Solid Waste: Transportation and Other Costs

The University of Tennessee County Technical Assistance Service
Solid Waste: Transportation and Other Costs

Prepared by:

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The University of Tennessee County Technical Assistance Service
Introduction

Siting of a landfill, compliance with subtitle D, and possible reduction of collection expenses are some of the reasons to study transportation procedures and cost.

The Environmental Protection Agency’s Resource Conservation and Recovery Act Subtitle D and the rules promulgated by the Tennessee Department of Environment and Conservation for the disposal of municipal solid waste in landfills require additional manpower, technical skills, equipment, operational practices, and cost. Because of the large amount of fixed cost associated with a Subtitle D landfill, the theory of economy-of-scale is a major factor in landfill cost, especially for landfills disposing of less than 200 tons per day.

This publication will provide information on truck transportation. It is intended to give general information which should be used for cursory evaluation only. Cost figures are based on a composite of the different public and private facilities which provided statistical information and are not intended to be substituted for or take precedence over detailed cost estimates or more in-depth, situation-specific evaluations.

There are numerous factors affecting truck costs, such as population densities, bridges, road systems, distance to travel, type of truck, net weight of the load, personnel cost, routing, scheduling, cost of capital, and daily operational procedures (maintenance, repair, insurance, administration, etc.). The types of trucks, operational procedures, cost, and general observations are a collection of information from counties, cities, equipment dealers, and private waste companies along with four years of experience of not only managing a transfer station and a collection system, but also operating and driving the different trucks. The data collected was arrayed to determine the number of best fit of the field data collected. If the mean or mode of the field data was in conflict with weight laws, the legal weight limit was used.
Acknowledgments

The assistance provided while developing this publication was most helpful and is appreciated. Thanks to Virgil Beller, Dickson County Solid Waste Management; Anthony Bolton, Chester County Executive; Ronald Brady, Hamblen/Morristown Solid Waste System; Robert Chaney, BFI; Jim Coe, Wilson County Solid Waste Management; Larry Hanson, Maury County; Don Hayes, P.E., EMPE; Brent Lewis, Jackson/Madison County Health Department; James Mantlow, Robertson County; Richard Martin, P.E., EMPE; Dan Myers, Hamblen County Highway Superintendent; Robert Owen, BFI; Mark Payne, Marion County; Don Potts, Jefferson County Sanitation Department; Roy Powell, Lawrence County Solid Waste Management; Pete Reed, Bi-County Solid Waste Management; Richard Riggins, P.E., Neel Schffer; Glenn Swinehart, P.E., Draper Aden Associates; Pat Wallace, P.E., Rutherford County; Diane Wiles, P.E., Metro Nashville/Davidson; Glen Youngblood, BFI for sharing ideas, data, advice, document review, and/or their experiences.

Additional thanks to Eddie Anderson, Stringfellow, Inc.; Ben Bailey, CMI Equipment; Sandy Edwards, Young Equipment; John Fox, Fox Equipment Company; John Jaker, Harris Group; Richard Nash, Holt Equipment; Bill Ponder, Neely Coble/Sunbelt Truck for providing pictures, specifications, and other assistance.

Also thanks to Trooper Burton Lawson, Tennessee Department of Safety, for his assistance and copies of both Tennessee Laws and the Federal Bridge Law on truck weights.
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The following suggestions may aid in cost reductions and may assist in compliance with parts of the Solid Waste Management Act of 1991 pertaining to the 25 percent reduction goal and the minimum level for collection services.

1. To reduce the cost of municipal solid waste (MSW) transportation, one should consider a source reduction program for the waste stream.

2. Commercial and industrial waste may contribute more than half the waste disposed of in the sanitary landfill. The University of Tennessee Institute for Public Service has an industrial service, the Center for Industrial Services (CIS), which provides free on-site consultation service. CIS will assist with “how-to’s” of reduction, recycling, and reuse of the waste stream.

3. A Class IV landfill for the disposal of demolition/construction wastes and/or certain special wastes having similar characteristics as inert waste will save transportation and disposal cost.

4. Some counties even divert clean wood waste from Class IV landfills to a chipper or to a controlled burn area. A tub grinder may reduce the air volume 40-70 percent of its original area. The wood chips may be used for mulch after processing or may be acceptable for a compost program. Incineration methods used to reduce the area volume by 95-99 percent include pit burners, wood furnaces, air curtain destructors, and a controlled burn area.

5. Divert yard waste to a compost process. A compost facility may be a large turn row system or a small static pile for a small generator.

6. Recycling programs may range from source separation or co-mingled to a drop-off center at a manned convenience station or transfer station.
The four types of trucks found most often in the transporting and collection of MSW are rear loaders, tandem front loaders, roll-offs, and tractor/trailers. Descriptions of each truck type, along with some general observations and application of the equipment, are listed with each type of truck. Also there is an example using one of the cost charts for the truck described to compute the cost of the truck. There are three different types of cost charts for each type of truck. Each chart has some assumptions listed. These assumptions are also reflected in the chart’s respective graph. Since labor costs are a large part of trucking expense, the charts and graphs have several different hourly pay rates on the horizontal axis. The charts and graphs allow time for servicing, washing, and employee breaks (lunch time is on the employee’s time). The cost figures in the charts consider the truck to be loaded to the proper capacity. The truck cost program will accept any combination of cost figures, hourly pay rates, and number of crew members on a case-by-case basis.

The first type of chart and graph presented after each truck section is based on the number of hours the truck is actually operating or the hours that would register on an engine hour meter. The charts and graphs that are based on the hour are entitled:

- Rear Loader Truck Cost per Hour of Actual Truck Run Time
- Front Loader Truck Cost per Hour of Actual Truck Run Time
- Roll-Off Truck Cost per Hour of Actual Truck Run Time
- Tractor Trailer Truck Cost per Hour of Actual Run Time

The second type of charts and graphs is based on the cost per route mile. Route mile is the mileage of the collection route. These charts pertain to commercial or roadside routes in which there are single boxes at the locations. This chart is not accurate for convenience center routes. These charts and graphs are entitled:

- Rear Loader Truck Cost per Mile on Collection Route
- Front Loader Truck Cost per Mile on Collection Route
- Roll-Off Truck Cost per Mile on Collection Route

The third type of charts and graphs is based on the cost per ton of a one-way mile of road. They are for transporting cost only. The charts consider the truck to be loaded to proper capacity. These charts and graphs are entitled:

- Rear Loader Truck Transportation Costs per Ton per One-Way Mile
- Front Loader Truck Transportation Cost per Ton per One-Way Mile
- Roll-Off Truck Transportation Cost per Ton per One-Way Mile
- Tractor Trailer Truck Transportation per Ton per One-Way Mile

All costs were compiled as accurately as possible. Private cost accounting methods were employed rather than governmental methods, which costs equipment when purchased rather than using
depreciation. Several of the governmental systems had solid waste costs blended into different accounts throughout the county general fund. This occurred most in fringe benefits and liability insurance. The private systems concurred or suggested figures that best represented their cost. Listed below are the costs considered and the area of the charts in which they are depicted.

“Labor Costs” includes annual leave, holidays, sick leave, insurance, retirement, and some administration costs. The only exception is the rear loader’s charts and graphs. It has two helpers, who are entered in the charts and graphs at a pay rate of $4.50 per hour. The truck cost program will accept any combination of hourly rates for the driver or the helpers on a case-by-case basis.

The “Contracted Services” line of the cost charts for each type of truck represents contracted services, such as advertising, telephone, contracts with government agencies, contracted repair and maintenance services, postage, printing, and others as charted by the State of Tennessee, Comptroller of the Treasury, Division of County Audit. These costs are also based on actual run time.

“Supplies and Materials” is a line item in each chart that includes such cost items as custodial supplies, diesel fuel, electricity, truck and equipment parts, garage supplies, gasoline, lubricants, natural gas, office supplies, tools, tires, tubes, water, sewer, other supplies and materials.

The line “Other Costs” consists of surety bonds, trustee’s commission, and insurance. The insurance types are:

- Building and Contents
- Liability
- Vehicle and Equipment

“Capital Cost” assumptions are printed below each chart, generally 5 percent over a five-year period. New equipment is programmed in the charts and graphs at government prices. The program has an amortization table built in, allowing any principal amount, number of years, and/or interest rate to be entered.

The charts and graphs for transportation cost per ton of MSW are figured on legal gross weights or industry gross weights, whichever is lower. With better packer equipment, densities of 800 to 1,000 pounds per cubic yard are being achieved. A lot of these better equipped trucks can be loaded over their legal gross vehicle weight (Tennessee’s and Federal Interstate Highway Weight Laws) and over their legal axle weight (Federal Interstate Highway Laws). Some of the trucks crossing the scale would be in compliance except for their short axle spacing (the spacing or distance between the axle centers per Federal Interstate Highway Laws).

Under Tennessee’s weight laws, a truck must be within the gross vehicle weight limit on state highways and roads. Under federal interstate laws, axle weights must comply with the gross vehicle weight formula, which includes axle weights, number of axles, and the spacing of the axles. If either the gross vehicle weight (formula method) or any axle weight is exceeded, the truck is in violation. Included on the following pages are examples of different trucks available to transport solid waste.
To determine the axle number of the trucks in the following illustrations, the axle nearest the front of the truck is the number one. The second nearest to the front is number two; the third is number three, and so forth.

Section 127 of the United States Code, Title 23, the bridge gross weight formula referred to as the Federal Interstate Law in this publication can be found in Appendix A.

Tennessee’s motor and other vehicles gross weight law, along with exceptions relating to counties trucking MSW, are in Appendix B. State law as it applies to counties that own and operate their own refuse trucks may be generalized as:

(A) Two-axle truck maximum gross weight is 40,000 pounds, TCA 55-7-203.

(B) A straight frame truck (single unit motor vehicle) hauling refuse designed to unload itself with three axles may load to a gross weight of 66,000 pounds (TCA 55-4-124 (2)).

(C) A straight frame truck (single unit motor vehicle) hauling refuse designed to unload itself with four axles may load to a gross weight of 73,280 pounds (TCA 55-4-124 (1)).
Truck Gross Weight Charts

(A) Rear Loader

State of Tennessee Highway Laws
Gross Vehicle Weight

40,000 pounds
TCA 55-7-203

Federal Interstate
Axle 1: Maximum 20,000 pounds
Axle 2: Maximum 20,000 pounds
Greater than 10-feet axle span, the Gross Vehicle Weight is 40,000 pounds
(B) Front Loader (Tandem)

<table>
<thead>
<tr>
<th>State of Tennessee Highway Laws</th>
<th>Federal Interstate</th>
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<td><strong>Gross Vehicle Weight</strong></td>
<td><strong>Axle 1:</strong> Maximum 20,000 pounds</td>
</tr>
<tr>
<td></td>
<td><strong>Axles 2 and 3:</strong> Maximum 34,000 pounds</td>
</tr>
<tr>
<td>66,000 pounds</td>
<td>An axle span of 17 feet,</td>
</tr>
<tr>
<td>TCA 55-4-124 (2)</td>
<td>the Gross Vehicle Weight is 48,500 pounds</td>
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<td>(See Table B)</td>
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</tbody>
</table>
(C) Front Loader (Triaxle)

State of Tennessee Highway Laws

Gross Vehicle Weight

73,280 pounds
TCA 55-4-124 (1)

Federal Interstate

Axle 1: Maximum 20,000 pounds
Axle 2: Maximum 20,000 pounds
Axles 3 and 4: Maximum 34,000 pounds

An axle span of 17 feet, the Gross Vehicle Weight is 53,500 pounds
(See Table B)
(D) Roll-Off (Tandem)

![Roll-Off Truck Diagram]

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<th>Federal Interstate</th>
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<td><strong>Gross Vehicle Weight</strong></td>
<td><strong>Axle 1:</strong> Maximum 20,000 pounds</td>
</tr>
<tr>
<td>66,000 pounds</td>
<td><strong>Axles 2 and 3:</strong> Maximum 34,000 pounds</td>
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<tr>
<td>TCA 55-4-124 (2)</td>
<td>An axle span of 21 feet, the Gross Vehicle Weight is 51,500 pounds (See Table B)</td>
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(E) Roll-Off (Triaxle)

State of Tennessee Highway Laws

<table>
<thead>
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<th>Gross Vehicle Weight</th>
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<tr>
<td>73,280 pounds</td>
<td>Axle 1: Maximum 20,000 pounds</td>
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<tr>
<td>TCA 55-4-124 (1)</td>
<td>Axle 2: Maximum 20,000 pounds</td>
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<tr>
<td></td>
<td>Axles 3 and 4: Maximum 34,000 pounds</td>
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<tr>
<td></td>
<td>An axle span of 21 feet,</td>
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<tr>
<td></td>
<td>the Gross Vehicle Weight is 56,000 pounds</td>
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<tr>
<td></td>
<td>(See Table B)</td>
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</tbody>
</table>
(F) Tractor Trailer

State of Tennessee Highway Laws

Gross Vehicle Weight

80,000 pounds
TCA 55-4-124 (2)

Federal Interstate

Axle 1: Maximum 20,000 pounds

Axles 2 and 3: Maximum 34,000 pounds

Axles 4 and 5: Maximum 34,000 pounds

Greater than 51-feet axle span,
the Gross Vehicle Weight
is 80,000 pounds
The rear loader’s tare weight for a 20- to 25-cubic yard refuse box mounted on a class 6-7 chassis ranges from 30,000 to 31,000 pounds. The cost charts for this truck use a three-person crew, with route density of 1,000 persons per square mile, a capital outlay cost of $60,000, and unloading close to the service area. The type of rear loader pictured is a good collection truck for a high population area to handle curbside or door-to-door collection. For transporting MSW, it has high labor costs and low payloads; the greater the distance between collection and disposal, the more the need to consider some type of transfer system.

One pitfall to avoid is purchasing a gross weight vehicle that is too light duty. Local governments do not pay the federal excise tax on a higher gross weight vehicle as does the private sector. When the gross vehicle weight capacity of a truck is sized by its actual tare weight plus its realistic payload, the truck gives better service and has less down time.

Another type of truck being used more frequently is the automated side loader with an easy entry cab; some offer dual side driving controls. This system reduces the helper needs of the service truck and may have a large body capacity. Sundries and capital outlay costs are more than the rear loader’s expense, but the labor and related expenses are less than most rear loader systems.

The number of homes collected each day varies with density of persons per square mile, routing, and travel time to transport to the landfill. The number of persons per square mile varied from 200 to 1,400 in the different communities observed. The truck cost for the lowest population was one-third more than the highest population density.

One rear loader service that collects 40 tons MSW per working day has a 10-mile, one-way trip to transport the refuse from its route to the landfill. Trip time from leaving the route, to the landfill, then back to the route usually is no less than an hour and no more than an hour and a half. The service has built a transfer station for its own use. The transfer truck operates 20-25 percent cheaper per hour and at less than half the cost per mile of the rear loaders, while transporting three times the weight per trip to the landfill.

In this example, one of the services provided by the Public Works Department is refuse collection. The department is planning its solid waste program. The department needs the cost of their refuse service. The department collects an average of 15 tons each of 260 working days it operates its rear loader trucks. The pay rate for the driver is $6 per hour. The two
helpers are paid $4.50 per hour and meet the basic assumptions stated on the charts. The landfill is 15 miles one-way from the service area.

Estimating cost for the service area:

(a) The crew's collection time is 2.5 hours to load the rear loader.

(b) In the chart titled “REAR LOADER TRUCK COSTS PER HOUR OF ACTUAL TRUCK RUN TIME,” the total cost under the column with the $6 pay rate is $42.49 per operating hour.

(c) The trucks collect a payload of 12,000 pounds or 6 tons.

(d) Multiply 2.5 hours (line a) by $42.49 cost per hour (line c) = $106.23 per load of 6 tons.

(e) Divide $106.23 (line e) by 6 tons equals $17.71.

(f) Collection cost of $17.71 per ton.

(g) The chart titled “REAR LOADER TRUCK TRANSPORTATION COSTS PER TON PER ONE-WAY MILE” in the $6.00 pay/hour column at the intersect of the 15 mile row is $0.52 per one-way mile per ton. Multiply $0.52 by 15 miles = $7.80 transportation cost per ton.

(h) $7.80 (line g) multiplied by 6 tons per load = $46.80 transportation cost per load.

(i) (Collection cost) $106.23 + (transportation cost) $46.80 = a load cost of $153.03.

(j) Multiply 15 tons by 260 days per year divided by 6 tons per load = 650 loads a year.

(k) Multiply 650 loads by a collection cost per load $106.23 = $69,049.50 annual collection cost per year.

(l) Multiply 650 loads by transportation cost per load $46.80 = $30,420.00 annual transportation cost.

(m) Add $69,049.50 collection and $30,420.00 transportation = $99,469.50 from house to disposal.
<table>
<thead>
<tr>
<th></th>
<th>$5.00</th>
<th>$6.00</th>
<th>$7.00</th>
<th>$8.00</th>
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<th>$10.00</th>
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<td>Fringe Benefits</td>
<td>3.51</td>
<td>3.76</td>
<td>22.04</td>
<td>23.42</td>
<td>24.79</td>
<td>26.17</td>
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<td>Contract Services</td>
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<td>3.06</td>
<td>3.06</td>
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<td>8.31</td>
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<td>8.31</td>
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<td><strong>Total</strong></td>
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<td><strong>$42.49</strong></td>
<td><strong>$44.12</strong></td>
<td><strong>$45.74</strong></td>
<td><strong>$47.37</strong></td>
<td><strong>$49.00</strong></td>
<td><strong>$50.62</strong></td>
<td><strong>$52.25</strong></td>
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</table>

Assumptions for this example are:

1. Trucks are scheduled a five-day work week:
   a. 52.14 weeks per year.
   b. The allowance for employee breaks, start-up, shut-down time is one hour.
   c. Truck service time scheduled once a week (no time was allotted for breakdowns).
2. The employee receives a two-week vacation, 11 holidays, and uses four days of sick leave per year.
3. Fringe benefits include partial individual health insurance and retirement benefits.
4. Capital outlay cost considers purchase price of $60,000 for the truck at 5 percent interest for five years.
5. Costs include loading the truck.
Rear Loader Truck
Costs per Hour of Actual Truck Run Time

DOLLARS PER HOUR
<table>
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<tr>
<th>Pay Rate</th>
<th>$5.00</th>
<th>$6.00</th>
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<td>Labor Cost</td>
<td>0.90</td>
<td>0.96</td>
<td>1.01</td>
<td>1.07</td>
<td>1.12</td>
<td>1.18</td>
<td>1.23</td>
<td>1.29</td>
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<tr>
<td>Fringe Benefits</td>
<td>0.27</td>
<td>0.28</td>
<td>0.29</td>
<td>0.30</td>
<td>0.31</td>
<td>0.32</td>
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<tr>
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<tr>
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<td>Capital Outlay</td>
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<td><strong>Total</strong></td>
<td><strong>$2.06</strong></td>
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<td><strong>$2.19</strong></td>
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Assumptions for this example are:

1. Trucks are scheduled a five-day work week:
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   b. The allowance for employee breaks, start-up, shut-down time is one hour.
   c. Truck service time scheduled once a week (no time was allotted for breakdowns).

2. The employee receives a two-week vacation, 11 holidays, and uses four days of sick leave per year.

3. Fringe benefits include partial individual health insurance and retirement benefits.

4. Capital outlay cost considers purchase price of $60,000 for the truck at 5 percent interest for five years.

5. Costs include loading the truck.
COSTS PER COLLECTION MILE

- Salary
- Fringe Benefits
- Contract Services
- Capital Outlay

PAY RATE FOR DRIVER:
- $5.00
- $6.00
- $7.00
- $8.00
- $9.00
- $10.00
- $11.00
- $12.00

Costs per Mile on Collection Route
Rear Loader Truck
### Pay Rate

<table>
<thead>
<tr>
<th></th>
<th>$5.00</th>
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<th>$7.00</th>
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<td>15 Miles</td>
<td>0.49941</td>
<td>0.51930</td>
<td>0.53918</td>
<td>0.55907</td>
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<td>0.59884</td>
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<td>25 Miles</td>
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<td>0.454209</td>
<td>0.470960</td>
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<td>0.504464</td>
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<td>40 Miles</td>
<td>0.374559</td>
<td>0.389474</td>
<td>0.404388</td>
<td>0.419302</td>
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<td>50 Miles</td>
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<td>0.376090</td>
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<td>0.404893</td>
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<td>0.424767</td>
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</tbody>
</table>

Assumptions for this example are:

1. Trucks are scheduled a five-day work week:
   a. 52.14 weeks per year.
   b. The allowance for employee breaks, start-up, shut-down time is one hour.
   c. Truck service time scheduled once a week (no time was allotted for breakdowns).
2. The employee receives a two-week vacation, 11 holidays, and uses four days of sick leave per year.
3. Fringe benefits include partial individual health insurance and retirement benefits.
4. Capital outlay cost considers purchase price of $60,000 for the truck at 5 percent interest for five years.
5. Trucks are hauling a payload of 6.0 tons.
6. Costs are for transporting refuse to the landfill from the last pick-up on the route (the cost per mile is a one-way mile).
CENTS PER MILE PER TON TO TRANSPORT

PAY RATE FOR DRIVER

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Transportation Costs per Ton per One-Way Mile

Rear Loader Truck
The front loader is a tandem axle truck with a rear axle rating between 36,000 to 44,000 pounds and a refuse box with front loading forks, a packing throat, a 20- to 28-cubic-yard body, and a tare weight range of 35,000 to 38,000 pounds. These trucks are used mostly for commercial or roadside green boxes. They are also used at convenience centers by some counties.

The purchase price for this type of truck may reach $110,000 for a basic model with 44,000-pound dual reduction tandem rear axle, 20,000 front axle, 300 horse power engine, 14/80r20-18 ply front tires, 11r22.5-14 ply rear tires, 8,000-pound rated fork, arm cycle time of 20 seconds, and maximum operating hydraulics of 2,500 psi.

The front loader is the most expensive to operate, to purchase, and has a very specialized use. These trucks are cabovers, and the axle span is generally shorter than a conventional cab. A cabover and conventional truck with the same cab to axle length will not have the same axle span. The cabover will generally have a 4- to 4.5-foot shorter axle span. The short span allows a shorter turning radius for better maneuverability, but this type of truck is very often tail heavy, causing higher axle weights the likelihood of crushing roads, culverts, or bridges. Tail heaviness also can pose safety problems in steering and braking of the truck. Federal interstate law, as it applies to the front loader, allows for a payload range of 11,000 to 13,500 pounds or 5.5 to 6.75 tons. Tennessee’s gross weight law for this same truck would be 66,000 pounds, which allows for a payload range of 28,500 to 31,000 pounds or 14.25 to 15.5 tons.

The short axle span causes the refuse box design to make the tail heaviness worse. The front loader refuse box has two sections. The section near the cab is the throat where the refuse is dumped into the top then pushed and packed to the rear of the body. Most throats are from 10 to 12 cubic yards. The body ranges from 20 to 28 cubic yards. The short span truck has over 60 percent of its containment body behind the center of the front tandem axle. One of the trucks had a throat density of 330 pounds and a body density of 800 pounds. The short span truck’s tare weight was 36,000 pounds. A loaded 36 cubic yard short span truck would have 21 cubic yards at 800-pound density on the back half of the box, or 16,800 pounds. The front half of the box would have 10 cubic yards at 330 pounds and 5 cubic yards at 800 pounds, or a front half weight of 7,960 pounds, a total net weight of 27,760 pounds with 68 percent of payload behind the center of the front tandem axle. This principle is the same as placing 1,000 pounds on the tailgate of a half-ton pickup instead of next to the cab.

Operational expense is high for this type of truck because of all the moving parts. It requires three to five times as long to load in a convenience center.
(road side dumpsters are not an accepted collection system after January 1, 1996), the heavy tare weight needs more fuel, and the body requires special parts that cannot be bought off the shelf of a standard truck parts store.

Some pitfalls are:

(1) Thin gauge refuse boxes. Rural routes have the roughest refuse timbers, steel, motor blocks, etc., and a thin gauged box will become sprung, have holes punched in the box, and will require extra repairs to rails, doors, and lift arms.

(2) Ughtweight rearends. Since tandem axles weight by law shouldn’t exceed 34,000 pounds, some purchase 36,000-pound suspension with rubber bushed components. These trucks constantly exceed 40,000-pounds plus for rear axle weights; 44,000 pound suspension with brass bushings should be used for the larger front loaders.

(3) Short cab to axle length can cause or make worse tail or rear axle heavy loads such as:
   (a) Safety in steering and braking can be a problem.
   (b) Heavy axle weights can damage roadways, especially during freezing and thawing weather.
   (c) Additional routing to avoid crossing non-posted gross vehicle weight bridges or culverts may have to back-track or assign longer ways around the route.

(4) Front loader trucks that off-load by ejection rather than by dumping are more stable unloading on an uneven landfill surface and are less likely to turn over.

There are systems or certain scenarios where the front loader is the most practical and economical of all types of refuse trucks. The charts have utilized some general assumptions, and graphs following each chart are based on the same assumptions. Figures used are a composite of statistical information in which the mean or the mode of the data was used to make the computations displayed in this publication. Given specific data, a more accurate chart can be developed along with the graph for an entity. In using the charts for the front loaders, please make note, the cost per mile is based on a route mile such as a commercial or a roadside system’s route; therefore, it would not be accurate for projecting cost to maintain a convenience system with a front loader. With no distance to travel between boxes, the hourly rate chart should be used to calculate collection cost for a convenience center system. To calculate the cost from the convenience center to the disposal site, one may use the chart for transportation, which uses one-way mileage.

An entity in the following example has just decided to set-up a convenience center system. They are considering using the refuse boxes from their closed out road-side-box system and replacing their worn out front loader collection truck to transport the refuse from the convenience center to the landfill. This example shows a roll-off truck’s load transport cost at 83 percent efficiency has a saving of $26,000 plus over a front loader system. See the Convenience Centers section of this publication for capital outlay and operational costs for the green box and the roll-off system.
Example: Compares a front loader to roll-off in a convenience center system which has three convenience centers, open five days a week, and a daily average attendance of 250. The county requires loads of Class IV demolition materials, and wood waste to be carried directly to their Class IV landfill. Large bulky items (stoves, couches, etc.) are also required to be taken directly to the landfill for recycling (scrap metal) or disposal.

(a) 250 visits times 3 centers equals 750 daily visits.

(b) 750 visits (line a) times 40 pounds per visit equals 30,000 pounds per day divided by 2,000 pounds per ton equals 15 tons per day.

(c) Assume the front loader goes to a center only when there are at least 22 full, six-yard, open top green boxes, so the truck can be fully loaded. The net weight of front loaders from convenience centers is 10 tons.

(d) Assume the roll-off is notified once the 80 percent full light comes on. The truck goes directly there and the 42-cubic-yard container is now 83 percent full. The net weight of a 42-cubic-yard container from a 4-cubic-yard compactor servicing a convenience center is 12 tons times 83 percent which equals a net weight of 10 tons.

(e) The front loader takes 1.5 hours to load 22 green boxes times $46.16 (chart titled “FRONT LOADER TRUCK COSTS PER HOUR OF ACTUAL RUN TIME”) the column for the driver pay rate of $8) equals $69.24 to load truck.

(g) The landfill is 15 miles one way (chart titled “FRONT LOADER TRUCK TRANSPORTATION COSTS PER TON PER ONE-WAY MILE”) the column for the driver pay rate of $8), gives a cost of 36 cents per mile per ton equals (0.36 x 10 tons x 15 miles) $54 transportation expense.

(h) The landfill is 15 miles one way (chart titled “ROLL-OFF TRUCK TRANSPORTATION COSTS PER TON PER ONE-WAY MILE”) the column for the driver pay rate of $8), gives a cost of 29 cents per mile per ton equals (0.29 x 10 tons x 15 miles) $43.50 transportation expense.

(i) Per load cost for the front loader $69.24 (line e) plus $54 (line g) equals $123.24.

(j) Per load cost for the roll-off $12.34 (line f) plus $43.50 (line h) equals $55.84.

(k) A year having 260 work days at 15 tons per day equals 3,900 tons from the convenience centers per year; a 10-ton net load for the front loader would equal 390 loads per year for the convenience center system.

(l) A year having 260 work days at 15 tons per day equals 3,900 tons from the convenience centers per year; a 10 ton net load for the compacted 42 cubic yard container at 83 percent capacity would equal 390 loads per year.

(m) Front loader cost per load of $123.24 times 390 loads per year equals $48,063.60 annual cost.
(n) Roll-off cost per load of $55.84 times 390 loads per year equals $21,777.60 annual cost (these figures will be used again in the section where transportation and transfer will be considered).

(o) With front loaders figured at 100 percent efficiency and roll-off at 83 percent efficiency the roll-off is $26,286.00 cheaper for operational cost per year.
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<tr>
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Assumptions for this example are:

1. Trucks are scheduled a five-day work week:
   a. 52.14 weeks per year.
   b. The allowance for employee breaks, start-up, shut-down time is one hour.
   c. Truck service time scheduled once a week (no time was allotted for breakdowns).
2. The employee receives a two-week vacation, 11 holidays, and uses four days of sick leave per year.
3. Fringe benefits include partial individual health insurance and retirement benefits.
4. Capital outlay cost considers purchase price of $110,000 for the truck at 5 percent interest for five years.
5. Costs include loading the truck.
Front Loader Truck Costs per Hour of Actual Truck Run Time

**Dollars per Hour**

**Pay Rate for Driver**

- Salary
- Fringe Benefits
- Contract Services
- Supplies/Materials
- Other Cost
- Capital Outlay

Costs per Hour of Actual Truck Run Time
### Pay Rate

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Assumptions for this example are:

1. Trucks are scheduled a five-day work week:
   a. 52.14 weeks per year.
   b. The allowance for employee breaks, start-up, shut-down time is one hour.
   c. Truck service time scheduled once a week (no time was allotted for breakdowns).
2. The employee receives a two-week vacation, 11 holidays, and uses four days of sick leave per year.
3. Fringe benefits include partial individual health insurance and retirement benefits.
4. Capital outlay cost considers purchase price of $110,000 for the truck at 5 percent interest for five years.
5. Costs include loading the truck.
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Assumptions for this example are:

1. Trucks are scheduled a five-day work week:
   a. 52.14 weeks per year.
   b. The allowance for employee breaks, start-up, shut-down time is one hour.
   c. Truck service time scheduled once a week (no time was allotted for breakdowns).

2. The employee receives a two-week vacation, 11 holidays, and uses four days of sick leave per year.

3. Fringe benefits include partial individual health insurance and retirement benefits.

4. Capital outlay cost considers purchase price of $110,000 for the truck at 5 percent interest for five years.

5. Trucks are hauling a payload of 9.5 tons.

6. Costs are for transporting refuse to the landfill from the last green box to the first box on the next load. The cost per mile is a one-way mile (miles from route to the landfill under the appropriate pay rate column).
Front Loader Truck Transportation Costs per Ton per One-Way Mile

Cent per Mile per Ton to Transport

<table>
<thead>
<tr>
<th>Pay Rate for Driver</th>
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</table>

Graph showing the relationship between pay rate for driver and transportation cost per mile for different mile ranges.
**Roll-Off Truck**

The roll-off trucks are available in several types, sizes, and styles. The most typical is the straight frame, conventional cab, and tandem axle. A tandem axle, straight-frame truck with 44,000 pounds rear suspension and a hoist rail may cost governmental agencies $72,000. This truck with a 12-cubic-yard container will have a tare weight around 32,000 pounds. With a 42-cubic-yard container the tare weight will be near 34,000 pounds.

Roll-off trucks are very versatile because there are so many different types of containers that may be used. Some of the types of containers used in MSW programs are:

A. The sectional recycling bin is an enclosed box with vertical sides from the container floor to waist height, sloping inward approximately with five small hinged doors mounted along its length. These bins have removable cross section panels which can be moved to allow recyclables to be placed in their assigned side access door and prevent commingling while in the same roll-off container.

B. The open top container is basically a container with a floor and four sides. Items are deposited over the sides. These containers are manufactured in a large range of sizes and cubic yardages and are generally used for bulky items which don’t work well in a compactor. On occasion, the boxes are used in a roadside program, but they have similar problems as green boxes (blowing litter, fires) plus densities less than a foot stomper load which causes the cost per ton to be very high.

C. Self-contained units have a compactor and an enclosed container built on a single frame. These units are generally used by medium to large commercial firms. The motors generally don’t require specialized electrical needs.

D. Enclosed containers are a complete box with a hinged back door the size of the height and width of the container. Most of these units have an opening to accommodate stationary compactors.

Stationary compactors vary in charge hopper size, horse power, and stroke. Some smaller compactors have a density of 400-600 pounds per cubic yard. The large units can achieve densities of 700-1,000 pounds per cubic yard. A 42-cubic-yard container packed by a large stationary compactor with MSW may cross the scales with net weights of 30,000 to 36,000 pounds.

During the time of the case studies, the densities for MSW were:

a. Roadside 30-cubic-yard open-top container had an average rate of 140 pounds per cubic yard.

b. A 42-cubic-yard enclosed container with small...
compactor had an average rate of 472 pounds per cubic yard.

c. Large compactor with a 42-cubic-yard enclosed container had an average rate of 786 pounds per cubic yard.

Roll-off rails are also mounted on trailers; some tandem axle trailers are mounted on a slide for bridge weight purposes. The roll-off trailer requires a tractor with a wet kit to hoist and cable the container.

Roll-offs have a variety of truck types for transporting containers, so there is usually a truck type available to meet various road and bridge weights. Points to consider:

(A) Equipment type and size. With the large variety of roll-off equipment style, size, type, gauge, throats, horse power, heights, lengths, and the different truck types adaptable to the roll-off system. Planning and knowing the MSW needs for a system allows the proper equipment to be selected which can be operated in a safe manner while minimizing cost per ton for the required service. If a self unloading truck unloads into a compactor:

(a) Throat size (at least 96 inches) becomes more important because of refuse bridging.

(b) More ram force (higher gpm pumps, larger horse power motors).

(c) A thicker or more reinforced box on the compactor and the receiver container become a must.

(B) (1) Truck chassis should have a gross vehicle weight to accommodate the actual loads placed on it. Light weight suspensions are one pitfall to watch for; since tandem axle weights by law shouldn’t exceed 34,000 pounds, some operators purchase 36,000-pound rear suspension vehicles. These trucks constantly exceed 40,000 pounds plus for rear axle weights; a 44,000-pound rear suspension with brass bushings is used most often for the roll-off truck chassis by the larger hauling companies.

(2) Generally when a choice is available the conventional cab chassis should be selected instead of a cabover chassis. Since the cabover’s axle span is 4 to 4.5 feet shorter, it can more easily become tail heavy and have a high rear axle weight. These higher axle weights may cause worse problems such as:

(a) safety problems in steering and braking

(b) damage to roadways

(c) may have to back track or assign more roundabout routes to avoid crossing non-posted gross vehicle weight bridges or culverts

(d) The cabover is more likely to rear-up when loading a heavy container.

(e) It is not as stable when unloading on an uneven landfill surface.

(C) Containers need to be sized to control weight, bulk, and the refuse’s physical properties. It can be a problem if a 40-cubic-yard open-top container is filled with roofing shingles at a house
repair site. Grossly overweight containers cause
damage to equipment, roads, and present safety
problems. Material density needs to be consid-
ered in container selection. Select containers
with rails that are compatible with the roll-off
hoist frame. Enclosed compactor receiver con-
tainers sizing needs to consider are:

(a) the packing density per cubic yard

(b) the truck’s gross vehicle weight

(c) the route to be traveled (request weight
limits for bridges and culverts)

Roll-offs can be used in a transfer station
setting. Since roll-offs can be effective transporters,
and rear-loaders aren’t very cost effective for transpor-
tation purposes, the following example shows how an
integrated collection program may be the most cost
effective.

In the example below, a roll-off is used in a
transfer station system for a rear loader company. The
company reduces its cost per ton to operate the system
by considering other transportation systems for its
program.

Example: Suppose a 42-cubic-yard container
with a large compactor is set up as a transfer station
using a roll-off truck for transportation:

(a) Utilizing a large compactor, compacting house-
hold refuse into a 42-cubic-yard container should
net 15 tons.

(b) Assume the landfill is 15 miles away and 15 tons
are collected each working day.

(c) Multiply 15 tons by $0.29 (chart titled “ROLL-
OFF TRUCK TRANSPORTATION COSTS PER
TON PER ONE-WAY MILE”) the column for the
driver pay rate of $8) by 15 miles = $65.25
transportation cost per load.

(d) The rear loader service mentioned in the rear
loader section which set up a roll-off transfer
system is transporting 40 tons 312 days of the
year or a total of 12,480 tons a year. The
additional equipment for the transfer station was
$7,000 for site work on their own lot, $30,000
for a compactor, $16,000 for four 42-cubic-yard
containers, and $25,000 for a used roll-off truck
to yard containers (spare for primary mover). These
capital costs were mostly offset by elimi-
nating one complete rear loader and crew.

(e) The service cost per load for transportation was
$41.30 (two person crew) per 6-ton load or a cost
of $6.88 per ton for transportation costs with a
rear loader.

(f) The roll-off transfer cost for transportation would
be $65.25 per load of 15 tons to equal $4.35 per
ton.

(g) If the transportation cost for the rear loader
verses the roll-off is $2.53 per ton ($6.88 -
$4.35), potential savings or cost avoidance
amounts to approximately $31,574.40 per year
($2.53 multiplied by 12,480 tons).
<table>
<thead>
<tr>
<th>Pay Rate</th>
<th>$5.00</th>
<th>$6.00</th>
<th>$7.00</th>
<th>$8.00</th>
<th>$9.00</th>
<th>$10.00</th>
<th>$11.00</th>
<th>$12.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor Cost</td>
<td>6.89</td>
<td>8.26</td>
<td>9.64</td>
<td>11.02</td>
<td>12.39</td>
<td>13.77</td>
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</tr>
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<td>Fringe Benefits</td>
<td>1.25</td>
<td>1.50</td>
<td>1.75</td>
<td>2.00</td>
<td>2.25</td>
<td>2.50</td>
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<td>3.00</td>
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<td>3.01</td>
<td>3.01</td>
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<td>3.01</td>
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<td>8.22</td>
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<td><strong>$40.64</strong></td>
<td><strong>$42.26</strong></td>
<td><strong>$43.89</strong></td>
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</tbody>
</table>

Assumptions for this example are:

1. Trucks are scheduled a five-day work week:
   a. 52.14 weeks per year.
   b. The allowance for employee breaks, start-up, shut-down time is one hour.
   c. Truck service time scheduled once a week (no time was allotted for breakdowns).
2. The employee receives a two-week vacation, 11 holidays, and uses four days of sick leave per year.
3. Fringe benefits include partial individual health insurance and retirement benefits.
4. Capital outlay cost considers purchase price of $72,000 for the truck at 5 percent interest for five years.
5. Costs include loading the truck.
DOLLARS PER HOUR

- Salary
- Fringe Benefits
- Supplies/Materials
- Contract Services
- Other Cost
- Capital Outlay

PAY RATE FOR DRIVER

$5.00  $7.00  $9.00  $11.00

$6.00  $8.00  $10.00

$12.00

Costs per Hour of Actual Truck Run Time

Roll-Off Truck
## Pay Rate

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<th></th>
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<th>$6.00</th>
<th>$7.00</th>
<th>$8.00</th>
<th>$9.00</th>
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<td>0.50</td>
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<td>0.09</td>
<td>0.10</td>
<td>0.11</td>
<td>0.12</td>
</tr>
<tr>
<td>Contract Services</td>
<td>0.15</td>
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<tr>
<td>Other Cost</td>
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<td><strong>$1.87</strong></td>
<td><strong>$1.93</strong></td>
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</table>

Assumptions for this example are:

1. Trucks are scheduled a five-day work week:
   a. 52.14 weeks per year.
   b. The allowance for employee breaks, start-up, shut-down time is one hour.
   c. Truck service time scheduled once a week (no time was allotted for breakdowns).
2. The employee receives a two-week vacation, 11 holidays, and uses four days of sick leave per year.
3. Fringe benefits include partial individual health insurance and retirement benefits.
4. Capital outlay cost considers purchase price of $72,000 for the truck at 5 percent interest for five years.
5. Costs include loading the truck.
Roll-Off Truck Transportation Costs per Ton per One-Way Mile

<table>
<thead>
<tr>
<th>Pay Rate</th>
<th>$5.00</th>
<th>$6.00</th>
<th>$7.00</th>
<th>$8.00</th>
<th>$9.00</th>
<th>$10.00</th>
<th>$11.00</th>
<th>$12.00</th>
</tr>
</thead>
<tbody>
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<td>0.27601</td>
<td>0.28857</td>
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<td>25 Miles</td>
<td>0.211353</td>
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<td>0.232513</td>
<td>0.243093</td>
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<td>0.264253</td>
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<td>0.285413</td>
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<td>40 Miles</td>
<td>0.188171</td>
<td>0.197590</td>
<td>0.207010</td>
<td>0.216429</td>
<td>0.225849</td>
<td>0.235268</td>
<td>0.244688</td>
<td>0.254107</td>
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<tr>
<td>50 Miles</td>
<td>0.181704</td>
<td>0.190800</td>
<td>0.199896</td>
<td>0.208992</td>
<td>0.218088</td>
<td>0.227184</td>
<td>0.236279</td>
<td>0.245375</td>
</tr>
<tr>
<td>75 Miles</td>
<td>0.171821</td>
<td>0.180423</td>
<td>0.189024</td>
<td>0.197625</td>
<td>0.206226</td>
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</tr>
<tr>
<td>100 Miles</td>
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<td>0.200295</td>
<td>0.208649</td>
<td>0.217002</td>
<td>0.225356</td>
</tr>
</tbody>
</table>

Assumptions for this example are:

1) Trucks are scheduled a five-day work week:
   (a) 52.14 weeks per year.
   (b) The allowance for employee breaks, start-up, shut-down time is one hour.
   (c) Truck service time scheduled once a week (no time was allotted for breakdowns).

2) The employee receives a two-week vacation, 11 holidays, and uses four days of sick leave per year.

3) Fringe benefits include partial individual health insurance and retirement benefits.

4) Capital outlay cost considers purchase price of $60,000 for the truck at 5 percent interest for five years.

5) Costs are for transporting refuse to the landfill from the last pick-up on the route (the cost per mile is a one-way mile).
Roll-Off Truck
Transportation Costs per Ton per One-Way Mile

Cent's per Mile per Ton to Transport

Pay rate for driver

$5.00 $6.00 $7.00 $8.00 $9.00 $10.00 $11.00 $12.00

Square 15 MILES  Plus 25 MILES  Diamond 40 MILES  Cross 50 MILES

Triangle 75 MILES
Transfer trailers used for MSW refuse are varied in type and style. The type of trailer being requested is the open-top walking floor. Open top walking floor trailers are most often used at transfer stations where MSW is pushed through a chute or an opening into the top of the trailer. These trailers have the cubic yard capacity to net loads at legal weights. This type of trailer has a lighter tare weight than the hydraulic cylinder eject trailer. This type of trailer also has the longest axle span; therefore, it is easier to comply with the bridge weight regulations. Utilizing this type of transfer station and trailers is very often the lower cost (capital and operational) and the least technical system to operate. Open top walking floor trailers are available in 125 cubic yards, but the 100-cubic-yard trailer is widely used.

Open-top walking floor are trailers which can be top loaded and have a hydraulic operated slated floor that will self unload. These trailers have a hydraulic top closer as an option. A wet kit is required on the tractor to operate the top and the walking floor. Walking floor trailers are easily used with compactors, bales, large dial-a-weight wireless bales, or the open-top loading system. Bales, large dial-a-weight wireless bale systems, or extrusion systems aren’t generally used in Tennessee because of the trailer/truck gross weight limit of 80,000 pounds. The design and construction of this type of trailers allows tare weights as low as 12,000 pounds for a trailer designed for use with a pre-load vault, to 18,000 pounds for top loading, and 20,000 pounds for a closed top compactor compatible trailers.

Hydraulic cylinder eject trailers have options. Some of these trailers load from the top while others attach to a large compactor. Some of the top-loaded hydraulic cylinder eject trailers are self-contained with their own motor and hydraulic systems built into the trailer. Most of the compactor loaded hydraulic cylinder eject trailers require tractors with wet kits. A very popular size trailer is 75 cubic yards. The tare weights of these trailers are higher than the walking floor trailer. The densities for these trailers per cubic yard are higher than the open top walking floor trailers.

Based on the State of Tennessee’s legal road weight, these trailers’ maximum weight of 80,000 pounds less their heavy tare weight with tractor of 48,000 pounds equals a legal net weight of 32,000 pounds, while a tandem axle roll-off truck can gross weight 66,000 pounds less a 34,000-pounds tare weight equaling a legal net weight of 32,000 pounds.

Roll-off trailers are available to transport roll-off containers. These trailers have advantages over the straight framed truck on bridge weights and legal road weights. Some of the large compactors can pack household MSW into a 42-cubic-yard container with a net weight of 36,000 pounds. If this container was
on a conventional tandem axle straight frame truck which has a tare weight of 34,000 pounds, the gross weight of the truck would be 70,000 pounds. This would be 4,000 pounds over weight under Tennessee’s weight law or 18,500 pounds over the Federal Bridge Law.

Baled waste may be transported on a flat bed trailer with good tarp procedures. The trailer is low cost but the baling equipment cost need to be considered. If the baled waste is going to a balefill, a baler can be effective in a transfer station. Baled waste can be transported in a conventional enclosed trailer.

Tractor trailer rigs require a more skilled driver to back the rig onto the working face of a landfill. Rear eject (walking floor or hydraulic cylinder ram) trailers are more stable unloading on an uneven landfill surface and are less likely to turn over than conventional tilt dumps. Tractor trailers do the best job of weight distribution for protection of bridges, culverts, and roads.
<table>
<thead>
<tr>
<th>Pay Rate</th>
<th>$5.00</th>
<th>$6.00</th>
<th>$7.00</th>
<th>$8.00</th>
<th>$9.00</th>
<th>$10.00</th>
<th>$11.00</th>
<th>$12.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor Cost</td>
<td>6.89</td>
<td>8.26</td>
<td>9.64</td>
<td>11.02</td>
<td>12.39</td>
<td>13.77</td>
<td>15.15</td>
<td>16.52</td>
</tr>
<tr>
<td>Fringe Benefits</td>
<td>1.25</td>
<td>1.50</td>
<td>1.75</td>
<td>2.00</td>
<td>2.25</td>
<td>2.50</td>
<td>2.75</td>
<td>3.00</td>
</tr>
<tr>
<td>Contract Services</td>
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<td>3.01</td>
<td>3.01</td>
<td>3.01</td>
<td>3.01</td>
<td>3.01</td>
<td>3.01</td>
<td>3.01</td>
</tr>
<tr>
<td>Capital Outlay</td>
<td>15.23</td>
<td>15.23</td>
<td>15.23</td>
<td>15.23</td>
<td>15.23</td>
<td>15.23</td>
<td>15.23</td>
<td>15.23</td>
</tr>
<tr>
<td>Total</td>
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<td>$40.92</td>
<td>$42.55</td>
<td>$44.17</td>
<td>$45.80</td>
<td>$47.43</td>
<td>$49.05</td>
<td>$50.68</td>
</tr>
</tbody>
</table>

Assumptions for this example are:

1. Trucks are scheduled a five-day work week:
   a. 52.14 weeks per year.
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<table>
<thead>
<tr>
<th>Pay Rate</th>
<th>$5.00</th>
<th>$6.00</th>
<th>$7.00</th>
<th>$8.00</th>
<th>$9.00</th>
<th>$10.00</th>
<th>$11.00</th>
<th>$12.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor Cost</td>
<td>0.28</td>
<td>0.34</td>
<td>0.39</td>
<td>0.45</td>
<td>0.50</td>
<td>0.56</td>
<td>0.61</td>
<td>0.67</td>
</tr>
<tr>
<td>Fringe Benefits</td>
<td>0.05</td>
<td>0.06</td>
<td>0.07</td>
<td>0.08</td>
<td>0.09</td>
<td>0.10</td>
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<td>0.12</td>
</tr>
<tr>
<td>Contract Services</td>
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<tr>
<td>Supplies/Materials</td>
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<tr>
<td>Other Cost</td>
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<td>0.13</td>
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<td>0.62</td>
<td>0.62</td>
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</tr>
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<td><strong>Total</strong></td>
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<td><strong>$1.95</strong></td>
<td><strong>$2.02</strong></td>
<td><strong>$2.08</strong></td>
<td><strong>$2.15</strong></td>
</tr>
</tbody>
</table>

Assumptions for this example are:

1. Trucks are scheduled a five-day work week:
   a. 52.14 weeks per year.
   b. The allowance for employee breaks, start-up, shut-down time is one hour.
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4. Capital outlay cost considers purchase price of $110,000 for the truck at 5 percent interest for five years.
COSTS PER COLLECTION MILE

Costs per Mile

PAY RATE FOR DRIVER

Salary
Fringe Benefits
Contract Services
Supplies/Materials
Other Costs
Capital Outlay

0.00 0.4 0.8 1.2 1.6 2.0 2.4

$5.00  $6.00  $7.00  $8.00  $9.00  $10.00  $11.00  $12.00
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<th>$9.00</th>
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<th>$11.00</th>
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</table>

Assumptions for this example are:

1. Trucks are scheduled a five-day work week:
   (a) 52.14 weeks per year.
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3. Fringe benefits include partial individual health insurance and retirement benefits.
4. Capital outlay cost considers purchase price of $110,000 for the truck at 5 percent interest for five years.
5. Costs are for transporting refuse to the landfill from the transfer point.
Transportation Costs per Ton per One-Way Mile

<table>
<thead>
<tr>
<th>Pay Rate for Driver</th>
<th>15 Miles</th>
<th>25 Miles</th>
<th>40 Miles</th>
<th>50 Miles</th>
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<td>$11.00</td>
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<td>0.38</td>
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</tr>
<tr>
<td>$12.00</td>
<td>0.36</td>
<td>0.40</td>
<td>0.46</td>
<td>0.52</td>
<td>0.54</td>
</tr>
</tbody>
</table>
Transfer station systems can be sized to fit any tonnage generated by the waste shed of the county. These systems can be as simple as a point where a small collector deposits a load into an open top trailer on a two-level lot to a system with major recycling on the front end, balers, conveyers, or has an integrated distribution system (rail, truck, barge). Some transfer stations aren’t under a shelter, while others have an opened-ended shelter over the dump pit or the open-top trailer, and others have a building with a tipping area and a recycling area. Building height is important. Some of the building designs not only require a 25-foot clearance for the tip area but also require the doors to the tipping area to be 25 feet. The tipping floor should be sized considering waste stream storage needs during breakdowns, routing, schedules, and the transportation system.

The two-level floor system is used with open-top trailers (walking floor or hydraulic cylinder eject) and dump pits (whether a walking floor pit or a hydraulic cylinder eject pit or a charge conveyer) for balers (recyclables or MSW) or compactors (roll-off or transfer trailers). A transfer station system being, built with increasing frequency in several areas of the United States, is a system containing a two-floor level building and using open-top walking floor trailers for transportation. This system has a tipping floor with an elevation higher than the open top trailer (13' 8"). With the tip floor level being slightly higher than the open top trailer, refuse is pushed into the trailer by a rubber tired wheel loader or a backhoe. The refuse is dumped and/or pushed into a hole in the floor with a trailer under it or into a chute over the trailer.
Two-Level Transfer Station

The two-floor level transfer station is gaining popularity because costs for the building, equipment, technology, and transportation are less expensive. The building costs are less because: (1) less tip floor area is needed (trailers can be yarded), (2) simple design and minimal utility (electric, water, sewer) requirements give a lower cost per square foot to construct, and (3) basic building has minimal operational cost (maintenance, insurance, etc.). Only one piece of equipment is required on the tipping floor. The wheel loader or backhoe are types of equipment that are in abundance (service, parts, selection, competitive pricing are available). Simple building, equipment, and material flow (standard operational procedures) require less labor and/or manpower cost per ton of MSW.

Open top walking floor trailers can easily be loaded to legal road weight limits and more easily comply with bridge weight standards. These trailers have the highest legal payload potential. They have the lowest cost per ton of MSW for capital outlay and day to day cost. This trailer, with a hydraulic closer for the top, costs approximately $35,000.

Several transfer stations use a compactor system, where the refuse is dumped into a pit. The pit will usually have a walking floor or hydraulic push cylinder to charge the compactor box. The MSW is then compacted into a heavy boxed trailer. One type of trailer used in this system is a 75-cubic-yard hydraulic cylinder eject. These trailers have a higher tare weight and a shorter axle span than the open top walking floor trailer. There are walking floor trailers available for use with a compactor. Small transfer stations may use a compactor with roll-off containers to transport the refuse.

MSW balers are also used in transfer stations. Baled waste can be transported in and on several different types of trailers or trucks. It can be hauled on a flat bed (trailer or truck), a standard box trailer, walking floor trailer, or in a train boxcar. These bales are wire tied and range from 3 to 4 feet in height and width and are 4 to 5 feet long.

One of the newest transfer systems on the market is the untied densified baler (dial-a-weight wireless baler). Refuse is directly dumped into the hopper, the operator inputs the weight desired, a single bale is then formed to meet desired weight while not exceeding a width of six feet or a height of seven feet. This system transfers the bale from the baler to a trailer in three minutes. Bales can be loaded in lighter weight trailers to maximize payload. This system can also load roll-off containers and requires less land area than most systems. The smallest such baler can bale up to 28 tons per hour. The larger baler production rate is 100 tons per hour.

When designing a transfer station system, consider front-end recycling. Some transfer stations have storage areas both inside and outside for recycled material. Recyclables are placed into a set-aside area or placed into a bulk storage bunker until a full load can be collected. Recycle drop-off centers are located at some transfer stations. Most vendors of transfer station equipment have different types of recycle equipment.
Convenience Centers

The cost may vary a great deal from center to center even within the same county. Is the site itself county-owned, rented, leased, or purchased? Lot excavation (cubic yardage, soil type) cost can vary from site to site. Culvert placement and depth of the rock base also vary. To cover an acre lot with compacted stone one inch thick requires 261.4 tons. A compacted rock base meets the paving definition in the 1200-1-7-.10(3)(b) Convenience Center Rules. Fence cost per linear foot should be fairly constant from site to site. Fence prices per linear foot were quoted $5.45 to $6.90 to a county and a quote of $395 to $600 for entrance gates. The communication equipment, the attendant’s shelter, and the out-house facilities (if the shelter does not have in-door plumbing) have varying price ranges. Operational basic costs include wages, fringe benefits, and insurance (liability, workers’ compensation). Other possible operational expenses could be utilities (electric, water, sewer), rent, and note payments.

Green box convenience center versus a roll-off convenience system

Twenty-eight 6-cubic-yard green boxes equals one compacted 42-cubic-yard container. Twenty-two 6-cubic-yard green boxes from a convenience center will load the largest front loader. The roll-off has a lower tare weight than the front loader and a higher legal gross bridge weight, giving a greater payload over the front loader. Operational costs are less for the roll-off because it doesn’t have the number of working parts, and the lighter truck and faster loading cycle gives better fuel mileage. To load a front loader as described above takes 90 minutes while in the convenience center, the roll-off takes 20 minutes to swap containers. While these trucks were hauling to a landfill less than 20 miles away, the front loader hauled three loads or the equivalent of 66 6-cubic-yard green boxes in a shift. On the same shift, the roll-off hauled five 42-cubic-yard containers or the equivalent of 140 6-cubic-yard green boxes.

In the front loader section of this publication, the operational cost for a convenience center was discussed. The front loader’s loading cost was $69.24 per load or $6.92 per ton. The roll-off loading cost was $12.34 per load or $1.23 per ton at 83 percent efficiency. The annual cost, assuming 15 one-way trips to the landfill with front loaders figures at 100 percent efficiency and roll-off at 83 percent efficiency; the roll-off is $26,286 cheaper for operational cost per year than the three convenience centers.
## Capital Outlay for the Two Systems
### Three Convenience Centers

<table>
<thead>
<tr>
<th>Item</th>
<th>Green Box</th>
<th>Roll-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clearing &amp; Excavating</td>
<td>$10,000 (3/4 acre)</td>
<td>$8,000 (1/2 acre)</td>
</tr>
<tr>
<td>Culvert</td>
<td>$3,000</td>
<td>$3,000</td>
</tr>
<tr>
<td>Rock $6/ton 10&quot; base</td>
<td>$11,763 (1,961 tons)</td>
<td>$7,842 (1,307 tons)</td>
</tr>
<tr>
<td>Fence $5.50/lin. foot</td>
<td>$6,061 (1,102 feet)</td>
<td>$4,246 (772 feet)</td>
</tr>
<tr>
<td>Entrance gate</td>
<td>$500</td>
<td>$500</td>
</tr>
<tr>
<td>Shelter &amp; sundries</td>
<td>$2,400</td>
<td>$2,400</td>
</tr>
<tr>
<td>Septic system</td>
<td>n/a</td>
<td>$800</td>
</tr>
<tr>
<td>Concrete pad</td>
<td>n/a</td>
<td>$4,000</td>
</tr>
<tr>
<td>Electrical set up</td>
<td>$500</td>
<td>$2,500</td>
</tr>
<tr>
<td>Signs</td>
<td>$500</td>
<td>$500</td>
</tr>
<tr>
<td>Communication (two-way radio)</td>
<td>$600</td>
<td>$600</td>
</tr>
<tr>
<td>Landscaping</td>
<td>$1,000</td>
<td>$1,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$36,324</strong></td>
<td><strong>$35,388</strong></td>
</tr>
<tr>
<td><strong>Equipment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green boxes (33)</td>
<td>$16,500</td>
<td>n/a</td>
</tr>
<tr>
<td>Compactors</td>
<td>n/a</td>
<td>$14,000</td>
</tr>
<tr>
<td>42 cubic containers (1.33)</td>
<td>n/a</td>
<td>$5,200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$16,500</strong></td>
<td><strong>$19,200</strong></td>
</tr>
<tr>
<td><strong>Total/Center</strong></td>
<td><strong>$52,824</strong></td>
<td><strong>$54,588</strong></td>
</tr>
<tr>
<td><strong>Three Centers for the System</strong></td>
<td><strong>$158,472</strong></td>
<td><strong>$163,764</strong></td>
</tr>
<tr>
<td><strong>Trucks</strong></td>
<td><strong>$110,000</strong></td>
<td><strong>$72,000</strong></td>
</tr>
<tr>
<td><strong>TOTAL CAPITAL OUTLAY</strong></td>
<td><strong>$268,472</strong></td>
<td><strong>$235,764</strong></td>
</tr>
</tbody>
</table>
## Operational Costs for the Two Systems

<table>
<thead>
<tr>
<th>Item</th>
<th>Green Box</th>
<th>Roll-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land (rent $1,200/year)</strong></td>
<td>$1.200</td>
<td>$1.200</td>
</tr>
<tr>
<td><strong>Construction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clearing &amp; Excavating</td>
<td>$10,000 (3/4 acre)</td>
<td>$8,000 (1/2 acre)</td>
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<tr>
<td>Culvert</td>
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<tr>
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<tr>
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</tr>
<tr>
<td>Septic system</td>
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</tr>
<tr>
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<td>$4,000</td>
</tr>
<tr>
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</tr>
<tr>
<td>Signs</td>
<td>$500</td>
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</tr>
<tr>
<td>Communication (two-way radio)</td>
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</tr>
<tr>
<td>Landscaping</td>
<td>$1,000</td>
<td>$1,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$36,324</strong></td>
<td><strong>$35,388</strong></td>
</tr>
<tr>
<td><strong>Construction cost @ 5% over 5 years</strong></td>
<td>$8,390</td>
<td>$8,174</td>
</tr>
<tr>
<td><strong>Equipment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green boxes (33)</td>
<td>$16,500</td>
<td>n/a</td>
</tr>
<tr>
<td>Compactors</td>
<td>n/a</td>
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<tr>
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<td>$5,200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$16,500</strong></td>
<td><strong>$19,200</strong></td>
</tr>
<tr>
<td><strong>Equipment cost @ 5% over 5 years</strong></td>
<td>$3,811</td>
<td>$4,435</td>
</tr>
<tr>
<td><strong>Operational (10 hours/day)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wages $5/hr (260 days/year)</td>
<td>$13,000</td>
<td>$13,000</td>
</tr>
<tr>
<td>Fringes</td>
<td>$1,603</td>
<td>$1,603</td>
</tr>
<tr>
<td>Contract Services</td>
<td>$1,069</td>
<td>$1,069</td>
</tr>
<tr>
<td>Supplies and Materials</td>
<td>$891</td>
<td>$891</td>
</tr>
<tr>
<td>Other Cost</td>
<td>$1,247</td>
<td>$1,247</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$17,810</strong></td>
<td><strong>$17,810</strong></td>
</tr>
<tr>
<td><strong>Total Yearly Cost/Center</strong></td>
<td><strong>$31,211</strong></td>
<td><strong>$31,619</strong></td>
</tr>
<tr>
<td><strong>CENTER SYSTEM COST</strong></td>
<td><strong>$93,633</strong></td>
<td><strong>$94,857</strong></td>
</tr>
<tr>
<td><strong>3,900 tons/year divided into convenience centers equal cost/ton:</strong></td>
<td><strong>$24.01</strong></td>
<td><strong>$24.32</strong></td>
</tr>
</tbody>
</table>

**Prices for 1992 are:**

- (1) **Front Loader Truck:** $110,000
- (2) **Roll-Off Truck:** $72,000
- (3) **Green Box 6-Cubic Yard:** $500
- (4) **42-Cubic Yard Enclosed Container:** $4,000
- (5) **4-Cubic Yard Compactor:** $14,000
When the green box roadside system was compared to a roll-off roadside system of non-compacted open top containers, the front loaders were more efficient. A case study where 30-cubic-yard open-top roll-off containers were used in a roadside program found a density of 140 pounds per cubic of the container. The average payload over a three-month period was 2.1 tons per container. The roll-off trucks were hauling from 10.5 to 12.6 tons or 150 to 180 cubic yards per day at a cost of $22.71 per ton (based on the chart titled “ROLL-OFF TRUCK COSTS PER HOUR OF ACTUAL TRUCK RUN TIME”). In a front loader roadside case study, the trucks were collecting 50-60 6-cubic-yard containers while hauling from 22.73 to 27.27 tons per day at a cost of $13.36 per ton (based on the chart titled “FRONT LOADER TRUCK COSTS PER HOUR OF ACTUAL TRUCK RUN TIME”). In this case the front loader truck saves $9.36 per ton over the roadside roll-off truck program.

Observance of one convenience center system for a three-month period revealed that the average user deposited 40.07 pounds of refuse per visit. The population density for this system service area is 56 persons per square mile (county population less city population with collection service divided by the county square miles less city square miles with collection services). In one year, 9.26 trips would be made to the convenience station per person. Fifty-six persons per square mile times 9.26 trips per person per year equals 518.56 visits per year per square mile. A convenience centers open five days a week equals 260.7 days per year. 518.56 visits per year per square mile divided by 260.7 equals 1.99 visits per square mile per day open. Rule 1200-1-7-.10(2) Convenience centers’ rule for minimum level service under square miles method is a center per 180 square miles, with population density of 56 persons per square mile, with the center open five days per week, and with 1.99 visits per square mile per day equals 358 visits per day for this center.

One convenience center system opened all of its centers from 7 a.m. to 7 p.m., seven days per week for the first few months of operation. Each center kept records of the hour of day and day of the week for visits. Saturday clearly had the most visits, and Sunday was slightly ahead of Friday which was almost tied with Monday visits. The other three days, which had the fewest visits overall, had almost the same number of visits. Ranked in descending order: Tuesday, Thursday, and Wednesday. This system now is open five days per week and 10 hours per day. The centers are closed Tuesday and Thursday.
The three convenience center scenario assumes the 15 tons of MSW per 260 working days is 21 percent of the waste stream. The 3,900 tons equates to a daily tonnage rate of 10.69. The total daily tonnage generation rate is 50.9 for the county. To construct a landfill to meet the subtitle D standards with a daily tonnage rate of 50.9 would require a cost of $48 per ton (CTAS publication *Guidelines for Decision Makers: Solid Waste Management* prepared by Geneil Hailey, November 1991).

Example 1 assumes that 71 percent of the waste stream is collected and disposed of by the private sector charging a rate to cover collection, transportation, and tipping fees. The landfill is set as an enterprise fund, and everyone pays when they cross the scale. The landfill is 15 miles from the collection routes.

### Example 1.

<table>
<thead>
<tr>
<th>Cost summary per ton</th>
<th>Green Box</th>
<th>Roll-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convenience Center</td>
<td>$24.01</td>
<td>$24.32</td>
</tr>
<tr>
<td>Collection (Loading)</td>
<td>$6.92</td>
<td>$1.23</td>
</tr>
<tr>
<td>Transportation (15 miles one way)</td>
<td>$5.40</td>
<td>$4.35</td>
</tr>
<tr>
<td>Landfill (waste stream of 50.9 tons/day)</td>
<td>$48.00</td>
<td>$48.00</td>
</tr>
<tr>
<td><strong>TOTAL COUNTY COST PER TON</strong></td>
<td><strong>$84.33</strong></td>
<td><strong>$77.90</strong></td>
</tr>
<tr>
<td><strong>TOTAL COUNTY COST YEARLY</strong></td>
<td><strong>$328,887.00</strong></td>
<td><strong>$303,810.00</strong></td>
</tr>
</tbody>
</table>
Example 2 also assumes that 71 percent of the waste stream is collected and disposed of by the private sector charging a rate to cover collection, transportation, and tipping fees. The landfill is set as an enterprise fund, and everyone pays when they cross the scale. The landfill is 75 miles away and has a tip fee of $23 per ton.

**Example 2.**

<table>
<thead>
<tr>
<th>Cost summary per ton</th>
<th>Green Box</th>
<th>Roll-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convenience Center</td>
<td>$24.01</td>
<td>$24.32</td>
</tr>
<tr>
<td>Collection (Loading)</td>
<td>$6.92</td>
<td>$1.23</td>
</tr>
<tr>
<td>Transportation (75 miles one way)</td>
<td>$18.00</td>
<td>$15.00</td>
</tr>
<tr>
<td>Landfill (waste stream of 250 tons/day)</td>
<td>$23.00</td>
<td>$23.00</td>
</tr>
<tr>
<td><strong>TOTAL COUNTY COST PER TON</strong></td>
<td><strong>$71.93</strong></td>
<td><strong>$63.55</strong></td>
</tr>
<tr>
<td><strong>TOTAL COUNTY COST YEARLY</strong></td>
<td><strong>$280,527.00</strong></td>
<td><strong>$247,845.00</strong></td>
</tr>
</tbody>
</table>

Example 2 has a yearly savings of $55,965 for the roll-off system which transports the refuse 75 miles at a lower tip rate versus the 15 mile distance for a small landfill. In Example 1, the roll-off system has a savings of $25,077 per year. In Example 2, the roll-off system has a savings of $32,682 per year. Comparing Example 1, green box system, to Example 2, roll-off system, shows a savings of $81,042 per year.

To demonstrate the effect of cost: if a county producing 50 tons per day can reduce its cost per ton by $1, the savings will be $18,250 per year. The charts and graphs have a lot of application for costing scenarios. Accurate data equals realistic cost figures. If available, your data should be used instead of the generalized default values.
**General Observations and/or Tips**

(A) Trucks and other equipment should be rated to perform their actual tasks. One of the collection services which kept records on each of their trucks had purchased a lighter duty truck to save on capital cost. It was the only truck the service traded at four years of age. The service had less miles on the lighter truck when it required an in-frame overhaul. In the four years, it required two transmission rebuilds and two repairs on the rear suspension. Other costs besides several box repairs included overtime to catch-up routes and additional run time of the other trucks. Capital outlay is the single largest line cost shown in the charts. A proper sized truck working the route is cheaper than a light duty truck sitting in the repair shop. A proper sized truck is safer to operate on the road. When considering type of equipment or truck needed, contact your Technical Assistance Provider, he/she may know a system using the equipment or the truck being considered. The list (as of November 1992) of the Solid Waste Technical Assistance Providers and their agencies are shown in Appendix C. Visit these sites, and ask questions related to the equipment or truck being considered.

(B) Axles weights should be considered when sizing the equipment and/or trucks. Bridges, culverts, and road damage are concerns, but also consider the liabilities local government may be exposed to from an accident on a damaged road. If the government truck driver is in an accident through no fault of the driver, a claim still might be made against the agency if the truck was loaded over its class weight and/or over the legal gross vehicle weight. Such a suit might state that there would have been less damage or the accident might have been avoided if the weight had been within the requirements.

(C) Bid specifications should be based on needs. Since capital outlay is the big expense, research the system’s needs and seek assistance if only to confirm your study results. Require vendors in all bids to list customers (at least five) nearest your system, who use the exact product bid. Also require a list of vendors who stock parts and supplies for the bid item. Contact or visit their customers. Ask their competitors who their customers are. Evaluate the bids thoroughly, since the lowest price bid isn’t always the cheapest bid. Consider actual cost, but also evaluate cost avoidance.

(D) Establish a Standard Operational Procedure (SOP) for each job class. Include the chronological work order, task procedures, and emergency procedures. Set minimal production standards. During an observation period, Service A collected 2.4 tons per hour while Service B collected 2 tons per hour. Both services have similar rear loader systems. They have the same size and brand of rear loader. The routes are also very similar. Service A during its downtown route has the driver stopping the truck next to large piles of refuse on the sidewalk. He promptly exits the cab, where he and one helper carry a bag in each hand and throw the bags into the throat of the rear loader. In Service B the driver remained in the cab while the two helpers picked up one bag at a time, carried the bags into the street directly behind the truck where it was placed into the throat of the truck. If Service A’s truck cost per hour is $40.86, their collection cost per ton is
$17.03. If Service B’s truck cost per hour is $44.12, their collection cost per ton is $22.06. In this scenario the difference in cost per ton is $5.03. Six tons per load at $5.03 per ton equals a savings per load of $30.18. The generation rate of 30 tons per day is 1,825 loads per year. At $5.03 per load, Service A saves $9,197.75 per year.

(E) Keep records. Every system has some method of recording each dollar expended. Trucks, equipment, and personnel are spending time on the routes. Time is money. Trucks and equipment depreciate with time. Route records should include time spent, service quantity, and volume of the MSW collected. These figures assist in evaluating the entire system as well as its components. Analyzing different collection procedures, routes, and production levels will aid in determining minimal costs. The record base will aid in establishing or adjusting collection rates whether billed as a utility or when requesting an appropriation from local government. Keeping service and repair records on each truck assists in servicing and evaluating the truck’s performance.

(F) Know the current and project future solid waste needs to establish the type of services needed. The needs should be used to establish the type and kind of equipment to be purchased. A certain process or equipment that is the most efficient for one community isn’t necessarily the most efficient for another community.

(G) Calculate the total cost per ton for each aspect and for the entire solid waste system. As shown in the first part of this summary, example one has a lower transportation cost than example two; however, example two has the lowest cost when the total solid waste system is considered.

The costs reflected in this publication are the mean, mode, and/or legal limits of field-gathered data. Since the charts and graphs are based on this data, they reflect field cost of services studied. Those services are not necessarily using trucks in the most efficient manner nor have they purchased the type of truck to best fit their needs.
Three questions are addressed by this pamphlet with regard to the Bridge Formula.

1. What is it?
2. Why is it necessary?
3. How is it used?

"What is it?"

The bridge gross weight formula provides a standard to control the spacing of truck axles on vehicles that use highway bridges.

\[ W = L \times N \]

Where:
- \( W \) = The maximum weight in pounds that can be carried on a group of two or more axles to the nearest 500 pounds.
- \( L \) = Spacing in feet between the outer axles of any two or more consecutive axles.
- \( N \) = Number of axles being considered.

"Why is the formula necessary?"

An individual set of bridge design computations cannot be completed for every type of truck that may use the highways; to do this for every type truck would take years. Consequently, the nation’s bridge engineers have selected what is referenced as a design vehicle. This one vehicle is considered representative of all vehicles that will use a bridge during the 40- to 50-year life of the structure. A more common description would be to call the design vehicle an umbrella loading, as shown.

Figure 1.
Assuming that the umbrella loading illustrated above creates the most severe situation for any bridge design, bridge members are built strong enough to handle the umbrella loading and, in effect, the bridge is protected from being over-stressed by any future truck that may use the structure. The umbrella loading described in Figure 1, which is used for interstate highway bridge design, was adopted in 1944 with specific axle weights and spacing as shown. For years, enforcement officials have worked to check truck weights to keep the axle loads and gross loads within legal limits. With the passage of the Federal-Aid Amendments of 1974, the states also became concerned with the spacing of axles when enforcing weight laws on the interstate system.

Axle spacing is equally as important in design of bridges as are axle weights. This is illustrated by what happens when a person tries to walk across ice that is not thick enough to support his/her weight; the person is likely to fall through. However, if that person stretched out prone on the same ice and scooted across, it is unlikely that he/she would break through. This is true because the load, or weight, is spread over a larger area in the latter situation. A similar comparison can be made between trucks crossing a bridge.

In view (A) of Figure 2, the stress on bridge members as the long truck rolls across is much less than that caused by the short truck in view (B), even though the trucks have the same total weight and individual axle weights. One can see that an extremely long truck would have its load spread out like the person scooting across ice. Whereas the short truck is similar to a person standing up on ice with the total load placed in a limited area.

After umbrella loading was adopted in 1944, many interstate bridges were built during the late 1950s and 1960s. Simultaneously, bigger and heavier trucks were being placed into use than was anticipated in 1944. It was not practical to consider rebuilding all bridges for newer trucks that either were or could be placed on the road. The logical and economical action not only was to control the gross and axle weights of trucks but also to control the spacing of the axles. The U.S. Congress concurred with this approach. In 1974, when the higher axle and gross weight limits were adopted for the interstate system (20,000 pounds—single axle, 34,000 pounds—tandem axle, 80,000 pounds—gross), the bridge formula was written into Section 127 of the United States Code, Title 23. The bridge formula assures that allowable weight of heavy trucks is correlated with the spacing of axles to prevent over stressing of highway bridges; in other words, preventing an effect similar to a person standing erect on thin ice. Over stressing can occur even when the gross weight and each individual axle weight of a truck are within lawful limits.
"How is the formula used?"

Some definitions are needed before completing sample applications of the bridge formula.

**Gross Weight** — The weight of a vehicle and/or vehicle combination without load plus the weight of any load thereon. The federal gross weight limit on the interstate is 80,000 pounds.

**Single Axle Weight** — The total weight transmitted by all wheels whose center may be included between two parallel transverse vertical planes 40 inches apart, extending across the full width of the vehicle. The federal single axle weight limit on the interstate is 20,000 pounds.

**Tandem Axle Weight** — The total weight transmitted to the road by two or more consecutive axles whose centers may be included between parallel vertical planes spaced more than 40 inches and not more than 96 inches apart, extending across the full width of the vehicle. The federal tandem axle weight limit on the interstate is 34,000 pounds.

A distinction is made at the 8-foot distance in Table B (page 59) due to the tandem axle weight definition causing a considerable difference in the axle load, depending on whether the spacing of the axles is 8 feet and less or more than 8 feet. The axle weight limit for any spacing greater than 8 feet (96 inches) shall be in accordance with the bridge formula. The tandem axle weight definition is not applicable when the axle spacing exceeds 96 inches. For example, three axles with an extreme spacing of 97 inches (more than 8 feet) can carry a load of 42,000 pounds as shown in Figure 3.

![Figure 3.](image)

The federal law states that any consecutive two or more axles may not exceed the weight as computed by the formula even though single axles, tandem axles, and gross weights are within legal requirements.

![Figure 4.](image)

The most common vehicle (axle arrangement) checked for weight limit requirements is shown in Figure 4. While the bridge formula law applies to each combination of two or more axles, experience shows that axle combinations numbers 1 through 3, numbers 1 through 5, and numbers 2 through 5 are the critical combinations that must be checked. If these are found satisfactory, others will be satisfactory.

*AASHTO definitions. These weight limits may vary from state-to-state depending on local laws and limits in effect before the federal limits were established in 1956.*
### Table B

**Permissible gross loads for vehicles in regular operation**

Based on weight formula: \( W = 500 \left( \frac{L}{N-1} + 12N + 36 \right) \) modified

<table>
<thead>
<tr>
<th>Distance in feet between the extremes of any group of 2 or more consecutive axes</th>
<th>Maximum load in pounds carried by any group of 2 or more consecutive axes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 axes</td>
<td>3 axes</td>
</tr>
<tr>
<td>4</td>
<td>34,000</td>
</tr>
<tr>
<td>5</td>
<td>34,000</td>
</tr>
<tr>
<td>6</td>
<td>34,000</td>
</tr>
<tr>
<td>More than 6</td>
<td>38,000</td>
</tr>
<tr>
<td>9</td>
<td>39,000</td>
</tr>
<tr>
<td>10</td>
<td>40,000</td>
</tr>
<tr>
<td>Example</td>
<td>51,000</td>
</tr>
<tr>
<td>(see page 60)</td>
<td>57,500</td>
</tr>
<tr>
<td>Tandem Axle Weight (see pages 58)</td>
<td></td>
</tr>
</tbody>
</table>

**Interstate Gross Weight Limit**

<table>
<thead>
<tr>
<th>Weight Limit</th>
<th>80,000</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(see page 58)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. The permissible loads are computed to the nearest 500 pounds. The modification consists in limiting the maximum load on any single axle to 20,000 pounds.

2. The following loaded vehicles must not operate over HS-44 bridges: 3-52 (3 axles) with wheelbase less than 18 feet; 2-52-2 (2 axles) with wheelbase less than 45 feet; 3-3 (6 axles) with wheelbase less than 45 feet; and 7-, 8-, and 9-axle vehicles regardless of wheelbase.
The vehicle with weights and axle dimensions as shown in Figure 5 will be used to illustrate a bridge formula check.

![Figure 5](image)

Before checking the axle 1 through 3 combination, a check should be made to see that single, tandem and gross weights are satisfied. The single axle Number 1 does not exceed 20,000 pounds, tandems 2-3 and 4-5 do not exceed 34,000 pounds, and the gross weight does not exceed 80,000 pounds. Thus, these requirements are satisfied so the first bridge formula combination is checked as follows:

![Figure 6](image)

**Check of 1 thru 3**

W (actual weight) = 
12,000 + 17,000 + 17,000 = 46,000 pounds
(Figure 6)

N = 3 axles
L = 21 feet

W maximum = 500 \( \left( \frac{L N}{N-1} + 12N+36 \right) \)

\[= 500 \left( \frac{21 \times 3}{3-1} + (12 \times 3) + 36 \right) = 51,500\# \]

W maximum = 51,500\# which is more than the actual weight of 46,000\# so the bridge formula requirement is satisfied.

Example — Bridge Table B

This same number (51,500\#) could have been obtained from Bridge Table B as shown by reading down the left side to \( L = 21 \) and across to the right where \( N = 3 \).

![Figure 7](image)

*Now check axles 1 thru 5*
\[ W \text{ (actual)} = 12,000 + 17,000 + 17,000 + 17,000 + 17,000 = 80,000\# \text{ (Figure 7)} \]

\[ W \text{ maximum, from Table B for } L \text{ of 51 feet and } N \text{ of 5} = 80,000\# \]

Therefore, this axle spacing is satisfactory.

\[ 17,000 \text{ Ibr. } + 17,000 \text{ Ibr. } + 17,000 \text{ Ibr. } + 17,000 \text{ Ibr. } = 68,000\# \]

This is a “TILT” or violation in that the actual weight exceeds the maximum allowed weight for the given axle spacing. To correct the situation, some load must be removed from the truck or the axle spacing (34-foot dimension) increased.

\[ W \text{ maximum, from Table B for } L \text{ of 34 feet and } N \text{ of 4} = 64,500\# \text{ (Figure 8)} \]

Now check axles 2 thru 5

\[ W \text{ (actual)} = 17,000 + 17,000 + 17,000 + 17,000 = 68,000\# \text{ (Figure 8)} \]

\[ W \text{ maximum, from Table B for “} L \text{” of 34 feet and “} N \text{” of 4} = 64,500\# \]

Exception to Formula and Table B

There is one exception to use of the formula or Table B; that is two consecutive sets of tandem axles may carry a gross load of 34,000 pounds each providing the overall distance between the first and last axles of such consecutive sets of tandem axles is 36 feet or more. For example, a 5-axle truck tractor semi-trailer may be used to haul a full 34,000 pounds on the tandem of the tractor (axles 2 and 3) and the tandem of the trailer (axles 4 and 5) provided there is a spacing of 36 feet or more between axles 2 and 5. A spacing of 36 feet or more for axles 2 through 5 is satisfactory for an actual W of 68,000 pounds even though the formula or Table B computes W maximum to be 66,000 to 67,500 pounds for spacings of 36 to 38 feet. This special exception is stated in the federal law.

Bridge Formula Application to Single Unit Trucks

The same procedure described above can be used to check any axle combinations but as a general rule several axles spaced close together will usually give the most critical situation.
The truck in Figure 9 satisfies single axle restrictions (12,000# is less than 20,000#), tandem axle restrictions (30,000# is less than 34,000#) and gross limits (57,000# is less than 80,000#). With these restrictions satisfied, a check will be made for bridge formula requirements, axles 1 through 4.

\[
W \text{ (actual)} = 12,000 + 15,000 + 15,000 + 15,000 = 57,000#
\]

W maximum for “N” of 4 and “L” of 23 feet = 57,500 from Table “B”

Since axles 1 thru 4 are satisfactory, check axles 2 thru 4:

\[
W \text{ (actual)} = 15,000 + 15,000 + 15,000 = 45,000#
\]

W maximum for “N” of 3 and “L” of 9 feet = 42,500# (from Table B)

This is a TILT or a violation. The load would have to be reduced, axles added, or spacing changed to meet requirements.

**CAUTION**

This pamphlet has attempted to explain the purpose of the bridge formula and federal requirements applicable to the interstate system, but procedures to determine the related weight limits and axle spacing requirements for specific vehicles may vary from state to state.
Appendix B

55-4-124. Registration of vehicles hauling certain materials [Repealed effective June 30, 1992].
(a) Any vehicle, freight motor vehicle, truck-tractor, trailer or semitrailer or combinations of such vehicles which transport crushed stone, fill dirt and rock, soil, bulk sand, coal, phosphate muck, asphalt, concrete, other building materials, forest products, unfinished lumber, ferrous and non-ferrous scrap metal, agricultural lime, liquid fertilizer, solid waste and agricultural products shall be permitted to register as follows:

(1) Such vehicles hauling such products in a single unit motor vehicle having four axles and designed to unload itself, with a gross weight not exceeding 73,280 pounds including the load thereon, shall be permitted to register as a Class 10 vehicle, or purchase the appropriate special zone tag; and

(2) Such vehicles hauling such products in a single unit motor vehicle having three axles and designed to unload itself with a gross weight not exceeding 66,000 pounds including the load thereon, shall be permitted to register as a Class 9 vehicle, or purchase the appropriate special zone tag.

(b) The provisions of this section shall be void and of no effect after June 30, 1992. If the commissioner of transportation is formally notified by an appropriate federal official that as a result of any provision of this section Tennessee will lose federal funds, then such provision shall be void and inoperative.

c) Nothing contained in this section shall be construed as authorizing such vehicles to use that portion of the state highway system designated as the interstate system. [Acts 1982, ch. 953, 1; 1983, ch. 319, 2; 1987, ch. 152, 1; 1987, ch. 153, 1, 2; 1988, ch. 514, 1.]

55-7-203. Maximum weight per axle or group of axles allowed. Except as otherwise provided by law, no freight motor vehicle shall be operated over, on, or upon the public highways of this state where the total weight on a single axle or any group of axles exceeds the weight limitations set forth below in subdivisions (1)-(7).

(1) (A) No axle shall carry a load in excess of 20,000 pounds.

(B) Axle combinations and fifth-wheel placement on the tractor shall insure equal weight distribution on weight carrying axle combinations, and such axle combination shall be equipped with brakes having power motivation.

(C) An axle load as set out herein is defined as the total load transmitted to the road by all wheels whose centers may be included between two parallel transverse vertical planes, 40 inches apart, extending across the full width of the vehicle.

(2) The total gross weight concentrated on the highway surface from any tandem axle group shall not exceed 34,000 pounds for each such tandem axle group. “Tandem axle group” means two or more axles spaced 40 inches or more apart from center to center having at least one common point of weight suspension.
(3) The total gross weight of a vehicle, freight motor vehicle, truck-tractor, trailer or semitrailer nor combinations of such vehicles operated over, on or upon the public highways of this state shall not exceed 80,000 pounds; provided, that none of the foregoing shall be operated over or on the interstate system of this state where the total gross weight of such vehicle or combination thereof including the load therein exceeds 73,280 pounds or where the weight exceeds 18,000 pounds on any single axle or where the weight exceeds 32,000 pounds on any tandem axle group unless the weight is distributed on a group of two or more consecutive axles produced by application of the following formula:

\[ W = \frac{500 (LN + 12N + 36)}{(N-1)} \]

Where \( W \) = overall gross weight on any group of two or more consecutive axles to the nearest 500 pounds, \( L \) = distance in feet between the extreme of any group of two or more consecutive axles, and \( N \) = number of axles in group under consideration, except that two consecutive sets of tandem axles may carry a gross load of 34,000 pounds each providing the overall distance between the first and last axles of such consecutive sets of tandem axles is 36 feet or more, except such vehicles, or combinations thereof operating under special permits now authorized by law; provided, that wherever a maximum permissive gross weight of 80,000 pounds or of lengths prescribed in 55-7-201 or a height of 13 1/2 feet is authorized for any vehicle or combination of vehicles, it is the legislative intent that the prescribed weight, length, and height limits shall be strictly enforced, and it shall be unlawful for any state, county, or municipal officer to allow or permit any additional weight, length or height by way of tolerance or otherwise, except that the commissioner of transportation may issue special permits pursuant to 55-7-205.

(4) A “freight motor vehicle,” as used in this section, includes both the tractor or truck and the trailer, semitrailer or trailers, if any, and the weight of any such combination shall not exceed the maximum fixed herein; provided, however, that no freight motor vehicle with motive power shall haul more than one vehicle unless otherwise provided.

(5) No freight motor vehicle shall haul a trailer on any highway of this state when such trailer (including its load) weighs more than 3,500 pounds, and the hauling of a trailer which, including its load, weighs more than 3,500 pounds is hereby prohibited and declared unlawful. Provided, however, that such restrictions on hauling a trailer in excess weight of 3,500 pounds by a freight motor vehicle as described in the preceding sentence, shall not be applicable whenever a converter dolly or equivalent fixed connection having the same safety characteristics is appropriately installed or placed under the trailer to be hauled by such freight motor vehicle. For the purposes hereof, a “trailer” is defined as a vehicle without motive power designed or used for carrying freight or property wholly on its own structure; provided, however, that it shall not be unlawful for any motor vehicle subject to this part to have a semitrailer, which, for the purposes hereof, is defined as a vehicle for the carrying of property or freight and so designed that some part of the weight of such semitrailer or its load
rests upon or is carried by the motor vehicle to which it is attached. Provided, that the hauling of a trailer (to the extent herein permitted) or a semitrailer shall be subject to the further provisions hereof. Provided further, that this part is not intended to prohibit the movements of spools carrying wire or cable, when used for construction or repair purposes. Provided further, that the weight limitation respecting trailers shall not be applicable to implements designed to distribute fertilizer while such vehicles are being drawn by a freight motor vehicle between the plant and the farm.

(6) If the gross weight of a freight motor vehicle does not exceed the sum obtained by computing the total weight allowable for the number and type of its axles the driver shall be cited for violation of an axle weight limitation while transporting crushed stone, fill dirt and rock, soil, bulk sand, coal, phosphate muck, asphalt, concrete, other building materials, solid waste, tankage or animal residues, livestock and agricultural products over the state highway system other than the portion designated as the interstate system.

(7) For purposes of enforcement of this section, weight restrictions shall be deemed to have a margin of error of 10 percent of the true gross or axle weight for all logging, coal and machinery trucks when being operated over the state highway system other than the portion designated as the interstate system.

(A) “Coal truck,” for the purposes of this subdivision, means those trucks used for hauling coal and coal products.

(B) “Logging truck,” for the purposes of this subdivision, means those trucks used for hauling logs, pulpwood, bark, wood chips or wood dust from the woods to the mill or from the mill to a loading or storage place or market.

(C) “Machinery truck,” for the purposes of this subdivision, means those trucks used for hauling machinery by the owner/operator within a 100-mile radius of the base location of such owner/operator’s area of operation, subject to the limitation of one such truck per owner/operator.
Appendix C
Solid Waste Technical Assistance List

Tennessee Department of Environment and Conservation

*Division of Solid Waste Assistance
Paul Evan Davis, Director ...............................................................(615) 532-0070
Genell Hailey, Deputy Director ......................................................(615) 532-0070
Joyce Dunlap, Manager of Grants Administration Section .............(615) 532-0075
Don Manning, Manager of Special Waste Section .......................(615) 532-0076
DeAnna Moore Fry, Manager of Recycling Section.......................(615) 532-0074

* Division of Solid Waste Management
Mike Apple, Deputy Director ........................................................(615) 532-0780
Frank Victory, Manager of Solid Waste Management Program ..........(615) 532-0780

State Planning Office
Ruth Neff, Executive Administrative Assistant ................................(615) 741-5782
Maxine McManus, Solid Waste Education Coordinator ...................(615) 741-5782
Jesse Hale, Policy Analyst ..............................................................(615) 741-1676

The University of Tennessee Institute for Public Service
Tom Ballard, Assistant Vice President ............................................(615) 974-6621
Chuck Shoopman, Director of Program Services .........................(615) 974-6621

* County Technical Assistance Service
Rodney Carmical, Acting Executive Director .................................(615) 242-0358
Ron Fults, Legal Services Coordinator ...........................................(615) 242-0358
Lewis Bumpus, Solid Waste Management Consultant ....................(615) 242-0358
Mike Stooksberry, Solid Waste Management Consultant ...............(901) 587-7077

* Municipal Technical Advisory Service
Bob Schwartz, Executive Director ...................................................(615) 974-0411
Anne Gilbert, Solid Waste Management Consultant ......................(615) 974-0411

* Center for Industrial Services
T. C. Parsons, Executive Director ...................................................(615) 242-2456
Albert Tieche, Solid Waste Coordinator ...........................................(615) 242-2456
Arlen Ferguson, Waste Reduction Engineer ....................................(901) 423-3710
Glossary


Avoided cost
Costs a utility may pay for electric power purchased from a waste-to-energy facility based on how much it would have cost the utility to generate the power itself or, costs not incurred because of diversion of waste from a landfill (e.g., disposal environmental and opportunity costs)

Cab-Over-Vehicle
Vehicle with a cab at the front end over the engine

Class III Disposal Facility
Refers to a landfill which is used or to be used for the disposal of farming wastes, landscaping wastes, and/or certain special wastes having similar characteristics

Class IV Disposal Facility
Refers to a landfill which is used or to be used for the disposal of demolition/construction wastes and/or certain special wastes having similar characteristics as inert waste

Collection
Gathering of MSW for subsequent management (i.e., landfilling, incineration, or recycling)

Composting
The controlled biological decomposition of organic solid waste under aerobic conditions. Organic waste materials are transformed into soil amendments such as humus or mulch

Curbside Collection
Collection at individual households or commercial buildings by municipal or private haulers for subsequent transport to management facility

Disposal Facility
A collection of equipment and associated land area which serves to receive waste and dispose of it. The facility may incorporate one or more disposal methods

Drop-Off-Center
A method of collecting recyclable or compostable materials in which the materials are taken by individuals to collection sites, or centers, and deposited into designated containers

Economics of Scale
Increases in production capacity that reduce the average cost per ton of output

Fixed Costs
Cost that do not vary with level of output of a production facility (e.g., administrative costs, building rent, mortgage payments)
Gross Weight
Total weight of vehicle and its load

Gross Vehicle Weight
The gross weight rating in pounds the vehicle is designed to carry. Landfilling-disposing of solid waste on land in a series of compacted layers and covering it, usually daily, with soil or other materials

Leachate
Contaminated water emanating from a landfill

Leachate Collection and Removal System
Pipes used to collect leachate that settle on a liner and prevent it from migrating into groundwater

Integrated Solid Waste Management
A practice of disposing of solid waste that utilizes several complimentary components, such as waste reduction, recycling, composting, energy recovery, and landfill

Municipal Solid Waste (MSW)
Includes non-hazardous waste generated in households, commercial and business establishments and institutions; and excludes industrial process wastes, demolition wastes, agricultural wastes, mining wastes, abandoned automobiles, ashes, street sweepings, and sewage sludge

Permits
The official approval and permission to proceed with an activity controlled by the permitting authority. Several permits from different authorities may be required for a single operation

Recycling
Collecting components of MSW and processing them into a form in which they can be reused as raw materials for new products

Reuse
Taking a component of MSW and possibly with some slight modification (e.g., cleaning, repair), using it again for its original purpose (e.g., refillable beverage bottles)

Solid Waste
Defined in Resource Conservation Recovery Act (RCRA) as “garbage, refuse, sludge from waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities...”

Source Separation
Separation at a household or commercial establishment of MSW into different recyclable components
Tandem
Having close-coupled pairs of axles

Tare Weight
A deduction from the gross weight of the vehicle made in allowance for the weight of the vehicle

Tipping Fee
Price charged for delivering MSW to landfill, incinerator, or recycling facility; usually expressed in dollars per ton

Transfer Station
Facility at which MSW is transferred from collection vehicles to larger trucks or rail cars for longer distance transport

Windrow System
A composting system in which waste is placed in windows to compost and either aerated (in static pile system) or turned periodically

White Goods
Large, metal household appliances (e.g., stoves, dryers, refrigerators, etc)

Volume Reduction
The processing of waste materials so as to decrease the amount of space the material occupy. Reduction is presently accomplished by three major processes: (1) mechanical, which uses compaction techniques (bailing, sanitary landfills, etc.) and shredding; (2) thermal, which is achieved by heat (incineration) and can reduce volume by 80-90 percent; and (3) biological, in which organic waste fraction is degraded by bacterial action (composting, etc.)

Yard Wastes
Leaves, grass clippings, pruning, and other natural organic matter from yards and gardens
The University of Tennessee does not discriminate on the basis of race, sex, color, religion, national origin, age, handicap, or veteran status in provision of educational opportunities or employment opportunities and benefits.

The University does not discriminate on the basis of sex or handicap in its educational programs and activities, pursuant to requirements of Title IX of the Educational Amendments of 1972, Public Law 92-318, and Section 504 of the Rehabilitation Act of 1973, Public Law 93-112, and the Americans With Disabilities Act of 1990, Public Law 101-336, respectively. This policy extends to both employment and admission to The University.

Inquiries concerning Title IX, Section 504, and the Americans With Disabilities Act of 1990 should be directed to Mr. Gary W. Baskette, Director of Business Services, 100 Student Services and Administration Building, Knoxville, Tennessee 37996-0213, (615) 974-1622. Charges of violation of the above policy should also be directed to Mr. Baskette. E15-1570-00-017-93