PART C

APPENDICES

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APPENDIX CC-I WORK STUDY OBSERVATIONS

Notes: The data below were collected while following collection vehicles; the original notes have been edited but are in a form similar to the original record. The distance meter readings are taken from the meter of the observation vehicle that was following the truck, and the time is clock time in hours, minutes and seconds.

Station denotes a loading point or storage facility

Arr denotes the time when the vehicle arrives and stops at the storage facility that is to be emptied.

Dep denotes the time when loading at the particular location has been completed, and the vehicle moves off.

No. of bowls Solid waste that is not loaded directly into the truck by the hydraulic system of a compactor truck is loaded using large plastic bowls with rope handles. Though the actual volume of refuse placed into such bowls varies considerably, the number of times that bowls must be filled to clear the waste is an indication of the quantity of the waste and of the time of the operation. At first the numbers of bowls were not counted; these occasions are marked thus *.

Trolley a wheeled container specially designed for Airtech compactor trucks, of capacity 1 m^3, as shown in figure B-2.11

CC-I.1 Compactor truck - 'A' -, 25 November

Vehicle model: Airtech Schörling 4R, approximately three years old
Total body volume approx. 12m^3 (Appendix CC-I.6)

Station	Distance meter (km)	Time	Notes	No. of Bowls
	304	7.19'	**Start** (Tools carried in hopper)	
1	305	7.23'	**Arr** (One trolley behind pile which must first be cleared with bowls. Loading cycle takes about 44 s. Emptying trolley takes 111 s.	*
		7.39'30"	**Dep** (One loader rides on vehicle)	
2	305	7.40'30"	**Arr** (Little waste around. Trolley missing one back wheel. Trolley emptied in 40 s.)	*
		7.43'30"	**Dep**	
3	306	7.45'	**Arr** (Trolley ¾ full. Waste around very wet)	*
		8.00'	**Dep** (Backing out of site - roadworks)	
4	307	8.04'40"	**Arr** (Trolley full. Coconuts picked up by hand; dead cat thrown in, 6 men needed to move trolley; cycle to empty trolley took 99 s.)	*
		8.11'45"	**Dep**	
5	308	8.13'40"	**Arr** (Trolley approx. 20% full; also masonry bin; trolley had no front wheel, could not be moved.)	6
		8.17'40"	**Dep**	

compactor truck - 'A' - continued

Station	Distance meter (km)	Time	Notes	No of Bowls
6	308	8.20'00"	**Arr** (2 trolleys 1 very full, 1 full; front wheel of one trolley stuck in soft ground, 85 s. to manoeuvre; 227 s. to load one full trolley.)	19
		8.39'40"	**Dep**	
7		8.41'00"	**Arr** (Good site, 2 trolleys with little waste outside; 167 s. to load one trolley, 247 s. to load other; rat holes.)	2
		8.50'40"	**Dep**	
8		8.52'10"	**Arr** (One trolley approx. 2/3 full; but much on ground)..	10
		9.01'30"	**Dep**	
9	310	9.04'50"	**Arr** (Hotel. Waste in side room, waste very wet, all loaded manually, loaders walk in waste; some waste in plastic bags; loading cycle 56 s.	13
		9.20'	**Finished** (Tea break - washed well first)	
		9.33'22"	**Dep**	
		(9.35'47"	Arrive hotel; truck reverses, cleaner guides.)	
10	311	9.38'42"	**Arr** (Garbage in room; loaded in plastic bags and bowls.)	18
		9.58'	(Vehicle and area washed down; breakfast break)	
		10.15'	**Dep**	
	313	10.23'	**Arrive check point**	
		10.29'	**Depart check point**	
	318	10.43'	**Arrive weighbridge** (Water still draining from load.)	
		10.47'	**Depart weighbridge**	
		10.56'30"	(Turning off main road onto road leading to tip)	
	322	10.58'	**Arrive Malad disposal site**	
		11.01'	At tipping place	
		11.03'	Body empty; hopper to be cleaned	
		11.08'	Hopper clean	
	323	11.10'30	**Depart disposal site**	
	323	11.13'	Arrive main road	
	327	11.20'	**Arrive weighbridge**	
		11.24'26"	**Depart weighbridge**	
			(Traffic delays because of road works)	
	335	11.48'30"	**Arrive chowki** (Tools returned. Log sheet)	
		11.51'40"	**Depart chowki**	

Weights: (A second load, in the same vehicle, was weighed on 1 December)

		Both axles [kg]		Front axle [kg]		Rear axle [kg]	
		25 Nov	1 Dec	25 Nov	1 Dec	25 Nov	1 Dec
Empty	Written on cab	9,180					
	Measured	9,360	9,360				
Loaded	Written on cab	16,200		6,000		10,200	
	Measured	16,500	17,440				

CC-I.2 Contractor's truck - 'B' -, 26 November

Vehicle Type: Contractors - open truck
Truck body - Height 1.37m , Length 3.86m, Width 2.30m, Tailboard ~ 56cm high.

Refuse containers: Most refuse in steel pipe sections about 1m diameter.

Station	Distance meter (km)	Time	Notes	No of Bowls
	424	7.26'30"	**Depart motor loader chowki** (Crew have one two-prong rake. 1 spade, 1 broom, 1 bowl)	
1	424	7.30'	**Arr** (Two men in truck to receive loads, one sweeping. Dry waste - leaves, soil.)	4
		7.35'40"	**Dep**	
2	424	7.37'05"	**Arr** (Two men lift ring. Site clean.)	7½
		7.42'27"	**Dep** (Truck moves at 10 km/hr)	
3	427	7.44'	**Arr** (Much foliage - another vehicle will collect tree cuttings. Labourers pulling branches apart and away from refuse. 40L bin brought by lady. 1.2 m dia riveted ring. Two labourers without footwear. Dryish waste.)	4
		7.54'05"	**Dep** (1 loader walking to next station)	
4	427	7.58'	**Arr** (Foliage removed. Two lift ring. Branches broken. Waste fairly dry. Overseer present.)	13½
		8.05'40"	**Dep** (Truck speed up to 20 km/h.)	
5	428	8.13'	**Arr** (Waste in rectangular cage. Dry waste and foliage. Bowls carefully inverted to make pile at front of truck. Basket from lady who had made house to house collection.)	19
		8.22'50"	**Dep**	
6	428	8.25'50"	**Arr**	6
		8.29'50"	**Dep**	
7		8.33'20"	**Arr** (Pipe bin - small quantity of dry waste.)	4
		8.36'50"	**Dep**	
8		8.38'	**Arr** (Driver always stops engine for loading. Garden area - leaves and branches.)	4
		8.41'	**Dep**	
9	429	8.43'04"	**Arr** (Steel ring and rag pickers. Clearing outside ring first - 14 bowls. Wet waste, plenty of flies. Bin dimensions major axis minor axis height 1.26m 1.15m 0.6m Distorted ring was full. Rag picker watches as waste is lifted. Ring held 18 full bowls.)	29
		9.00'	**Dep** (Vehicle reverses out. Turning takes long time. Waste in truck is in vertical columns - there seems to be considerable space between each 'column').	

contractor's truck - 'B' - continued

Station	Distance meter (km)	Time	Notes	No of Bowls
10		9.10'	**Arr** (Big pipe bin (riveted) with more around. First bowl very full. One rake between the whole crew is not enough. Medium waste - plenty of old sugar cane - which is lifted out of bowl and thrown forward. When truck is nearly full, there is only enough space for one man to receive and empty the bowls in the truck. Insecticide in coconut shell spread over site.)	
		9.27'	**Dep** (Waste up to tailboard, but tailboard still open. Very busy traffic. 3 minutes to do 'U' turn.)	
11	430	9.32'10"	**Arr** (Ring 1.17m dia, 0.64 m high about 10% overloaded and extra around. About 12 bowls within ring. Waste is wet and heavy. Lady with 30L bucket. 12 yr. old girl with 30-40 L bucket - too heavy for her.)	16
		9.39'45"	**Dep** (Typical speed 14 km/h)	
12		9.46'37"	(Stop for one basket - then reversing alongside hotel in shopping area. Loaders had to move car sideways to allow truck's approach. Another car moved by its driver.)	1
13		9.54'50"	**Arr** (Hotel - food waste. Extra bin with broken glass and wet waste. Tailboard closed for last few loads. Insecticide spread.)	9
		10.03'30"	**Dep**	
14	431	10.06'30"	**Arr** (Waste in kerosene or ghee tins ~ 10 tins. Baskets and sacks emptied and returned. Overseer checks paperwork.)	5
		10.10'30"	**Dep**	
15	432	10.13'05"	**Arr** (Compactor trolley bin tipped over to empty. [Overseer had required crew to do extra load.] Drain adjacent totally blocked but dry. Bowls passed over tailboard. Filling - full at back - about 20 cm above tailboard, but middle not full. Covering with gunny tarpaulin takes 2 - 3 min.)	13
		10.26'20"	**Dep** (Four ride on top of cab, two in cab, one in back with load. Open road speed ~ 30 km/h)	
	434	10.35'30"	**Arrive checkpoint**	
		10.39'	**Depart checkpoint** (Load has settled. Final volume - straight line from top at front to top of tailboard. But voids within load - say 20% of volume.)	
	439	10.53'40"	**Arrive weighbridge**	
		10.56'	**Depart weighbridge**	

contractor's truck - 'B' - continued

Station	Distance meter (km)	Time	Notes	No of Bowls
	444	11.06'45"	**Arrive disposal site**	
		11.08'44	Stopped on tip at unloading point. (Longer handled tines for pulling waste out - feet of labourers covered in waste. Even plastic bags separated but plastic bottles ignored. At least 15 open trucks here unloading at a particular instant. Municipal truck has many children around it. Trucks slip and dig into waste when trying to pull off upgrade after emptying. Sacks of recyclables thrown off incoming trucks. Truck floor lumpy - corrosion tears.)	
		11.42'	Truck empty	
		11.44'	Pulls away	
		11.46'	Stopped at gatehouse of disposal site, labourers wash	
		11.52'20"	**Depart disposal site**	
	448	12.02'35"	**Arrive weighbridge**	
		12.04'35"	**Depart weighbridge**	

Weights:

		Both axles [kg]
Empty	Written on cab	not shown
	Measured	4,840
Loaded	Written on cab	not shown
	Measured	7,900

Volume: 7.6 m^3 (Appendix CC-I.6)

CC-I.3 Compactor truck - 'C' -, 30 November

Vehicle Type: Airtech Schörling (older type; carrier plate rams internal [figure CC-III.1])
Total body volume approximately $15m^3$ (Appendix CC-I.6)

Station	Distance meter (km)	Time	Notes	No. of bowls
	1087	8.02'	**Depart motor loader chowki**	
1	1089	8.10'08"	**Arr** (Large amount of paper; muddy surface makes it difficult to move trolley; 212 s. to lift and empty trolley.)	6
		8.19'00"	**Dep**	
2	1089	8.21'10"	**Arr** (Large numbers of flies; trolley full but not heaped; 7 bowls fill hopper, 35 s. cycle time for packer plate; waste is loose, dry, vegetable.)	18
		8.33'10"	**Dep**	
3	1089	8.34'10"	**Arr** (Front *[jockey]* wheel damaged, at an angle, so trolley was difficult to move.)	1
		8.38'23"	**Dep**	
4	1090	8.39'20"	**Arr** (Near school, large proportion of paper; picker was collecting paper; surroundings clean)	
		8.43'28	**Dep**	
5	1090	8.45'54	**Arr** (Trolley very full, one wheel broken - trolley required 6-7 men to slide it into position; piles of refuse around trolley; loaders working fast)	12
		8.56'25	**Dep** (loaders walking to next station)	
6	1090	8.57'30"	**Arr** (Trolley light, approx. ½ full dry waste; loading would have finished at 9.00'35" but for sweeping up of powdery waste that fell from truck between hopper and body)	1
		9.01'55"	**Dep** (Busy road)	
7	1091	9.05'	**Arr** (Trolley completely broken, waste in front and on side; some loaders waiting while others loaded bowls; packing cycle 35 s., loading cycle (lifting to lowering of trolley) 54 s.; 2 bins brought by others (sweepers?); 2 cows feeding)	8
		9.14'20	**Dep**	
8		9.15'12	**Arr** (Everything OK - trolley in good condition, little waste around, trolley full - slightly heaped; 1 bowl of spillage; sweeper brought two baskets.)	4
		9.20'	**Dep**	
9	1092	9.20'57	**Arr** (Trolley not full; some paper scattered; picker present; waste has high moisture content)	4
		9.25'30"	**Dep**	
10		9.28'10"	**Arr** (Busy road; reversing to trolley; trolley 2/3 full; site left very tidy; 4 minute break for water)	1
		9.36'35"	**Dep**	

Station	Distance meter (km)	Time	Notes	No. of bowls
11	1092.9	9.41'40"	**Arr** (Rough ground; trolley about 80% full; problems manoeuvring trolley; hopper filled with 8 bowl loads; Plastic bags)	9½
		9.53	**Dep**	
12	1093	9.58'10"	**Arr** (Level ground; trolley well heaped; site clean; spillage about ½ bowl)	
		10.03'00"	**Dep** (Walking to next station)	
13	1093	10.03'30	**Arr** (Trolley amidst parked cars; good surface; trolley 80% full)	
		10.07'05	**Dep**	
14	1094	10.09'30	**Arr** (Trolley had damaged front wheel; trolley 80% full, 6 labourers needed to move it; clean site; truck blocking lane during operation)	2
		10.16'20"	**Dep**	
15		10.22'45"	**Arr** (Clean site; trolley 80% full; no problems)	
		10.28'05"	**Dep**	
16	1095	10.29'20"	**Arr** (Trolley approx. 2/3 full; ideal conditions)	
		10.31'07"	**Dep**	
17	1095	10.33'35"	**Arr** (Trolley very full; heavy waste on all sides; said to be two days' waste; front wheel of trolley broken so that front of trolley was resting on road; six could not move it so truck was manoeuvred closer; 7min 45 s. to lift and empty trolley)	12
		10.54'00"	**Dep** (Truck full; maximum speed rarely 40 km/h)	
	1098	11.03'50"	**Arrive checkpoint**	
		11.06'40"	**Depart checkpoint**	
	1100	11.11'	**Arrive weighbridge**	
		11.17'	**Depart weighbridge**	
	1105	11.26'55"	**Arrive disposal site** Approx. 4m 50s spent at tipping face	
	1105	11.36'	**Depart disposal site**	
	1110	11.45'	**Arrive weighbridge**	
		11.51'	**Depart weighbridge**	
		12.10'	**Arrive motor loader chowki** (tools deposited)	
	1115	12.13'10"	**Depart motor loader chowki** (Part of route on dual carriageway - speeds up to 50km/h)	
	1127	12.47'40"	**Arrive Bandra depot**	

Weights:

		Total [kg]	Front axle [kg]	Rear axle [kg]
Empty	Written on cab	8,990		
	Measured	8,900	2,942	6,080
Loaded	Written on cab	15,244	5,080	10,164
	Measured	16,220	3,700	12,320

CC-I.4 Contractor's truck - 'D' 2 December

Vehicle Type: Contractors - open truck
Truck body - Height 1.3m , Length 3.8m, Width 2.28m.

Station	Distance meter (km)	Time	Notes	No. of bowls
	842	7.30	**Depart motor loader chowki**	
1	842	7.45' 8.35'	**Arr** (The waste is mostly food waste and paper) **Dep**	79
2		8.42' 8.48	**Arr** (Mostly vegetable waste and coconut shells) **Dep**	6
3		8.55' 9.15'	**Arr** (Food waste, paper and leaves) **Dep**	42
4		9.20' 9.32'	**Arr** (Mostly food waste) **Dep** (The crew were planning to go to the disposal site at this stage, until the observer asked them to go via the weighbridge. When they knew that the load was to be weighed, they decided to collect more waste before going to the weighbridge.)	21
5		9.35' 10.10'	**Arr** (Food waste, old flowers, dry leaves) **Dep**	62
6		10.14 10.28	**Arr** (Food waste and paper) **Dep**	30
		11.05 11.55	**Arrive disposal site** **Depart disposal site**	
	867	12.30'	**Arrive motor loader chowki**	

Weighbridge readings [kg]:

Empty	4,890	Loaded	8,790

Volume of load: Body volume 11.3 m^3 (Appendix CC-I.6)

CC-I.5 DATA FROM MOTOR LOADER CHOWKI LOGBOOK

This appendix provides some information taken from the motor chowki log book. The main aim in collecting this information was to check the data collected by following the collection vehicles (as presented in appendices CC.I.1 to 4), to see if this data is typical of normal rounds (i.e. when the crews are not being observed).

(i) Time at disposal site - compactor trucks

Information was taken from the motor loader chowki concerning the collection round that was taken by compactor truck 'A' on 25 November. The start time of the morning shift, the time of arrival at the disposal site, and the length of time spent at the disposal site for a number of days in November 1992 are shown in the table below

Table CC-I.1 Arrival times at disposal site

Day in November	6	7	8	9	10	11	12	13	14	15	16	17	18
Day of week	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed
Start time	7	7	7	7	7	7	7	7	7	7	7	7	7
Arrival time at tip	11.50	11.40	11.45	11.40	11.20	10.50	11.15	12.30	11.00	(1)	11.25	11.30	11.55
Time spent on tip (min.)	10	15	10	10	10	10	10	10	10	(1)	15	10	10
Arrival times at tip of vehicles from other rounds						11.05 10.20	10.50 11.00 10.45 10.55	10.35 10.50		10.00 10.10 11.10 10.45 10.25			10.50 10.58 12.10 10.45 10.15

Notes

(1) Vehicle breakdown during previous collection round

Comments: There is some indication that the rounds may not be of equal size, that is, that some rounds take more time to complete. This difference may be due to the number of stops that must be made, the condition of the trolleys, the distances that must be covered, or the traffic conditions. This difference is suggested in the data for 18th November, when one truck arrived at the disposal site almost two hours after one of the others.
It appears from these records that the collection rounds on Sundays take less time. This may be because the traffic is lighter, or because fewer mukadams are available and so there is less supervision, resulting in lighter loads.

(An anecdote related by the Junior Overseer at the motor loader chowki gives an indication of the attitude of one of the compactor truck drivers to his work. It was told that one driver always drives the same truck, and that when this particular truck is off the road for repairs or maintenance, he prefers to take leave rather than to drive another truck. With an attitude like that, one may be sure that the driver will take care of his vehicle to the best of his knowledge and ability.)

(ii) Contractor's open trucks

The records showed that there were usually twelve contractor's trucks working in the mornings and ten during the afternoon. Thirteen were engaged one morning when there were too few municipal vehicles.
According to the records, all the contractor's trucks start the morning shift at 7.00 am and the afternoon shift at 2.00 pm.
Some brief extracts from the records are shown below

Table CC-I.2 Timings of open trucks on disposal site

Day in November	11 Wed	12 Thu	13 Fri	14 Sat	23 Mon	24 Tue
Time of arrival at disposal site (morning shift)	11.20 12.45	10.05 11.10	10.20 11.10	10.15 12.10	10.40, 10.40, 10.45, 10.50 11.05, 11.10, 12.55	10.15, 10.30, 10.50, 10.50, 11.20
Time spent unloading at disposal site (min)	10 (1) 30	30 30	30 30	35 43	35, 35, 30, 35, 35, 30, 35	30, 25, 35, 35, 35
Time of arrival at disposal site (afternoon shift)					5.05, 5.40, 5.40, 6.20	
Time spent unloading at disposal site (min)					25, 25, 25, 25	

Notes

(1) This time seems very small, and so may have been recorded incorrectly

It is mentioned in Part D that the times at which trucks leave the main disposal site are not recorded. It appears that the times of departure are sometimes recorded at the Malad site.

(iii) Tractors and trailers

The records show that two tractors with trailers are employed in the ward each day, starting the morning shift at 7.30 am. The number of trips for each tractor and the times of arrival at the disposal site are shown in the table below. The records show that the tractors are on the disposal site for 10 minutes.

Table CC-I.3 Operational data for tractors and trailers

Vehicle	Date	11 Nov	12 Nov	15 Nov	17 Nov
Tractor 1	**Number of trips**	4	2	5	4
	Arrival time at tip			8.30, 9.55, 10.20, 11.25, 12.15	8.35, 9.40, 10.45, 11.50
Tractor 2	**Number of trips**	4	4		4
	Arrival time at tip				8.35, 9.40, 10.45, 11.50

CC-I.6 VEHICLE VOLUMES

(i) Compactor trucks

There were two types of compactor truck operating in K-West Ward:

- The older type has all the hydraulic cylinders that operate the carrier and packer plate (figure CC-III.1) inside the hopper side walls, and has a single three stage telescopic ram operating the ejector plate. The compactor truck labelled 'C' (Appendix CC-I.3) is of this type. Since the rams are all inside the side walls, they are more exposed to dust, and so the seals are likely to have a shorter life. The catches that hold the hopper onto the body when the hopper is lowered appeared to be inadequate.
- The newer type has a very similar external appearance, except that the two carrier plate rams are outside the side walls of the body. The ejector plate arrangement is very different - there are two separate rams: one pushes a sliding frame and the other pushes the ejector plate relative to the sliding frame. Truck 'A' of Appendix CC-I.1 is of this type. There is some uncertainty about the internal dimensions that are presented below, because the ejector plate of the vehicle that was measured was not fully retracted.

Note: Both of the models mentioned above are Airtech Schörling, and should not be confused with the completely different Airtech Multipack, which was not in operation in K-West Ward at the time of the study. The Multipack has two large rams above a lower body, and these two rams are used for raising the trolley containers and packing the waste, and raising the hopper during unloading. The system for operating the ejector plate was not observed.

Figure CC-I.1 Definition of dimensions for Table CC-I.1

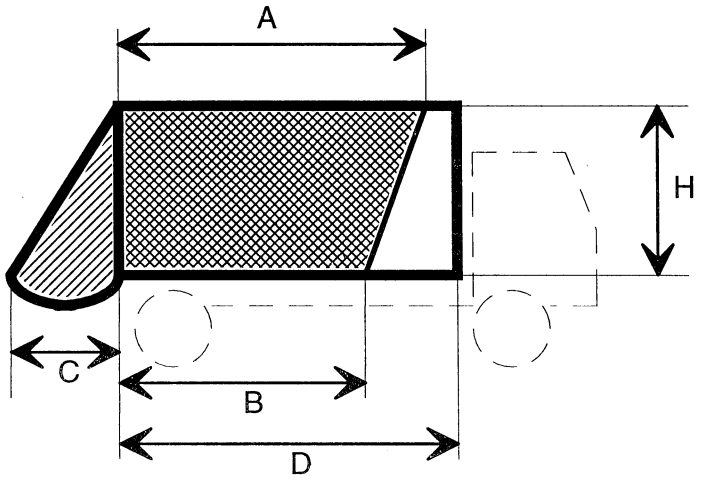

Table CC-I.1 Dimensions and volumes of compactor truck bodies

Body type [Appendix No.]	A m	B m	C m	D m	H m	W [width] m	Hopper volume [m^3]	Volume of fixed body [m^3] ½[A+B].H.W
'C' [CC-I.3]	3.35	2.65	0.6	3.57	2.00	2.30	1.4	**13.8**
'A' [CC-I.1]	3.25	2.55	0.6	3.75	1.80	2.23	1.2	**11.6**

(ii) Contractors' open trucks

The volume of refuse in an open truck is difficult to determine because there is no clearly defined top surface to the load - it can be piled up above the top of the body, or it may be above the body in some parts and below the top of the body in other parts. It is difficult to assess how high the load is in the middle of the body when looking from ground level. It also appeared during observations that refuse was piled up in columns as one bowl's contents are placed exactly above the contents of the preceding load. This technique may lead to gaps in the waste. It was observed that the waste settled in transit, probably as a result of vibration.

Figure CC-I.2 Dimensions for calculating the capacity of open trucks

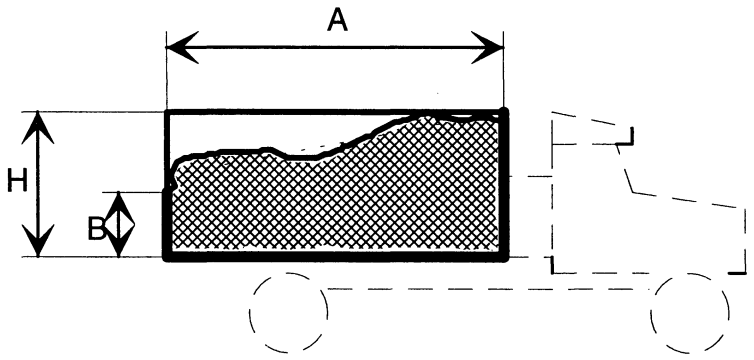

Table CC-I.2 Estimates of refuse volumes in open trucks

Vehicle identification [Appendix]	A [m]	B [m]	H * [m]	W [width] [m]	Estimate of percentage of voids	Estimate of volume of refuse [m^3]
B [CC-I.2]	3.86	0.56	1.37	2.30	20	**7.6**
D [CC-I.4]	3.80	-	1.30	2.28	-	**11.3**

Notes:

B It was estimated that the waste was piled about 20cm higher than the top of the tailboard; the top of the load was assumed to follow a straight line to the top of the front of the body.
The refuse seemed to settle to the top of the tailboard before arrival at the disposal site - if the overall settlement was 30 cm (the deeper parts settling more), and the percentage of voids is ignored, the volume of refuse is 6.8 m^3.

D No further information is available

APPENDIX CC-II.1 MCGB ESTIMATES OF VEHICLE COSTS

Cost comparison of various types of vehicles

	Types of vehicles		
	OPEN TRUCK	COMPACTOR	DUMPER PLACER
	Rs	Rs	Rs
Cost of vehicle (Approximately)	400,000	650,000	450,000
Depreciation/shift (Life = 10 years)	55	90	65
Interest on capital/shift (@ 12% per year)	65	110	75
Wages of Driver and Cleaner per shift	100	100	100
Fuel and Lubricating oil charges (for 50 Km/shift)	50	50	50
Maintenance & repair charges per shift	75	75	75
Other miscellaneous charges (like taxes per shift)	15	15	15
Cost of vehicle per shift	360	440	380
Cost of labourers per shift	350	350	300
	(6 lab + 1 Muk)	(6 Lab + 1 Muk)	(6 Attendants only)
	710	790	680
Supervision charges	105	110	100
Total cost of transportation of refuse/shift	815	900	780
Average weight removed by vehicles in a shift [tonnes]	3.5	7.0	12.0
Transport cost/tonne	235	130	65
Average volume removed [m^3]	6	22	30
Cost per m^3.	135	40	26

APPENDIX CC-II.2 CALCULATION OF UNIT COSTS FOR COMPACTOR TRUCKS USING *SENS* PROGRAM

This appendix first considers how to convert the data from earlier appendices to suit the requirements of the program, and then presents the unit costs. A manual for the program is available at WEDC; some familiarity with this manual will assist the reader to follow this appendix. The *SENS* program is a tool to allow the estimation of unit costs and can be extended to systems that are not in current use. It breaks the collection operation into a number of different steps, using data for each individual step to synthesise times and costs for new operations. The program considers up to five alternatives simultaneously. In the first section, four sets of data will be considered:

A This refers to data collected for compactor truck A on 25 November, as presented earlier in Appendix CC-I.1 .

C This column is based on data for compactor truck C on 30 November (Appendix CC-I.3).

MCGB This column uses data presented in a report by MCGB, as presented in Appendix (CC-II.1), together with data drawn from A and C, which are shown in brackets.

New This column is a proposed alternative to the existing system. Since wage costs are a major part of current costs, this proposal aims to improve manpower productivity by providing more trolley containers, and spending more on maintaining them. If all of the waste is in the trolleys, and if the trolleys are kept in good condition so that a smaller crew can manoeuvre them into position, it should be possible to operate the system with a smaller team (vehicle cleaner plus two labourers). On occasions the help of the mukadam would be needed. Times for loading are taken from times observed for compactor trucks A and C when the storage areas were in a clean condition.

Explanatory notes	A	C	MCGB	New
Design capacity (volumes from CC-I.6) [m^3]	12	15	15	12
Vehicle actual capacity ratio (If body is full = 1.0)	1	1	1	1
Compaction ratio (Density of waste estimated by estimating volumes of waste in each weighed load, by counting trolleys and/or bowls; volume of waste before compaction compared with truck body volumes. For MCGB 22/15. For *New* 1.2:1 gives a payload of 6480 kg	1:1	1.2:1	1.47:1	1.2:1
Refuse density (From weighbridge results and estimated volumes For MCGB 7000/22) [kg/m^3]	595	425	318	450
Container capacity [m^3]	1.0	1.0	1.0	1.0
Actual capacity ratio (i.e. fraction occupied. This value may need adjustment to give the actual number of collection points visited. For *New* a lower value is used since it is essential that waste does not overflow, so extra spare capacity is needed)	1.2	1.05	1	0.75
Container capital cost [Rs]	6500	6500	(6500)	6500
Interest rate (12% p.a. MCGB)	12	12	12	12
Container life span (A guess, data not available. Life likely to be longer for new system since more maintenance)	5	5	(5)	5
Days between collection (1 day assumes trolleys emptied once per day.)	1	1	1	1
Vehicle capital cost [lakh Rupees]	7.85	7.85	6.50	7.85
Vehicle interest rate	12	12	12	12
Vehicle life span [years]	10	10	10	10
Vehicle availability factor (This indicates how many standby vehicles are needed. Calculated from data in Appendix CC-III October 1972 67.9%, November 66.9%) [%]	67.4	67.4	100	67.4
Container loading time (Total time vehicle stationary at loading stations divided by number of stations. For MCGB system timing should give one trip per shift; for *New* system average of stations A.2, C.8, 12, 15, 16) [seconds]	712	439	(400)	237

Explanatory notes (continued)	A	C	MCGB	New
Team loading one container (cleaner included)	7	7	7	3
Number of loaders with one truck (as above)	7	7	7	3
Number of containers per station	1	1	1	1
Vehicle unloading time (i.e. time spent on disposal site) [min]	12.5	9.1	(10)	10
Report time, Delay allowance (Time when vehicle not moving, loading or unloading can be included as report time or as delay allowance) [min]	47.9	18	(30)	30
Time between stations (For *New* the time has been reduced because less waste would be stored on each site, so the sites would be closer together.) [s]	169	155	(150)	125
Distance between two stations (Total distance between first and last storage points divided by number of intermediate stages. For *New* it is less since more stops are made) [m]	667	375	(350)	350
Distance from collection area to boundary (Taken as half the sum of the distances from last collection point to weighbridge and from the weighbridge to the motor loader chowki) [km]	7.5	5	(5)	7.5
Distance to disposal site from weighbridge. [km]	4	5	(5)	5
Urban speed (Average speed between collection area weighbridge and chowki, and to/from depot.) [km/h]	20.1	20.9	(20)	20
Country speed (Average speed between weighbridge and disposal site.) [km/h]	23.4	31.7	(27)	27
Extra distance to the depot (both directions) [km]	24	24	(24)	24
Two shifts per day, changeover time between shifts irrelevant				
Working hours per day (In this case the time must be chosen to allow enough time for one trip per shift, but not enough for two.) [h]	12	12	(12)	12
Container maintenance cost per year (as a fraction of its annual cost...values are guesses. For *New* system more must be spent on trolleys to ensure that the wheels are always in good condition)	0.02	0.02	0	0.1
Vehicle maintenance cost per km (Based on MCGB figure with other miscellaneous charges added, and inflated by 35% for A, C and *New*) [Rs/km]	2.35	2.35	1.73	2.35
Working days per year	365	365	365	365
Fuel consumption (The vehicle is operating under different conditions- running reasonably fast, moving slowly, and stationary, operating the compaction mechanism. Estimates are very approximate. For MCGB to give a cost of Rs 50 per shift) [litres/km]	0.5	0.5	0.136	0.5
Cost of fuel per litre [Rs/litre]	6.81	6.81	6.81	6.81
Number of drivers (Two; one per shift)	2	2	2	2
Drivers wages per month [Rs]	2700	2700	1500	2700
Loader's wages per month (See Appendix AA-IV.1) [Rs]	2446	2446	1500	2446
Supervision; This is mainly to cover the salaries of the mukadams who supervise the collection crews, but can also include more senior supervisors. It is expressed as a percentage of the wages bill. For A and C one mukadam is required for a team of 8 (i.e. 12.5%), and 7.5% is added for JO's etc. For MCGB it is Rs 110 plus one mukadam (Rs 50) on a wage bill of Rs 450 per shift. For *New* it is taken as twice the value for A and C, since the wages bill is halved but the supervision costs remain the same. [%]	20	20	35.5	40
Insurance, taxes and import duties are all set at zero.	0	0	0	0
Wage overheads are assumed to cover wages of relief workers to cover one day off per week, so one days wages for six days' work gives a percentage of 16.7 [%]	16.7	16.7	0	16.7
Estimated collection cost per tonne [Rs/tonne]	**218**	**206**	**138**	**191**

APPENDIX CC-II.3 CALCULATION OF UNIT COSTS FOR OPEN TRUCKS USING *SENS* PROGRAM.

The same approach is used for the open trucks as for the compactors, except that, in the case of contractors, the vehicles and driver are paid for by means of a set hire charge, so that the calculations are considerably simpler. The following notes apply to the table below.

B This refers to data collected for contractor's truck B on 26 November, as presented earlier in Appendix CC-I.2 .

D1 This column is based on data for contractor's truck D on 2 December (Appendix CC-I.4), but considering the situation where loading stopped when it would normally be judged to be complete.

D2 As for D1, but considering also the extra refuse that was loaded onto the truck when the crew became aware that the load was to be weighed.

MCGB This column uses data presented in a report by MCGB, as presented in Appendix CC-II.1, for a vehicle owned and operated by MCGB, together with data drawn from B and D, which are shown in brackets.

Explanatory notes	B	D1	D2	MCGB
Design capacity (volumes from CC-I.6) [m^3]	12.2	11.3	11.3	12
Vehicle actual capacity ratio (For B 7.6/12.2; for D1 the number of bowl loads was counted: 148 for D1 and 240 for D2; so value for D1 is 148/240	0.62	0.62	1.0	0.5
Compaction ratio (Likely to be less than 1:1, but 1.0:1 will be used here for simplicity)	1:1	1:1	1:1	1:1
Refuse density (from weighbridge results and volumes. For MCGB 3.5 tonnes/6m^3) [kg/m^3]	403	345	345	583
Container capacity (total volume divided by number of stops e.g. for B 7.6/15, for D1 (11.3x0.62)/4) [m^3]	0.507	1.74	1.88	(1)
Actual capacity ratio (Container design not important here)	1	1	1	1
Container capital cost (Not considered here, therefore 0)	0	0	0	0
Interest rate (MCGB 12%) [%]	12	12	12	12
Container life span (Not relevant since cost is zero)				
Days between collection	1	1	1	1
(Vehicle data not required for B and D since trucks are rented; suggested 0 for capital cost and 10 years for lifetime. For MCGB see below)				
Vehicle capital cost [Lakh Rs]				4.0
Vehicle interest rate [%]				12
Vehicle life span [years]				10
Vehicle availability factor [%]				100
Container loading time (average values) [s]	504	1320	1370	(900)
Team loading one container	6	6	6	7
Number of loaders (For MCGB includes vehicle cleaner)	6	6	6	7
Number of containers per station	1	1	1	1
Vehicle unloading time (i.e. time spent on disposal site) [min]	45.6	(42)	50	(45)
Report time and delay allowance [min]	7.8	(10)	(10)	(10)
Time between stations [s]	253	380	312	(300)
Distance between stations [m]	570	(1000)	(900)	(600)
Distance from collection area to boundary (Less for contractors' trucks since they may not return to the chowki between shifts. Figures for D1 and D2 come from A and C. For MCGB as for A) [km]	3.5	(6.3)	(6.3)	(7.5)
Distance to disposal site from weighbridge (Values for D taken from A and C) [km]	4.5	(4.5)	(4.5)	(4.5)
Urban speed (All based on data for B) [km/h]	17.6	[18]	[18]	[18]
Country speed (All based on data for B) [km/h]	25.7	[26]	[26]	[26]

Explanatory notes (continued)	B	D1	D2	MCGB
Extra distance to the depot (This does not apply to contractor's vehicles since it is in their own time, therefore zero. For MCGB, as for A and C) [km]	0	0	0	24
Two shifts per day, changeover time between shifts not relevant				0
Working hours per day (Values chosen to allow two full loads)				
Container maintenance per year (Not considered here)	0	0	0	0
Vehicle maintenance (For B and D, paid by contractor, therefore zero. For MCGB Rs 75 plus Rs 15 for other charges, for approx. 50 km shift, so 90/50) [Rs/km]	0	0	0	1.8
Working days per year	365	365	365	365
Fuel consumption (Zero for B and D because contractor's responsibility. For MCGB Rs 1 per km)	0	0	0	0.147
Cost of fuel (Not relevant to B and D)				6.81
Number of drivers (It appears that one contractor's driver works for two shifts each day, but no data need be entered here since the driver is paid for as part of the hire charge. For MCGB 2, as for A and C)	0	0	0	2
Drivers wages per month (For B and D not relevant since none paid for)				1500
Loaders' wages per month (As for compactor trucks)	2446	2446	2446	1500
Supervision (One mukadam for each team of six - 16.7% plus 7.5% for JO's etc as before. For MCGB one mukadam for a team of eight - 12.5% and 105/(350+100)) [%]	24.2	24.2	24.2	35.8
Insurance, taxes and import duties (Zero as before)	0	0	0	0
Wage overheads (For loaders with B and D as for A & C) [%]	16.7	16.7	16.7	0
Rental per shift for contractors' vehicles [Rs]	230.4	230.4	230.4	-
Estimated collection cost per tonne [Rs/tonne]	**381**	**480**	**298**	**222**

APPENDIX CC-III DATA FROM VEHICLE WORKSHOPS RECORDS

APPENDIX CC-III.1 WORKSHOP RECORDS FOR 13 COMPACTOR TRUCKS AT BANDRA DEPOT, OCTOBER 1992

This table shows the numbers of compactor trucks that were available during most of the days in October 1992, and reasons why the other vehicles were not available.
The word *repairs* should be taken to include routine servicing, and *test preparation* refers to the annual roadworthiness test and includes the time taken by the test itself.

Day in October	Available	Chassis repairs	Body repairs	Test preparation	Spare
1st	9	1	2	1	
3rd	9		3	1	
6th	8	2	2	1	
7th	9		3	1	
8th	8	1	2	2	
9th	9	1	1	2	
10th	9	1		1	2
12th	9	1	1	1	1
13th	9	3		1	
14th	9	2		1	1
15th	7	3	2	1	
16th	8	3	1	1	
17th	8	3	1	1	
19th	8	3	1	1	
20th	9	2	1	1	
21st	9	2	1	1	
22nd	9	2	1	1	
23rd	9	2	1	1	
24th	8	3	1	1	
27th	8	4		1	
28th	9	2	1	1	
29th	9	2	1	1	
30th	9		1	2	1
31st	9	1	1	2	
TOTALS	207	44	28	28	5

APPENDIX CC-III.2 WORKSHOP RECORDS FOR 13 COMPACTOR TRUCKS AT BANDRA DEPOT, NOVEMBER 1992

Notes A blank indicates that the vehicle was available
M indicates mechanical repairs, relating to chassis, motor, transmission etc
A Airtech - repairs associated with the body and compaction mechanism (made by Airtech)
P "Passing" - preparation for annual test, and taking the test.
Ser means the vehicle is in the workshop for routine servicing.
Sp means the vehicle was operational but not used; it was being kept as a spare.

Date in	Compactor trucks, identified by numbers on registration plates												
Nov.'92	413	444	455	486	528	550	572	592	7632	7634	7636	7721	7738
1st			M	M				M	P				A
2nd			M	M				M	P				A
3rd			M			P		M	P				
4th	Ser		M			P	A	M	P				
5th			M			P	A		P				
6th						P	A		P	Sp			
7th						P			P				M
8th		A				P			P				M
9th		A				P			P				M
10th		A				P			P				M
11th		A				P			P				M
12th		A		M		P			P		Ser		M
13th			M			P	M		P		M		
14th						P	M		A		M	A	
15th			M			P	M		A		M	A	
16th			M			P	M		A		M	A	
17th						P	M		Sp		M	M	
18th							M				M	M	
19th			P				M				M	M	
20th		M	P				M				M		
21st		M	P				M				M		M
22nd			P				M			M	M		M
23rd			P				M			M	M		M
24th			P				M			M	M		
25th			P				A		Sp		M		
26th			P				A		Sp		M		
27th		Ser	P				A				M		
28th			P				Sp		Sp		M	M	
29th			A					M			M	M	
30th			A					M			M	M	

APPENDIX CC-III.3 EXTRACTS FROM VEHICLE RECORDS

The following extracts give some appreciation of the types of records that are kept, and how the data are presented.

(i) Status of vehicles

There are 76 vehicles at this Depot. Of these there are two types associated with solid waste collection: *Refuse* trucks which are open, high-sided vehicles which tip to unload, and *Refuse compactors*, of the type described in Appendix CC-I.6. For the four wards served from this depot, three refuse trucks are required for the first shift, and three for the second. Nine compactors are required for the first shift, and eight for the second.

Category	PS Proposed to scrap	PP Police passing (i.e. preparation for annual test)	LL Long lay up (i.e. laid up for over a month)	RR Running repairs	AV Available
Refuse Trucks (total 12)	4	5		1	2
Refuse compactors (total 13)				5	8

(ii) Repairs to compactor trucks

The following problems were abstracted from the depot records to illustrate the types of work carried out by the maintenance crew. This table adds more details to the information presented in Appendix CC-I.2.

Day in November 1992	Vehicle identification	Description of defect
6	572	Lifting arm jack pin
9	7738	Right side pulling, no pickup
11	444	Airtech (body repairs)
12	486	Gear lever broken, labourers' seat needs welding
13	455	Radiator hose leak, silencer
	572	Front left handle damaged
14	7636	Chassis cracked
	7632	Packer jack leaking
	7721	Body mounting angle cracked
16	455	Rear leaf spring broken
19	572	Bosch pump
20	444	Differential oil leak, radiator choked, manifold, spring assembly
23	7634	Alternator failed, ram oil leak
24	572	Fan belt
25	572	Ram oil leak
28	7721	Clutch bolt
30	7721	Front joint broken, gear box
	592	Steering clutch

(iii) Repairs to compactor bodies

The bodies of compactor trucks are subject to high stresses in a corrosive and dusty environment, so it is inevitable that problems develop and repairs are required. A quick

perusal of the repair records indicated that the following repairs had been undertaken for the fleet of compactor trucks at Bandra: (The vehicle components are shown in figure CC-III.1)

Figure CC-III.1 Definition of compaction mechanism components

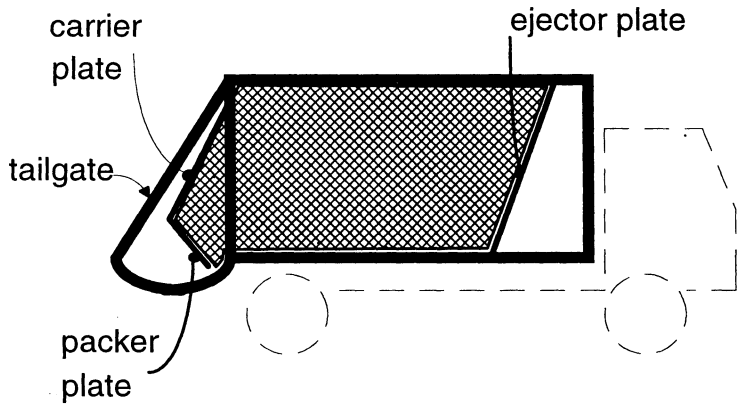

Plate base of hopper corroded; replaced
Tailgate jack mounting
Welding packer plate
Hydraulic pipe broken
Packer plate slow (two trucks)
Lifting arm pin broken
Carrier plate checked
Packer plate came out
Container lifting bracket
Packer plate jack leaking
Oil pipe broken
Ram oil leak
Oil leak on power takeoff
Tailgate jack broken
Packer plate bracket
Tailgate jack came out

This list only gives an indication of the type of problem that is experienced. A more detailed scrutiny of the records might lead to useful information which would assist in the prevention or early diagnosis of failures.

(iv) Clutch repairs

In refuse collection vehicles, clutches are often the most commonly replaced components. It takes about 6 hours to replace a clutch. The following extract from the servicing records indicates the frequency at which clutches have been replaced for some of the compactor trucks.

The clutches of refuse trucks (simpler vehicles that are less heavily loaded than compactor trucks) are quicker to replace, and last longer (often more than one year).

Vehicle registration number	Months when clutch replaced	Average clutch life (months)
7632	9/91, 12/91, 4/92	3.5
7634	8/91, 1/92, 2/92	3
7636	7/91, 11/91, 1/92	3
413	8/91, 11/91, 11/91, 2/92	2
444	5/91, 10/91, 4/92	5.5

(v) Other data and information from informal discussions

- Compactors are given priority with respect to servicing and repairs.
- Fuel consumption estimates: compactor trucks - about 20 litres per shift
  refuse trucks - about 4 km/l.
- A history document is kept for each vehicle at Santa Cruz, but maintenance costs are not recorded.
- Diesel fuel supplied from the pump at Bandra costs Rs 6.81 per litre.
- Airtech, the manufacturers of the compactor bodies and trolley bins, give a guarantee of 2 years on the compactor bodies, and provide their own mechanics to service the bodies. Airtech have trained the municipal staff to carry out repairs and have helped with repairs of vehicles even after the warranty period on those particular vehicles has expired.
- No tax or insurance charges are payable for the refuse collection vehicles.
- Cleaners always accompany drivers of heavy vehicles. The cleaner's job includes checking the oil, water and diesel fuel levels of the vehicles. They are paid Rs 2250 per month, plus an extra monthly *waste allowance* for working with refuse trucks.
- A mechanical road sweeper is owned by MCGB; spares for it are not readily available so it is used only occasionally - for one shift each week on Sundays.

APPENDIX CC-III.4 STAFFING AT BANDRA DEPOT

The following is a list of the establishment at Bandra Depot, according to the shifts on which they are employed. The 'General' shift is a normal daytime shift not related to any of the three shifts.

Job description	Shift			
	General	First	Second	Third
Sub Engineer	1			
Junior Engineer	1			
TTK		1	1	
SR	1	2		
SA	1			
Foreman	1			
Assistant foreman	1			
Mechanic	3			
Fitter I	7			
Fitter II	5	1	1	
Welder II	2			
Carpenter II	2			
Tyre man	1			
Tyre pressure man	1			
Auto Electrician	1	1		
Helper	1			
Cleaner	3	15	14	
Labourer	19	3	1	
Oil/greaser	1			
Washerman	1		1	
Sweeper	1	1	1	
Driver	8	35	25	4
Ambulanceman cum driver	2	1	1	1
JCB operator		1		
TOTALS (ALL SHIFTS 176)	**65**	**61**	**45**	**5**