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# Machine Cost Analysis Using the Traditional Machine-Rate Method and CHARGEOUT!

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*“The aim in developing a machine rate should be to arrive at a figure that, as nearly as possible, represents the cost of the work done under the operating conditions encountered and the accounting system in force.”*

- Donald Maxwell Matthews, 1942. p.54  
*Cost control in the logging industry*  
McGraw-Hill Book Company, Inc.  
New York.

## ABSTRACT

Forestry operations require ever more use of expensive capital equipment. Mechanization is frequently necessary to perform cost-effective and safe operations. Increased capital should mean more sophisticated capital costing methodologies. However the machine rate method, which is the costing methodology most frequently used, dates back to 1942.

CHARGEOUT!, a recently introduced discounted cash flow methodology is compared with seven machine rate methods using data representing a skidder. I found that use of machine rate methods can lead to either over or under-estimates of machine owning and operating costs, depending on the machine rate model used. CHARGEOUT!'s calculated rate will provide a user-specified rate of return.

The differences between the results calculated by the machine rate methods occur because of different implicit assumptions used within the models' formulas. The differences between CHARGEOUT! and the machine rate models occur largely because of the inability of the machine rate models to properly incorporate the time value of money.

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Whereas CHARGEOUT! can be sufficiently constrained so as to more-or-less replicate a machine rate calculation, doing so sacrifices much of CHARGEOUT!'s power and flexibility. Machine rate models cannot be configured to replicate CHARGEOUT!'s calculations. Machine rate models cannot be configured to calculate cash flows, allow for uneven costs or machine hours, incorporate loans that have a different life than the expected machine life, incorporate financing, or perform an after tax analysis. Machine rate models cannot calculate a costing rate that will provide a specified rate of return. CHARGEOUT! is a capital costing model that overcomes these limitations.

## INTRODUCTION

Matthews (1942) published the first methodology to determine how much to charge for logging equipment. This "machine rate" methodology was widely adopted and is still the most common methodology for determining machine charge-out rates for timber harvest operations.

Miyata (1980) produced a machine rate methodology easily adapted for hand calculators. Brinker, et al. (2002) produced a version for spreadsheets. The Caterpillar Tractor Company (2001) and Fight, et al. (2003) use similar methodologies. The USDA Forest Service Forest Operations Research Unit (n.d.) has an on-line version that incorporates a capital cost recovery formula into the capital cost calculation. The FAO's (1992) version is described with examples from machines to oxen. It is incorporated into PACE, a computer program developed to calculate machine rates, road construction costs, and harvesting costs (FAO, n.d.). Virginia Tech (n.d.) also has an on-line edition.

The machine rate method does have advantages. It is simple and produces a single costing rate. It does make sense to have one rate over a machine's life rather than have it change, depending on the machine's age. Matthews (1942, p.55) noted:

*"The uniform charge thus developed should be adhered to throughout the life of the machine, regardless of its age. ...It would be confusing to change continually the rate charged against a job for a given piece of equipment or to make different charges for pieces of equipment of the same size or type of different ages."*

The traditional machine rate methodology provides charge-out rates out to two (or more) decimal places. However, the methodology can provide answers that differ by dollars. Miyata and Steinhilb (1981, p.1) noted:

*"Choosing the right cost analysis method has been difficult because of the large number of methods... If an inappropriate method is chosen or incorrect information is used in the calculations, the erroneous results may lead to poor decisions regarding the total logging operation."*

Whereas their observation was astute, Miyata and Steinhilb (1981) did not provide guidelines for selecting an appropriate costing method.

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Machine rate models have a number of problems. All machine rate models are based on cost averages. They do not consider the time value of money, do not take into consideration the timing of costs, and are limited with respect to costs that they incorporate. The only rate they calculate is pre-finance and pre-tax. Machine rate models do not do a good job of accounting for financing costs. While the machine rate models can produce cost estimates for new machines, the models are difficult to adapt for used equipment, which may have partially worn replaceable parts. Machine rate models cannot do a good job of incorporating inflation and cannot be used to calculate the rate of return on investment.

Discounted cash flow methods for evaluating forest harvest equipment are not new. Butler and Dykstra (1981), and Tufts and Mills (1982) proposed discounted cash flow methodologies to evaluate machine replacement decisions.

While Butler and Dykstra (1981) propose a practical method to estimate maintenance and repairs costs, they calculate a simple average of the annual net present values, which ignores the time value of money. Tufts and Mills (1982) deal appropriately with the time value of money. However, while they propose the concept of an annual equivalent cost, they do not carry the concept through to calculating a machine charge-out rate.

Burgess and Cubbage (1989) proposed a means of evaluating yearly machine costs using cash flows on a before- and after tax basis using Lotus spreadsheet templates. They also provided comparisons with machine rate methods. However, their methodology produces a different cost rate for each year of the machine's life, which they then average to come up with a comparison with the machine rate. As with traditional machine rate models, this simple averaging of costs over time also ignores the time value of money, unless the discount rate is 0%.

Bilek (2007) introduced CHARGEOUT!, an improved model for determining the charge-out rate for a piece of capital equipment based on discounted cash flows. Like the machine rate models, CHARGEOUT! produces a single rate. Unlike machine rate models, CHARGEOUT!'s rate produces a specified rate of return. CHARGEOUT! offers many additional advantages over the machine rate methods. CHARGEOUT! incorporates options allowing:

- different depreciation rates;
  - an economic life that can be different than the depreciable life;
  - variable operating hours over time;
  - variable repairs and maintenance schedules;
  - a loan financing term that can be different than the machine's life;
  - automatic inflation adjustments;
  - a variable tire replacement schedule that depends on productive machine hours;
  - a variable major rebuild schedule;
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- the ability to calculate the rate of return on investment if given a charge-out rate;
- the ability to conduct the cost analysis before tax and finance, before tax, or after tax.

Bilek (2008) introduced an improved version of the CHARGEOUT! model that compared CHARGEOUT!'s results with those of four machine rate models. This paper includes comparisons with those models, in addition to three others.

## OBJECTIVE

The overall purpose of this paper is to compare CHARGEOUT!'s results with those of traditional machine rate calculations. As a part of this comparison, different machine rate calculations are also compared and contrasted.

## METHODS

The analysis was conducted in six stages:

1. Select machine rate models to compare.
2. Enter a common set of input cost and operating data.
3. Place the machine rate models into a common format and adjust their calculations so that they are comparable with each other.
4. Constrain the CHARGEOUT!! model so that its calculation is comparable with a machine rate calculation.
5. Reformulate CHARGEOUT!! so that the machine rate models run automatically within it.
6. Run the models, then use the hourly rates as calculated in the machine rate models as inputs into CHARGEOUT!! to calculate cash flows and financial summary data and to compare with CHARGEOUT!'s break-even hourly rate calculation.

**First:** Seven readily available machine rate models were selected to compare with CHARGEOUT!.

- “MR Calculator” – a USDA Forest Service model from the Forest Operations Research Unit.  
Available from: [www.srs.fs.usda.gov/forestops/downloads/MRCalculator.xls](http://www.srs.fs.usda.gov/forestops/downloads/MRCalculator.xls)
  - Miyata (1980), Appendix B;
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- Brinker, Kinard, Rummer, and Lanford (2002), Table 2;<sup>2</sup>
- “Machine Costing Spreadsheet,” a machine rate model from Virginia Polytechnic Institute.  
Available from: <http://www.cnr.vt.edu/harvestsystems/Costing.htm>.
- FAO, 1992. Cost control in forest harvesting and road construction. FAO Forestry Paper 99. Rome. Especially Chapter 3: “Calculation of Machine Rates.”  
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- Matthews, Donald Maxwell. 1942. Cost control in the logging industry. New York: McGraw-Hill Book Company, Inc. 374 pp. Especially pp. 53-61.
- Caterpillar Tractor Company. Caterpillar Performance Handbook. Edition 32. October. Peoria, Illinois. Especially Chapter 20: “Estimating Owning and Operating Costs.”

**Second:** to compare and contrast the models, a common set of data was used. The data represent the costs of a logging skidder, but are not specific for any one brand or model. The following assumptions were used:

• Purchase price (including tires)	\$200,000
• Salvage percentage of total purchase	25%
• Economic life	5 years
• Annual interest rate	10%
• Tire cost	\$9,000
• Tire life	4,000 productive machine hours
• Tire installation cost factor	15%
• Insurance and <i>ad valorem</i> tax (% of average capital invested)	4%
• Fuel consumption (gal/hp/hour)	0.03
• Fuel cost (off-highway)	\$2.75/gallon
• Horsepower	180
• Oil and Lubrication	40% of fuel cost
• Repair and maintenance	100% of straight-line depreciation
• Other consumables	\$1,140
• Other consumables life	300 productive hours
• Scheduled machine hours/year	2,000
• Utilization rate	85%

**Third:** to put all the machine rate models in a common format in Microsoft Excel, modifications needed to be made in the machine rate models to make them comparable

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<sup>2</sup> A version of Brinker, et al.’s model was initially available to download. However, it contained a number of mathematical errors. The authors were contacted and the downloadable version is no longer available. The version that was evaluated in this paper was constructed directly from Table 2 in their circular.

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with each other. For example, not all the models incorporated a tire installation factor on top of the tire cost. Columns were added to show cost per scheduled machine hour (SMH) and per productive machine hour (PMH) for all models. A variable to account for miscellaneous operating costs was incorporated into all the models. The capital cost factor was modified to account for taxes if the after tax option was chosen. In addition, mathematical corrections to some of the machine rate models had to be made.

**Fourth:** a new version of CHARGEOUT! was constructed for this analysis.

**Fifth:** a scenario was constructed so that CHARGEOUT!'s cost calculation would not be considering any information that the machine rate models could not incorporate.

CHARGEOUT!'s constraints follow:

- CHARGEOUT!'s cost calculation was set to "Before tax and finance."
- New equipment was assumed (no major overhaul, tire life and cost equal to new tires).
- Loan was ignored.
- Only one compounding period per year for interest charges.
- Inflation was set at 0%.
- State and federal income taxes were ignored.
- Tax loss treatment variable was ignored.
- IRS depreciation rates were ignored.
- Section 179 deduction was ignored.
- Special first-year depreciation allowance was set at 0%
- Ad valorem (property) tax valuation basis was set as average capital invested.
- Maintenance expenses were included with repairs expenses and the maintenance expense variable was set to return \$0.
- Repairs expenses were "Estimated" as a constant percentage of straight-line depreciation.
- Engine oil was based on "Fuel cost."
- Other variable costs per scheduled hour were \$0.
- Major equipment rebuild cost was set at \$0.
- The machine would be scheduled for a constant 2,000 hours/year for five years at a constant utilization rate of 85%.
- All cost and revenue sensitivity factors were set at 100%

**Sixth:** the hourly rates that were calculated by CHARGEOUT! and the machine rate models were then put into CHARGEOUT! to use its discounted cash flow features to determine the net present values and internal rates of return that would be earned if those machine rates were charged. The results were compared and contrasted.

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## RESULTS

The results of the calculations in terms of charge-out rates per scheduled machine hour are shown below (Table 1).

**Table 1. Summary before tax and finance machine costs per scheduled machine hour (\$/SMH) under CHARGEOUT! and seven machine rate models for sample skidder data**

	ChargeOut!	----- Machine rate models -----					
		MR Calculator	Miyata (1980)	Virginia Tech	Matthews (1942)	Brinker, et al. and FAO (1992)	Caterpillar (2001)
Ownership and other fixed costs	\$ 25.08	\$ 25.10	\$23.52	\$ 24.80	\$ 23.39	\$ 24.80	\$ 22.37
Variable operating costs	36.82	35.28	37.20	35.85	37.07	38.10	38.10
Total \$/SMH	\$ 61.90	\$ 60.38	\$60.72	\$ 60.65	\$ 60.45	\$ 62.90	\$ 60.47

Points to note:

- If the actual data conform to the assumptions built into the machine rate method (e.g., average costs, constant operating hours, constant repairs and maintenance costs, etc.), then the machine rate methods all provide approximations of hourly costs that are not substantially different than CHARGEOUT!'s rate.
- Although the rates are close to the CHARGEOUT! rate, none of the machine rate methods equal the rate determined using the discounted cash flows.
- Some of the machine rates are shown in red to highlight charge-out rates from methods that would return less than the desired rate of return on investment.
- Brinker, et al. and the FAO (1992) returned the same charge-out rates.

The net present values and internal rates of return that would be earned if the modeled rates were charged are shown below (Table 2):

**Table 2. Summary before tax and finance net present values and internal rates of return under CHARGEOUT! and seven machine rate models for sample skidder data**

	ChargeOut!	----- Machine rate models -----					
		MR Calculator	Miyata (1980)	Virginia Tech	Matthews (1942)	Brinker, et al. and FAO (1992)	Caterpillar (2001)
NPV @ 10% nominal	\$ -	\$ (11,229)	\$ (8,623)	\$ (9,169)	\$ (10,670)	\$ 7,890	\$ (10,571)
IRR	10.0%	7.8%	8.3%	8.2%	7.9%	11.6%	7.9%

As expected, CHARGEOUT!'s net present value was \$0 and the internal rate of return was exactly equal to the required rate of return. That was not the case with any of the machine rate models.

If the problem is varied slightly...

- Financial gearing is 40% with a 4-year fixed-rate loan at 7.00%;
- Federal income taxes are 35% and state income taxes are 10% with a flow-through tax treatment;
- Double-declining balance depreciation is used with a Section 179 write-off of \$250,000;
- The contractor is subject to self-employment tax;
- Inflation is 3%;
- The salvage value and charge-out rate are both indexed to inflation;
- The desired charge-out rate is one that will make the after tax net present value equal to \$0.

...these variables cannot be incorporated into the machine rate calculations. Under these conditions, the break-even charge-out rate, which is the rate that will produce an after tax net present value equal to \$0, drops to \$58.01.

Increasing maintenance and repairs later in the machine's life, one-off overhaul costs, etc. would also impact the break-even rate but cannot be incorporated into any machine rate method.

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## CONCLUSIONS

- The machine rate methods all provide reasonable approximations of the cost of running new equipment. However, their rate calculations will not return the specified return on investment. In addition, they are quite limited. They do not incorporate a number of important costs. They are not easily modified to cost out used equipment, and they cannot incorporate factors such as variable operating hours or non-constant maintenance and repairs costs. The machine rate method's use of average costs can lead to misleading answers if those costs represent items that make up a large percentage of the total costs.
- Reliance on the machine rate method can lead to either over- or underestimation of actual machine owning and operating costs.
- CHARGEOUT! is a flexible machine costing methodology that incorporates variable cost schedules, variable operating hours, inflation, financing, and taxes in a discounted cash flow framework that returns a single charge-out rate that will return exactly the specified rate of return. Alternatively, the framework can be used to determine the net present value and internal rate of return that will be earned on any specified charge-out rate.

## DISCUSSION

The machine rate method was an innovation in 1942 when Matthews published the method for approximating machine costs, and although there have been advancements, the methodology is still an approximation. However, machine rate methodologies are very limited in terms of the data, types of costs, and types of problems that they can incorporate. In addition, incorporating the rates determined by machine rate models into job bids could lead to over- or underestimates of costs, if the objective is to achieve at least a minimum specified rate of return. CHARGEOUT! provides the power and flexibility needed to calculate accurate machine costs.

If one complicates the costing problem by incorporating inflation, using IRS-approved depreciation rates under the modified accelerated cost recovery system (MACRS) and Section 179 write-offs, purchasing a used piece of equipment with partially used tires and an expected major engine rebuild say in year 2, with a loan that is shorter than the machine's expected economic life, then the machine rate models cannot handle the variables. CHARGEOUT! easily incorporates these complexities. In addition, CHARGEOUT! handles variable scheduled operating hours, productivity rates, and uneven maintenance, and repairs costs.

Machine rate models can easily provide misleading answers to "What-if" questions. For example, if annual scheduled operating hours increase, one would expect maintenance and repairs costs to increase. However, several machine rate models will show repairs and maintenance costs as a set percentage of annual depreciation so as the operating

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hours increase, the fixed cost per operating hour decreases in these models. Such modeled decreases in maintenance and repairs costs because of increases in operating hours are not likely to be reflected in actual practice.

Although it may not be possible or practical to charge the rates calculated by CHARGEOUT!, the information provided by this model should enable contractors to make better and more informed bids and should help with capital equipment utilization and acquisition decisions.

When Matthews published his machine rate method, a new Caterpillar D6 logging tractor cost \$4,100 (June 1939 dollars), which would be worth \$62,742 in today's dollars. Today, a used 2008 Caterpillar D6K-XL is being offered at \$170,000 (clevelandbrothers.com, n.d.). Logging equipment is expensive. With automated systems, it is becoming more capital intensive. And skyline and high-lead equipment is even more costly. As capital equipment becomes a larger portion of a contractor's total expenses, the accuracy of capital equipment costing models becomes more critical to the operation's total success or failure.

While CHARGEOUT! is more powerful and flexible and its results are superior to those of machine rate models, any financial model is no more than an aid to decision-making, and many other factors (e.g. supply and demand in the marketplace, desire to provide service to a long-term client, the difficulty of the terrain, etc.) will affect a contractor's financial decisions. And while CHARGEOUT! does not guarantee success, it does provide a better benchmark on which to base capital equipment costing decisions.

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