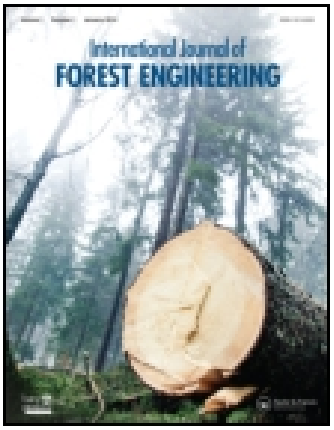

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The COST model for calculation of forest operations costs

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TECHNICAL NOTE

The COST model for calculation of forest operations costs

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Since the late nineteenth century when high-cost equipment was introduced into forestry there has been a need to calculate the cost of this equipment in more detail with respect to, for example, cost of ownership, cost per hour of production, and cost per production unit. Machine cost calculations have been made using various standard economic methods, where costs have been subdivided into capital costs and operational costs. Because of differences between methods and between national regulations, mainly regarding tax rules and subsidies, international comparisons of machine costs are difficult. To address this, one of the goals of the European Cooperation in Science and Technology (COST) Action FP0902 was to establish a simple format for transparent cost calculations for machines in the forest biomass procurement chain. A working group constructed a Microsoft Excel–based spreadsheet model which is easy to understand and use. Input parameters are easy to obtain or possible to estimate by provided rules of thumb. The model gives users a simultaneous view of the input parameters and the resulting cost outputs. This technical note presents the model, explains how the calculations are made, and provides future users with a guide on how to use the model. Prospective users can view the model in the Supplementary Material linked to this article online.

Keywords: machine cost calculation; equipment; capital costs; operational costs

Introduction

Since the late nineteenth century when high-cost equipment was introduced into forestry there has been a need to calculate the cost of this equipment in detail, with separate labor costs, operational costs and investment costs (e.g. Williams 1908). Machine cost calculations have been made using standard economic methods, where costs have been subdivided into capital costs and operational costs. Various methods to calculate the costs for logging equipment span from the early work in the 1940s (Matthews 1942), through some influential work in the 1980s and early 1990s by Miyata (1980), Sundberg and Silversides (1988), and FAO (1992), to more recent work by Franklin (1997), von Hofsten et al. (2005), Bilek (2007), and Hogg et al. (2010). These proposed methods all give slightly different results, as shown by Bilek (2009) and Sperandio (2010).

Most calculations are made with one of two main objectives in mind: to establish the cost of a particular machine; or to set a price for the work done with the machine. The first objective is mainly used when companies or research organizations compare different machines, either to decide which one to invest in or to determine whether it might be profitable to replace an existing machine. The second objective comes into play when contractors wish to negotiate the price of their services with potential employers. Although the contractor needs to cover costs for the use of a machine, this is only part of the price of his services. Depending on business considerations, a contractor can make a number of decisions affecting the price of the work, e.g. how much profits he needs or the share of overhead costs to be allocated to a certain machine in a specific deal. A long-term client providing a large amount of work might get a different price for the same work from a once-off client for a small amount of work. Information on the costs

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(standards) per unit also provides forest owners with information from which to calculate the financial consequences of forest operations, thus supporting them in their planning.

So, although to a large degree the calculations are the same, there are many philosophical differences in the use of the calculations, depending on the original objective for the calculation. Thus, it is important to realize that the hourly cost of operating a machine is not the same as the price charged per hour for the work done using the machine.

A feature of most of these cost models is that, for obvious reasons, they are adapted to the tax rules, subsidies, and other regulations of the country where they were first developed. This often makes comparisons of machine costs between countries difficult, and in today's internationalized research world this tends to increase the difficulties in using research results from countries other than one's own. This is found to cause fragmentation of research efforts and problems in Europe and elsewhere in terms of the communication and exchange of research results, not only among researchers but also among other players in the field such as forest industries, machine manufacturers, forest owners, and enterprises working the field of forest biomass for energy (COST 2009). To increase the comparability of cost calculations within the European Union and worldwide, one of the tasks of the European Cooperation in Science and Technology (COST) program's Action FP0902 (Development and Harmonisation of New Operational Research and Assessment Procedures for Sustainable Forest Biomass Supply) was to establish a simple format for cost calculations (costs per hour) of machines in the forest biomass procurement chain.

The task was managed by a specific working group, with the aim of producing a basic cost calculation tool that can be used internationally for machine costing and which facilitates scenario testing and sensitivity analysis. The group decided to construct a Microsoft Excel–based spreadsheet model that would be easy to understand and use. Input parameters would be easy to obtain or possible to estimate by provided rules of thumb. The model would ideally give the user a simultaneous view of the input parameters and the resulting cost outputs. The model produced can be downloaded from the COST Action FP0902 website (http://www.forestenergy.org/) under the heading "COST action FP0902 - Costing model." This technical note presents the model, explains how the calculations are made, and provides future users with a guide how to use the model.

The COST model: description and user guide

The COST model serves the purpose of calculating machine costs per unit of output, productive machine hour (PMH), month, or year. If needed, the time-based costs can easily be converted by the user to costs per scheduled machine hour (SMH), day, or week. The model is comprehensive and will serve the purposes of experienced foresters and contractors alike. The model requires specific cost-related inputs, from which it generates relevant costing information. The spreadsheet consists of an input section (Figure 1), where cost and machine data are entered, and an output section (Figure 2), where the results are presented. "Input" cells are formatted to appear in blue tables, "pre-emptive calculations" are formatted in faded grey and orange, and "output" will appear in red tables. All of the individual cells where inputs are required have comments to assist the user in the use of the model and the interpretation of what is required in the particular cells. The precision of the output will be a reflection of the accuracy of the data input – i.e., garbage in, garbage out!

Input section

The main input section is divided into four parts: fixed costs; operational (variable) costs of the machine; labor costs; and productivity data. In addition, some general input is needed, such as the units of currency, and the units of production (e.g. m^3, ha) that the cost output is related to.

Fixed costs

Fixed or standing costs are costs that need to be recovered by machine operators irrespective of the amount of work a machine does or the revenue it earns and are associated only with owning the machine. The fixed costs are made up of capital costs and other fixed costs.

Capital costs are the costs of the investment in the equipment and the interest on that investment. In the model, depreciation costs C_d are calculated by the straight-line method:

$$C_d = \frac{P - S}{N} \qquad \text{(money/year)} \quad [1]$$

where:

P = investment cost
S = salvage value
N = expected economic life in years

Machine Cost Calculation - Business Model

Date:

INPUT

Machine type	
Country specific currency	
Unit of costing	m^3
Machine fixed cost inputs	
Purchase Price or Replacement Cost	
Base machine	2 000 000,00
Attachment	0,00
Salvage value (Enter either % or monetary cost figure)	
Base machine	10%
Attachment	0%
Base machine (monetary cost figure)	0,00
Attachment (monetary cost figure)	0,00
Expected Economic Life (PMH)	
Base machine (PMH)	10 000,00
Attachment (PMH)	0,00
Interest rate	12%
Machine Tax/Registration (Base machine & attachment)	100,00
Machine Insurance (Base machine & attachment)	200,00
Machine transfers	300,00
Garaging for Machine	0,00

Machine variable cost inputs	
Fuel - cost (cost/litre)	10,00
Fuel consumption (l/PMH)	20,00
Oil and lubricant cost	100,00%
Maintenance and repair cost	
Base machine	100%
Attachment	0%
Base machine - Annual monetary cost figure	0,00
Attachment - Annual cost figure	0,00
Running gear:	
Number of additional tracks/chains	0,00
Cost per track/chains	0,00
Estimated track/chain set life (PMH)	2 000,00
Track/chains cost per Set	0,00
Number of tyres or other main running gear	6,00
Cost per tyre or other main running gear	20 000,00
Estimated tyre or other main running gear set life (PMH)	5 000,00
Tyre or other main running gear cost per set	120 000,00
Consumables	
Consumable 1, purchase price per unit	0,00
Consumable 1 life (PMH)	50,00
Consumable 2, purchase price per unit	0,00
Consumable 2 life (PMH)	50,00
Consumable 3, purchase price per unit	0,00
Consumable 3 life (PMH)	50,00
Consumable 4, purchase price per unit	0,00
Consumable 4 life (PMH)	50,00
Consumable 5, purchase price per unit	0,00
Consumable 5 life (PMH)	50,00
Other annual item/s cost	2 000,00

Operator costs	
Number of operators/shift	1
Average net wage (cost/hour)	50,00
Subsistence allowance	0,00
Other operator costs	1 000,00
Social charges - as % (a), or absolute value (b)	
a) Social charges (pensions/levies etc.) as a percentage	5,00%
b) Social charges (pensions/levies etc.) real number, per year	0,00
PPE (costs per year)	100,00
Training (costs per year)	100,00
Phone charges (costs per year)	100,00
Insurance (employers liability) (costs per year)	100,00
Operator transport (costs per year)	100,00

Productivity and operations (general input)	
Number of working days per year	250,00
Number of shifts per day	1,00
Scheduled hours per shift	9,00
Production (units/PMH)	20,00
Average size of unit (or work object) eg. tree volume	1,00
Productivity: m^3/PMH	20,00
Machine Utilisation	0,85
Overheads machine + operator/s - as % (a), or absolute value (b)	
a) Overhead costs as (%) over fixed and variable costs	0,00%
b) Overhead costs as absolute value (costs per year)	0,00

Pre-emptive calculations	
Scheduled hours/annum	2250
Productive hours/annum	1912,5
Estimated annual productivity (production/annum)	38 250,00
Social charges (pensions/levies etc.)	5 675,00
Company overheads for machine + operator(s) (costs per year)	0,00
Expected Economic Life (EEL years)	
Base machine	5,23
Attachment	0,00
Salvage value (SV)	
Base machine	200 000,00
Attachment	0,00
Number of sets over useful life:	
Additional tracks/chains	0
Tyres or other running gear	2,0

Figure 1. The input section of the spreadsheet.

The costs for tires or other main running gear should be deducted from the purchase price if the calculation is done for a machine that needs several tire sets during the expected economic life. In this case the depreciation and interest costs of the tires or tracks are made in the machine variable costs. The salvage value is the value of the machine at the end of its expected economic life. It should be noted that the salvage value is strongly related to the age of the machine when it is disposed of. The salvage value appears to drop relatively fast in the first few years and after that tends to decline more gradually.

Interest costs (C_I) are calculated as the interest on the average annual investment (AAI):

$$C_I = I \times AAI = I \times \left(\frac{(P-S)(N+1)}{2N} + S\right) \quad \text{(money/year)} \quad [2]$$

Version Number: 1.1

OUTPUT:

Fixed costs	Annual	Monthly	PMH	Cost/m^3	% of Total
Depreciation					
Base machine	344 250,00	28 687,50	180,00	9,00	17,99%
Attachment	0,00	0,00	0,00	0,00	0,00%
Total	344 250,00	28 687,50	180,00	9,00	
Interest on Average Annual Investment					
Base machine	152 655,00	12 721,25	79,82	3,99	7,98%
Attachment	0,00	0,00	0,00	0,00	0,00%
Interest Total	152 655,00	12 721,25	79,82	3,99	
Insurance	200,00	16,67	0,10	0,01	0,01%
Garaging for machine	0,00	0,00	0,00	0,00	
Machine Tax/Registration	100,00	8,33	0,05	0,00	0,01%
Machine Transfers	300,00	25,00	0,16	0,01	0,02%
Total Fixed Costs	497 505,00	41 458,75	260,13	13,01	26,00%
Variable costs	**Annual**	**Monthly**	**PMH**	**m^3**	**% of Total**
Fuel	382 500,00	31 875,00	200,00	10,00	19,99%
Oil and lubricants	382 500,00	31 875,00	200,00	10,00	19,99%
Maintenance and repairs					0,00%
Base Machine	382 500,00	31 875,00	200,00	10,00	19,99%
Attachment	0,00	0,00	0,00	0,00	0,00%
Total	382 500,00	31 875,00	200,00	10,00	19,99%
Additional tracks/chains	0,00	0,00	0,00	0,00	0,00%
Tyres and other main running gear	55 854,00	4 654,50	24,00	1,46	2,92%
Total	55 854,00	4 654,50	24,00	1,46	2,92%
Consumable 1	0,00	0,00	0,00	0,00	0,00%
Consumable 2	0,00	0,00	0,00	0,00	0,00%
Consumable 3	0,00	0,00	0,00	0,00	0,00%
Consumable 4	0,00	0,00	0,00	0,00	0,00%
Consumable 5	0,00	0,00	0,00	0,00	0,00%
Other	2 000,00	166,67	1,05	0,05	0,10%
Total Variable Costs	1 205 354,00	100 446,17	625,05	31,51	62,99%
Operator Costs	**Annual**	**Monthly**	**PMH**	**m^3**	**% of Total**
Operator wages (normal time)	112 500,00	9 375,00	58,82	2,94	5,88%
Other operator costs	1 000,00	83,33	0,03	0,03	0,05%
Operator benefits and overheads	6 175,00	514,58	3,23	0,16	0,32%
Total Operator Direct Costs	119 675,00	9 972,92	62,08	3,13	6,25%
Net Costs (excluding profit margin)	1 822 534,00	151 877,83	947,26	47,65	95,24%
Company overheads and management costs	0,00	0,00	0,00	0,00	0,00%
Profit margin (%)	5,00%				
Gross Costs (including profit margin)	1 913 660,70	159 471,73	994,62	50,03	100,00%
Profit Margin (before tax)	91 126,70	7 593,89	47,36	2,38	4,76%

Figure 2. The output section of the spreadsheet.

Where I = interest rate in percent divided by 100 (i.e. 5% gives $I = 0.05$).

These are the same formulas used earlier by e.g. Miyata (1980), FAO (1992), and Franklin (1997). In the model, the capital cost for the base machine and potential attachments are separated, because these two often have very different expected economic life spans.

Other fixed costs are annual costs for machine tax, registration, insurance, and garaging. Machine transfer costs are included as a fixed cost because the number of work sites per year for a machine tends to be rather constant in a regional context or over the machine's life. However, where this is not the case and there are frequent transfers that need to be calculated in, the user should take this into account separately. (It can be included under "other annual items.")

Variable costs

Variable or running costs are incurred when the machine is working, whether performing its intended task or travelling empty, or at least when the engine is running. These costs are solely concerned with machine use and as such are charged on a PMH or production-unit basis in the calculation model. Labor costs are a special case. They often consist of a mix of fixed and variable costs; therefore, they are treated separately from the machine variable costs.

Machine variable costs

These are the costs for fuel, lubrication, maintenance and repair, running gear, and other consumables.

Fuel costs are calculated from the fuel price and fuel consumption per PMH. Lubrication costs are calculated as a percentage of the fuel cost. Fuel consumption can be tricky to work out unless the owner has good records with which to support a certain long-term fuel consumption rate. Consumption depends largely on the machine's engine power, its mechanical condition, the work that is it expected to do, whether it is matched to the specific work envisaged, and the skill, attitude, and training level of the operator. For those who need assistance with assigning a fuel or lubrication cost, rules of thumb are included in the comments to these inputs.

Two options exist for entering data for maintenance and repair costs: either a percentage of purchase price divided by the expected economic life of the machine, or the actual annual costs. The actual annual cost should preferably be based on known repair and maintenance costs from workshop records and job cards. Because the model is generic and not machine-specific, these costs are entered as overall annual costs and not separated into specific types of maintenance or repair costs. As with fuel costs, rules of thumb are included in the comments. It should be noted that there is a strong relation between maintenance costs of the machine and the expected economic life. When working with relatively new machines and disposing of the machine at a relatively low age, maintenance costs are less than noted in the rules of thumb.

Costs for running gear consist of two parts: "additional track/chains" and "tires or other main running gear." The former refers to tire or bogie tracks, and tire chains. It is important to remove the cost of the first sets of tyres or running gear from the investment cost of the machine if the option to calculate the costs for "tyres or other main running gear" separately is used. The costs for "tires or other main running gear" are calculated in the same way as the investment and interest costs for the base machine but based on the expected economic lifespan of the main running gear; i.e. tires and main running gear are treated the same way as attachments. The reason is that main running gear can have a very different expected economic life from the base machine. It was decided to put this calculation in the machine variable cost section because running gear is seen as a consumable item with little or no salvage value.

Other consumables might be cutter bars, saw chains, wire rope, or other materials that are consumed during the use of a machine. These can be entered separately in the model.

Operator costs

Operator costs are the sum of operator salaries and other operator costs (remunerations), which will include varying social charges and other operator benefits. Salaries are calculated from the number of workers needed to operate the machine during a shift, average hourly salary of those workers, work days per year, shifts per day, and hours per shift. Note that the maximum number of work days per year can vary substantially between countries depending on the number of statuary holidays and vacation days taken per year. Under "other operator costs" should be entered the annual cost for additional payments for e.g. overtime work, compensation for night work, etc., in addition to the normal salary. Social charges can be entered as either a percentage or a fixed annual cost. Operator benefits can include e.g. subsistence allowance, protective clothing, training costs, phone charges, insurance, and transport.

Productivity and operations

Under this heading some basic data for the operations are entered relating to time inputs and work outputs. Work time data is entered in the form of the number of scheduled work days per year, shifts per day, and hours per shift. The machine utilization (percentage), together with the scheduled work time, results in productive machine hours (PMH). Productivity data will be in the desired units per PMH, either measured or estimated. Finally, there is a section for company overhead, i.e. the machine's share of administrative and other pooled costs within the company.

Output section

In the output section, the cost calculations are presented per year, month, PMH, and productive unit. It provides a comprehensive breakdown of all costs in monetary terms and also as a percentage of the total cost. There is also a possibility for the user to set a profit margin for the operation and thus get not only a calculated net cost but also a gross cost for the machine use.

Discussion

To present one generic cost calculation model for all types of forest equipment, generalizations and simplifications have been necessary, and these are explained here. To make a model that is usable by all participating countries and to increase the comparability of research results, some factors clearly influencing operational costs have been left out of the model. It was felt not appropriate to include any other taxes or subsidies, other than the machine tax/registration fee, given the differences in tax systems and subsides between countries and even between regions within countries. It is obvious that this is something the user needs to add to the model if applicable. However, we urge users of the model to clearly state the effects of these various kinds of tax reliefs and subsidies on their presented costs. Otherwise, the goal of comparability in results is lost.

Fixed costs are treated in the same way, using the straight-line method as in Miyata (1980) and Franklin (1997), with the exception that the cost for tires or other main running gear can be deducted from the machine cost and depreciated separately, in the same way as an attachment. This allows the user who calculates the costs for a machine that only needs one set of main running gear during its economic life to set the costs for running gear to zero and get exactly the same results as in Miyata (1980) and Franklin (1997), given that the cost of that set of main running gear is included in the investment cost.

For salvage values in the calculations, 10% is recommended as a rule of thumb, but for a machine owner who frequently replaces the machines to reduce delays and costs due to repairs, which are lower for newer machines, this number should be adjusted. There is a lack of studies dealing with the salvage value of machines. However, Spinelli et al. (2011) investigated dealers' asking prices for used machinery; these appear to drop relatively quickly during the first few years and after that to decline gradually, to approximately 30% at an age of 10 years for large machines. Because the asking price is what the dealer asks for the used machine when he advertises it, it will be considerably higher than the salvage value he pays when he buys the machine. The asking price has to cover his expenses for refurbishment of the machine and storage as well as providing a margin for profit and negotiations.

Operational costs have intentionally been kept in an aggregated form and not been specified in too much detail, as in e.g. the Flis model (von Hofsten et al. 2005). This enables users with no or limited access to good long-term records from trustworthy machine owners to use the model. This is also the reason for comments presenting "rules of thumb" and published data in these sections. Detailed models work well as long as users have access to high-quality data; if not, there are simply more inputs for which the user has to estimate a reasonable value – i.e. the guesswork increases. In today's competitive world, the number of contractors that allow researchers access to their data on operational costs is declining.

Operator costs are based on the assumptions that workers are paid by the hour and that they work the scheduled number of hours per shift and the scheduled number of work days per year. If the workers are paid on a piece-rate basis, the user has to calculate the average hourly salary from the productivity figures in the "productivity and operations" section and the piece rate. Because there is no separation between scheduled machine hours (SMH) per shift and the number of hours the operator works in the shift, the average hourly salary has to be adjusted if these two deviate from each other, because the model uses SMH as the time worked per shift. As an example, if a worker operates the machine for 6 hours per shift and works with other tasks for 2 hours per shift, the actual salary per hour has to be multiplied by 8/6 to represent the salary cost per SMH.

During the development of the COST model, there were many discussions on a number of cost items that cannot be seen as strictly machine costs and that are influenced by object size, system choices, or corporate decisions. These "system costs" include e.g. relocation costs, administration and management costs, profit margin, and risk. Some of these costs will be of importance in analysis of the complete machine system used, but should perhaps not be included in the machine cost calculation, instead being added at a later stage of the analysis. If the model is used to calculate the cost for a single operation, users should be aware that there is a risk that the relocation cost might skew the estimate of the hourly machine cost. One can then choose to set the yearly relocation cost in the model to zero and calculate the relocation costs for the operation in question as a separate activity.

Costs such as administration and management, profit margin, and risk are not tied to a specific machine but to the operation of a complete harvesting system, and they will change according to business decisions made by the management of the company. We have included the possibility of adding both company overhead and profit margin to the model, but they are not included in the net costs of the machine. Users should be aware of the large intercompany variability that exists between items considered as overhead. As the cost items included vary between companies, only those that are directly linked to the operation of a specific machine should be included if the intention is to compare two machines intended for the same work task. Otherwise, overhead costs that are not linked to the analyzed work might dilute or increase the differences between the compared machines. When comparing machine costs, it is always safest to compare net costs unless it is clearly stated what has been included as overhead.

It is easy and recommendable to do sensitivity analyses with the model and test how the result changes if inputs are changed. This is important especially for cost items that make up a relatively large share of the total costs, such as investment, interest, machine utilization, fuel, and repair and maintenance costs, or where the input data are of a lower quality. It is not uncommon that the stated purchase price for a machine will differ by more than 10% depending on whether the retailer or the contractor is asked. The dealer usually gives a price for a minimum configuration of the machine, while the contractor gives the price for a machine equipped for the work at hand.

Our hope is that through the COST model, cost calculations will be harmonized not only in forest biomass operations research but in all types of forest operations research. This would ensure that machine costs are comparable between countries. However, we are aware that national regulations and subsidies will affect the outcome and hope that users clearly describe these deviations in their publications. In order to maintain the comparability of cost calculations made with the COST model it is of utmost importance that when local adaptations to the general guidelines pertaining to the model have been made, the user states what has been done and why.

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