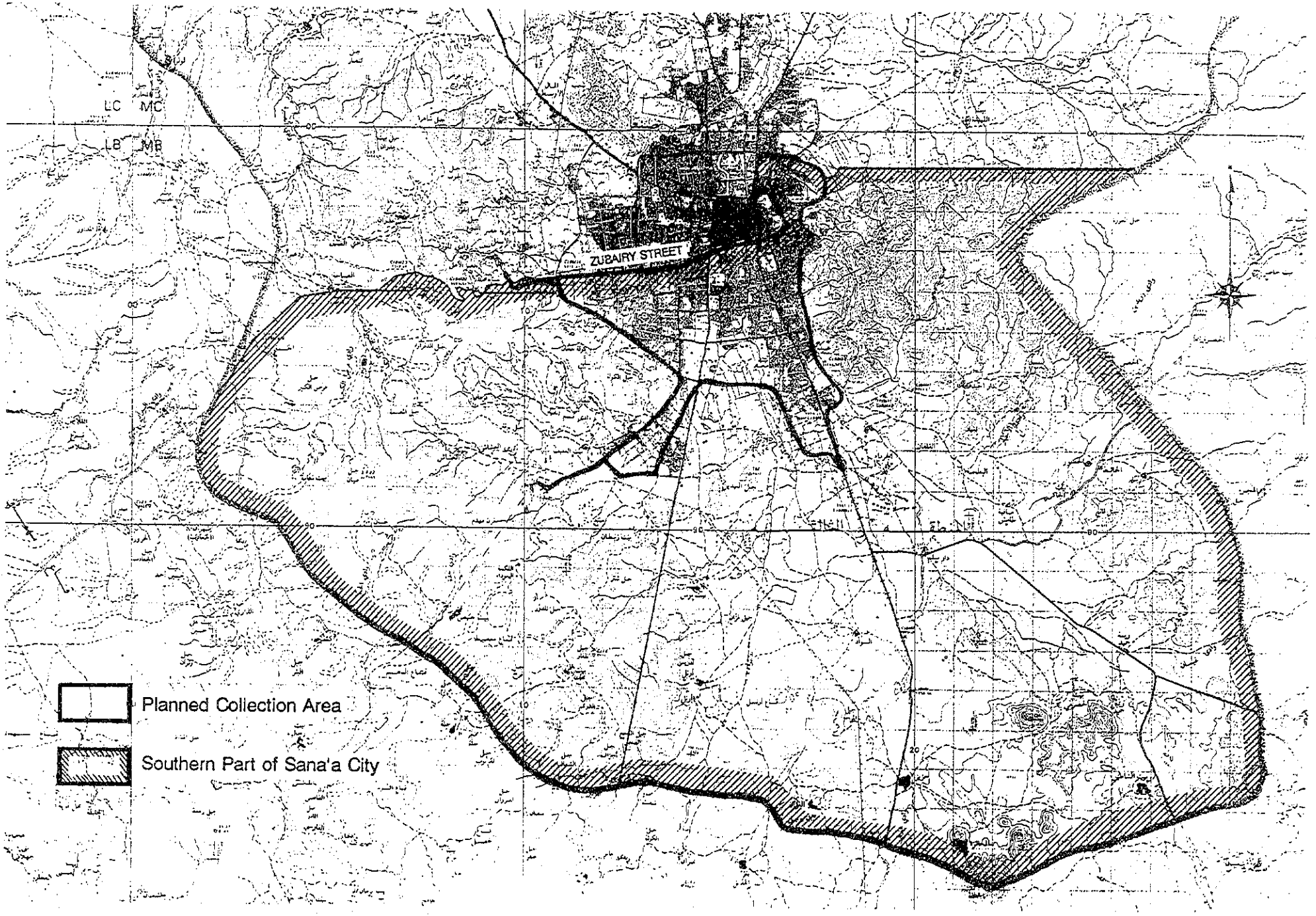

Fig.3.1 Planned Collection Area Map in Southern Part of Sana'a City

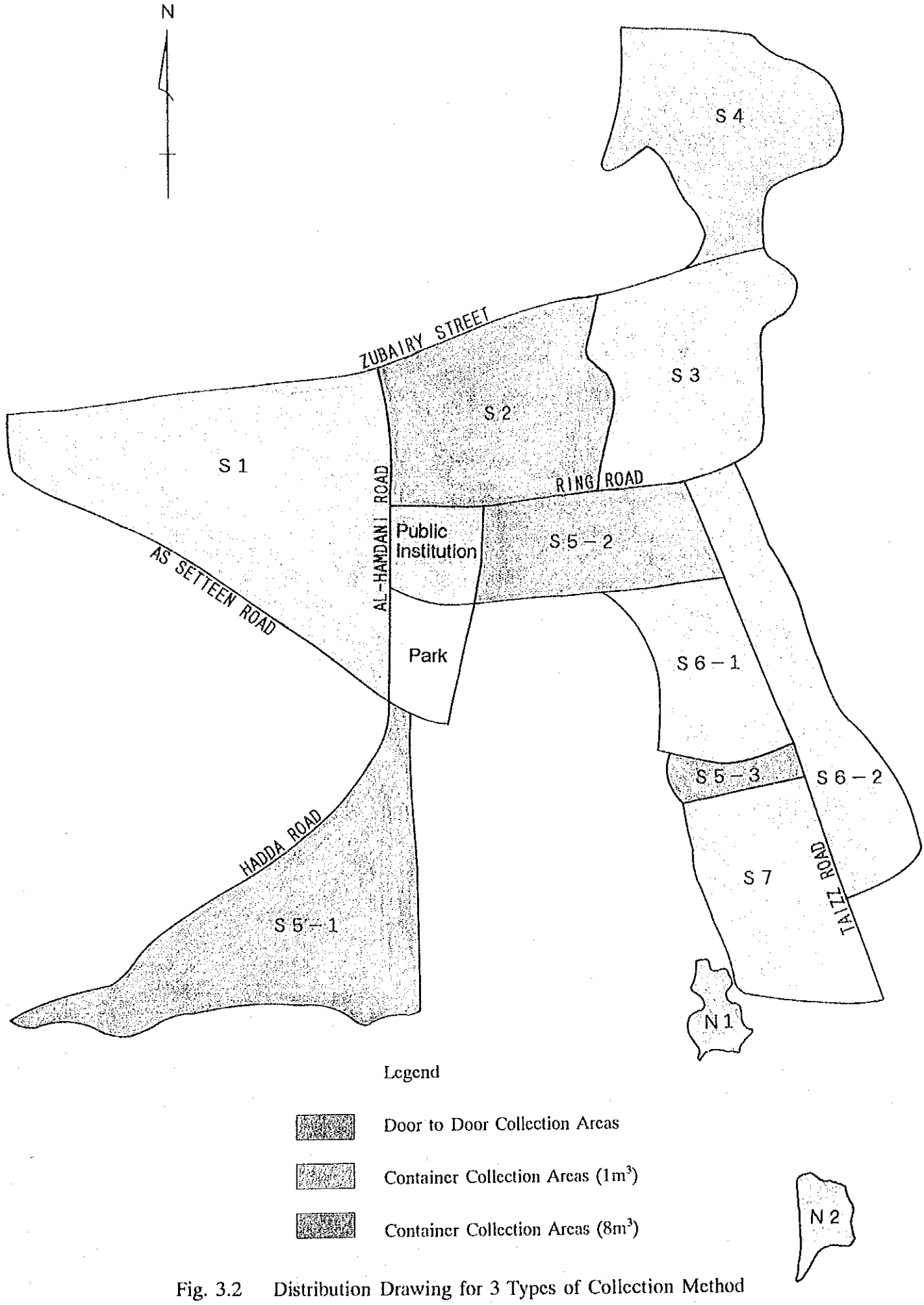

Fig. 3.2 Distribution Drawing for 3 Types of Collection Method

(4) Framework of the Design

The basic framework for the estimated number of equipment is as shown below:

1) Target Year

1992 shall be made the target year because the future population cannot be estimated.

2) Population (1992)

Sana'a City	1,076,090
Northern Area	695,628
Southern Area	380,462

3) Population in Collection Area

The population to be covered by the collection plan is determined according to the following, since the population covered per collection area was not determined by SCP.

a. Estimation of the population in each existing collection area

(1)	Area of Southern Part of Sana'a City	40 km^2
(2)	Population of Above Area	380,462
(3)	Population Density	380,462/40 ≒ 10,000 persons/km^2

The above mentioned density enables the calculation of the population of each collection area, and the population of the densely populated area (S2,S3,S4) is calculated by doubling the value of the density. These results are shown in Table 3.3.

b. Calculation of the population in the new collection area

The designated new collection areas are the new developed residential areas (S7, N1, N2 as shown in fig 3.2), where collection services are not conducted and especially a lot of uncontrolled wastes can be seen. The estimated population of these new collection areas as well as the existing is shown in Table 3.4.

Table 3.3 Population of Existing Collection Area

Name of Collection area	Area Coverage (km^2)	Population Density (person/km^2)	Population Coverage (persons)
S1	4.45	10,000	44,500
S2	2.55	20,000	51,000
S3	2.29	20,000	45,800
S4	2.30	20,000	46,000
S5	5.24	10,000	52,400
S6	3.20	10,000	32,000
Total	20.03		271,700

Table 3.4 Population of New Collection Area

Name of Collection area	Area Coverage (km^2)	Population Density (person/km^2)	Population Coverage (persons)
S7	1.95	10,000	19,500
New Area 1	0.32	10,000	3,200
New Area 2	0.24	10,000	2,400
Total	2.51		25,100

c. Target Population

From the above, the target population in this plan will be 296,800 as shown in Table 3.5.

Table 3.5 Outline of Designed Area

Collection Area Coverage	22.54 km^2
Population Area Coverage	296,800
Number of Collection Area	6 existing collection areas 3 new collection areas point sources (2 markets, 1 public facility)

4) Waste Generation Rate

The results of the survey conducted by SCP show a waste generation rate of 0.8 kg/ day/person. It is more appropriate to adopt a mean value considering that this survey was conducted in the central area of Sana'a. Therefore by discussing the survey results with SCP, the waste generation rate was settled at 0.6 kg/person/day, 75% of the value indicated by SCP's survey results.

5) Apparent Specific Gravity

SCP estimates a waste apparent specific gravity of 0.8 t/m^3, but the over-whelming majority of the wastes transported to the final disposal site are of domestic origin. This project, therefore , adopts a value, 0.4t/m^3, which is the closest to the general apparent specific gravity applied to developing countries.

6) Generation Waste Amount in Point Sources

Markets and public equipment are the point sources in Sana'a City and their respective waste generation amount observed during SCP surveys will be used in this plan. These values were judged to be appropriate according to the results of the field survey.

7) Target Waste Collection Amount

Consequently, the calculation of the target collection amount is shown in Table 3.6.

Table 3.6 Target Collection Amount

Name of Collection Area	Area Coverage (km^2)	Population (persons)	Target Collection Amount (tons/day)
S1	4.45	44,500	26.70
S2	2.55	51,000	30.60
S3	2.29	45,800	27.48
S4	2.30	46,000	27.60
S5	5.24	52,400	31.44
S6	3.20	32,000	19.20
S7	1.95	19,500	11.70
New Area 1	0.32	3,200	1.38
New Area 2	0.24	2,400	1.44
Big Market	–	–	5.00
Middle Market	–	–	3.00
Public Equipment	–	–	8.00
Total			193.54

(5) Equipment for the Final Disposal Site

1) General Specification

a. Equipment for Loading Cover Soil

– Wheel Loader

Table 3.7 General Specification of Wheel Loader

Item	Specification
Bucket Capacity	1.9 m^3

b. Equipment for Transportation of Cover Soil

- Dump truck

The dump truck for cover soil transport will also be used to transport illegally dumped waste, mainly construction waste, when necessary. The loading capacity will be changed to $10m^3$, from the requested capacity of $20m^3$, to facilitate operation in towns. Assuming the unit weight of soil is 1.4 ton/m^3, the specification of the dump truck is shown in Table 3.8.

Table 3.8 General Specification of Dump Truck

Item	specification
Chassis	Gross vehicle weight Not less than 24 tons
Body	Capacity: 10 m^3 Mechanism: Tipping motion

2) Calculation of Required Number of Equipment

a. Calculation of the covering soil volume

Wastes are spread and compacted with the use of bulldozers and landfill compactors, and based on the present compacted condition, the thickness of spread wastes are about 50cm. Based on this thickness, the volume of covering soil required for 100 tons of waste is as shown below.

Table 3.9 Calculation of Covering Soil Volume

Item	Quantity	Unit	Remarks
Waste Disposal Amount	100	ton	
Waste Volume After Spreading and Compaction	166	m^3	100/0.6 0.6: Apparent specific gravity (ton/m^3)
Spreading and Compaction Area	332	m^2	166/0.5 0.5: Thickness of waste layer (m)
Volume of Covering Soil	66	m^3	332 × 0.2 0.2: Thickness of cover soil layer (m)

b. Calculation of required time

– Wheel Loader

$$(1)\ \text{Excavation and Loading time} = V_1 \times \frac{Cm}{60\delta_1 fE}$$

– Dump truck

$$(2)\ \text{Transportation time} = V_1 \times \frac{Cm}{60\delta_2 fE}$$

Table 3.10 Calculation Parameter for Covering Soil Volume

Item		Wheel Loader	Dump Truck
Covering soil volume	V_1	66 m^3	66 m^3
Excavation volume of 1 cycle	δ_1	1.5 m^3	–
Loading volume of 1 cycle	δ_2	–	10 m^3
Change coefficient of soil volume	f	0.75	0.75
Operation efficiency	E	0.85	0.85
Time required for 1 cycle	Cm	1.0 min	*10 min

Note: (Cm) of the Dump Truck is assumed to be 10 min, considering the easy procurement of soil inside the site.

Table 3.11 Time required for the Loading and Transport of Covering Soil

Item	Required time (hour)
Wheel loader	1.15
Dump truck	1.73

c. Calculation of required number of equipment

The time needed for the excavation and transportation of the covering soil for 100 tons of waste is 1.15 hours for the wheel loader and 1.73 hours for the dump truck. Based on this, the number of required equipment will be 1 wheel loader and 2 dump trucks, as shown in Table 3.12.

Table 3.12 Required Number of Soil Covering Equipment

Designed collection amount (ton) Wd	Actual operation time per day (hour) T_0	Required disposal time per 100 tons		Required number of equipment	
		Wheel loader (hour) t_1	Dump truck (hour) t_2	Wheel loader	Dump truck
587.5	7.0	1.15	1.73	0.7	1.5
Required number of equipment				1	2

Note: Designed collection amount (587.5 ton) is shown in Table 5.1.

- Capability of disposal amount per day

  Wheel loader T_0/t_1 = 608.7 tons/day/unit

  Dump truck T_0/t_2 = 404.6 tons/day/unit

- Required Number of Equipment

  Wheel loader Wd/608.7 = 0.7 ≃ 1 unit

  Dump truck Wd/404.6 = 1.5 ≃ 2 units

(6) Equipment for Collection and Transportation

1) General Specification

a. Compactor (for collection by containers)

- Chassis : Because the road is comparatively wide, a large vehicle with forward control will be adopted.

- Body : A hydraulic operation loading system similar to the one used at the moment will be attached to the body. The capacity will be 15m^3 based on the GVW and the specific gravity of waste.

b. Compactor (for door to door collection)

- Chassis : Because the road is comparatively narrow, a medium size vehicle with forward control will be adopted.

- Body : A compaction type equipment with functions similar to the one presently used will be employed. The capacity will be $10m^3$ based on GVW of the vehicle and the specific gravity of waste.

c. Detachable container truck (point sources and areas uncovered by collection services)

- Chassis : Because the road is comparatively wide, a large vehicle with forward control will be adopted.

- Body : Due to the poor quality of roads, this vehicle, which meets the specifications, was adopted for the loading of $8m^3$ containers.

d. Dump Truck (transportation of heavy waste)

- Chassis : A large vehicle will be used because its role is to transport heavy loader containing lots of construction wastes. This vehicle will also have a forward control function.

- Body : The capacity will be $10m^3$ in consideration of GVW and the specific construction waste gravity (1.4 tons/m^3). For the discharge of heavy loads, it has a tipping mechanism.

e. Wheel Loader (loading of heavy waste)

- Bucket Capacity : A bucket capacity of $1.9m^3$ will be used as the above mentioned dumping truck would require its dumping clearance.

f. Small Tipper

– Chassis	:	GVW will be 4.5 tons considering the collection work in narrow roads.
– Body	:	Loading capacity will be 1.5m^3 in consideration of GVW. And it has a tipping mechanism for effective unloading at the transfer stations.

2) Calculation of required number of equipment

a. The terms in the calculation of the number of containers for compactors, based on the present collection, are as shown below.

- The number of containers which can accommodate the waste generation amount will be the basic quantity.
- To avoid the excessive storing of waste in one container, the necessary quantity of containers will be double the basic quantity mentioned above.
- The same conditions will be taken into account for the containers of Detachable Trucks, and the quantity will be 1.5 times the basic.
- The results of the calculation are shown in Table 3.13. The bases of the calculation are shown in Table 3.14 – Table 3.16.

Table 3.13 List of Collection and Transportation Equipment

Equipment		Required number	Name of collection area	Gross Weight of Vehicles	Body specification
1	Compactor truck with container loading system	4	S1,S3,S6	Not less than 17.5 tons	Capacity: 15 m^3
	Container ($1m^3$)	500	S1,S3,S6		Capacity: 1 m^3
2	Compactor Truck	8	S2,S4,S5	Not less than 13 tons	Capacity: 10 m^3
3	Detachable container truck	2	S7 New Area	Not less than 15 tons	Container loading system for unpaved roads
	Container ($8m^3$)	20	Market etc.		Capacity: 8 m^3
4	Dump truck	1	Southern Area	Not less than 24 tons	Capacity: 10 m^3 With Tipping motion
	Wheel loader	1	Southern Area		Bucket capacity: 1.9 m^3
5	Small Tipper	6	S1 to S6	Not less than 4.5 tons	Capacity: 1.5 m^3 With tipping motion

Table 3.14 Calculation of required 15m^3 Compactor Truck for Container Collection

Container Collection Area				Unit	Calculation
Design Condition	Body Capacity		15.00	m^3	a
	Compression ratio		1.40		b
	Maximum loading capacity		21.00	m^3	c = a x b
	Container capacity		1.00	m^3	d
	Number of trips to landfill site		2.00	Trip	e
	Maximum amount to be transported per day		42.00	m^3	f = c x e
	Collection amount per day		0.60	kg/person/day	g
	Specific gravity of waste		0.40	t/m^3	h
	Maximum weight to be transported per day		16.80	t	i = f x h

Calculation of Waste Amount	Name of Area	Area (km^2)	Population (j)	Target waste generation (k= j x g ÷ 1000)	Population density
	S1	4.45	44,500	26.70	10,000/km^2
	S2	0.00		0.00	20,000/km^2
	S3	2.29	45,800	27.48	20,000/km^2
	S4	0.00	0	0.00	20,000/km^2
	S5	0.00	3	0.00	10,000/km^2
	S6	3.20	32,000	19.20	10,000/km^2
	S7	0.00	0	0.00	20,000/km^2
			122,300	73.38	

Number of Required Equipment				
	Calculation of required number of Equipment			Calculation
	Required Number 4.37 units ≒ 4 units			$1 = \sum k \div i$
	Calculation of required number of containers			Calculation
	Designed Waste Amount	0.8	m^3	m
	Margin	2		n
	Required number of containers 458.63 units ≒ 500 units(including reserves)			$o = \sum j \div h \div m \times n$

Table 3.15 Calculation of Required $10m^3$ Compactor Truck for House to House Collection

House to House Collection Area				Unit	Calculation
Design Condition	Body Capacity		10.00	m^3	a
	Compression ratio		1.40		b
	Maximum loading capacity		14.00	m^3	c = a x b
	Number of trips to landfill site		2.00	Trip	d
	Maximum amount to be transported per day		28.00	m^3	e = d x c
	Collection amount per day		0.60	kg/person/day	f
	Specific gravity of waste		0.40	t/m^3	g
	Maximum weight to be transported per day		11.20	t	h = e x g
Calculation of Waste Amount	Name of Area	Area (km^2)	Population (j)	Target waste generation amount (k= j x g + 1000)	Population density
	S1	0.00	0	0.00	10,000/km^2
	S2	2.55	51,000	30.60	20,000/km^2
	S3	0.00	0	0.00	20,000/km^2
	S4	2.30	46,000	27.60	20,000/km^2
	S5	5.24	52,400	31.44	10,000/km^2
	S6	0.00	0	0.00	20,000/km^2
	S7	0.00	0	0.00	10,000/km^2
			149,400	89.64	

Table 3.16 Calculation of Required Detachable Container Truck

Container (8m³) Collection District				Unit	Calculation
Design Condition	Container capacity		8.00	m³	a
	Frequency of collection per day		1.00	time	b
	Maximum amount to be transported per day		8.00	m³	c
	Collection amount per day		0.60	kg/day/person	d
	Specific gravity of waste		0.35	t/m³	e
Calculation of Waste Amount	Name of Area	Area (km²)	Population (f)	Generation waste amount (g= f x d x 1000)	Population density
	S7	1.95	19,500	11.70	10,000/km²
	New Area 1	0.23	2,300	1.38	10,000/km²
	New Area 2	0.24	2,400	1.44	10,000/km²
			24,200	14.52	41.49 (m³)
Required equipment	Calculation of required number of containers			Calculation	
	Designed waste amount	6.4	m³	h	
	Margin	1.5		i	
	Required number of containers 9.72 ≒ 10 units			J = ∑g + e + h x i	
	Calculation of required number of trucks			Calculation	
	Required time per trip	45	min/unit	k	
	Hours of operation per day	7.5	hour	l	
	Number of trips per day	10	trip	m = l + k	
	Required Vehicles 1 unit			n = J + m	
Calculation of waste amount	Name of area	Area (km²)	Population (m)	Actual waste amount (t/day) n	Remarks
	Market 1	0.00	0	5.00	Big Market
	Market 2	0.00	0	3.00	Middle Size Market
	Public facilities	0.00	2,500	8.00	
			2,500	16.00	45.71 (m³)
Required number of equipment	Calculation of required number of containers			Calculation	
	Designed waste amount	0.8	m³	o	
	Margin	1.5		p	
	Required Number (unit: 10 units)			q = ∑n + e + o x p	
	Calculation of required number of trucks			Calculation	
	Required time per trip	45	min/unit	k	
	Hours of operation per day	7.5	hour	l	
	Number of trips per day	10	trip	m = l + k	
	Required vehicles (unit: 1 unit)			n = q + m	

(7) Equipment for Maintenance

1) General Specification for a Workshop Truck

Minimum equipment for repair will be installed in the workshop truck for repair works in the site. Table 3.17 shows the list of these equipment.

(8) Operational Equipment

1) General Specification of Four Wheel-Drive Vehicle

a. Engine displacement

In consideration of the alleys and lanes, a small vehicle with an engine displacement of 1000cc will be used.

2) Calculation of Required Number of Four Wheel-Drive Vehicle

a. The following conditions will be taken into consideration in the calculation:

(1)	Collection Area	20 km^2
(2)	Ratio of Road and Park Areas to (1)	40%
(3)	Ratio of Road Area to (2)	80%
(4)	Estimation of Road Length (assumed width is 6m)	(1)×(2)×(3)÷6.0 = 1,066 km
(5)	Milcage	150km/day

b. Calculation of Required Number of Vehicles

- Assuming that 3 days round patrol is adopted

Required vehicles 1,066 ÷ 150 ÷ 3 = 2.3 therefore, 2 units

Table 3.17 Main Equipment for Workshop truck

Material Classification	Item
a. General equipment and tools	Hand tools Electric equipment and tools Measuring equipment and tools
b. Air compressor	Air compressor Hose set Gun set
c. Hydraulic & electrical equipment and tools	Hydraulic gauge set Battery charger set
d. Welding equipment and tools	Welder Arc welding set Gas welding set
e. Lubricating equipment and tools	Grease pump set Drum pump set Oiler
f. Engine service equipment and tools	Cylinder gauge set Nozzle tester set Compression gauge set Valve lifter set
g. Tire repair tools	Hydraulic tire removing tool set Tube repair tool set
h. Miscellaneous	Mono-rail crane Hydraulic press Machinist's vice Lever block Work bench Fire extinguisher

3) General Specification for the Telecommunications System

a. Required number of wireless phones

- Central station 1 unit (with antenna)
- Receiver 26 units (for all planned equipment with the exclusion of the wheel loader)
- Handy Phone 4 units (mayor, SCP head, head of operations, head of technology section)

(9) Number of Equipment for Educational Programmes

2) Required Number

Video Projectors	1 unit
Screen	1 set

3.2.6 Necessity of Technical Cooperation

The equipment to be introduced are mainly vehicular in kind, and there are no particularly difficult equipment for the operation and maintenance aspect. The experience of SCP in handling and managing their equipment will also be fully applied to the equipment mentioned in the Project. Conclusively, the operation and maintenance of these new equipment will not particularly require any technical cooperation.

3.2.7 Basic Policy in the Implementation of Cooperation

According to the results of the study stated above, the implementation of this project will largely affect the improvement of SWM and environment in Sana'a City. In addition, Sana'a is also considered to be fully capable of operating and maintaining the equipment to be granted. Based on these observations, it will be of extreme importance for a reasonable facility plan to formulate and implement the Grant Aid program. Therefore, based on the scheme the Japanese Grant Aid program, the Basic Design will be carried out.

3.3 Project Description

3.3.1 Executing Agency and Operation Structure

The executing agency of the Project is SCP and its organization is shown in Fig.3.3. With the introduction of new equipment through the implementation of the Project, operation and maintenance departments personnel will be reinforced and its SWM will be smoothly carried out.

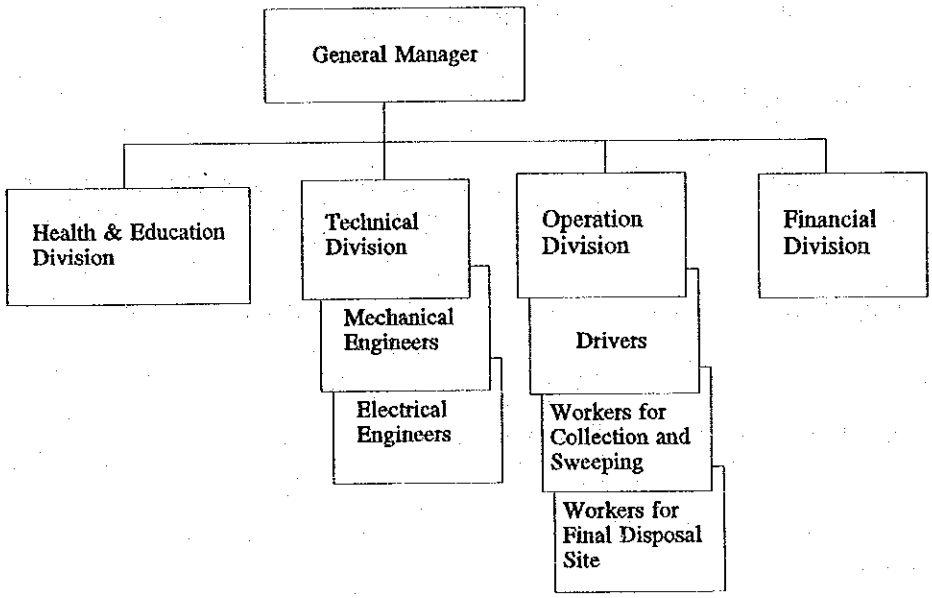

Fig.3.3 Organization of SCP

3.3.2 Outline of the Equipment

The following are the results of the study on the details of the requested equipment and the list of equipment is shown in Table 3.18.

(1) Equipment for Cover Soil of the Final Disposal Site

a. Purpose

Cover soil for wastes spread and compacted.

b. Required equipment

–	Wheel loader	($1.9m^3$)	1	for the excavation and loading of cover soil
–	dump truck	($10m^3$)	2	for the transportation of cover soil

(2) Equipment for Collection and Transportation

a. Purpose

The collection of wastes from households, hotels, restaurants, markets and business shops in the city of Sana'a, and their transport to the final disposal site.

b. Required equipment

–	compactor	($15m^3$)	4	for collection and transportation of wastes discharged by house-holds in containers ($1m^3$)
–	container	($1m^3$)	500	containers for the above compactor

–	compactor	($10m^3$)	8	for door to door collection and transportation of wastes discharged by households
–	detachable container truck		2	the collection and transportation of wastes discharged in new residential areas in containers ($8m^3$)
–	container	($8m^3$)	20	container for the above truck
–	dump truck	($10m^3$)	1	collection and transport of wastes, e.g. construction waste
–	wheel loader	($1.9m^3$)	1	loading of heavy waste into the dump truck
–	small dump truck	($1.5m^3$)	6	supplementary collection and transportation of wastes

(3) Maintenance Equipment

a. Purpose

Equipment needed in repair works and for waste collection and transportation and the final disposal site.

b. Required equipment

–	workshop truck	1	for repair works at the site (final disposal site and collection area)

(4) Operational Equipment

a. Purpose

A vehicle to regularly patrol cleaning services conditions and to take the lead during service hours to efficiently collect waste.

b. Required equipment

– Four Wheel–Drive Vehicle (1,000cc)	2	to patrol the site designated to the operations division
– telecommunications system	1 set	to direct the vehicles for effective collection and to gather information

(5) Educational Equipment

a. Purpose

For the effective implementation of educational programmes on SWM.

b. Required equipment

– video projector	1	for the presentation of educational programmes made by SCP
– screen	1 set	

(6) Spare Parts

Parts that shall be necessary 2 years after the above equipment are introduced.

Table 3.18 Required Equipment

Equipment Name		Q'ty	Collection Area	GVW	Body Specification
Equipment for collection and Transportation	Compactor for the collection of wastes in containers(1m^3)	4	S1,S3,S6	Not less than 17.5 tons	Capacity: 15 m^3
	1 m^3 container	500	S1,S3,S6	–	
	Compactor for door to door collection	8	S2,S4,S5	Not less than 13 tons	Capacity: 10 m^3
	Detachable container truck	2	S7 New area	Not less than 15 tons	Container loading system for unpaved roads
	8 m^3 container	20	S7 New Area	–	
	Dump Truck	1	Southern Area	Not less than 24 tons	Capacity: 10 m^3 Mechanism: Tipping motion
	Wheel Loader	1	Southern Area	–	Bucket capacity: 1.9 m^3
	Small Dump Truck	6	S1 to S6	Not less than 4.5 tons	Capacity: 1.5 m^3 Mechanism: Tipping motion
Equipment for final disposal site	Dump Truck	2	Final disposal site	Not less than 24 tons	Capacity: 10 m^3 Mechanism: Tipping motion
	Wheel Loader	1	Final disposal site	–	Bucket capacity: 1.9 m^3
Equipment for maintenance	Workshop truck	1	Final disposal site	Not less than 9 tons	Repair tool for disposal equipment
Equipment for operation	Four Wheel-Drive Vehicle	2	Southern Area	–	
	Telecommunications system	1	Headquarters: 1 unit, Vehicles: 26 units, Handy phones: 4 units		
Equipment for education	Video projector	1	Screen 1 set, Multi video system		

3.3.3 Protection of Equipment

The SCP headquarters is located west of Sana'a city, and is close to the west end of Zubary Street that divides the city into 2 parts,southern part and northern part. SCP headquarters holds an area of approximately 30,000m^2, and also has a workshop and a transfer station. The equipment being used at present are parked within the headquarters area which is big enough to accommodate the new equipment to be introduced in this project. SCP has a substantial supply of electricity and water that the implementation of the project will not bring about any problems on the maintenance of the equipment.

3.3.4 Operation and Maintenance Plan

(1) Organization and Administrative Plan

The maintenance of equipment is mainly the responsibility of the technical division. About 50 mechanics are employed in the workshop to do repair works and maintain the equipment. The current maintenance system conducts the works smoothly according to the system shown in Fig.3.4.

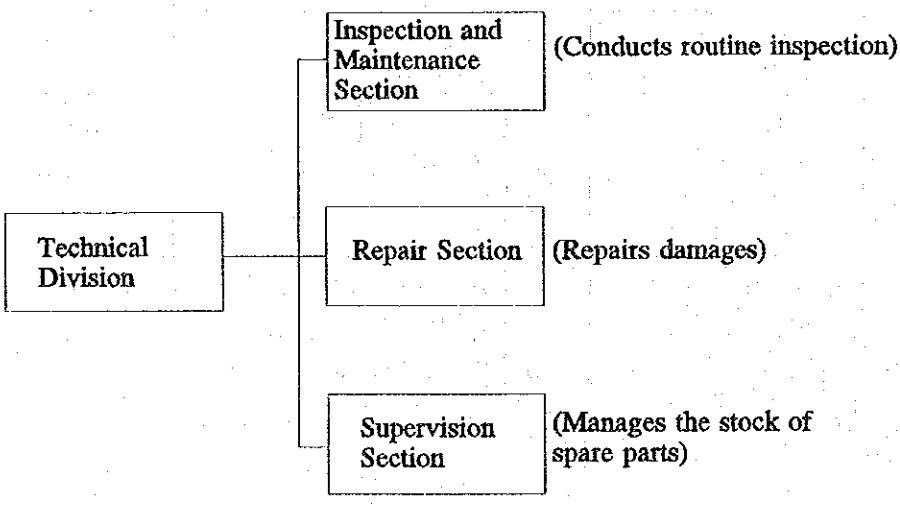

Fig.3.4 Structure of the Technical Division

The maintenance system required by the Project will be formed through the reinforcement of the current situation. As for the maintenance of the spare parts, the difficulties can be overcome by the use of computers. The additional construction of a storage area is most desirable, however, because the capacity of the storage areas may not be able to accommodate the existing and new equipment.

(2) Organization of Maintenance

Although the number of people employed at present (50) is judged to be sufficient in terms of the scale of the existing equipment, twenty more employees will have to be added as a result of the implementation of the Project. The planned organization of the technical division is shown in Table 3.19.

Table 3.19 Organization of Engineering Division

Position	Number
General Manager	1
Manager	3
Mechanic	10
Assistant Mechanic	28
Lubricator	4
Painter	4
Wheel Mechanic	5
Lathe Technician	2
Spare Parts	4
Accountant	5
Total	70

(3) Operational Cost

The number of staff required for future operations was determined based on the equipment required in this plan, and is shown in Table 3.20. An increase of 400 people in the personnel was taken into account when Sana'a made its budget. Therefore, the budget of Sana'a City can accommodate the employment of 392 people.

On the other hand, the operation and maintenance cost will be 700 million rial (see Table 3.21) after the implementation of the plan, in spite of the fact that budgetary measures were adopted.

The implementation of this plan is expected to have no problems in terms of personnel and expenses.

Table 3.20 New Employment Plan

	Regular Staff					Contract workers etc.
	Items	No. of workers per unit	Frequency of shift operation	No. of units	No. of Persons	No. of Persons
Collection and transportation	Compactor	3	2	12	72	209
	Detachable container truck	2	2	2	8	
	Small Tipper	3	2	1	6	
	Wheel Loader	3	2	6	36	
		1	2	1	2	
	Sub-total				124	
Final disposal site	Dump truck	1	2	2	4	
	Wheel Loader	1	2	1	2	
	Sub-total				6	
Workshop	Mechanic				20	
Others	Mechanic of telecommunication				2	
	Gatekeeper				5	
	Supervision and education				22	
	Administration				4	
Sub-total					183	209
Total					392	

Table 3.21 Estimation of Annual Maintenance Cost

unit: Rial

Equipment	No. of units	Daily travelling distance per unit (km/unit)	Annual travelling distance (km)	Fuel cost	Oil cost	Main-tenance cost	Total
Compactor ($15m^3$)	4	200	72,000	1,296,000	129,600	64,800	1,490,400
Compactor ($10m^3$)	8	150	54,000	972,000	97,200	48,600	1,117,800
Detachable Container truck	2	200	72,000	1,296,000	129,600	64,800	1,490,400
Dump truck	1	150	54,000	972,000	97,200	48,600	1,117,800
Wheel truck	1	50	18,000	342,000	34,200	16,200	372,600
Small tipper	6	150	54,000	972,000	97,200	48,600	1,117,800
Dump truck	2	30	10,800	194,400	19,440	9,720	223,560
Wheel Loader	1	10	3,600	64,800	6,480	3,240	74,520
Total							7,004,880

Terms of the Estimation:

1. Fuel consumption rate is 4.5l/km
2. The unit fuel cost is 4 Rial/l
3. Oil cost is 10% of the fuel cost
4. Maintenance cost is 5% of the fuel cost