Since these costs are based on tachometer-hours, no adjustment is necessary to account for one hour per shift for equipment decontamination. The application cost per sq meter is:

$$\$0.3869/\text{gal} \times 0.4\ \text{gal/yd}^2 \times 1.19599\ \text{yd}^2/\text{m}^2 = \$0.19/\text{m}^2$$

At 350 gallons every 21.25 minutes, the average hourly dump rate is 988 gallons. Adjusting for seven operating hours per eight-hour shift, the hourly rate is 864 gallons or 1808 m^2/hr.

While Carr Aviation of Pasco, Washington, was not able to supply as much detailed information as other aviation companies, they did supply their basic price schedule which can be converted to a dollar-per-gallon basis. These prices do not include the cost of the chemicals. Further, since these prices are based on the cost of application per gallon rather than per hour, no adjustment for seven hours output per eight-hour shift is necessary.

The declining cost per gallon with increased coverage, shown in Table A.1.4.1.1, suggests that a very rough estimate of $0.50 per gallon for very large volumes would not be too low. It is quite possible that lower rates would be charged. At $0.50 per gallon, or $0.24 per sq meter, these were the highest cost estimates for aerial application obtained. The information supplied by Carr Aviation was insufficient to estimate the rate of treatment.

TABLE A.1.4.1.1. Charges for Aerial Application by Carr Aviation

Coverage (gal/acre)	Cost (1982 $)	$/gal
3	3.60	1.2000
5	4.40	0.8800
8	4.90	0.6125
10	5.40	0.5400

Table A.1.4.1.2 summarizes the aerial-application costs on a per-gallon basis. The representative cost is taken as $0.32 per gallon, which is lower than the average of the separate cost estimates. The reason for this is that application with the large-capacity planes used for fire fighting is more likely than with the smaller and higher per-gallon cost aircraft. Further, as explained earlier, the cost figures supplied by the Forest Service are for non-continuous operation and are therefore probably higher than would be the case in the event of continuous application of a fixative.

TABLE A.1.4.1.2. Summary of Aerial Application Cost Estimates by Source

Source	Cost (1982 $/gal)
U.S. Forest Service	0.50
Butler Aviation	0.23
Columbia Ag Service	0.39
Carr Aviation	0.50
Representative	0.32

Table A.1.4.1.3 presents the costs on a per-sq-meter basis. Also included is the cost of the fixative. These costs are based on a fixative application rate of 0.4 gallon per sq yard. Different application rates would imply different costs.

TABLE A.1.4.1.3. Summary of Aerial Application of Fixative Cost Data[a]

Source	Cost (1982 $/m^2)		
	Aer. App.	Fixative	Total
U.S. Forest Service	0.24	0.05	0.29
Butler Aviation	0.11	0.05	0.16
Columbia Ag Service	0.19	0.05	0.24
Carr Aviation	0.24	0.05	0.29
Representative	0.15	0.05	0.20

(a) Based on 0.4 gallon of fixative per sq yard.

Estimates for the rate of surface treatment ranged from Columbia Ag Service's 1,808 sq meters per hour to the Butler Aviation high-volume rate of 16,461 sq meters per hour. Since the larger aircraft is more likely to be used, we take 14,000 sq meters (6,690 gallons) per hour as a representative application rate. A cost of $0.15 per sq meter for the cost of application is taken as representative, bringing the total cost with the fixative to $0.20 per sq meter.

The representative inputs include, for labor, one pilot, one flight crewman, and two ground crewmen. The hourly cost of labor is estimated at $140 per hour. Equipment is one tanker airplane at $1960 per hour. The resulting costs per sq meter are $0.01 for labor and $0.14 for equipment.

As mentioned earlier, this discussion has been premised on a standard application of lignosite - 0.4 gallon per sq yard. However, tree foliage will greatly increase the total surface area for each sq meter of ground. For this reason and because of the difficulty in achieving an even coating of fixative, a higher application rate will probably be necessary. If we assume one gallon of fixative per sq yard, this will raise the costs by a factor of 1.0 ÷ 0.4 = 2.5 and lower the rate to

$$14{,}000\ m^2/hr \div 2.5 = 5600\ m^2/hr$$

The total cost is $0.495 per sq meter. The labor cost is $0.025 per sq meter, and equipment and materials cost $0.350 and $0.120 per sq meter, respectively. We take these costs to be representative of fixative application to wooded areas.

A.1.4.2 Defoliate

Defoliation as a decontamination technique is described in Section A.1.2.4. Wooded areas will likely require a heavier application than orchards. Here we assume that a 50% greater application of materials would be used. As a result, all input costs would be increased by 50%:

$$\text{Labor: } \$0.0006/m^2 \times 1.5 = \$0.0009/m^2$$

$$\text{Equipment: } \$0.0015/m^2 \times 1.5 = \$0.0023/m^2$$

$$\text{Materials: } \$0.0105/m^2 \times 1.5 = \$0.0158/m^2$$

$$\text{Fuel: } \$0.0020/m^2 \times 1.5 = \$0.0030/m^2$$

The total cost per sq meter is $0.0220. The rate is reduced by one-third:

$$8831\ m^2/hr \times 0.667 = 5554\ m^2/hr$$

A.1.4.3 Clear

Clearing involves removing trees and bushes. The data for this operation come from Means' Building Construction Cost Data 1982 (p. 24). The labor specified for this operation and the hourly costs are:

1 Foreman @ $22.25	$ 22.25
4 Building laborers @ $19.40	77.60
1 Medium-equipment operator @ $24.95	24.95
Total labor	$124.80

The equipment listed for clearing and the hourly costs are:

1 Chipping machine	\$ 16.11
1 Front-end loader	72.46
Total equipment	\$ 88.57

The rate is given by Means as 0.60 acres per day. Converting to sq meters per hour and adjusting for one hour lost per shift for personnel and equipment decontamination, we get:

$$0.60 \text{ ac/day} \div 8 \text{ hr/day} \times 4046.7 \text{ m}^2\text{/ac} \times 7/8 \text{ adj} = 266 \text{ m}^2\text{/hr}$$

Dividing the hourly coverage rate into the hourly costs gives the costs in terms of dollars per sq meter:

$$\text{Labor: } \frac{\$124.80/\text{hr}}{266 \text{ m}^2/\text{hr}} = \$0.469/\text{m}^2$$

$$\text{Equipment: } \frac{\$88.57/\text{hr}}{266 \text{ m}^2/\text{hr}} = \$0.333/\text{m}^2$$

The total cost per sq meter is \$0.802.

A.1.4.4 Grub and Scrape

The operation of clearing does not include removal of tree stumps, and as long as they remain, soil scraping using front-end loaders cannot be done effectively. Therefore, removing the stumps, a procedure called grubbing, is a prerequisite for mechanized scraping.

The source for grubbing is Means' Building Construction Cost Data 1982 (p. 24). The labor and the associated hourly labor costs for this activity are one medium-equipment operator and two heavy-truck drivers. Since the cost of hauling material is handled separately in this work (see Section A.6.2), we exclude the two truck drivers along with the two dump trucks. The equipment for this procedure is one 1.5-cubic yard hydraulic excavator costing \$70.51 per hour.

The production rate is given as 1.20 acres per day. The following converts this figure to sq meters per hour and adjusts for one hour per shift devoted to personnel and equipment decontamination:

$$1.20 \text{ ac/day} : 8 \text{ hr/day} \times 4046.7 \text{ m}^2/\text{ac} \times 7/8 \text{ adj} = 531 \text{ m}^2/\text{hr}$$

Dividing the hourly labor and equipment costs by the hourly coverage rate gives the costs in terms of dollars per sq meter:

$$\text{Labor: } \frac{\$24.95/\text{hr}}{531 \text{ m}^2/\text{hr}} = \$0.047/\text{m}^2$$

$$\text{Equipment: } \frac{\$70.51/\text{hr}}{531 \text{ m}^2/\text{hr}} = \$0.133/\text{m}^2$$

$$\text{Total: } \$0.047/\text{m}^2 + \$0.133/\text{m}^2 = \$0.18/\text{m}^2$$

The cost and rate for scraping are taken to be the same as for scraping vacant land. These costs are shown in Table A.1.4.4.1. This table also shows the total costs for the entire grub and scrape operation. Since scraping is the more costly procedure, the rate for the whole operation is set equal to the rate for that procedure. This requires that 656 ÷ 531 = 1.24 grubbing crews are required for every scraping crew.

TABLE A.1.4.4.1. Summary of Grub and Scrape Data for Wooded Areas

Procedure	Rate (m^2/hr)	Cost (1982 $\$/m^2$) Total	Labor	Equipment
Grub	531	0.18	0.05	0.13
Scrape	656	0.41	0.18	0.12
Total	656	0.59	0.23	0.36

A.1.4.5 Manual Scrape

While use of earthmoving equipment for scraping is not feasible in wooded areas without first clearing and grubbing, scraping can be accomplished without clearing and grubbing if done manually. The inputs for this operation are simply a laborer plus minor hand equipment such as a shovel and a wheelbarrow. The hourly cost for a common laborer is $17.45, and we estimate $1.00 per hour to be sufficient to cover equipment.

The coverage rate will be highly variable, depending on such things as hardness of the soil, roughness of the terrain, and how far the soil has to be moved to dump trucks for disposal. Various rate estimates for hand excavation are given in Means' Building Construction Cost Data 1982 (pp. 29, 30). These figures vary from four to eight cubic yards per day for excavating pits or trenches. We assume a base rate of eight cubic yards per day. If the surface is scraped to a depth of six inches, then each cubic yard represents six sq yards of area scraped. Eight cubic yards per day, with adjustment for an hour per shift for personnel decontamination, is equivalent to:

$$8\ yd^3/day \div 8\ hr/day \times 6\ yd^2/yd^3 \times 0.836\ m^2/yd^2 \times 7/8\ adj = 4\ m^2/hr$$

Dividing the hourly cost figures by the hourly coverage rate yields costs in terms of dollars per sq meter:

$$\text{Labor:}\ \frac{\$17.45/hr}{4\ m^2/hr} = \$4.36/m^2$$

$$\text{Equipment:}\ \frac{\$1.00/hr}{4\ m^2/hr} = \$0.25/m^2$$

$$\text{Total:}\ \$4.36/m^2 + \$0.25/m^2 = \$4.62/m^2$$

A.1.4.6 Cover Scraped Land

Section A.1.1.9 discusses covering the ground with uncontaminated soil as a decontamination operation. If a wooded area has been cleared and grubbed, covering is essentially the same as it would be for vacant land. We use the same costs here. (See Section A.1.1.9.)

A.1.4.7 Cover Unscraped Land

Covering the ground with soil as a decontamination operation is described in Section A.1.1.9. This operation involves two basic steps, soil excavation and soil placement. The cost and rate of soil excavation are the same as those listed in Section A.1.1.9. Placement of soil by hand in a wooded area is essentially the reverse of manual scraping as described in Section A.1.4.5. We assume, however, that the placement rate is 50% faster than scraping. Table A.1.4.7.1 summarizes the cost data. The rate of the combined operation is set equal to that of the more costly suboperation, placement. This means that 6 ÷ 812 = 0.001 excavation crews would be needed for each placement crew.

A.1.5 Asphalt Streets, Roads and Parking

The operations for decontaminating paved surfaces include vacuuming, flushing with water at various pressures, special chemical techniques, and road construction procedures. These are described in detail in this section.

TABLE A.1.4.7.1. Summary of Data for Covering Wooded Areas with Uncontaminated Soil Without Grubbing

Procedure	Rate (m^2/hr)	Cost (1982 $/m^2) Total	Labor	Equipment
Excavation	812	0.166	0.043	0.123
Placement	6	3.08	2.91	0.17
Total	6	3.24	2.95	0.29

A.1.5.1 Mobile Vacuumized Street Sweeping

While other operations have greater decontamination effectiveness, the cost per sq meter of vacuuming is so low in comparison that it would likely be used alone or in conjunction with other procedures in essentially all instances in which pavement decontamination activities are undertaken. There are four basic types of mobile street sweepers in use by cities, highway departments, and airports. These are the mechanical rotary-broom type, the recirculating air type, the vacuum type, and the dustless vacuum type. Within the spectrum of costs encompassed by the various pavement decontamination methods, there is relatively little difference among the costs of using these devices, and the reports from the different sources disagreed as to the ranking of the vacuum types by cost. The least effective for the purposes of radiation decontamination is the mechanical rotary-broom type. This machine is intended primarily for picking up large debris such as cans, bottles, hubcaps, and mufflers. Other machines do a better job of removing small particles and are used most commonly in dusty or sandy locales. The best machine for decontamination purposes is the dustless vacuum type - a machine most commonly used at airports for cleaning runways. Because of its high filtration at the vacuum exhaust and containment skirts underneath, this type of equipment creates little or no airborne dust which could recontaminate neighboring areas.

Unlike some decontamination procedures, vacuumized street sweeping is a common operation. Therefore, it is relatively easy to get fairly reliable cost estimates by using information provided by municipal public works departments and other users of vacuumized street sweepers. The estimates obtained range from $0.0020 to $0.0057 per sq meter.

The estimates of the cost per sq meter are directly tied to the average vehicle operating speed. Users reported a wide range of average speeds--from 1.42 miles per hour to 10 miles per hour. Manufacturers claim effective operation for some models at speeds as high as 15 miles per hour. Actual operating rates are determined by such factors as volume of material collected per unit pavement area, the time necessary to dump collected material, the power of the vacuum, the type of material to be picked up, and the desired cleanliness to be attained. These factors suggest that subsequent vacuumings will be less costly than the first. There will be a smaller volume of material to be picked up, and the material which is picked up is less likely to include branches and other objects which can jam the intake ducts. Even if the vehicles operate at the same average speed while vacuuming, fewer trips to the dump site will be required per hour and thus total productivity will be higher. Despite the cost difference for subsequent vacuumings, data limitations precluded deriving separate estimates for the different surface treatments.

Vacuumized street sweeping requires a mobile vacuum street sweeper and a driver. Other inputs include such things as fuel, filters, brooms, and maintenance. For purposes of decontamination, it may be helpful to use a sweeping compound. Maintenance is apparently a major expense, and equipment reliability is not very high. Some sources reported that this equipment required as much as one hour maintenance for every three hours operation. The information collected indicates that labor comprised anywhere from 18.5 to 60 percent of sweeping costs. A reasonable estimate based on the more reliable of these figures is that labor comprises 50 percent of vacuuming costs. The remaining costs are for equipment (15 percent), maintenance (25 percent), and fuel (10 percent).

Several factors bear on the effectiveness of vacuumized street sweeping as a decontamination technique. Small particles (diameter less than 10 microns) tend to lodge themselves in surface irregularities and thereby become more difficult to remove than larger particles. The size distribution of particles resulting from a reactor accident is likely to have relatively heavy concentrations of particles in the 1 to 10 micron range (U.S. Nuclear Regulatory Commission 1975). Further, the longer the time between initial exposure and vacuuming, the more difficult will be particle removal, as particles will have become more deeply embedded in the surface. Surface irregularities, both of microscopic and macroscopic sizes, will reduce vacuum effectiveness. The available information on the effectiveness of mobile vacuuming is scant, the best being Radiological Reclamation Performance Summary Vol. II (Owen et al. 1967). Removal efficiencies are also reported by other researchers (Horan et al. 1970; Julin et al. 1978; Wallace et al. 1975; The Product Information Network 1982), spanning a range of from 32 to 98 percent. Further, these sources do not provide any detail as to particle size or the velocity of the mobile vacuum.

Most street sweepers in use are the mechanical rotary-broom type, and while several cities that use vacuum-type sweepers were contacted, only a few of these kept adequate records from which cost per sq meter could be calculated. Some cities, such as Walla Walla and Spokane in Washington, use vacuum street sweepers and keep good records, but since street flushing and vacuuming operations and records are combined, it was impossible to identify the respective shares of each.

The City of Kennewick, Washington, uses a vacuumized street sweeper. The interdepartmental rental rate which the Street Department is charged for the vehicle by the equipment pool is $2,600 per month. This covers capital, maintenance, depreciation, fuel, and so forth. To convert this monthly charge to a dollars-per-sq-meter figure, we need to estimate the number of hours of operation per month and the average hourly rate of sweeping. The main factor affecting the number of hours worked per month is the number of shifts. With two shifts per day, as opposed to one, the monthly equipment cost can be spread out over twice as many hours and twice the sweeping area. At 176 hours per month for a single shift, the equipment cost is $14.77 per hour. With two shifts per day, the equipment cost is halved, falling to $7.385 per hour.

The labor cost reported was $10.64 per hour plus 35 percent for benefits and administrative overhead, bringing the total labor cost to $14.36 per hour.

There was considerable uncertainty in establishing a production rate for Kennewick street sweeping, since the Street Department keeps no mileage records. They did indicate that there were 140 street miles in the city, meaning a total of 280 potential production curb-miles. However, not all streets are swept. A total of 250 production miles in the city is a reasonable estimate. These can all be swept in a month if there is no heavy loading of debris as occurs with leaves in the fall. Coverage of 250 miles in the 176 working hours of a month works out to 11.36 miles per shift or 1.42 miles per hour. This is a particularly low speed compared with those reported by other sources. It is also much lower than the top operating speed possible of 5 miles per hour. For the purpose of estimating Kennewick's cost per sq meter, the rate of 1.42 miles per hour served as a lower bound for operating speed. Another estimate was derived by assuming 30 miles per shift or 3.75 miles per hour based on production rates reported by other sources.

Assuming one hour per shift is lost to special radiation protection measures, the production rate at 1.42 miles per hour is as follows:

$$1.42 \text{ mi/hr} \times 5280 \text{ ft/mi} \times 8 \text{ ft wide} \times 0.093 \text{ m}^2/\text{ft}^2$$
$$\times\ 7/8 \text{ shift-hr/8-hr shift}$$
$$= 4882.5 \text{ m}^2/\text{shift-hr}$$

With one shift per day, the total cost per hour is:

$14.77/hr for equip. + $14.36/hr for labor = $29.13/hr

Dividing by the average hourly production rate of 4883 sq meters gives a cost per sq meter of $0.0060. With two shifts per day the hourly cost would be:

$7.385/hr for equip. + $14.36/hr for labor = $21.75/hr

Dividing by the hourly producti[illegible]e yields an average cost of $0.0045 per sq meter.

Alternatively, at an operating speed of 3.75 miles per hour, the estimated production for a shift hour is:

$$3.75 \text{ mi/hr} \times 5280 \text{ ft/mi} \times 8 \text{ ft wide} \times 0.093 \text{ m}^2/\text{ft}^2$$
$$\times\ 7/8 \text{ shift-hr/8-hr shift}$$
$$= 12{,}890 \text{ m}^2/\text{shift-hr}$$

At this rate, the cost per sq meter with one shift per day is:

$$\$29.13/\text{hr} \div 12{,}890 \text{ m}^2/\text{hr} = \$0.0023/\text{m}^2$$

With two shifts per day, the cost per sq meter falls to:

$$\$21.75 \div 12{,}890 \text{ m}^2/\text{hr} = \$0.0017/\text{m}^2$$

The costs for the separate inputs, labor and equipment, are calculated in the same way. Table A.1.5.1.1 summarizes these results.

TABLE A.1.5.1.1. Summary of Vacuumized Street Sweeping Data for Kennewick, Washington

	Rate (m^2/hr)	Cost (1982 $\$/m^2$)		
		Total	Labor	Equipment
1.42 mph				
1 shift/day	4,883	0.0060	0.0029	0.0030
2 shifts/day	4,883	0.0045	0.0029	0.0015
3.75 mph				
1 shift/day	12,890	0.0023	0.0011	0.0011
2 shifts/day	12,890	0.0017	0.0011	0.0006
Representative				
2 shifts/day	10,000	0.0030	0.0019	0.0011

Based on these data, a cost of $0.0030 per sq meter with an average production rate of 10,000 sq meters per hour is selected as representative of Kennewick's street sweeping operations. Labor comprises about 64 percent and equipment about 36 percent of total costs.

The City of Pasco, Washington uses an Elgin Whirlwind V349 street sweeper. The Public Works Department pays an interdepartmental annual rental fee of $50,700 for the sweeper. This covers all equipment-related costs such as capital, depreciation, interest, maintenance, parts, and fuel. The operator's wage is $9.56 per hour, to which should be added an additional 70 percent for benefits and administrative overhead, according to the city engineer. However, weather, equipment breakdowns, and operator time off prevent regular eight-hour per day operation. On the other hand, the equipment is occasionally operated two shifts per day. These factors make it preferable to use total yearly labor costs rather than hourly figures. Table A.1.5.1.2 provides this information for the last three years. Direct cost refers to total wages, and total cost represents wages plus 70 percent for benefits and administrative overhead. The figures for 1982 are estimated from data for the first nine months of the year.

TABLE A.1.5.1.2. Yearly Labor Cost for Vacuumized Street Sweeping in Pasco, Washington

	Costs (1982 $)		
Year	Direct Cost (Wages)	Benefits and Administrative Overhead	Total Labor Costs
1980	12,292	8,604	$20,896
1981	16,564	11,595	$28,159
1982	19,437	13,609	$33,046

Despite detailed information about total mileage, actual production miles must be estimated. Inspection of the sweeping log for 1982 shows total miles per day ranging from about 19 to about 44. On most days mileages are between 20 and 30. Comparing the record of engine hours on the vacuum motor to total miles driven, it is estimated that each vacuum engine hour corresponds to three production miles. In all cases this estimate results in production miles being somewhat less than each day's total miles as should be the case. From February 17, 1982, to November 24, 1982, the vacuum engine logged 1415 hours. At 3 miles per hour, this equals 4245 production miles. Over the same period there were 219 operating shifts. This yields an average 19.38 production miles per shift. For the remaining parts of 1982 we estimate 50 shifts, bringing the total shifts to 269. Multiplying by the miles per shift gives 5214 estimated production miles for 1982.

Multiplying total hourly cost for labor ($16.252) by the number of shifts (269) and by 8 hours per shift produces an estimated total labor cost of $34,974. This is somewhat more than the $33,046 listed earlier. The difference is apparently due to the operator's working at sweeping for less than 8 hours on some shifts. The total number of sweeper operator hours for the year was about 2033. The average hours per shift was about 7.55.

The following converts total vacuum miles to area, assuming an 8-foot width:

$$4245 \text{ prod. miles} \times 5280 \text{ ft/mi} \times 8 \text{ ft wide} \times 0.093 \text{ m}^2/\text{ft}^2$$

$$= 16{,}675{,}718 \text{ m}^2/\text{yr}$$

Allowing for one hour out of eight for radiation control measures gives:

$$16{,}675{,}718 \times 7/8 = 14{,}591{,}253 \text{ m}^2/\text{yr}$$

The cost per sq meter is:

$$\$83{,}746/14{,}591{,}253 \text{ m}^2 = \$0.0057/\text{m}^2$$

Hourly production is:

$$14{,}591{,}253 \text{ m}^2/2033 \text{ hr} = 7177 \text{ m}^2/\text{hr}$$

The share of costs accounted for by labor is:

$$\frac{\$33{,}046}{\$83{,}746} = 39.5\%$$

and the share for capital (including fuel, maintenance, etc.) is 60.5 percent. In other words, the cost per sq meter for labor is $0.0023 and the cost per sq meter for capital is $0.0034.

The Department of Public Works in San Francisco supplied detailed cost information on their street sweeping operations. Their costs by major input, in terms of production miles are shown in Table A.1.5.1.3.

Of the four input categories, only labor and equipment need to be adjusted for the one hour per shift for radiation control. This is accomplished by multiplying by 8/7 to give $8.87 per mile. With an eight-foot wide sweeper swath, one mile of sweeping will cover 3928 sq meters. Dividing the total cost per lane mile, $15.06, by 3928 yields a cost of $0.0038 per sq meter. These calculations are summarized in Table A.1.5.1.4.

San Francisco uses 15 Tymco recirculating air street sweepers. The operation performance standard is 25 production miles per eight-hour shift, and this standard is reportedly very close to actual production mileage. The hourly production rate, adjusted for one hour per shift for radiation control, is:

TABLE A.1.5.1.3. Street Sweeping Costs by Input for San Francisco, California

Input	Cost (1982 $/Lane mi)	Percent of Total
Fuel	1.28	9.3
Maintenance and Repair	2.88	21.0
Capital	1.78	13.0
Labor	7.76[(a)]	56.6
Total	13.70	100.0[(b)]

(a) Labor cost at $7.56 per mile plus $5.00 pers shift. Shift differential converted to cost per mile based on 25 miles per shift.

(b) Parts do not add to 100 due to rounding.

TABLE A.1.5.1.4. Adjusted Street Sweeping Costs by Input for San Francisco, California

Input	Cost (1982 $)		Percent of Total
	$/Lane mi	$/m^2	
Fuel	1.28	0.0003	8.5
Maintenance and Repair	2.88	0.0007	19.1
Capital	2.03	0.0005	13.5
Labor	8.87	0.0023	58.9
Total	15.06	0.0038	100.0

$$25 \text{ mi/shift} \div 8 \text{ hr/shift} \times 5280 \text{ ft/mi} \times 8 \text{ ft width} \times 0.093 \text{ m}^2/\text{ft}^2$$

$$\times\ 7/8 \text{ hr/shift} = 10{,}742 \text{ m}^2/\text{hr}$$

The Maintenance and Operations division of the Washington State Department of Transportation reports its street sweeping costs as shown in Table A.1.5.1.5.

Washington uses mechanical rotary broom type sweepers. Nonetheless, their cost and productivity information is reported here since it seems to be not greatly different from other road sweeping information.

TABLE A.1.5.1.5. Street Sweeping Costs by Input for Washington State Department of Transportation

Input	Cost (1982 $/Lane mi)
Labor	9.55
Equipment	11.82
Materials	0.15
Total	21.52

As with the San Francisco data, the labor figure must be adjusted for one hour per shift for decontamination by multiplying by 8/7. This gives the adjusted costs shown in Table A.1.5.1.6.

TABLE A.1.5.1.6. Adjusted Street Sweeping Costs by Input for Washington State Department of Transportation

Input	Cost (1982 $)		Percent of Total
	$/Lane mi	$/m^2	
Labor	10.91	0.0019	47.7
Equipment	11.82	0.0020	51.7
Materials	0.15	0.0000	0.7
Total	22.88	0.0039	100.0[(a)]

(a) Parts do not add to 100 due to rounding.

The Washington Department of Transportation defines a lane mile as having a width of 12 feet. This gives an area of 5892.48 sq meters per lane mile. Dividing this figure into the cost per lane mile gives a cost of $0.0039 per sq meter. Sweepers, however, have an effective sweeping width of 8 feet. It would therefore seem necessary to adjust the cost upward to reflect using an 8-foot sweeper on a 12-foot wide lane. The adjusted area of a lane mile is computed as follows:

$$8 \text{ ft wide} \times 5280 \text{ ft/mi long} \times 0.093 \text{ m}^2/\text{ft}^2 = 3928.32 \text{ m}^2/\text{lane mi.}$$

Recalculating the cost per sq meter yields $0.0058.

The average production is 1.43 lane miles per hour. After allowing for one hour per shift for radiation control, we obtain an average hourly rate of production of:

$$1.43 \text{ mi/hr} \times 5280 \text{ ft/mi} \times 12 \text{ ft wide} \times 0.093 \text{ m}^2/\text{ft}^2$$
$$\times 7/8 \text{ production-hr/shift hr}$$
$$= 7373 \text{ m}^2/\text{hr}$$

The Maintenance Section of Cal-Trans, State of California, operates a mixed vacuum and mechanical sweeper fleet. The model of vacuum sweeper used is an FMC Model 12 Sanavac. For the 1981-82 fiscal year they recorded a total of 114,432 "broom-down" (production) miles and a total cost of $4,638,773. The cost breakdown is shown in Table A.1.5.1.7.

TABLE A.1.5.1.7. Street Sweeping Cost Breakdown from Cal-Trans, State of California

Input	Percent
Salaries	43
Equipment	55
Material	1
Other	1
Total	100

These figures are considerably different from those reported by other sources. A simple gross calculation of the cost per sq meter based on total production miles and total cost yields a cost per sq meter of $0.0103. This figure is much higher than those calculated from data supplied by other sources. Further inquiry revealed that about half of the Cal-Trans sweeping miles require an escort truck as a safety feature to warn passing traffic. Also, the Cal-Trans operation must be different in other respects, as evidenced by the existence of five-person sweeping crews. Their standard crew consists of one supervisor, one lead worker, and three workers. Salaries are in the range of $10 to $12 per hour.

Apparently, the Cal-Trans sweeping operation entails considerably more than just mobile street sweeping. Cleanup of litter on shoulders, medians, and culverts, as well as minor road maintenance, may be involved. The problem is to adjust the Cal-Trans figures to reflect the cost of sweeping alone. A few simple, crude steps were taken to get a rough estimate for sweeping costs. The first is to divide the labor costs by five, since we are interested in a one-man, one-sweeper operation. The second step is to reduce the equipment cost to account for the unneeded escort vehicle. If the cost of an escort truck is half the cost of the sweeper, and the escort truck is used on half the sweeper miles, then the escort truck generates roughly 25 percent of the total equipment costs. Multiplying equipment costs by 0.75 yields the adjusted figure. The adjusted figures are shown in Table A.1.5.1.8.