United States
Department of
Agriculture

Forest Service

Forest
Products
Laboratory

General
Technical
Report
FPL–GTR–178

ChargeOut! Discounted Cash Flow Compared with Traditional Machine-Rate Analysis

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Abstract

ChargeOut!, a discounted cash-flow methodology in spreadsheet format for analyzing machine costs, is compared with traditional machine-rate methodologies. Four machine-rate models are compared and a common data set representative of logging skidders' costs is used to illustrate the differences between ChargeOut! and the machine-rate methods.

The study found that the machine-rate methodologies were not standardized and the methodologies had differences in accounting for ownership, other fixed costs, and variable operating costs. The result was that two of the machine-rate models calculated hourly rates that were higher than needed to provide the specified return on capital, and two of the machine-rate models calculated hourly rates that were insufficient to provide the specified return. In contrast, ChargeOut!'s break-even rate returned exactly the specified return.

Differences between the results calculated by the machine-rate methods occur because of different implicit assumptions used within the models' formulas, largely because the machine-rate models are unable to properly incorporate the time value of money.

Whereas ChargeOut! can be sufficiently constrained to approximately 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, or perform an after-tax analysis. ChargeOut! can do all of these.

Keywords: Machine, charge-out rate, break-even analysis, capital equipment costing, machine rate, depreciation, inflation, discounted cash flow analysis

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Conversion Table

To convert from	To	Multiply by
Gallons	liters	3.785
Horsepower	kilowatts	0.746

January 2009

Bilek, E.M. Ted. 2008. ChargeOut! Discounted Cash Flow Compared With Traditional Machine-Rate Analysis. General Technical Report FPL-GTR-178. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 15 p.

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ChargeOut! Discounted Cash Flow Compared with Traditional Machine-Rate Analysis

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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)

Introduction

Machine-Rate Methodology

A methodology for determining how much to charge for machine usage was presented by Matthews (1942). This "machine rate" methodology was widely adopted and is still the most common methodology for determining machine charge-out rates for timber harvest operations. A variation on Matthews's machine-rate methodology easily adapted for hand calculators was presented by Miyata (1980). An updated version adaptable to spreadsheets is presented by Brinker and others (2002). A similar costing methodology is incorporated into Caterpillar Tractor Company (2001) and into Fight and others (2003). The Food and Agriculture Organization of the United Nations (FAO) (1992) has a detailed description of the machine-rate method with examples from machines to oxen.

Online versions of machine-rate calculations are available from the U.S. Forest Service (www.srs.fs.usda.gov/forestops/downloads/MRCalculator.xls) and from Virginia Tech (www.cnr.vt.edu/harvestingsystems/Costing.htm, Machine Rate Spreadsheet). A version of the machine-rate methodology is incorporated into PACE (Production and Cost Evaluation), a computer program developed by the FAO to calculate machine rates, road construction costs, and harvesting costs (www.fao.org/docrep/T0579E/t0579e08.htm).

Miyata (1980) notes,

> *"The advantage of this [machine rate] method is simplicity. This method is generally used for estimating equipment cost for comparison with other equipment, or with the production cost (dollars per unit of output) of alternative equipment."* (p. 7)

Another advantage of the machine-rate methodology is that it produces a single rate, rather than multiple rates over a machine's life. It makes sense to charge one rate over a machine's life, rather than have it change, depending on the machine's age. According to Matthews (1942),

> *"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."* (p. 55)

Although the traditional machine-rate methodology provides charge-out rates out to two (or more) decimal places, the methodology can provide answers that differ by dollars.

All machine-rate methodologies provide estimations of machine costs. However, most provide conflicting charge-out rates. Miyata and Steinhilb (1981) noted,

> *"Choosing the right cost analysis method has been difficult because of the large number of methods—an incomplete literature review found 30 different ways of calculating machine rates and logging costs—and a lack of uniformity in defining the components used in the 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."* (p. 1)

Incorrect information can be a problem no matter how good the calculation methodology. If incorrect or inappropriate costs are put into a costing model, good results cannot be expected to come out of it. But what is an appropriate method?

In their introduction to machine rates, Brinker and others (1992) noted the major weaknesses of the machine-rate method:

> *"The use of the machine rate requires caution on the part of the manager. Since the result of the machine rate calculation is an average cost, actual cash expenditures for ownership costs will be greater than estimated costs early in the machine's life, and will be less than estimated in later years. Actual operating costs have the opposite characteristic over time when compared to the estimated cost. It also follows that complete system costs determined by the machine rate must also be interpreted carefully, since it is most likely that the*

> *machines in the system will not all be the same age. Additionally the machine rate does not consider after-tax cash flow, which may estimate a greater cost than is actually realized. Machine rate costs are also affected by several other basic assumptions, such as the total hours of machine life; lack of consideration of the time value of money; no discounting of future dollar values; the cost of interest, insurance, and taxes, which are calculated as a percentage of average fixed value rather than actual costs; and maintenance and repair, which may be calculated as a percentage of depreciation rather than a predicted maintenance cost if accurate maintenance records are not maintained."* (p. 4–5)

Miyata (1980) illustrates the possibility of changing costs over the equipment life. He includes examples of declining balance and sum-of-the-years' digits depreciation in addition to straight-line depreciation. In addition, he shows an alternative method of calculating average capital invested that varies annually based on the equipment's beginning and ending depreciated values each year. Despite this, he does not show or even describe how one might incorporate these changing costs into his machine cost calculation. In a follow-up paper (Miyata and Steinhilb 1981), annual variations in costs are not considered.

Machine-rate equipment costing methods do not allow differences in yearly operating hours or repairs and maintenance schedules. They do not account properly for irregular cash flows required to replace machine components, such as tires, that wear out periodically but not annually. Machine-rate models do not account for differences in allowable depreciation schedules. Machine-rate models do not allow for inflation.

Machine-rate costing models are reasonably straightforward to compute and can generally be performed on a calculator. Whereas they provide an approximate before-tax charge-out rate, they do not consider taxes. They do not calculate what a contractor needs to charge to make a specified after-tax rate of return.

Machine-rate costing models do not consider cash flows. They do not provide answers that relate to financial measures such as net present value or internal rate of return. The way they are adjusted for interest on borrowed money and capital is just an approximation that does not correctly reflect the time value of money.

Most machine-rate models base their interest charges on a figure called average capital invested (ACI), which is sometimes called average annual investment (AAI) or average value of yearly investment (AYI). The ACI is calculated using

$$\text{ACI} = \frac{(\text{Purchase} - \text{Salvage})}{(2 \times \text{Economic life})} + \text{Salvage} \qquad (1)$$

The ACI formula calculates an average that represents neither capital investment, nor the capital on which interest must be earned. Insurance or property taxes could possibly be based on ACI. For this reason, calculating ACI may be desirable. However, ACI is not accurate to use in determining the required dollar return on invested capital.

Machine-rate models cannot be used to evaluate the impact of changing costs or charge-out rates over a machine's life, nor can they be used for financial planning purposes. They do not give any indication of cash flows, when outflows are due, or when inflows should be planned.

Discounted cash-flow methods for evaluating forest harvest equipment are not new. Discounted cash-flow approaches for evaluating machine replacement decisions were proposed by Butler and Dykstra (1981) and Tufts and Mills (1982).

In their paper, Butler and Dykstra (1981) propose a practical method to estimate maintenance and repair costs. However, 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 and propose the concept of an annual equivalent cost but 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 (IBM Corporation, Armonk, New York) spreadsheet templates. They also provided comparisons with machine-rate methods.

The major limitation of the Burgess and Cubbage (1989) method is that it produces a different cost rate for each year of the machine's life. It then averages these cash flows to arrive at a comparison with the machine rate. Two problems are inherent with this approach: (1) simply averaging these yearly cash flows ignores the theoretical concept of discounting and the time value of money, and (2) in practice, a large forest owner is unlikely to be sympathetic to paying different rates for the same job depending on the equipment age.

ChargeOut! is an improved model for determining the charge-out rate for a piece of capital equipment based on discounted cash flows (Bilek 2007). It overcomes the theoretical limitations of machine-rate models in that it appropriately incorporates the time value of money. In addition, it incorporates many features not included in machine-rate models (see Appendix I). Whereas ChargeOut!'s results are theoretically superior to those of machine-rate models, the models' results have not previously been compared directly.

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. Modify 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 Stage—Select Machine-Rate Models to Compare

Four machine-rate models were selected to compare with ChargeOut!. The machine-rate models were selected on the basis of their ready availability. Four were used because they all have variations in the way they handle costs resulting in different hourly costs.

- "MR Calculator"—a U.S. Forest Service model (available from www.srs.fs.usda.gov/forestops/downloads/MRCalculator.xls)
- Miyata (1980), appendix B
- Brinker and others (2002), table 2—A version of the Brinker and others (2002) model was initially available to download. However, it had a number of mathematical problems. I contacted the authors 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.
- Machine Costing Spreadsheet, a machine-rate model from Virginia Polytechnic Institute, referred to in this paper as the Virginia Tech model (available from: http://www.cnr.vt.edu/harvestingsystems/Costing.htm)

Second Stage—Enter a Common Set of Input Cost and Operating Data

To compare and contrast the models, a common set of data was used. The data represent typical costs for a logging skidder but are not specific to 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 *ad valorem* tax (percentage of average capital invested) 4%
- Fuel consumption (gal/hp/h) 0.03
- Fuel cost (off-highway) $2.75/gallon
- Horsepower 180
- Oil and lubrication 40% of fuel cost
- Repairs 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%

Although these data are considered to be representative, persons considering purchasing a skidder or bidding for a job are encouraged to review the original ChargeOut! documentation (Bilek 2007) and enter their own data in either the original or the revised downloadable version of ChargeOut! (available at no charge from www.fpl.fs.fed.us/documnts/fplgtr/fpl_gtr178_chargeout.xls).

Third Stage—Place the Machine-Rate Models into a Common Format

To put all the machine-rate models in a common format in Microsoft Excel (Microsoft Corp., Redmond, Washington), I needed to make modifications in the machine-rate models to make them comparable with each other. The modifications made by machine-rate method follow.

MR Calculator

- Tire cost was increased by 15% to account for tire installation, as provided in Miyata (1980) and Miyata and Steinhilb (1981).
- A variable for *ad valorem* (property) taxes was included to make the calculation compatible with Miyata (1980) and Miyata and Steinhilb (1981), although for the sample data, this variable was set at 0.
- Columns were added to show all the costs per year, per scheduled machine hour (SMH), and per productive machine hour (PMH). The ownership costs per year and per productive machine hour were calculated from the costs per scheduled machine hour. The operating costs per year and per scheduled machine hour were calculated from the costs per productive machine hour.

- The variables for labor cost and labor fringe benefits were ignored for three reasons:
  - The focus of this paper is the machine-rate calculation, not the labor rate or a comprehensive operating cost rate.
  - Not all the machine-rate models include a labor rate.
  - The labor rate is a sunk cost in this evaluation (sunk costs have been incurred and cannot be recovered to any significant degree). This is because the labor costs should be identical across all the models.

Miyata (1980)

- The variable for labor cost was ignored.
- Although Miyata's model specified the salvage value as a percentage of the purchase price without tires, the salvage value has been re-specified as a percentage of the purchase with tires to make the salvage calculation compatible with Brinker and others (2002), who do not include tire values in their model. If this adjustment were not made, the salvage value percentage would have to be changed to force the salvage estimate to be $50,000.
- A variable for miscellaneous operating costs was added to account for the possibility of items such as a saw bar as provided in MR Calculator.
- Interest cost was removed from insurance and taxes to separate capital charges from other fixed costs.
- Columns were added to show all the costs per year, per SMH and PMH. Note that in his original formulation, Miyata calculates fixed costs on an annual basis and operating costs per productive machine hour. This means that these hourly costs cannot be added together without adjusting them.
- The ownership costs per scheduled machine hour and per productive machine hour were calculated from the costs per year. The operating costs per year and per scheduled machine hour were calculated from the costs per productive machine hour.

Brinker and Others (2002)

Variables for tire cost, a tire installation factor, and tire life were added to make the calculation compatible with MR Calculator, Miyata (1980), Miyata and Steinhilb (1981), and the Virginia Tech models.

- A variable for miscellaneous operating costs was added to account for the possibility of items such as a saw bar as provided in MR Calculator.
- Columns were added to show all the costs per year, per SMH and PMH. Brinker and others (2002) calculate ownership costs on a yearly basis and operating costs per productive machine hour.
- The individual components in the ownership costs per SMH and per PMH were calculated from the costs per year. The individual components in the operating costs per year and per scheduled machine hour were calculated from the costs per productive machine hour.

Virginia Tech

- The variable for labor cost was ignored.
- A variable for miscellaneous operating costs was added to account for the possibility of items such as a saw bar as provided in MR Calculator.
- Interest cost was removed from insurance and taxes to separate capital costs from other fixed costs.
- Columns were added to show all the costs per year, per SMH and PMH. The Virginia Tech model calculates fixed costs per SMH and variable costs PMH.
- The individual components in the ownership costs per year and per PMH were calculated from the costs per SMH. The individual components in the operating costs per year and per SMH were calculated from the costs per PMH.

Fourth Stage—Modify the ChargeOut! Model

A new version of ChargeOut! was constructed for this analysis. Version 1.2MR has a number of changes compared with the previous version. Some are small changes and error corrections that do not make a significant difference in the calculations. Others are new features that make the model even more powerful and flexible.

The differences between the latest release and the previous version are noted in the textbox on the facing page.

Fifth Stage—Constraining ChargeOut! Variables

ChargeOut! needed to be constrained to make it approximate a machine-rate calculation. The machine-rate models are based on single-period pre-income tax estimates using limited input variables. ChargeOut!'s inputs had to be constrained to conform as closely as possible to the machine-rate format. The constrained ChargeOut! variables follow.

- The sensitivity factors for revenue, fixed operating costs, and variable operating costs were set at 100%. These factors allow an analyst to increase all revenues, fixed operating costs, or variable operating costs in ChargeOut! by a given percentage with single entries. The effect of changing these revenues or costs is immediately reflected in the financial measures and break-even charge-out rate.
- The initial tire value and initial tire life were set equal to the replacement tire value and life, respectively. This was

Differences between ChargeOut! 1.2MR and ChargeOut! 1.03, the current website version

- Four different machine-rate calculations based on published machine-rate models are incorporated within ChargeOut! MR on a new worksheet, "MR Models." The machine-rate models use common input variables directly from the ChargeOut! model worksheet.
- The Year 1 charge-out rate is now a variable that either is linked to a machine-rate calculation, is equal to the break-even calculated rate, or is entered directly.
- The initial tire life is now a user-entered variable. This is to allow for used tires on a used piece of equipment that will be eventually replaced with new tires.
- The depreciation calculation for straight line depreciation over the asset's economic life has been corrected. Note that this depreciation method is not necessarily allowed by the Internal Revenue Service (IRS).
- There is a minor correction to the equivalent annual interest rate calculation if the loan interest rate entered is variable.
- The model now includes a full loan repayment table showing the interest payment and principal repayment each period.
- The model now includes a loan interest rate calculator to calculate the real interest rate if the loan rate is "Variable" with inflation.
- The model now allows the annual insurance cost to be based on either the Average Capital Invested (ACI) or the Replacement Cost.
- The "Horsepower," "Crankcase oil capacity," and the "Time between oil changes" are now on the "Fuel & oil calculations" worksheet because these factors were not used elsewhere on the ChargeOut! worksheet.
- The "Average capital invested" calculation now includes the initial tire cost.
- Comments were modified in the economic life, salvage value, utilization, and repairs and maintenance to account for the data provided in Brinker and others (2002).
- Data from Brinker and others (2002) were added to the oil and fuel calculations.
- Two columns were added to the cash-flow table; one with the discounted cost per scheduled machine hour and the other with the discounted cost per productive machine hour.
- The utilization factor is now entered each year, so it may change throughout the machine's life.
- There are summary rows for the total operating costs plus loan payment plus taxes divided by the total scheduled hours and total operating hours for each year.
  - These figures provide the minimum cash payments that must be recovered each year to stay in business for the short term.
  - They do not include any capital cost recovery or return on equity capital.
- State and federal income tax rates are now entered separately. In addition, state income taxes are deducted from federal taxes in the composite income tax-rate calculation.
- Charge-out rates can now be "Constant" without using the "Negotiated" rate cells. If "Constant," the hourly rate does not change from year to year.
- This version has a line for a planned major rebuilding cost (such as an engine rebuild in any year of the asset's life). As it is, the cost is not capitalized. Rather, it is written off in the year it occurs. This would be appropriate if the rebuild was not an upgrade and was required in order for the machine to operate for its expected economic life.

done both to replicate the assumptions in the machine-rate models and to simulate the purchase of a new machine. The machine rate models do not handle used equipment well.

- No loan was assumed, as loans complicate an analysis. Loan interest is tax deductible, whereas loan principal repayments are not. The amount of principal and interest varies each year depending on the size of the loan, the interest rate, the length of the loan, and the number of loan payments per year. The length of the loan may be different than the machine's economic life. These changing cash flows resulting from financing will have an effect on both the before and after-tax rates of return. Incorporating loans into ChargeOut! is easy. However, because the machine-rate method does not incorporate financing, financial gearing in ChargeOut! was set to 0%.
- Loan and deposit payments per year were set to 1. Although no loan was assumed, deposit interest rates are entered into ChargeOut! as annual percentage rates. If the number of compounding periods per year increases, ChargeOut!'s equivalent annual interest rate also increases, which in turn raises its discount rate, the required return on invested capital. Machine-rate models allow for the entry of a single interest rate, with no entry for the number of compounding periods each year. Implicitly, this is an equivalent annual rate; the rate as if interest were charged and paid only once each year.

- Depreciation rates allowed by the IRS were ignored. Because machine-rate calculations are all on a pre-tax basis, ChargeOut!'s built-in depreciation schedules are irrelevant. Capital is recovered in ChargeOut! through the capital recovery factor formula, not through depreciation.
- The IRS Section 179 deduction is assumed to be $0. The Section 179 write-off is a tax deduction that only affects income taxes and therefore after-tax analysis. See the latest edition of the IRS Publication 946: *How to Depreciate Property*, available from the IRS website (www.irs.gov/publications/p946/index.html), for information on this and more detailed tax implications.
- Special first-year depreciation allowance is assumed to be 0%. The special first-year depreciation write-off only affects an after-tax analysis.
- Loan interest rate is … "Fixed." If it is fixed, it is constant from year-to-year. If it is "variable," it is linked to inflation. In this configuration, this variable is in effect and not used because there is no loan.
- Inflation is 0%. ChargeOut! is constructed to index the operating costs to inflation. Salvage values and revenues may also be linked to inflation, if the analyst so chooses. The machine-rate method does not incorporate inflation into either the costs or into the salvage values. An analyst may or may not implicitly incorporate inflation into the machine-rate "interest" variable.
- State and Federal income tax rates are 0%. All machine-rate models are on a before-tax basis, so ChargeOut! was constrained to perform a pre-tax analysis only.
- Tax-loss treatment is "flow through." However, tax losses in ChargeOut! may be allowed to "flow through," "carry forward," or be lost ("none"). Because the income tax rate is 0%, this variable is not used.
- *Ad valorem* tax mill rate is 0. These are taxes on the capital value of a firm's assets. Some, but not all of the machine-rate methods had allowances for *ad valorem* taxes. In this configuration, the variable is not used.
- *Ad valorem* tax valuation basis is "ACI." If there are *ad valorem* taxes, ChargeOut! allows them to be based on either average capital invested (ACI), straight-line book value (SLB), or a custom valuation that can change each year. When they were included, the machine-rate models examined had *ad valorem* taxes based on ACI only.
- Maintenance and repairs functions' forms are "Estimated" as a percentage of straight-line depreciation. In ChargeOut! these costs may also be "Custom" and entered each year, if more detailed and comparable maintenance and repairs records are available.
- Initial maintenance as a percentage of straight-line depreciation is 0%. ChargeOut! separates maintenance and repairs costs and the machine-rate models combine maintenance with repairs. Maintenance includes the more routine and expected upkeep. Setting this percentage at 0 effectively combines the maintenance costs with the repairs for a single repairs and maintenance estimate.
- Productive hours until maintenance costs increase by 50% is 999,999,999. This variable is not used in this formulation because the maintenance and repairs costs are combined in the repairs percentage.
- Initial repair costs as a percentage of straight-line depreciation is 100%. This is to account for all maintenance and repair costs. The percentage comes from the common data set. Brinker and others (2002) provide a table of repairs and maintenance estimates as a percentage of annual depreciation.
- Productive hours until repair costs increase by 50% is 999,999,999. Normally one would expect repairs costs to be lower early in the machine's life and rise as the machine ages. An increasing repair cost function could be created in ChargeOut! by either using a smaller number of productive hours until costs rise by 50% (for example, 3,000), or by using custom maintenance and repair functions and entering costs for each year. However, in the machine-rate models, repairs and maintenance costs are constant. Using this large number forces ChargeOut!'s repair costs to be constant from year to year at the initial percentage specified.
- Engine oil is based on "Fuel cost." In ChargeOut!, engine oil cost may also be based on estimated use. If the latter is selected, then the next two variables are oil cost and oil consumption per productive hour. For this formulation, engine oil is based on fuel cost and these later two variables are not used.
- Other lubricants (percentage of engine oil cost) is 0%. ChargeOut! allows the lubrication cost to be separated into engine oil and other lubricants, such as hydraulic oil. The machine-rate methods all combine the oil and lubrication percentages.
- Other annual fixed costs are $0. ChargeOut! allows for other fixed costs that are not otherwise included.
- Other variable costs are $0. ChargeOut! allows for other variable costs that are not otherwise included. These are on a per scheduled hour basis.
- Major equipment rebuild cost is $0. ChargeOut! allows for the possibility of a major equipment rebuild (such as an engine) at some point in the equipment's life. The machine-rate models cannot incorporate this type of variable.
- Rebuild to occur in year 0. A rebuild could occur at any time in the equipment's life from year 1 onward. Setting this value to 0 shows that a rebuild cost is not incorporated into the analysis.

Table 1—Machine costs per scheduled machine hour under CHARGEOUT! and four machine-rate models

	CHARGEOUT! (Break-even cost, US$)	Machine-rate models (US$)			
		MR Calculator	Miyata (1980)	Brinker and others (2002)	Virginia Tech
Ownership and other fixed costs	25.08	26.28	23.52	24.80	24.80
Variable operating costs	36.82	35.85	37.20	38.10	35.09
Total $/SMH[a]	61.90	62.14	60.72	62.90	60.65

[a] SMH is scheduled machine hour.

Table 2—Pre-tax net present values and internal rates of return with charge-out rates determined by CHARGEOUT! and four machine-rate models

	CHARGEOUT! (Break-even cost, US$)	Machine-rate models (US$)			
		MR Calculator	Miyata (1980)	Brinker and others (2002)	Virginia Tech
Net present value @ 10.0%	0	1,787	(8,924)	7,588	(9,470)
Internal rate of return (%)	10.0	10.3	8.4	11.4	8.3
Charge-out rate ($/SMH[a])	60.29	62.14	60.72	62.90	60.65

[a] SMH is scheduled machine hour.

- The scheduled operating time was set as a constant at 2,000 h per year. CHARGEOUT! allows for this annual scheduled operating time to change over the machine's life. Under the machine-rate models, the annual scheduled operating time is a constant.
- The utilization rate was set as a constant at 85%. The utilization rate, also known as the productive time factor, is the portion of scheduled operating time during which a machine actually operates. CHARGEOUT! allows for this percentage to change over the machine's life. Under the machine-rate models, the utilization rate is a constant.

By placing these constraints on CHARGEOUT!, the model uses the same variables as the machine-rate models. However, CHARGEOUT! uses these variables in a cash-flow model to calculate net present values, rates of return, and a charge-out rate that incorporates the time value of money.

Sixth Stage—Run the Models

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.

Results

Results of the calculations in terms of charge-out rates per SMH are shown in Table 1.

Two of the machine-rate models calculate costs that are less than those calculated by CHARGEOUT! Two calculate a cost higher than CHARGEOUT!. CHARGEOUT!'s rate includes a return on capital, which is the interest (10%) that was specified in the input data.

The pre-tax net present values and rates of return that would be earned on the equipment if these calculated rates were charged are shown in Table 2. The rate calculated by CHARGEOUT!, $60.29/SMH, returns a net present value of $0 and exactly 10%, the required return on invested capital that was specified through the deposit interest rate (3%) and the required risk premium (7%). The point where net present value equals $0 is the definition of a financial break-even rate. The charge-out rate of $60.29/SMH is the rate required to break even financially and return exactly 10%. If variables change, (for example, if inflation is entered as 3% rather than 0% or if income taxes are increased from 0%), then this financial break even will also change.

The rates calculated by two of the machine-rate models, Miyata (1980) and the Virginia Tech model, return less than the specified rate of return and also return corresponding negative net present values. Two machine-rate models, MR Calculator and Brinker and others (2002), return positive net present values and internal rates of return higher than the specified rate.

It is useful to look at the cost breakdowns in further detail, considering components of both the fixed and variable costs to understand the differences in rate calculations. First, ownership and fixed cost are found in Table 3. MR Calculator has the highest total ownership cost

Table 3—Ownership and other fixed costs per scheduled machine hour under ChargeOut! and four machine-rate models

	ChargeOut! (U.S. $)	Machine-rate models (U.S. $)			
		MR Calculator	Miyata (1980)	Brinker and others (2002)	Virginia Tech
Capital cost	22.28	22.28	20.83	22.00	22.00
Insurance and taxes cost	2.80	4.00	2.69	2.80	2.80
Total ownership and other fixed costs	25.08	26.28	23.52	24.80	24.80

followed by ChargeOut!. Brinker and others (2001) and the Virginia Tech model have identical ownership and other fixed costs. Miyata (1980) shows the lowest total ownership costs.

In contrast to the other machine-rate models that use average capital invested, MR Calculator uses the capital recovery formula, based on the time value of money, to calculate annual capital charges. In this configuration, with no financial gearing, ChargeOut!'s ownership cost calculations are equivalent.

The annual capital charge (ACC) is calculated based on the interest and capital that must be recovered each year from the initial cash outflow for the equipment less the present value of the salvage at the end of the equipment's economic life. It is calculated using Equation (2).

$$\text{ACC} = \text{CR} \times \left(\text{Purchase} - \frac{\text{Salvage}}{(1+r)^n} \right) \tag{2}$$

where

ACC	is	annual capital charge,
Purchase		purchase price, including tires,
Salvage		salvage value at the end of the equipment's economic life,
r		annual interest rate on capital, which is in decimal form,
n		equipment's economic life, and
CR		capital recovery factor:

$$\text{CR} = \frac{r \times (1+r)^n}{(1+r)^n - 1} \tag{3}$$

For example: for an $r = 10\%$ and an economic life of 5 years, CR is

$$\text{CR} = \frac{0.10 \times (1+0.10)^5}{(1+0.10)^5 - 1} \tag{4}$$

$$= 0.263797$$

And for a purchase price of $200,000, a salvage of $50,000, and an economic life of 5 years, the capital charge calculation follows using the annual capital charge formula (Eq. (2)):

$$\text{ACC} = 0.263797 \times \left(\$200{,}000 - \frac{\$50{,}000}{(1+0.10)^5} \right) \tag{5}$$

$$= \$44{,}570/\text{year}$$

If there are 2,000 scheduled machine hours in a year, then the hourly charge is $44,570 per year/2000 SMH/year = $22.28/SMH, which is the rate calculated in this formulation of ChargeOut! I acknowledge that this calculation going from an annual cost to an hourly cost by simply dividing by the number of hours in a year ignores the time value of money for the year. However, I believe that further refining the calculations would add considerable complexity to what would amount to spurious accuracy.

Note that while MR Calculator notes that the purchase price should be entered, "Less tires, if you want detail," by doing so, the capital recovery on the initial tire value is lost. This is because the capital recovery factor would be applied to a machine without tires, but when the machine was sold, it would be sold with tires. ChargeOut! includes the initial tire cost in the purchase price and value that must be recovered.

Brinker and others (2002), Miyata (1980), and Virginia Tech base their capital costs on straight-line depreciation plus an interest charge on average capital invested (ACI). The difference is that Brinker and others (2002) and Virginia Tech include the initial tire value in their ACI calculation, which results in a higher hourly capital charge. Miyata (1980) does not include the initial tire value in the ACI calculation.

The insurance and taxes cost is also different between the models. Although income taxes are not included in the machine-rate models, annual *ad valorem* taxes on the value of the capital equipment are included in all but MR Calculator. In this configuration, ChargeOut! follows Miyata (1980), Brinker and others (2002), and the Virginia Tech models, basing insurance charges on average capital invested. ChargeOut! has the option to base insurance

Table 4—Variable operating costs per scheduled machine hour under CHARGEOUT! and four machine-rate models

	CHARGEOUT! (U.S. $)	Machine-rate models (U.S. $)			
		MR Calculator	Miyata (1980)	Brinker and others (2002)	Virginia Tech
Repairs and maintenance	14.10	12.75	14.10	15.00	12.75
Fuel[a]	12.62	12.62	12.62	12.62	17.67
Oil and lubrication[a]	5.05	5.05	5.05	5.05	N.A.
Tires/tracks[a]	1.87	2.20	2.20	2.20	2.20
Other (e.g., saw bar)	3.17	3.23	3.23	3.23	3.23
Total variable operating costs	36.82	35.85	37.20	38.10	35.09

[a] Fuel and lubrication are combined as a single user-entered cost in the Virginia Tech model.

charges on a percentage of the equipment's replacement cost, its average capital invested, its straight-line book value, or a custom valuation that can vary from year to year.

The reason these four models do not have identical insurance estimates is that CHARGEOUT!, Brinker and others (2002), and Virginia Tech include tires in ACI, while Miyata (1980) does not. MR Calculator bases its insurance and taxes calculation on replacement cost, which results in a higher charge.

Whereas one might assume that variable operating cost estimates should be the same in all the models, that assumption is incorrect. Only the fuel and oil and lubrication costs are the same. This is shown in Table 4.

Repairs and maintenance costs differ in part because of the differences in depreciation calculations as discussed earlier. However, repairs and maintenance costs also differ because the models do not make their calculations per productive machine hour in the same way. Although MR Calculator and the Virginia Tech models have their repairs and maintenance calculations denominated per productive machine hour, they divide their annual cost by the number of scheduled (not productive) machine hours. This results in the lower hourly repairs and maintenance estimates that are shown.

Recalculating repairs and maintenance in terms of productive machine hours in the MR Calculator and Virginia Tech models would increase the repairs and maintenance costs in MR Calculator and the Virginia Tech models by 15%, the difference between one minus the utilization factor (1.00 –0.85). This would make their repairs and maintenance $14.10/SMH, the same as calculated by Miyata (1980).

Miyata (1980) and Brinker and others (2002) calculate their depreciation in terms of PMH, which results in a higher hourly repairs and maintenance estimate. Brinker and others (2002) do not deduct tires from their initial purchase price, so their annual depreciation is higher than Miyata's. This results in a higher repairs and maintenance estimate for Brinker and others (2002).

MR Calculator

An additional feature in MR Calculator's repairs and maintenance calculation is a monthly cost estimate equal to the cost per productive machine hour times the utilization rate times 166. There are two problems with this formula. First, it takes a cost that is already denominated in terms of productive (not scheduled) machine hours and multiplies it again by the utilization rate. The cost is multiplied by the utilization rate twice. This is incorrect.

The second problem comes from multiplying the result by 166 (= 2000 hours/year divided by 12 months/year), which allows monthly repairs and maintenance costs to decrease as the utilization factor decreases and increase if the utilization factor goes up. Whereas this trait might be desirable, the problem is that it is based on 2000 scheduled hours per year (166 = 2000/12), and if the scheduled hours increase, MR Calculator shows a decrease in monthly repairs and maintenance (R&M) costs. Unless an increase in operating hours results in a decrease in total repairs and maintenance costs, this is an error.

Fortunately, MR Calculator does not use this monthly repairs and maintenance estimate in any further calculations. However, using this number in a longer-term cash-flow budget could lead to difficulties.

In this formulation to make CHARGEOUT!'s results comparable to those of the machine-rate models, CHARGEOUT! is constrained to duplicate the repairs and maintenance costs in Miyata (1980). However, any pattern of maintenance and repair costs could be entered into CHARGEOUT! Furthermore, CHARGEOUT!'s repairs and maintenance costs do not have to be constant over each year of the equipment life. The model can handle a separate cost estimate for each year.

A further difference in the variable costs is with charges for tires and tracks. Tires/tracks and other variable cost items

that are periodically replaced do not have the same costs in ChargeOut! as they do in the machine-rate models. The reason is that ChargeOut! is a discounted cash-flow model, whereas the machine-rate models all use average costs. That means that in ChargeOut!, costs are recognized in the year in which the cash outflows occur rather than simply being averaged. For significant replacement items, the timing can make a difference in the charge-out rate. In this example, tires are being over-charged in the machine-rate models.

Specific differences between ChargeOut! and the machine-rate models are shown itemized in Appendix II.

Conclusions

Using costing estimates determined by standard machine-rate models as machine charge-out rates can result in rates that are either higher or lower than required to provide the desired return on capital.

Basing costs on averages can result in machine cost estimates that do not properly incorporate a return on investment. Using those costs to determine charge-out rates can result in over- or under-estimation of costs. Either can result in poor business decisions.

Using standard guidelines for machine costing can result in different machine cost estimates, depending on the assumptions that are or are not included in the machine-rate model used.

Limited discounted cash-flow techniques can be incorporated into machine-rate models (e.g., the use of the capital recovery factor to determine capital costs as in MR Calculator) that can make them more accurate. However, machine-rate models are still single-period pre-tax models that depend on cost averages, which do not reflect the actual cash flows that might be expected in the equipment operation. Therefore, their results should not be used in any subsequent cash-flow analysis.

Whereas ChargeOut!, a discounted cash-flow model, can be configured to approximate a machine-rate model, doing this ignores many of ChargeOut!'s variables and much of its flexibility and power are sacrificed in the process. Even if ChargeOut! is so constrained, it still calculates a machine cost that, if charged, would return exactly the required rate of return. If an alternative rate is entered into ChargeOut!, this model calculates the rate of return that would be earned and the net profit or loss that would occur. No machine-rate model can make these claims. Furthermore, while ChargeOut! can be configured to approximate a machine-rate model, no machine-rate model can be configured to approximate ChargeOut!'s results.

Discussion

Cost Averages

Using standard cost averages estimates from published literature for machine costs can create difficulties. A systematic error is an error that is not determined by chance but is introduced by an inaccuracy (as of observation or measurement) inherent in the system. Unless the methodologies that calculated those averages are the same as the methodologies used in the costing model, there is a source of systematic error. For example, if repairs and maintenance are estimated at 100% of straight-line depreciation including tire cost, then a model that calculates depreciation without tire cost will underestimate repairs and maintenance cost. If insurance costs are estimated at 4%, it is important to know the basis for that 4%. ChargeOut! allows the basis to be average capital invested, replacement cost, book value, or some other user-entered value so that average cost methodologies in the model can replicate those in machine cost literature.

The use of cost averages can also cause difficulties if the costs are periodic, but not necessarily the same each year. Tires are an example. In practice, if they run on tires, then trucks, skidders, and other machines are delivered with tires and their cost includes tires. When sold, their salvage value includes tires. Depreciation expense is taken on the full machine cost, including tires. Tires are replaced when they wear out or are no longer repairable. Replacement costs are not annual, but they may somewhat predictable, depending on the number of hours a machine operates. In ChargeOut!, cash flows out and tires are expensed when they are replaced. This method of accounting for tires follows the "original tire capitalization method" outlined in Revenue Procedures 2002-27 from the IRS. See more information at the website http://unclefed.com/Tax-Bulls/2002/rp02-27.pdf.

Repairs and Maintenance

Calculating repairs and maintenance on the basis of scheduled machine hours, although having it denominated in terms of productive machine hours is a big limitation in MR Calculator and the Virginia Tech models. For example, one would expect that if a machine was used on a double shift, the scheduled hours per year and R&M costs would be higher. However, given the calculations in these models, an increase in the number of scheduled hours actually decreases the hourly repairs and maintenance costs.

Caulfield and Tufts (1989) presented one company's data on average annual maintenance and repairs costs by age for 136-horsepower, 4-wheel-drive, articulated-frame, rubber-tired grapple skidders. The costs increased for the first 4 years before dropping back and then increasing again.

In ChargeOut! the repairs and maintenance functions may be either "Custom" or "Estimated." If they are "Custom," then individual maintenance and repairs costs are entered for each year of the machine's operation. These may be based on past experience, machine records, or the best data available. Even if such experience, records, or data are available, it is not possible to use them in a machine-rate model.

If the repairs and maintenance costs are "Estimated" in ChargeOut!, then the first year's costs as a percentage of depreciation are entered, along with an estimate of the number of productive hours until the costs increase by 50 %. The result is that in ChargeOut!'s "Estimated" costs, if the utilization rate or the number of scheduled hours are subsequently changed, then the repairs and maintenance costs will be automatically adjusted upwards or downwards. ChargeOut! can also be constrained to produce a constant cost for repairs or maintenance, as it was in the example presented in this paper.

In all of the machine-rate models, only one figure is entered or calculated that accounts for both repairs and maintenance. Logically, maintenance should be separate from repairs. Some items, such as replacing brakes or a clutch, are seen as routine and expected. Other items, such as ripping out the hydraulic system from running over a stump that was cut too high, are not as predictable. However, one might expect that as parts begin to show wear and tear that unexpected failures would become more common and that repair costs would increase. A case can be made for separating maintenance costs from repair costs. ChargeOut! allows this to be done. Alternatively, maintenance and repairs can be combined in ChargeOut!, if desired.

ChargeOut! provides the power and flexibility needed to calculate accurate machine costs. Although it may not be possible or practical to charge the rates calculated by ChargeOut!, the information provided by the model should enable contractors to make better and more informed bids and should help with capital equipment utilization and acquisition decisions.

Financing

Credit is a part of business. The relationship of debt to total capital is referred to as the financial gearing ratio, or just the gearing ratio. Borrowing money at a lower rate and investing it at a higher rate is a good way to make money and increase the rate of return on an owner's investment. Logically, the ability to borrow at a lower rate should have an effect on the break-even charge-out rate. Whereas it may be possible to use a lower average interest rate in a machine-rate calculation to reflect a low-cost loan, these models have no way to account for a loan that is paid off over a period shorter than the machine's economic life. ChargeOut! does this automatically. It also calculates the loan payment and a loan repayment schedule based on the number of payments per year and the length of the loan. The tax deductibility of the loan interest is considered and the loan may be either fixed or variable. If the rate is fixed, it does not change, no matter what the inflation rate is. If the loan interest rate is variable, it changes with different inflation assumptions.

The problem with loan financing is that it increases business risk, because although the hours worked may decline because of abnormal downtime or adverse business conditions, loan repayments must continue. This is in contrast to variable expenses such as fuel or hourly labor, which would decline if the number of hours worked went down. Increased business risk translates directly to increased risk of bankruptcy—the risk that a business will not have the cash to meet its obligations. In ChargeOut!, once a gearing ratio, loan interest rate, and repayment schedule are chosen, it is easy to test the revenue sensitivities to evaluate the riskiness of the position.

Machine-rate models do not incorporate loan financing directly. They do not calculate the impact of different gearing ratios on the break-even charge-out rate or on the expected rate of return.

Inflation, Depreciation, and Taxes

The machine-rate models all operate on a pre-tax basis. Inflation may or may not be implicitly included. In ChargeOut!, inflation is a user-entered variable that will have an effect on the break-even rate calculation. Inflation may have an effect on most costs and on the equipment's salvage value, but will have no impact on the annual depreciation expense. ChargeOut! calculates an after-tax break-even rate that will return exactly the specified return on capital. That is something that no machine-rate model can do.

Final Thoughts

While ChargeOut! is more powerful and flexible and its results are superior to those of machine-rate models, no financial model is 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) will affect a contractor's financial decisions. And while ChargeOut! does not guarantee success, it does provide a better benchmark on which financial decisions may be based.

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Appendix I—Features in CHARGEOUT! 1.2 MR Compared with Machine-Rate Models

Category	CHARGEOUT! 1.2 MR	Machine-rate models			
		MR Calculator	Miyata (1980)	Brinker and others (2002)	Virginia Tech
Allows for operating hours to change each year	Yes	No	No	No	No
Allows for productivity ratio to change each year	Yes	No	No	No	No
Allows for charge-out rate to change each year	Yes	No	No	No	No
Allows for variable revenue	Yes	No	No	No	No
Allows for accelerated depreciation rates	Yes	No	No	No	No
Allows for Section 179 write-off	Yes	No	No	No	No
Allows for special first-year depreciation write-off	Yes	No	No	No	No
Allows for maintenance and repairs costs to increase over the years	Yes	No	No	No	No
Separates routine maintenance from repairs costs	Yes	No	No	No	No
Allows for a major overhaul (e.g. engine rebuild at some time during the equipment life	Yes	No	No	No	No
Allows for a different initial tire life if different from replacement tire life (especially useful if purchasing used equipment)	Yes	No	No	No	No
Allows for after-tax analysis	Yes	No	No	No	No
Allows for different treatments of tax losses	Yes	NA	NA	NA	NA
Allows for sensitivity analysis to be easily carried out	Yes	No	No	No	No
Allows for sensitivity analysis on revenues	Yes	NA	NA	NA	NA
Allows for separate sensitivity analysis on fixed costs and operating costs	Yes	NA	NA	NA	NA
Incorporates inflation into the analysis	Yes	No	No	No	No
Indexes salvage value automatically to inflation	Yes or no, depending on the analyst's selection	NA	NA	NA	NA
Allows for different financing options	Yes	No	No	No	No
Allows the loan repayment period to be different than the asset's economic life	Yes	No	No	No	No
Calculates periodic loan repayments and provides a loan repayment table showing interest payments and principal repayments over the life of the loan	Yes	No	No	No	No
Provides built-in sensitivity analysis on key input variables	Yes	No	No	No	No
Calculates expected annual cash flows	Yes	No	No	No	No
Accounts for major expected parts replacements (e.g., tires)	Yes, in year expected	Average cost only	Average cost only	Average cost only	Average cost only
Allows for a major repair (e.g., a rebuild) at some time	Yes	No	No	No	No
Calculates a single charge-out rate that will provide a specified return on capital	Yes	No	No	No	No
Calculates expected return on capital given a charge-out rate	Yes	No	No	No	No

Model sources: Bilek 2007, MR Calculator, Miyata 1980, Virginia Tech, Brinker and others (2002).

Appendix II—Differences between ChargeOut! and Machine-Rate Models

	Machine-rate models			
ChargeOut!	MR Calculator	Miyata (1980)	Brinker and others (2002)	Virginia Tech
Annual ownership cost				
Capital cost recovery on full cost with tires. Capital cost is based on the cost of capital invested in the asset.	Capital cost recovery on full cost less tires, if desired. Capital cost is based on the cost of capital invested in the asset.	Straight-line depreciation plus interest on ACI[a], which does not include tire cost	Straight-line depreciation plus interest on ACI, which probably includes tire cost	Straight-line depreciation plus interest on ACI, which probably includes tire cost
Tires included in purchase?				
No, but is combined with the purchase price for the initial cash outflow	Yes or no	No	Probably. However, no variables are included for tire cost or tire life.	Probably. It is not specifically mentioned. There is no variable for initial tire value, although there is a user-entered variable for an hourly tire charge.
Treatment of tire replacement costs				
Replaced and expensed in the year at end of estimated productive life	Simple average annual cost	Simple average annual cost	Not included	Must be separately calculated
Tire installation factor?				
Yes	No	Yes	No	Will be included only if the analyst thinks to add it in a separate tire cost calculation
Different entries possible for initial tire value and life (useful for used equipment purchases)?				
Yes	No	Yes	No	No
Recovery of initial tire value?				
Capitalized and depreciated	May be double-costed if tires are both included in initial capital and written off through average costs	May or may not be recovered through average costs	Not included in the original	May or may not be recovered through average costs
Allowances for additional consumable parts (e.g., saw bar)?				
Yes, charged as they wear out	Yes, average annual cost	No	No	No
Repairs & maintenance (R&M) calculation				
May be calculated on the basis of SMH[b] or PMH[c] or customized	Calculated on the basis of SMH, but denominated in terms of PMH	Calculated and denominated in terms of PMH	Calculated and denominated in terms of PMH	Calculated on the basis of SMH, but denominated in terms of PMH

(Appendix II continued)

	Machine-rate models			
CHARGEOUT!	MR Calculator	Miyata (1980)	Brinker and others (2002)	Virginia Tech
Repairs & maintenance cost projections				
May be varied each year	Constant each year	Constant each year	Constant each year	Constant each year
Effect on R&M of reducing the utilization factor				
Hourly rate may be adjusted downwards, if appropriate	$/SMH decreases while $/PMH increases	$/SMH decreases while $/PMH increases	$/SMH decreases while $/PMH increases	$/SMH decreases while $/PMH increases
Effect on repair and maintenance (R&M) of reducing the scheduled annual hours				
Adjusted downwards if PMH decreases	R&M cost per productive hour increases proportionally, but R&M cost per year remains constant	R&M cost per productive hour increases proportionally, but R&M cost per year remains constant.	R&M cost per productive hour increases proportionally, but R&M cost per year remains constant.	R&M cost per productive hour increases proportionally, but R&M cost per year remains constant
Insurance and taxes are based on…				
Average capital invested, book value, replacement cost, or custom	Original purchase price for insurance only. *Ad valorem* taxes are not included in the model.	ACI[c]	ACI	ACI
Depreciation				
Used in tax calculations. Any IRS-approved method may be selected. In addition, straight-line depreciation over the asset's economic life is an optional automatic calculation. If none of these are suitable, a custom depreciation schedule may be entered.	Incorporated through the capital recovery factor in the ownership costs. Not used for tax purposes.	Straight line over the asset's economic life. Used in calculating ownership costs. Not used for tax purposes.	Straight line over the asset's economic life. Used in calculating ownership costs. Not used for tax purposes.	Straight line over the asset's economic life. Used in calculating ownership costs. Not used for tax purposes.

[a] Average capital invested.

[b] Scheduled machine hour.

[c] Productive machine hour.

Model Sources: Bilek 2007, Brinker and others (2002), MR Calculator, Miyata 1980, Virginia Tech.