Chapter B-2

Performance of Multipack compactor trucks

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B-2.1 INTRODUCTION

Since secondary collection or transportation of solid waste is often the major cost amongst all the stages of storage, collection and disposal, it is important that this operation is as cost-effective as possible. It is essential to collect reliable data on costs in order to make good decisions regarding purchases and allocation of resources. It is useful to be able to consider alternative methods of operation, and estimate the costs of possible alternatives - such costings can only be done if appropriate and reliable data are available. For all these reasons the contents of this chapter are important.

The work that is described here is similar in scope and objectives to part C in a previous report "Observations of solid waste management in Bombay, 1992", published by WEDC. In this previous report two types of refuse collection vehicle in Mumbai were studied:- open trucks provided by contractors and a conventional type of rear-loading compactor truck, known as the Airtech Shörling 4R. This chapter describes the operation in late 1993 in Mumbai of the next generation of Airtech compactor trucks, known as the Multipack. Two trucks of this type are shown in photographs 5 and 6 at the beginning of this report and figure B-2.1 illustrates some aspects of the design. It can be seen that these trucks are very different in appearance from the conventional rear-loading compactor. The basic concept of the design appears to be to simplify the hydraulics by minimising the number of hydraulic rams required to perform all operations. By using chains and cables, the pair of large rams on top of the body lift the one cubic metre wheeled containers (usually called trolley bins in Mumbai), compact their contents into the body and also raise the tailgate during emptying. The body is lower than most compactors, possibly because the packer plate, being hinged at the top, does not lift the waste but provides a force that is largely horizontal. The load is ejected by means of an ejector plate that is operated by two rams operating in tandem. A considerable amount of information relating to the maintenance of these trucks are presented in chapter D. This chapter is concerned with the operation of these vehicles in Mumbai, with observations, measurements and costs. The results presented here will be compared briefly with the data measured in 1992.

B-2.2 OBSERVATIONS OF OPERATIONS

The method used was simply to follow a truck and record the information as shown in appendix BB-2.1. The distance covered was recorded using the distance meter in the car being used by the observers. The quantity of waste loaded at each point was estimated by estimating the waste that was in each trolley bin, and counting the number of times that large plastic bowls were filled with refuse gathered from the ground near each container. (The tools used to collect waste from the ground were described in the previous report, and are shown in photograph 5.) An estimate of the volume lifted in a bowl was obtained by counting the number of bowl loads needed to fill a trolley bin. The times of the beginning and end of each event were recorded. Other observations were noted because useful ideas for improvements can be developed from observations of the difficulties experienced by the loading crews and the methods they develop to solve these problems.

It is important to remember that the crew probably do not work in their normal way when they are being observed, so it is usually necessary to add an extra time allowance to the measured values. In this case the crews were expected to collect only one load per shift, so the timing is not critical for the calculation of the cost of the system. The times are useful when seeking to find ways of modifying the procedures.

Amongst the observations recorded in appendix BB-2.1 are the following:

◊ Waste was deposited around the containers even if they were not full. This may simply be a question of habit - what was done before the trolley bins were introduced, or it may be because much of the waste was brought in handcarts that were emptied by tipping their contents onto the ground.

◊ The labourers experienced several difficulties moving the containers, especially if they were located on soft or uneven ground. Two dangers in the operation of moving containers were (i) the risk that the loader pulling the cart might be struck by a passing vehicle because he was obliged to go out into the road beyond the truck, and the trolley bin moved unpredictably as the crew struggled to get it into position, and (ii) the risk that the steel wheels of the container might crush a foot of one of the labourers, since they were only wearing plastic sandals.

◊ When the container was being tipped to unload the contents into the truck, it sometimes slipped and needed steadying by some of the crew.

◊ The axles of the rear wheels of the trolley bins were fixed so that the trolleys could only be moved perpendicular to the truck. This sometimes required the truck to move backwards to meet the container (as is happening in photograph 5), and when the truck hits a full container there is a risk that the sideways force on the heavy container might break the container's wheels.

◊ The vehicle that was followed during the afternoon shift passed the nearest disposal site (adding more than 30 minutes to the round trip time) and unloaded at a more distant site in the dark, with no lighting available apart from its own headlights.

◊ The average load for the three trips that were studied was 5.8 tons. For the purpose of comparison, the results of nine weighings in the City area of Mumbai are presented in appendix BB-2.1.4, and the average weights of these loads is 4.98 tons, with one as low as 3.1 tons. The reason for the City weights being lower may be that the density of the waste was less because the waste was collected from the business areas where there is more packaging and paper in the waste, or it may be that the loads that were weighed in the City area were less because the labourers were not being observed and so they stopped before the trucks were full.

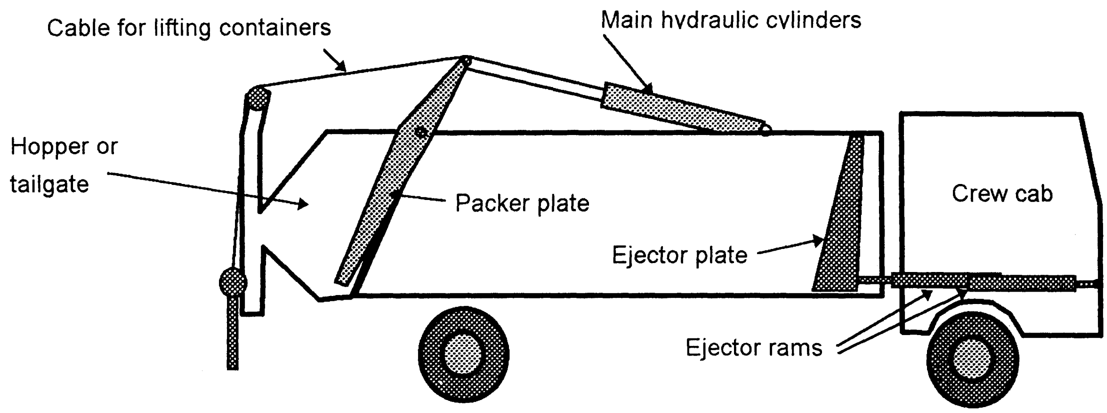

Figure B-2.1 Concept of Multipack truck design
This is not a precise representation nor to scale, but serves simply to indicate some of the design concepts of the Airtech Multipack truck.

The containers (or trolley bins) that are lifted by the trucks are an important part of the system, and if they are not maintained well the efficiency of the whole system may suffer. A common example is the wheels - if the wheels of the containers are not kept in good condition it will be difficult or impossible to move the container to the truck, resulting in delays or uncollected waste. Containers are often damaged when the waste inside them is set on fire. If they are not repainted quickly they will soon be ruined by corrosion. In Mumbai there was a contractual arrangement for repairing and repainting the containers. Each container was repainted on an annual basis, at a cost of Rs 400 per container. (The old paint was burned off and they were repainted with red oxide and yellow and black topcoats, as shown in photograph 7). The contractor also repaired wheels and other minor damage if parts and electricity were supplied. Such maintenance needs a system for collecting damaged containers and distributing repaired ones - both the information system to locate containers needing repair and the transportation system to bring them to the workshop. Damaged containers were sometimes seen overturned at collection points - to indicate that they needed repair and to prevent residents from putting more waste in them.

B-2.3 CALCULATIONS AND RESULTS

The SENS program was used to calculate the costs for each of the three trips that were studied, and also for a hypothetical case. The main inputs to the SENS spreadsheet are shown in appendix BB-2.2.

The hypothetical case considered how the work could be done with a smaller workforce. To make the work more efficient it would be necessary to increase the number of containers and persuade primary collection staff to ensure that all waste is placed into the trolley bin containers. It would also be necessary to provide concrete hard standing for each container so that it could be moved to the truck with a smaller workforce. This hypothetical case considers that the trucks would be operated with a crew of one driver, one mukadam, one cleaner and two loaders. The cleaner would be expected to help the crew on occasions. Clearly, such a change could not be instituted without considerable negotiation, and perhaps confrontation, with the labour unions. The results below could indicate whether it would be worth trying to negotiate a different working arrangement. Table B-2.1 summarises some of the data and some of the results for the three actual cases and the hypothetical case.

The results show a considerable variation in the cost per ton for the three observed trips, largely as a result of the different weights of waste collected. Most of the costs per shift are fixed, except for the fuel and maintenance which are according to distance travelled. Therefore the lowest cost per ton is achieved when the greatest weight is loaded. In both the first and third cases the vehicle was loaded to the utmost because waste was left in the last container - the truck could not take it all (appendix BB-2.1), so the deciding factor seems to be the density or the resistance to compaction of the waste.

Table B-2.1 Observed and calculated data

	Observed			Hypothetical
	7.12.93, am	8.12.93, am	10.12.93, pm	(reduced crew)
Time taken, starting at chowki (min.)	216	243	286	283
Weight of refuse collected (kg)	6280	5780	5340	
Uncompacted waste density (kg/m^3)	372	391	328	
Estimated compaction ratio	1.54 : 1	1.35 : 1	1.48 : 1	
Number of containers used	15	11	20	
Cost per ton collected (Rs)	**355**	**374**	**440**	**283**
Percentage of unit cost due to labour	73	75	69	59

It was the practice in Mumbai to estimate the maintenance cost of the vehicle as ten percent of the capital cost of the vehicle. This is 13% less than the estimate used in table B-2.1; using the Mumbai estimate of vehicle maintenance costs, the cost of the hypothetical option falls from Rs 283 per ton to Rs 280 per ton - a difference of one percent.

Using the SENS spreadsheet it is possible to investigate the effect of each of the variables, as illustrated in table B-2.2, to answer some "What if...?" questions. Representative or average values are taken from the three trips that were observed to give one value for the current system. The different "What if...?" scenarios are described in table B-2.2.

Table B-2.2 The effect of changes in variables on the unit cost of secondary waste collection

	Description of situation or modification to data	Unit cost (Rs/ton)	% change
A.	Existing situation - Multipack compactors in December 1993	390	
B	Using older compactor trucks (Airtech Shörling 4R)- operational data from 1992 report and same costs as for case A	311	-20%
C	As for case A but with a crew of three (from table B-2.1 above)	283	-27%
D	As for case A but with truck that costs twice the price	439	+13%
E	As for case A but with a 50% increase in maintenance costs, which results in an availability of 90%	394	+1.3%
F	As for case A but the container life being only three years	399	+2.3%
G	Truck with a 15 m^3 body, costing ten percent more	297	-24%

Case B (using the previous model of compactor truck) results in a lower unit cost because the capacity of the body is greater, even though the cost of this vehicle was ten percent more.

Case C is considerably cheaper because a smaller crew is used with the vehicle, and labour costs are the main component of the unit cost.

Case D shows that the contribution of the capital cost of the vehicle is not so significant - over the ten year life of the truck the unit cost is increased by only thirteen percent. This suggests that basing the selection of a vehicle on the capital cost alone may not be justified if there are other considerations that affect the unit cost throughout the life of the vehicle. In this case no benefits are assumed to result from selecting the more expensive vehicle, but possible benefits that might be expected are larger capacity, quicker loading times or higher availabilities. A further comment on vehicle prices is made at the end of this section.

Case E suggests that it may be worthwhile to spend more on maintenance if this results in shorter periods when the trucks are awaiting repair, or if the extra effort on preventive maintenance decreases the incidence of breakdowns. A 50% increase in maintenance costs is a very significant increase, and might enable the maintenance manager to hire more well-qualified craftsmen, or buy more equipment or invest more in replacement parts in a preventive maintenance programme.

Case F suggests that the data on the container life is not very critical to the cost of the collection service. (This may not be true if containers are emptied at longer intervals, since, in that case, more containers would be associated with each truck.) However, it must be remembered that defective containers make the collection operation more difficult and less efficient, and encourage careless dumping of waste by primary collectors and residents.

Case G again illustrates the importance of body volume when the number of trips per shift is fixed by negotiation with the labour unions. If each truck does only one trip per shift, then the largest possible truck will maximise the work that a crew of loaders do in one shift. (Of course there are other factors that also affect the optimum size of the vehicle, as discussed in chapter C-1.)

Table B-2.3 investigates the effect of refuse density. A denser waste results in a heavier load, reducing the unit cost. The compaction of dense waste is generally less that the compaction of light waste, though the actual values depend also on the nature of the waste and the performance of the truck. For example, a truckload of closed empty plastic bottles would have a very low bulk density, but would be compacted very little by many compacting mechanisms that operate by means of packer plates. Tree branches also may be difficult to compact because of their elasticity. In spite of these extremes, it is usual for low-density wastes to be compressed more. The compaction ratios shown in table B-2.3 are only guesses.

The density of solid wastes varies randomly to a considerable extent, but there are also more predictable variations - for example waste from a commercial district is likely to be of lower density that wastes from a slum area.

Another factor to bear in mind is that trucks should not be overloaded - as often happens with dense wastes in compactor trucks.

Table B-2.3 The effect of waste density on unit cost

Density (kg/m^3)	Compaction ratio	Unit cost (Rs/ton)	% change	Notes
363	1.45 : 1	**390**	-	Case A of table B-2.2
250	1.8 : 1	**460**	+18%	
300	1.6 : 1	**428**	+10%	
350	1.45 : 1	**403**	+3%	
400	1.35 : 1	**377**	-3%	
500	1.15 : 1	**352**	-10%	

Table B-2.3 shows that there can be a 28% range in unit costs for the magnitudes of densities that can be found in India. This also suggests that some care should be taken in comparing unit costs for refuse collection from one place to another (even different parts of the same city), because part of the variation may be due to the effect of refuse density.

For the purpose of internal accounting, a rental was charged by the Transport Department in Mumbai for the use of each vehicle. For compactor trucks, this charge was Rs 753 in 1993. Using the data obtained as described above, and assuming that the costs of the driver and the cleaner are borne by the Transport Department, the rental charges for the three trips studied were calculated to be Rs 952, Rs 890 and Rs 1067. It must be remembered that the data of this study were based on a small sample of observations, and some of the assumptions may be disputed, but these results do suggest that the internal rental charge may have been too low.

Further comment on vehicle prices When the purchase of compactor vehicles was being considered in Mumbai in 1991, the following quotations were received for the supply of Multipack trucks:

Crore Rs 3.18 3.19 3.245.

For the older model (4R) the following quotations were received

Crore Rs 3.45 3.46

The difference between prices of alternative chassis appeared to be about 1%.

Whilst government regulations may require the acceptance of the lowest tender (based on capital costs), the analysis of total costs per ton (including purchase, operation and maintenance) shows that the choice of the alternative having the lowest capital cost at the tender stage may result in a considerably higher expenditure over the service life of the equipment. The calculation of these *whole life* costs requires reliable values for operational data that are sometimes difficult to obtain, but, in view of the expenditure that can be saved, it is worthwhile to invest in the human resources needed to investigate carefully the whole life costs of alternative systems.

B-2.4 CONCLUSIONS AND RECOMMENDATIONS

◊ The costs of secondary collection of municipal solid waste are considerable, and so it is important to maximise the efficiency of this service to keep the expenditure as low as possible. Observation of collection crews in action can provide useful data which can lead to an estimation of the costs of collecting one ton of waste, and can provide useful insights into the problems experienced by the collecting crews. A knowledge of the costs of refuse collection is valuable when comparing alternatives and developing ways of improving efficiency.

◊ In Mumbai, labour costs were the major part of the expenditure on municipal refuse collection. Any way of reducing these costs would have a significant effect on the total costs of the operation. Improving the equipment and infrastructure so that a smaller crew can be used is one way of reducing total costs, but resistance to such moves from the labour unions is to be expected. There is also resistance to the crews undertaking more than one trip per shift. Faced with these restrictions, the only way to reduce costs seems to be increasing the load that is collected in one trip, by using larger vehicles.

◊ A computer program that models the collection operation is a valuable tool for the manager. The program must be prepared by someone with a good knowledge of refuse collection operations, so that it reflects actual problems and is sufficiently flexible. Such a program enables alternative strategies to be examined quickly and reliably.

◊ The selection of solid waste collection equipment should not be based solely on the purchase price. Other costs, related to operation and maintenance, can have a much larger impact than a small difference in purchase price, but some items of such cost information can often only be obtained by observation of normal operations. If a city does not already operate a particular type of vehicle, how can it collect such data? There are two possible ways - either to purchase one or two of the vehicles and operate them on a trial basis, or to observe the operation of the particular type of vehicle in another location. For this second alternative to be successful the following requirements should be met:

  ⇒ It is necessary to know where the particular type of vehicle is in operation. This information may be available from the supplier, but the need for such information is one reason why a network of solid waste managers throughout India should be established, so that colleagues keep each other informed about developments, including where the vehicles can be observed.

  ⇒ Observation of actual operations are important. Often labourers work differently - either faster or slower - when being observed, so it is important to be able to verify measured values by comparing them with times recorded in registers when the labourers are not being observed.

  ⇒ Local factors must be taken into consideration, such as local agreements with labour unions, the density and compressibility of the waste to be collected, and the road speeds and distances.

It may be necessary to amend regulations and procedures for evaluating tenders before this more realistic method of assessment of options can be implemented.

APPENDIX BB-2.1

WORK STUDY DATA FOR MULTIPACK TRUCKS, MUMBAI

BB-2.1.1 Compactor truck - '2504' -, 7 December 1993; first shift

Vehicle model: Airtech Multipack, approximately nine months old
Total body volume approx. 11m^3 (Airtech)
Crew:- 1 driver, 1 cleaner, 1 mukadam, 6 loaders

Station	Distance meter (km)	Time	Notes	No. of Bowls
	067	7.22	**Dep** motor loader chowki	
1	067	7.24'00"	**Arr** Two trolleys, one half full, one full; waste lying around, two loads palm branches loaded directly, fairly dry; uneven surface. First trolley loaded 7.28'40" Second trolley 7.34 ;89 s to load	7
		7.37'05"	**Dep**	
2	068	7.39'30"	**Arr** Four trolleys- two full, one 80% full, one empty, on hard standing with some holes Coconut shells, 17 bowls filled one trolley; four men could move a trolley; those pulling container risked injuring feet; no protective clothing, no loaders wearing uniforms; when trolley is lifted it tends to slide sideways, four men needed to keep it in position; when lifting material spilled from both sides; trolley loads require three or four compacting cycles to be emptied. First trolley 7.46'35" , 85s First trolley reloaded 7.54'55", 175s Second trolley 8.00, 103s Third trolley 8.03, 85s Fourth trolley 8.05'30" 88s	43
		8.08'00"	**Dep**	
3	068	8.11'52"	**Arr** Two trolleys - one full, one 80%. Trolleys off road on rough ground; Waste light - plastic, paper, fabric, incl commercial; loaders pulling trolleys at risk from traffic First trolley 8.17'20", 130s Second trolley 8.22'40", 175s	8
		8.27'50"	**Dep**	
4	069	8.30'43"	**Arr** Two trolleys, on road, partially blocking busy road, one full, one 90% First trolley 8.33'40", 90s Second trolley 8.36'05", 95s	2
		8.39'08"	**Dep**	
5	071	8.41'50"	**Arr** Two trolleys, both about 10% overloaded, back wheels of trolleys in depression at edge of road First trolley 8.43'45", 85s Second trolley 8.47'07", 123s	3
		8.50'37"	**Dep**	

compactor truck - '2504' - continued

Station	Distance meter (km)	Time	Notes	No of Bowls
6	071	8.53'00"	Two trolleys one 70%, one 90%, narrow busy road, trolleys kept in recess cut out of footpath, good surface; much foliage, mostly dry; loaders pick up bowls by rims, not ropes First trolley 9.01'57", wood shavings tipped into trolley, second load in first trolley 9.04'20" 100s Second trolley 9.08'40", 161s	14
		9.13'47"	**Dep**	
7	073	9.19'44"	**Arr** One full trolley clean area, trolley on road, good surface; serious traffic obstruction during loading; truck full, could not take all of bin's contents (Previous collection three days before - holidays - so truck was unable to collect from three stations that were normally served on this route. Trolley loading 9.21'27", ≈6 min.	0
		9.28'25"	**Dep**	
	075	9.36'30"	**Arrive motor loader chowki** to deposit tools	
		9.43'05"	**Depart chowki**	
	079	9.56'00"	**Arrive checkpoint** on Linking Road	
		10.01'15"	**Depart checkpoint**	
	084	10.13'32"	**Arrive weighbridge**	
		10.17'00"	**Depart weighbridge**	
	089	10.26'40"	**Arrive Malad disposal site** At tipping place 10.28. Vehicle reverses and stops suddenly to clear residue. Cleaner removes any scraps.	
		10.33'45"	**Depart disposal site**	
	094	10.42'50"	**Arrive weighbridge**	
		10.46'00"	**Depart weighbridge**	
	098	10.58'05"	Passed road leading to motor loader chowki	
	106	11.25'17"	**Arrived Bandra garage**	

Weighbridge results:

Full:	15 180 kg
Empty	8 900 kg
Load	**6 280 kg**

BB-2.1.2 Compactor truck - '2469' -, 8 December 1993; first shift

Vehicle model: Airtech Multipack, approximately nine months old
Total body volume approx. 11m^3 (Airtech)
Crew:- 1 driver, 1 cleaner, 1 mukadam, 6 loaders

Station	Distance meter (km)	Time	Notes	No. of Bowls
	24187	7.45	**Dep** motor loader chowki	
1	188	7.50	**Arr** Two trolleys, one half full, one 0.9m^3; Little overflow; trade and domestic refuse; fairly dry; road surface uneven. First trolley loaded 8.54'15", 80s to load Second trolley 8.57'30"; 60s to load	4
		8.00	**Dep**	
2	188	8.02'30"	**Arr** One trolley, 0.4m^3; drain silt lying outside; trolley on road, good surface; 4 men push trolley. Trolley loaded 8.07'20", 40s to load	4
		8.09'30"	**Dep**	
3	189	8.11	**Arr** 3 trolleys; 0.2m^3; 0.5m^3; 0.7m^3; waste scattered, trade waste, dry, ash and wood shavings, dirty site. First trolley 8.14'30", 50s Second trolley 8.17, 120s Third trolley 8.21'15", 70s	7
		8.22'15"	**Dep**	
4	190	8.29	**Arr** One trolley, 0.55m^3; domestic waste; nearby drain full of waste; Trolley loaded 8.34'30", 55s to load	1
		8.35	**Dep**	
5	192	8.41'15"	**Arr** No trolley there, new trolley placed there. Large quantity of waste scattered; market and commercial waste, bad conditions for loading. Trolley used to load waste as follows 1st load 18 bowls 1.1m^3; 8.43'30", 180s 2nd load 18 bowls 1.1m^3; 9.05'25", 170s 3rd load 21 bowls 1.15m^3; 9.19'45", 90s 4th load 23 bowls 1.2m^3; 9.35'35", 125s About 6 bowls of garbage left at the site. 10 bowls of refuse was added by nearby residents.	80
		9.44'30"	**Dep**	

compactor truck - '2469' - continued

Station	Distance meter (km)	Time	Notes	No. of Bowls
6	193	9.51'00"	**Arr** Three trolleys, one 1.1m^3; second 0.9m^3; third 0.8m^3; market and commercial waste very scattered; surface uneven; about 1m^3 brought by nearby traders during loading; 2 bundles of sugar cane waste added. 1st trolley loaded 9.59'45", 110s to load 2nd trolley, 9.59'50", 120s 3rd trolley, 10.04'35", 90s 3rd trolley refilled, 10.16'00", 90s 3rd trolley, refilled again, 10.23'20", 130s	50
		10.25	Start of tea break	
		10.34	End of tea break	
		10.34'45"	**Dep**	
	194	10.36'30"	**Arrive checkpoint** on Linking Road	
		10.40	**Depart checkpoint**	
	199	10.55	**Arrive weighbridge**	
		10.58	**Depart weighbridge**	
	203	11.09	**Arrive Malad disposal site**	
		11.17"	**Depart disposal site**	
	208	11.30	**Arrive weighbridge**	
		11.34	**Depart weighbridge**	
	212	11.47'30"	**Arrive motor loader chowki** Andheri to return implements	
		11.49	**Depart chowki**	
	220	12.19	**Arrived Bandra garage**	

Weighbridge results:

Full:	14 820 kg
Empty	9 040 kg
Load	**5 780 kg**

BB-2.1.3 Compactor truck - '2471' -, 10 December 1993, second shift

Vehicle model: Airtech Multipack, approximately nine months old
Total body volume approx. 11m^3 (Airtech)
Crew:- 1 driver, 1 cleaner, 1 mukadam, 6 loaders

Station	Distance meter (km)	Time	Notes	No. of Bowls
	541	2.56	**Depart motor loader chowki**	
1	541	2.58	**Arr** Two trolleys, one 0.7m^3, second 0.2m^3, little garbage lying around; waste dry, some commercial, nearby drain filled with debris; rag pickers collecting plastic etc.; uneven surface. First trolley loaded 3.00'30"; 120s second trolley 3.04'00"; 110s	1.5
		3.06'00"	**Dep**	
2	542	3.10'30"	**Arr** Two trolleys; one 0.7m^3, other 0.3m^3, Good surface, domestic, dry, some fish; first trolley slipped towards the inside of the truck during loading. First trolley loaded 3.13'30", 95s second trolley 3.15'15" 70s	0
		3.17'45"	**Dep** 'U' turns necessary - could they be avoided?	
3	544	3.20'50"	**Arr** Two trolleys, one 0.9m^3, other 0.3m^3; much scattered waste, dry commercial and domestic, goats grazing, four can pull trolley, severe obstruction to traffic; First trolley 15.22, 90s second 15.26, 120s	3
		3.28'34"	**Dep**	
4	545	3.34'30"	**Arr** Two trolleys, one 0.2m^3, other 0.05m^3; large amount of scattered waste, foliage loaded directly into compactor, domestic and hotel waste, plastic bottles, serious traffic obstruction, considerable loss of hydraulic oil when compaction mechanism is working; first trolley loaded 3.43'35", 180s second trolley was not loaded - too little waste inside.	6
		3.47'	**Dep**	
5	546	3.50'30"	**Arr** Three trolleys; first 1.1m^3, second 0.9m^3, third 1.0m^3, including hotel and commercial waste, mattress, rag pickers active, good surface so easy to move container; hydraulic system not working well - container dropped a short way; mukadam keeps loaders away from area under container, area left very clean, 1/3 truck load foliage left. First trolley loaded 3.53'43", 190s second trolley 3 56'35", 180s third trolley 4.04'15", 120s	12
		4.08'00"	**Dep**	

compactor truck '2471' continued

Station	Distance meter (km)	Time	Notes	No. of bowls
6	547	4.10'30"	**Arr** Three trolleys, all 1.0m^3, waste dry, domestic, commercial and hotel waste; ash, food, timber and cloth; very uneven surface, very untidy, probably because of rag pickers, who had collected 18 sacks of recyclable material, much scattered waste. First trolley loaded 4.12'20", 160s same trolley reloaded 4.21'25", 180s second trolley 4.32'35", 100s third trolley 4.36'45", 120s	18.5
		4.39'00"	**Dep**	
7	548	4.43'00"	**Arr** Three trolleys, one 0.3m^3, second 0.4m^3, third 0.7m^3; coconut, sugar cane, hotel and domestic waste, trolleys in ditch, difficult to move them; half of the road was blocked, serious risk of accidents. First trolley loaded 4.44'00", 90s second 4.46'30", 80s third 4.49'30", 75s	2
		4.52'30"	**Dep**	
8	548	4.54'20"	**Arr** two trolleys - 0.7m^3 and 0.6m^3; domestic, vegetable and garden waste, good surface First trolley loaded 4.56'40", 200s second 5.03'00", 180s	6.5
		5.10	**Dep**	
			Passed station with two trolleys which were inaccessible because a ditch had been dug in front of them for telephone cables.	
9	550	5.15'30"	**Arr** One trolley 0.6m^3, much spillage, dry domestic waste including fish and paper, horse tied to trolley; only 3/4 of trolley load could be loaded into truck; daylight could be seen above waste, though there was some foliage there; about 0.25m^3 was left in the container	16
		5.40'00"	**Dep**	
	555	5.55	**Arrive checkpoint** on Linking Road	
		6.03'22"	**Depart checkpoint**	
	559	6.15'00"	**Arrive weighbridge**	
		6.20'30"	**Depart weighbridge,** open road speed 40-45 km/h	
	564	6.29'30"	Passed turning for Chincholi (Malad) dumping ground	
	571	6.44'45"	**Arrived Gorai dumping ground**	
		6.48'00"	Unloading started, (in dark, no lighting); ejector plate operating well	
		6.52'00"	Unloading completed	
	572	6.58'10"	**Depart Gorai dumping ground** speed up to 50 km/h	
	579	7.15'20"	Passed turning to Chincholi dumping ground	

compactor truck '2471' continued

Station	Distance meter (km)	Time	Notes	No. of bowls
	583	7.22'50"	**Arrive weighbridge**	
		7.24'00"	**Depart weighbridge**	
	587	7.42'00"	**Arrive motor loader chowki** Andheri to return implements	
		7.43	Ready for departure; took approx. 10 minutes tea break	
		7.53	**Depart chowki**	
	595	8.20	**Arrived Bandra garage**	

Weighbridge results: Full: 14 280 kg
Empty 8 940 kg
Load 5 340 kg
Diesel consumption: approx. 20 litres

BB-2.1.4 Sample weights from Prabhadevi garage

In order to allow comparisons of the loads noted above with loads measured for vehicles of the same type operating in the City area of Mumbai, the following observations are provided. The weights are quoted in metric tons.

Full	16.00	14.90	12.50	14.10	13.55	15.24	14.18	13.08	13.20
Empty	9.04	9.00	9.40	9.08	9.08	9.10	9.00	9.04	9.20
Load	6.96	5.90	3.10	5.02	4.47	6.14	5.18	4.04	4.00

The average of these loads is 4.98 tons.

APPENDIX BB-2.2 CALCULATION OF UNIT COSTS FOR COMPACTOR TRUCKS USING *SENS* PROGRAM

This appendix first considers how to convert the data from appendix BB-2.1 to suit the requirements of the program, and then presents the unit costs. Costs will be calculated using a spreadsheet program known as SENS. 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. Data are taken from appendix BB-2.1

A This refers to data collected for compactor truck 2504 on 7 December.

B This column is based on data for compactor truck 2469 on 8 December

C This column is based on data for compactor truck 2471 on 10 December

Rec These are values recommended for alternative computations; often averages. This option estimates the cost if a smaller crew were used with each truck, and if all the waste were in containers, so that the crew were not involved in collecting up waste from the street.

Explanatory notes	A	B	C	Rec
Vehicle design capacity (volumes from manufacturer) [m^3]	11	11	11	11
Vehicle actual capacity ratio (If body is full = 1.0)	1.0	1.0	1.0	1.0
Volume loaded from trolleys (estimated, m^3) (v)	12.5	6.5	12.6	
Number of bowls (n) (Based on five observations, 17.5 bowl loads are needed to fill one trolley container, so estimated volume in one bowl is 1.0/17.5 = 0.057 m^3 .)	77	146	65	
Estimated uncompacted volume [m^3] v + 0.057n	16.9	14.8	16.3	16.0
Compaction ratio (Estimated uncompacted volume divided by estimated volume in truck.)	1.54:1	1.35:1	1.48:1	1.45:1
Refuse density (From weighbridge results and estimated uncompacted volumes) [kg/m^3]	372	391	328	363
Container capacity [m^3]	1.0	1.0	1.0	1.0
Number of containers in use	15	11	20	
Actual container capacity ratio (i.e. fraction of total container volume occupied. Uncompacted volume of waste divided by total volume of all containers used. For projected systems a value lower than 1.0 is used since it is essential that waste does not overflow, so extra spare capacity is needed)	1.13	1.35	0.82	0.75
Container capital cost [Rs] (Standing Committee Dec. 1991)	6407.5	6407.5	6407.5	6407.5
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] (December 1991, tenders)	7.16	7.16	7.16	7.16
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 1993 data for Multipack trucks in appendix DD-1.1 February 71% October 73%, November 72.5% average value 72% [%]	72	72	72	72
Container loading time (Total time vehicle stationary at loading stations divided by number of containers. For *Rec* system average of stations A.4, B.4, C.2 and 7 plus 30 s extra - these stations chosen because all or most of the waste was in the containers) [seconds]	417	717	366	256
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	2.15	1.84	2.23	1
Vehicle unloading time (i.e. time spent on disposal site) [min]	7.1	8	12.5	10

Explanatory notes (continued)	**A**	**B**	**C**	**Rec**
Report time, Delay allowance (Time when vehicle not moving, loading or unloading can be included as report time or as delay allowance) [min]	18.3	21.8	26	30
Time between stations (For *Rec* the time has been reduced because less waste would be stored on each site, so the sites would be closer together.) [s]	202	282	231	240
Distance between two stations (Total distance between first and last storage points divided by number of intermediate stages. For *Rec* it is less since more stops are made) [m]	1000	1000	1125	430
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	6.5	6.5
Distance to disposal site from weighbridge. [km]	5	4.5	12	5
Urban speed (Average speed between collection area weighbridge and chowki, and to/from depot.) [km/h]	19.1	17.9	17.6	18.2
Country speed (Average speed between weighbridge and disposal site.) [km/h]	32	22.5	28.2	27.5
Extra distance to the depot (both directions) [km]	16	16	16	16
Two loads per day, changeover time between shifts irrelevant				
Working hours per day (In this case the time must be chosen to allow enough time for two trips in two shifts, but not enough for three.) [h]	11	9	13	12
Container maintenance cost pei year (as a fraction of its annual cost.-.values are guesses. For *Rec* system more must be spent on trolleys to ensure that the wheels are always in good condition)	0.02	0.02	0.02	0.1
Vehicle maintenance cost per km (Based on MCGM figure with other miscellaneous charges added, and inflated by 35%) [Rs/km]	2.35	2.35	2.35	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. [km/litre]	2.0	2.0	2.0	2.0
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 (See appendix AA-1.2) 30 days/m [Rs]	6000	6000	6000	6000
Loader's wages per month (See appendix AA-1.2) [Rs]	5100	5100	5100	5100
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, B 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 *Rec* it is taken as twice the value for A, B and C, since the wages bill is halved but the supervision costs remain the same. [%]	20	20	20	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 leave, sickness etc. This is already included in values of appendix AA-1.2 so the value here is 0 [%]	0	0	0	0
Estimated collection cost per tonne [Rs/tonne] Values calculated using *SENS* program	**359**	**379**	**444**	**287**