A Comparison of Various Equipment Costing Methods

Comparing different common equipment costing methods may be useful in developing portions of contracts that deal with equipment costs and in negotiating change orders.

GEORGE PAPATHANASIOU & ALI TOURAN

Equipment cost is a major expense in construction. Equipment cost analysis is important to all parties to the construction contract. Contractors need an accurate estimate of equipment costs to ensure that they are not losing money by using rented or owned equipment on various jobs. The owner and the owner's representative need to be familiar with various equipment costing methods because, without this knowledge, they will be vulnerable in cost-reimbursable projects or in change order negotiation. There are a few well known methods for estimating equipment costs. Although these methods are based on the same general principles, the calculated hourly cost for a specific piece of heavy equipment varies depending on the costing method used.

Equipment Cost Components

The contractor has several options in equipment utilization: rent, lease, lease with the option to buy, or buy the equipment or subcontract portions of the project that rely heavily on equipment. In reviewing equipment costs, only the case where the contractor owns the equipment is presented here. In this instance, it is common practice to divide equipment costs into *owning* and *operating* costs. The owning costs consist of the following components:

- Depreciation;
- Cost of capital (the cost of facilities capital [CFC]); and,
- Other costs such as insurance, taxes and storage.

The operating cost components consist of:

- Fuel;
- Filter, oil and grease (FOG);
- Tires; and,
- Repair.

Operator's wages, which in some cases are considered part of the operating cost, are excluded here because this item varies from one location to another. A detailed description of each of

these costs is provided in many references.[1-3] Calculating equipment costs is done for various reasons, the most common ones being:

- The contractor wants to estimate the hourly cost of equipment ownership as accurately as possible. Knowing the real cost allows the contractor to prepare accurate and competitive bids, and to charge reasonable equipment rates for jobs. Also, in change order negotiations, the contractor would know where to draw the line, so that money will not be lost on changes.
- An owner wants to specify a well developed method for equipment pricing in the contract documents to serve both parties in pricing change orders. The method should result in a fair and realistic equipment rate. Without specifying a method in contract documents, the owner and contractor may have difficulty in agreeing to equipment cost assessments prepared by the other party. As an example, the Massachusetts Highway Department (MHD) stipulates that "actual cost data from the Contractor's accounting and operating records shall be used whenever such data can be determined for hourly ownership and operating costs for each piece of equipment."[4] A good contractor should be able to manage equipment fleet costs at rates lower than those published by professional publications. In the absence of such data, the MHD stipulates that the *Rental Rate Blue Book* should be used to estimate equipment costs.[5] Another example of contract language is from the Special Provisions section of Central Light Rail/Phase II Contract for Baltimore, a turnkey contract where the contractor was responsible for most of the design and all of the construction. Understandably, the contractor was carrying more risk compared to the traditional method where design documents are 100 percent complete. In the case of changes, under the Negotiated Payment Provisions the contract states: "C. *Equipment.* For any machinery or equipment . . . the compensation will be based on the equipment costs listed in the applicable edition of the *Cost Reference Guide for Construction Equipment.*"[6]
- In cost-reimbursable contracts, an equipment costing method may be specified to facilitate negotiation between parties and serve as the basis of payment to the contractor for equipment owned by the contractor. It is important to agree to the rates as early as possible as new equipment is added or removed. MHD standard specifications stipulate that "the current revisions to *Rental Rate Blue Book* will be used in establishing equipment rates. The 'current revision' applicable to specific extra work or force account work will be the revision in effect (the copyright date being the deciding factor) as of the Contractor's Notice to Proceed."[5]

Sources for Equipment Costing

Several professional publications are being used by the industry in estimating hourly equipment costs. Three of the most common are:

- *Construction Equipment Owning & Operating Expense Schedule* published once every few years by the U.S. Army Corps of Engineers (identified here as the CE method).[7] The version used here was published in 1997 (the most recent version available at the time of this study).
- *Cost Reference Guide for Construction Equipment* (identified here as the CRG method)[6] and *Rental Rate Blue Book* (identified here as the RBB method) published annually.[5]
- *Caterpillar Performance Handbook* published annually (identified here as the CAT method).[8]

The purpose of these methods is not necessarily the same. CAT's purpose is "to enable the machine user to estimate hourly owning and operating costs in order to optimize the unit cost of production."[8]

The aim of the CE method is to establish "predetermined equipment ownership and operating expense rates for construction and marine equipment." Also, "the use is for rate determination in construction contract[s], and

negotiation procurements related only to equipment which is contractor-owned."[7]

According to the RBB method, "the rates in [its] manual are intended as guidelines paralleling amounts an equipment owner should charge during rental or contractual periods to recover equipment-related costs."[5] CRG suggests that data provided are "specifically designed to assist contractors in preparing bids and assigning internal owning and operating costs."[6]

So, overall, the main objective of the CAT and CRG methods seems to provide an estimate of the actual cost of owning and operating the equipment. The RBB method's objective is to help the contractor come up with a charge-out rate for the equipment to be used at the job. The CE method can be used for both purposes, mainly because costs and assumptions are sufficiently well documented to allow the analyst to calculate a fair cost in various circumstances.

Equipment Comparison Group

A comparative analysis of these four methods will provide a way to select which method is best for certain conditions. (A similar, but somewhat more limited study was conducted by Douglas.[9]) For comparison, it is best to select a group of equipment for costing. For a typical earthmoving project, a scraper, a wheel-type front-end loader and an off-highway truck comprise a representative composite fleet for cost comparison. All are mid-size machines widely used in earthmoving projects such as dam or highway construction. The average hourly cost of these three machines will be used when comparing the various costing methods. This approach helps to alleviate any irregularity that may exist in the cost data pertaining to any single model because averaging these costs will reduce the effect of such anomaly. CAT, CRG, RBB and CE (prices adjusted for 1998 using appropriate cost indexes) methods were used in this analysis.

Basic Assumptions

Equipment costs are calculated for the year 1998. These costs do not include insurance or storage costs. Insurance and storage costs vary from contractor to contractor. The CE method does not provide estimates for these items and considers these as indirect costs. Insurance costs are estimated usually at 2 percent of the annual value of the machine.[10] Before estimating equipment hourly costs several parameters need to be specified. These parameters are assumed in such a way to make a reasonable comparison between the various methods possible:

Operating Conditions. Job conditions have a profound effect on equipment costs. Severe job conditions increase fuel consumption, repair and maintenance costs and may shorten equipment and tire lives. For example, in the case of the loader, severe job conditions may include loading shot rock, handling earth with high density, continuous work on rough or very soft terrain, and traveling long distances with adverse grades on poorly maintained haul roads.[8] The CRG and RBB methods assume that the equipment is in average condition and is working in non-severe job conditions. The CE and CAT rates calculated here are for average operating conditions. Where it was necessary to assume a locality for labor rates or other cost items, an average index was calculated to represent the United States.

Economic Life. An estimate of the economic life of the equipment plays an important role in calculating owning and operating costs. Complete consistency does not exist between the various costing methods about the machine's economic life.

According to the CRG method, "economic hours reflect the average economically productive life of a machine used under average conditions." RBB assumptions are more or less compatible with the CRG method since both methods are published by the same organization. CRG assumes an economic life of 17,000 hours for the scraper, 11,000 hours for the loader and 16,800 for the truck.

The CE method assumes an economic life of 10,000 to 12,000 hours for all scrapers (11,000 hours used here), 12,000 hours for off-highway trucks and 10,000 to 12,000 hours (11,000 hours used here) for wheel-type front-end loaders.

The CAT method assumes a useful life of 17,000 hours for the scraper, 10,000 hours for the loader and 40,000 hours for the truck — recognizing that useful life can vary according to local economic conditions, proper maintenance, etc.

Each method's assumed economic life in cost calculations was followed in the context of these assumptions. Using consistent life hours for the various methods was considered. However, it was decided to use values suggested by each source since the user of each method will work with the useful life values recommended by the particular method. Therefore, in order to compare hourly costs calculated using various methods, it would be more rational to use the appropriate method's assumptions.

Estimated Usage (Hours Per Year). Another important assumption is the number of hours of usage per year. According to the CRG method, costs are distributed over 2,112 hours per year, (*i.e.*, over 12 months of single-shift usage amounting to an average of 176 hours per month). These hours are not the working hours per year; they include standby and storage. In calculating owning and operating costs, the CRG method uses 2,112 hours for depreciation calculation and economic life for the rest of the cost items. The same approach is used in the RBB method, where hourly costs are given based on monthly, weekly, daily and hourly rentals. Monthly rates are based on 176 hours per month and these hourly rates were used as a basis for comparison.

The CE method calculates an average working hours per year (WHPY) for each of the regions into which it divides the United States. WHPY is calculated on a 40-hours-per-week, 52-weeks-per-year basis reduced for weather, holidays, maintenance, repairs, mobilization, demobilization and miscellaneous downtime. The average WHPY calculated for eight regions (excluding Alaska, Hawaii, Puerto Rico and Kwaljalein Island, which differ significantly from the average) is 1,470 hours. The CE method uses economic life for the calculation of depreciation and repair costs and WPHY for CFC.

Since the CAT method does not suggest an annual usage, the estimator must determine the usage. However, the hours per year used in various formulae are working hours. Here, economic life is used for depreciation calculation and WHPY for other items.

Delivered Price. The initial price of the equipment is important in obtaining a cost calculation. The prices used by the CRG and RBB methods are suggested by the manufacturer and include an allowance for discounts. CRG method prices do not include sales tax, however. Knowing assumed prices is significant because several cost items are a function of equipment's original price; one could use the original price in pinpointing sources of potential differences between various costing methods.

The CE method provides prices for all equipment listed. It assumes an average sales tax rate of 6.33 percent, a freight rate of $3.99 per 100 pounds and a discount of 7.5 percent.[7]

The CAT method stipulates that in the delivered price, all costs including sales taxes and freight charge must be included.

Tires. Most costing methods suggest that the price of tires should be deducted from the price of equipment and expensed as an operating cost item. The CRG method does not mention if it excludes the price of tires from equipment price. However, because tire cost is treated as an operating expense, it is logical to assume that it is deducted from the price before calculating depreciation. Both the CE and CAT methods deduct tire cost from the delivered price in order to calculate depreciation.

Comparisons

Two separate comparisons are made. The first is a comparison of equipment hourly costs calculated using the CRG, CAT and CE methods. The purpose of this comparison is to evaluate these methods for cost estimating by the machine owner. The second compares costs between the CE and RBB methods. This comparison is performed to evaluate these two methods for the purpose of calculating how much a contractor's machine will cost the project owner. The CE method was included in

both groups because it is the most flexible system (because this method documents all assumptions, equations and sources of cost data clearly). This approach allows the user to tailor costs according to the intended purpose.

Here, the price data reported by CE were used. In order to be compatible with CRG method assumptions, the sales tax was excluded from the reported prices in the first comparison study. In the second comparison (comparing the RBB method with the CE method), the sales tax was included because the RBB method included the sales tax in its pricing model. Prices reported in the CE method are for equipment manufactured in 1994 and include discount, tax and freight costs. These prices were adjusted where necessary to calculate owning and operating costs for 1998. Table 1 shows the basis for the original equipment prices.

TABLE 1.
Original Equipment Prices

Equipment	Original Price for CE/RBB Comparison*	Adjusted Price for CE/CAT/CRG Comparison**
Scraper	$604,544	$568,779
Loader	$245,978	$231,441
Truck	$586,640	$551,940

Notes: *Includes initial price, sales tax, discount & freight cost.
**Includes initial price, discount & freight cost.

Calculation of Owning Costs: CE Versus CAT Versus CRG Methods

Depreciation. The CE and CAT methods use straight-line depreciation using the machine's economic life with an allowance for salvage value. In the CE method, salvage value is estimated based on current new and used equipment price advertisements, etc. The CRG method uses 2,112 hours per year to calculate the depreciation cost (which includes an allowance for standby and storage). The method does not include an allowance for salvage value at the end of the equipment's life. (For the purpose of comparison here, no salvage value was assumed for all methods.)

The following equation is based on a principle suggested by the CE and CAT methods (the CRG method does not provide a formula for depreciation calculation):

Hourly Depreciation =
(Original Price - Tire Price)/Total No. of Hours

As can be observed in Table 2, the hourly estimate of depreciation cost calculated by the CE method is considerably larger than depreciation estimates using CAT or CRG because the CE method uses a relatively short life for equipment. Given equipment trends in recent years, the CE method's estimate of machine's economic life seems a bit low and may be out-dated, especially in the case of scrapers and trucks. The CE method uses the same traditional values used over the past several decades.

CFC. All methods use the same method for the CFC calculation with the difference that the CE and CAT methods use WHPY in the formula and the CRG method uses economic life. The cost of money rate used in the CRG and CE methods is the one set by the U.S. Treasury Department (adjusted twice a year on January 1 and July 1). Here, a rate of 6.25 percent was used (for 1998). The following formula is used to calculate CFC:[7]

(Equipment Price × Average Value Factor × Cost of Money Rate)/No. of Hours

TABLE 2.
Hourly Depreciation Cost (CE/CRG/CAT)

	Method		
Equipment	CE	CRG*	CAT
Scraper	$49.11	$21.71	$31.78
Loader	$20.02	$13.63	$22.03
Truck	$44.08	$24.91	$13.22
Average	$37.74	$20.08	$22.34
Comparison (%)	100	53.2	59.2

Note: *The data for the CRG method comes from the relevant table in the source document.

TABLE 3.
Hourly CFC Rates (CE/CRG/CAT)

	Method		
Equipment	**CE**	**CRG***	**CAT**
Scraper	$13.71	$12.03	$13.14
Loader	$ 5.58	$ 5.43	$ 5.64
Truck	$13.16	$10.71	$12.16
Average	$10.82	$ 9.39	$10.31
Comparison (%)	100	86.8	95.3

Note: *The data for the CRG method comes from the relevant table in the source document.

TABLE 4.
Total Hourly Owning Costs (CE/CRG/CAT)

	Method		
Equipment	**CE**	**CRG**	**CAT**
Scraper	$62.82	$33.74	$44.92
Loader	$25.60	$19.06	$27.67
Truck	$57.24	$35.62	$25.38
Average	$48.55	$29.47	$32.66
Comparison (%)	100	61.3	67.3

where:

Average Value Factor = $((N-1)(1+S)+2)/2N$ (N is the number of years in the depreciation period and S is the salvage value expressed as a percentage of the equipment price)

Table 3 presents the hourly CFC rates for the three methods.

Overhaul & Overhead Costs. The CRG method correctly considers overhead costs as equipment costs but here the focus is on direct equipment costs. Therefore, this cost is not included in the calculations. Further, the cost of major overhauls is considered by many sources to be an operating cost rather than owning cost. (Overhaul costs, as reported in the CRG method, will be considered in the equipment repair costs.)

Total Owning Costs. Total owning costs can be calculated by summing up the cost components calculated so far (see Table 4). It is evident from Table 4 that there is consistency between the CAT and CRG methods. The only major difference between the CE estimate and the other two estimates is depreciation cost.

Calculation of Operating Costs: CE Versus CAT Versus CRG Methods

Fuel. The CE method uses a fuel factor, which when multiplied by the machine's horsepower, gives the equipment's hourly consumption. This fuel factor depends on the type of fuel (gasoline or diesel) and the load on the engine. Under average working conditions, this factor translates to approximately 0.05 gallons per horsepower per hour for diesel engines. The consumption multiplied by the cost of fuel per gallon gives the fuel cost per hour. The CAT method uses estimated hourly consumption for low, medium and high load factors. In the CRG method, fuel costs are calculated according to average load factors and the price of fuel per gallon.

For the purpose of this comparison a price of $1.11/gallon was used (as stipulated by the CRG method). Also, an average or medium load factor is assumed for calculating fuel consumption. Table 5 provides the hourly fuel costs.

Fuel/Oil/Grease. The CE method calculates the cost of filter, oil and grease (FOG) as a percentage of the hourly fuel cost, adjusted for labor costs. The CAT method gives the consumption of the machine and suggests that local prices must be used. Here, for the CAT calculations, the hourly consumption rates given in the *CAT Performance Handbook* are used.[8]

The CRG method calculates this cost as a function of the machine's price and the fuel cost. It includes the cost for oil, grease, filters, labor and lube truck.

Table 6 provides a comparison of the FOG costs.

Tires. The CE method calculates the hourly cost of tires as the cost of the new tires plus the

TABLE 5.
Hourly Fuel Cost (CE/CRG/CAT)

	Method		
Equipment	**CE**	**CRG***	**CAT**
Scraper	$15.48	$18.98	$16.65
Loader	$ 8.06	$ 7.86	$ 8.06
Truck	$15.15	$14.43	$15.15
Average	$12.90	$13.76	$13.29
Comparison (%)	100	106.7	103

Note: *The data for the CRG method comes from the relevant table in the source document.

TABLE 6.
Hourly Cost of FOG (CE/CRG/CAT)

	Method		
Equipment	**CE**	**CRG***	**CAT**
Scraper	$5.35	$7.28	$2.04
Loader	$3.69	$2.49	$1.18
Truck	$5.54	$6.61	$2.63
Average	$4.86	$5.46	$1.95
Comparison (%)	100	112.3	40.1

Note: *The data for the CRG method comes from the relevant table in the source document.

cost of one recapping (half of the original price) divided by the expected life of the equipment (maximum tire life) plus the life of the recapped tires (80 percent of the maximum tire life). The estimates of maximum tire life as provided by the CE method are: scraper — 5,000 hours; loader — 5,000 hours; and, truck — 7,000 hours.

The CE method uses different wear factors for drive, front and trailing axles. It calculates the price of tires at the time of equipment manufacture, modifying current prices using a tire cost index. The CE method is used to estimate the price of tires for calculating tire costs for both the CE and CAT methods.

The CAT method assumes a range for tires' life in average conditions with no additional life from recapping. It assumes that new tires run to destruction. There is no allowance for tire repair cost. For the CAT method, the tire life values used are: scraper — 1,500 to 3,000 hours (2,250 hours used here); loader — 1,000 to 3,000 hours (2,000 hours used here); and, truck — 2,000 to 4,000 hours (3,000 hours used here).

The CRG method includes the cost of repairs and replacement in tire cost. Average tire life (in hours) for the scraper is 2,700 hours, for the loader 3,000 hours and for the truck 3,000 hours.

Table 7 presents the estimated tire prices (in 1998) and Table 8 shows the hourly cost of tires.

Repairs. The CE method estimates the repair cost based on the total equipment value, deducting the cost of tires. It assumes a repair cost factor (RCF) that includes: labor cost for the direct repair of the equipment, repair parts and

TABLE 7.
Estimated Tire Prices (1998)

Equipment	**Price of Tires**
Scraper	$28,583
Loader	$11,170
Truck	$23,037

TABLE 8.
Hourly Cost of Tires (CE/CRG/CAT)

	Method		
Equipment	**CE**	**CRG***	**CAT**
Scraper	$12.75	$11.61	$12.70
Loader	$ 4.15	$ 5.60	$ 5.59
Truck	$ 7.18	$12.98	$ 7.68
Average	$ 8.03	$10.06	$ 8.66
Comparison (%)	100	125.4	107.8

Note: *The data for the CRG method comes from the relevant table in the source document.

TABLE 9.
Hourly Repair Costs (CE/CRG/CAT)

	Method				
		CRG*			
Equipment	**CE**	**Overhaul**	**Field Repair**	**Total**	**CAT**
Scraper	$38.70	$24.59	$24.13	$48.72	$15.73
Loader	$15.90	$ 5.23	$ 4.84	$10.07	$ 6.50
Truck	$31.34	$19.19	$10.75	$29.94	$ 8.50
Average	$28.65	$16.34		$29.58	$10.24
Comparison (%)	100			103.2	35.7

Note: *The data for the CRG method comes from the relevant table in the source document.

supplies (including sales taxes and freight charges) for all required repairs and major overhauls, service trucks, equipment and tools, and supporting repair facilities. The RCF is adjusted to current price levels using a cost index. Regional variations in the cost of labor and parts are taken into consideration by using a labor adjustment factor (LAF).

The CAT method estimates an average cost per hour for the first 10,000 hours and adjusts it for the additional useful life. The CAT method states that the use of these averages is questionable, especially for special attachments and when a machine is moving from job to job. It suggests these averages be used for comparative purposes and gross estimates only. CAT repair costs do not cover ground engaging tools, service truck mileage costs, servicing personnel travel costs, machine transportation, risk or insurance, or parts and labor price escalation.

TABLE 10.
Total Hourly Operating Costs (CE/CRG/CAT)

	Method		
Equipment	**CE**	**CRG**	**CAT**
Scraper	$72.28	$86.59	$47.12
Loader	$31.80	$26.02	$21.33
Truck	$59.21	$63.96	$33.96
Average	$54.43	$58.86	$34.14
Comparison (%)	100	108.1	62.7

Unlike the CE or CAT methods, the CRG method separates overhaul costs from field repair. Overhaul is considered an owning cost. Here, the sum of these items is used for the repair costs in this comparison to be compatible with the CE and CAT classifications. Table 9 shows a comparison of the hourly repair costs.

Ground Engagement Components (GECs). Since GECs are not included in the operating cost according to the CE and CAT methods, they are excluded from the calculation of the operating cost.

Total Operating Costs. Total operating costs can be calculated by summing up the cost components calculated so far (see Table 10). By reviewing these cost items, it can be seen that estimates of fuel costs are close for all three methods. FOG costs are close for the CE and CRG methods, while the CAT estimate is significantly lower. The difference in tire cost between the CRG and CE methods can be explained by different assumptions about the original price of tires and tire life. In fact, if the CRG method's tire multipliers are applied to adjust for tire life and price, the CE costs are reached. In repair costs, the difference between these methods is significant. The CAT method's estimate of repair cost is by far the lowest of the three methods (consistent with

TABLE 11.
Total Hourly Owning & Operating Costs (CE/CRG/CAT)

	Method		
Equipment	**CE**	**CRG**	**CAT**
Scraper	$135.10	$120.33	$92.04
Loader	$ 57.40	$ 45.08	$49.00
Truck	$116.45	$ 99.58	$59.34
Average	$102.98	$ 88.33	$66.79
Comparison (%)	100	85.8	64.9

TABLE 12.
Revised Hourly Rates for the CE Approach Using the CRG Method's Economic Life Values

Equipment	CE-Revised Total Hourly Costs
Scraper	$103.53
Loader	$ 57.41
Truck	$ 94.50
Average	$ 85.15

the lower estimate for FOG costs). It can be seen that the CAT method offers an optimistic view of equipment operating costs compared to other methods. The CRG and CE method estimates for repair costs are very close.

Total Owning & Operating Costs: CE Versus CAT Versus CRG Methods

Equipment hourly costs can be calculated by adding the owning and operating costs (see Table 11). For all practical purposes, the main cost parameter used in contract language is the total hourly rate. In the case of the CE and CRG methods, the total cost is relatively close on average (although there are significant differences in individual cost components). The CAT method estimate of the hourly cost is considerably lower than the other two methods—especially compared to CE, most of which can be explained by the CAT method's low estimate of repair costs. In fact, the main source of cost variations is due to the high estimate of depreciation in the CE method and the low value of repairs in the CAT method. If depreciation and repair costs are excluded from each method, the balance of cost is very close for all three.

The more recent publications and sources give equipment longer economic lives. (Even CE method analysts may be in the process of updating their database of economic lives.) At this point, while it might not be advisable to use longer lives to calculate operating costs, a more realistic approach would be to use the economic life suggested by the CRG method for estimating depreciation costs (since equipment lasts longer than what is suggested by the CE method economic life values). One important thing to remember is that this cost analysis is not for tax and depreciation accounting purposes; it is rather to give a realistic estimate of true owning and operating costs.

Using economic lives suggested by the CRG method (17,000 hours for the scraper, 11,000 hours for the loader and 16,800 hours for the truck) and using the CE approach, Table 12 provides a revised hourly owning and operating costs calculation. The average hourly cost calculated in Table 12 is about 10 percent lower than the estimate given in Table 11 for CE method costs and is very close to the CRG method estimate.

Calculation of Owning Costs: CE Versus RBB Methods

According to the RBB method, "the rates in this manual are intended as guidelines paralleling amounts an equipment owner should charge during rental or contractual periods to recover equipment-related costs." In this capacity, the RBB method is not designed for estimating internal costs to the owner of the equipment. Because of this, the RBB method rates are compared with CE rates (the CAT method is omitted since it is more suitable for estimating actual costs to the owner of equipment).

In the RBB method, the owning cost is divided into four elements: depreciation, major overhaul, CFC and indirect costs. As with the previous comparison, major overhaul is

TABLE 13.
Owning Costs Breakdown

Equipment	Depreciation	Major Overhaul	CFC	Indirect Costs
Conventional Scrapers	0.28	0.41	0.18	0.13
Articulated Loaders	0.40	0.25	0.22	0.13
Rear Dump Trucks	0.37	0.32	0.18	0.13

Note: From Ref. 5.

treated as a repair cost and is reported later. Also, indirect costs are not included in this comparison in order to be compatible with the CE method. The RBB method considers freight, discounts and sales taxes (incompatible with the CRG method because in CRG prices, sales taxes were not included). The original equipment prices provided in Table 1 are used in this analysis. Table 13 gives the breakdown of owning costs according to the RBB method. Ratios in Table 13 are used to calculate depreciation and CFC for the RBB method. Also, the owning costs for the RBB method are adjusted for 1998 using the appropriate rate adjustment table because RBB costs are reported for 1998, while the equipment prices are from 1994. Table 14 gives the hourly owning costs suggested by the RBB method.

Depreciation. Both methods use straight-line depreciation with an allowance for salvage value. The salvage value used in the CE method is 15 percent of the delivered price. The RBB method does not specify the salvage value used in the calculations. Note that the CRG and RBB methods are inconsistent in this respect; while CRG does not consider salvage, RBB does.

In Table 15 economic life hours (as described previously) are used in calculating costs. Since the CE method's hours are much smaller, its depreciation estimates are higher, accordingly.

CFC. Table 16 presents the CFC comparison between the RBB and CE methods.

Major Overhaul & Indirect Equipment Costs. Indirect equipment costs are not considered as part of owning costs by the CE method and are excluded for the purpose of comparison. Major overhaul costs reported in the RBB method would be included in the repair cost, consistent with the CE method.

Total Owning Costs. Table 17 gives total hourly owning costs.

Calculation of Operating Costs: CE Versus RBB Methods

The hourly operating costs in the RBB method are compatible with those published for the

TABLE 14.
Elements of Owning Costs According to the RBB Method

Equipment	Monthly	Monthly Hours	Hourly Owning (1998)	Hourly Owning (1994)*	Hourly Depreciation	Hourly Overhaul	Hourly CFC
Scraper	$17,630	176	$100.17	$96.86	$27.12	$39.71	$17.44
Loader	$ 6,555	176	$ 37.24	$36.13	$14.45	$ 9.03	$ 7.95
Truck	$11,940	176	$ 67.84	$65.81	$24.35	$21.06	$11.85

Note: *Adjustment factors for 1994 come from the RBB method rate adjustment table (Ref. 5).

TABLE 15.
Hourly Depreciation Cost (CE/RBB)

	Method	
Equipment	**CE**	**RBB**
Scraper	$44.12	$27.12
Loader	$17.99	$14.45
Truck	$39.63	$24.35
Average	$33.91	$21.97
Comparison (%)	100	64.8

TABLE 16.
Hourly Cost of CFC (CE/RBB)

	Method	
Equipment	**CE**	**RBB**
Scraper	$16.24	$17.44
Loader	$ 6.61	$ 7.95
Truck	$15.64	$11.85
Average	$12.83	$12.41
Comparison (%)	100	96.8

CRG method. For the CE method, the only difference is in repair costs because those costs are a function of the depreciable amount — in this comparison a 15 percent salvage value is assumed (as opposed to 0 percent in the previous comparison) to be compatible with the RBB method. For the cost of fuel, FOG and tires, refer to Tables 5, 6 and 8. Table 18 gives the repair costs for the CE and RBB methods. The reason repair costs here are different from the repair costs reported in Table 9, is that the RBB method's overhaul costs are included in the repair costs. RBB reports overhaul costs as part of owning costs. The CE and CAT methods consider overhaul as an operating cost (since major overhaul is a function of equipment operation and varies according to equipment usage, unlike owning costs that are mostly a function of ownership). The RBB method overhaul cost estimates are significantly higher than the CRG method's estimates. No reason for this difference is provided in either the RBB or CRG documents. A comparison of overhaul costs in Tables 9 and 18 shows that average overhaul costs in the RBB method is $23.27 per hour compared to $16.34 per hour for the CRG method. The field repair portion of the RBB method estimate is taken from Table 9.

Table 19 gives total hourly operating costs.

Total Owning & Operating Costs: CE Versus RBB Methods

Table 20 summarizes total hourly owning and operating costs. The average difference between the two methods is less than 3 percent. However, calculating the differences between individual machines shows that the difference (Δ) is also a function of machine type. The large difference in the scraper hourly rate can be attributed mainly to the large overhaul cost suggested by the RBB method. The total repair estimate for the scraper by the CE method (which includes overhaul costs) is 11,000 hours multiplied by $41.26 per hour, or $453,860. This value is 75 percent of the original investment in the machine. While this price may be rather low, it is certainly within the ballpark for average working conditions. For example, *Walker's Building Estimator's Reference Book* estimates that repair costs for a scraper in the same price range ($550,000) is $37.00 per hour.[11] This cost is close to the CE estimate. *Walker's* also estimates that repair budget during scraper's life is about 70 percent of the original price.

TABLE 17.
Hourly Owning Costs (CE/RBB)

	Method	
Equipment	**CE**	**RBB**
Scraper	$60.36	$44.56
Loader	$24.60	$22.40
Truck	$55.27	$36.20
Average	$46.74	$34.39
Comparison (%)	100	73.6

TABLE 18.
Hourly Repair Costs (CE/RBB)

	Method			
Equipment	**CE**	**Overhaul**	**RBB Field Repair***	**Total**
Scraper	$41.26	$39.71	$24.13	$63.84
Loader	$16.95	$ 9.03	$ 4.84	$13.87
Truck	$33.39	$21.06	$10.75	$31.81
Average	$30.53	$23.27		$36.51
Comparison (%)	100			119.6

Note: *These values are taken from Table 9.

TABLE 19.
Hourly Operating Costs (CE/RBB)

	Method			
Equipment	**CE**	**Overhaul***	**RBB Operating****	**Total**
Scraper	$74.84	$39.71	$62.07	$101.78
Loader	$32.85	$ 9.03	$21.20	$ 30.23
Truck	$61.26	$21.06	$44.10	$ 65.16
Average	$56.32			$ 65.72
Comparison (%)	100			116.7

Note: *Taken from Table 18. **These values are taken from Ref 5.

TABLE 20.
Hourly Owning & Operating Costs (CE/RBB)

	Method		
Equipment	**CE**	**RBB**	**Δ**
Scraper	$135.20	$146.34	8.2%
Loader	$ 57.45	$ 52.63	-8.4%
Truck	$116.53	$101.36	-13.0%
Average	$103.06	$100.11	-2.9%
Comparison (%)	100	97.1	

Summary & Conclusions

The first comparison presented here analyzed equipment costs for 1998 using three different methodologies (CE versus CRG versus CAT). All three methods produced consistent results with two important exceptions. First, the CAT method's estimates of equipment repair and FOG costs were significantly lower than either the CE or CRG method estimates. Although it would be difficult to verify the cause of this difference, it may be interpreted as the CAT method's optimistic view of its equipment repair costs. Second, the CE method's estimates of depreciation costs were much higher than ei-

ther the CAT or CRG method. This difference is mainly due to the rather short equipment life assumed by the CE method. Given new equipment trends, these values seem rather on the low side and can be adjusted upwards to reflect more realistic equipment lives. This adjustment will result in a reduction of total owning and operating costs. If the CRG method equipment lives were used for the comparison group, the CE method hourly rates would decrease by 17 percent ($102.98 per hour versus $85.15 per hour — compare Tables 11 and 12).

The CRG method recommends using its cost rates for the contractor's internal cost analysis. However, the contractor's internal cost analysis should be based on actual cost data from its equipment fleet. Industry averages do not serve well for this purpose. When a contractor is bidding competitively, the contractor has to know what would be the expected costs. No cost estimate from a manual is a substitute for actual historical data. If such data are not available, or if the contractor plans to set up a comprehensive cost compilation system for the fleet, then either the CAT, CE or CRG methodologies can be used. The contractor can then enter the actual data (with respect to fuel consumption, repair, etc.) in the system as these costs become available. For such purposes, the CE or CAT method is favorable because both provide all the background information and formulae. The CRG method provides costs and the general basis for cost estimating without specifying all the assumptions. In other words, it is not a completely open and transparent system.

The second comparison (CE versus RBB methods) was done to develop a basis for equipment rates in contract negotiation and the pricing of changes. The CE method's assumptions were adjusted so that it could be compared with RBB rates. The results of the cost analyses using both methods are very close. There are, however, two important concerns. First, it is not quite clear why there is such a large difference between CRG and RBB rates. As an example, major overhaul costs in the RBB method for the same equipment are much higher than in the CRG method. The CE method's results are consistent with the results of the first comparison. The main difference being that in the second analysis, a 15 percent salvage value was assumed; this assumption results in an increase in CFC and a decrease in depreciation costs. Also, sales taxes were included in the price of equipment, which increases owning costs. Both of these changes were made to replicate the RBB method assumptions. The CE method's flexibility — because its mathematical model is reported in full detail — lets the user change assumptions and tailor it to meet more specific needs. Although both the CE and RBB rates are very close, they may be reduced to reflect the CE method's overestimated depreciation costs. The effect of increasing equipment life hours for the CE approach, based on the values suggested by CRG, is to lower the CE method's average hourly rate by about 17 percent (compare the rate given in Table 12 with the CE rates in Tables 11 and 20). So, for the purpose of contract negotiations or changes' pricing, either RBB or CE rates can be used and then be reduced by a predetermined factor. For the equipment group studied here, a reduction range of 15 to 20 percent seems justified (more or less comparable with MHD's *Standard Specifications*, where MHD stipulates that "equipment operating rates shall be reduced by 20 percent to eliminate duplicate and excessive costs"[4]).

ACKNOWLEDGMENTS — *The authors would like to thank the anonymous reviewers for their valuable and constructive comments. Thanks are also due to Don Miller for his thoughtful review of this paper prior to submittal.*

NOTE — *The specific equipment used for the cost comparisons was: scraper, CAT 631E Series II; wheel-type front-end loader, CAT 966F Series II; and off-highway truck, CAT 773B. For more information about these models please refer to the* Caterpillar Performance Handbook.[8]

GEORGE PAPATHANASIOU *is a Civil Engineer with Gnomon General Contractors in Athens, Greece. He holds a B.S. in Civil Engineering from the National Technical University of Athens and an M.S. in Construction Management from Northeastern University.*

ALI TOURAN *is Associate Professor of Civil and Environmental Engineering and the coordinator of the Construction Management Program at Northeastern University. He holds M.S. and Ph.D. degrees in Civil Engineering from Stanford University. His areas of expertise are construction cost and productivity analysis, risk assessment and project management. His recent research has been in simulation modeling, analysis of risk in turn-key capital projects and risk modeling in transportation systems.*

REFERENCES

1. Nunnally, S.W., *Managing Construction Equipment,* 2nd ed., Prentice-Hall, Inc., Upper Saddle River, NJ, 2000.

2. Peurifoy, R.L., Ledbetter, W.B., & Schexnayder, C. J., *Construction Planning, Equipment and Methods,* 5th ed., McGraw-Hill, Inc. New York, NY, 1996.

3. Day, D.A., & Benjamin, N.B.H., *Construction Equipment Guide,* 2nd ed., Wiley, Inc., New York, NY, 1991.

4. Massachusetts Highway Department, *Standard Specifications for Highways and Bridges,* 1995.

5. *The Rental Rate Blue Book,* Primedia Information, Inc., San Jose, Calif., 1998.

6. *Cost Reference Guide for Construction Equipment,* Primedia Information, Inc., San Jose, Calif., 1998.

7. *Construction Equipment Ownership and Operating Expense Schedule,* U.S. Army Corp of Engineers, Washington, D.C., 1997.

8. *Caterpillar Performance Handbook,* 29th ed., Caterpillar, Inc., Peoria, Ill., 1998.

9. Douglas, J., "Equipment Costs by Current Methods," *Journal of the Construction Division, ASCE,* Vol. 104, No. 2, 1978.

10. Church, H.K., *Excavation Handbook,* McGraw-Hill, Inc., New York, NY, 1981.

11. *Walker's Building Estimator's Reference Guide,* 25th ed., Frank R. Walker Co., Chicago, Ill., 1995.