Harvesting Costing

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Abstract

Harvesting costing plays a key role in harvesting planning, controlling, and execution of harvesting operations. Since economic sustainability is the key factor of all production processes of enterprises, the expenses may not exceed the financial returns over a longer period. Therefore harvesting costing is one of the most important issues for forest companies, depending on highly qualified personnel and a well-organized system of planning, execution, and controlling. Harvesting costing is very complex, since many burden centers have to be considered in cost calculation. Machines and equipment used in harvesting operations in general are expensive, specifically if high volumes of wood assortments have to be produced or heavy stems have to be manipulated. For cost calculation of harvesting systems, a series of information are necessary. First, all operational conditions of a forest area have to be known, because they determine the use of the adequate equipment and its productivity. The forest type (planted or native), tree dimension, terrain conditions, soil properties, and wood utilization have to be considered for decision taking and cost calculation. If the equipment or machines that match with all requirements are determined, the respective costs of the system may be calculated. Country-specific data like taxes, labor, and social costs or fuel prices have to be collected for cost calculation. In a second step, costs linked to an equipment or machine specifications like fuel consumption, necessary spare parts, accessories to be used, mechanical availability, life span, capital costs, interest rates, and maintenance costs, among others, have to be risen and included in the calculations. The costs itself may be classified after fixed or variable costs. Fixed costs are costs that have to be paid periodically, independent of the quantity of goods produced. This would be interest rates for capital costs, labor costs, machine insurances, or depreciation allowance. The fixed costs make it necessary that own equipment and machines of a company show a high productivity to reduce the share of the fixed costs on the total costs. The variable costs are directly linked to the quantity of goods produced, in case of harvesting the volume of wood. Examples for variable costs would be fuel consumption of a machine and maintenance costs depending on machine hours or lubricants. Costs may be reduced if the harvesting process is planned carefully and the machine and equipment are used with high efficiency over the whole "hour budget" set for operation. The working hours per day and how many days a week the employees and operators work determine the productivity of the machines and equipment and influence directly on the costs. Other costs that have to be considered are the ones that have influence of the cash flow of a company. Residual value of machines or savings or additional expenses that could be made if harvesting operation is outsourced to a third party have also been considered in overall cost calculation. Costs for harvesting operations have to be analyzed on a periodical basis and compared to existing alternatives. Internal rate of return, net present value, and cash flow should be checked for evaluation of efficiency of performed operations. Cost accounting for different periods and units produced offer numbers that allow benchmarking of a company's harvesting operation. The present article introduces harvesting costing terminology, data collection, and cost reporting, showing how harvesting costs might be calculated and checked for efficiency.

Keywords
Wood Harvesting • Costing Variables • Machine Costs

Introduction

Harvesting costs depend on equipment investment, stand size, tree species and volume removed, terrain, and even degree of difficulty due to proximity to houses, power lines, public roads, noise restriction areas, and other restrictions posed by forestry-related ordinances. Harvesting costs also depend on the type of equipment used, season in which the operation occurs, and a host of other factors (Sohns 2011; Grammel 1988).

Overcoming these costs typically requires tracts with large volumes of relatively valuable material. At this time and based on current cost and revenue estimates, woody biomass for energy and other bio-based products may not generate enough revenue on its own to be profitable.

Harvesting costing mainly consists of the operational costs of machines and equipment as well as the operator and workers necessary for its handling. Knowing well these costs is an indispensable requirement for planning, executing, and controlling harvesting operations with the respective equipment (Machado and Malinovski 1988; Freitas et al. 2004). The costs for machines and equipment result from their price of purchase and operation (Machado 1989; Freitas et al. 2004).

Calculation of these costs may vary according to the methodology applied. In 1956 the Food and Agriculture Organization (FAO) developed their own methodology which since then is widely applied all over the world. In 1971 the German Curatorship for Forest Operations (KWF) implemented some modifications resulting in the FAO/ECE/KWF model. Both systems present their cost results in the unit "effective working hours." Besides the international known systems, a series of local cost calculation models, some of them based on other units, also exist.

The objective of the following chapters is to introduce the basic terms and definitions of harvesting costing and to provide examples for calculating machine and equipment costs in forest harvesting operations.

Today a variety of free Logging Cost Analyses Worksheets and Calculators are available in the internet. The worksheets are computerized spreadsheet calculators that provide basic, usable information to determine operating costs for harvesting equipment, systems, and operations. Hourly operating costs, productivity, logging costs, harvesting system costing models, and road construction and maintenance models are available.

Some examples can be verified at the following websites (access 10/2014):

http://www.fs.fed.us/t-d/programs/forest_mgmt/projects/textbook/cost/
http://www.srs.fs.usda.gov/forestops/products/tools.html
http://www.kwf-online.org/arbeitsverfahren/maschinenkalkulation.html
http://www.fao.org/docrep/t0579e/t0579e05.htm

Requirements

For cost calculation in forest harvesting operations, basic information is required. Starting from this information, a person in charge for planning the operation can make the necessary calculation for decision taking which equipment or machine offers the best cost-benefit option (Fight et al. 1999). Reliable sources for basic data for cost calculation may come from own experiences, from other companies that already applied a harvesting operation under comparable conditions, or from service offers of third parties. Also information about interest rates, fuel costs, labor and social costs, and taxes that have to be paid are necessary to get real costs for a given operation. For calculating machine costs, the producer or provider of the equipment in many cases provide fact sheets with important data of fuel consumption, lubricants, maintenance interval, productivity, and others.

General Requirements

The most important items necessary for cost calculation are listed in Table 1.

Depending on the harvesting system to be used, the basic information for cost calculation might be easy to obtain. Regardless if an ax, chainsaw, or complex felling machines are used, the difference might be to get reliable estimations of the productivity of the system under the conditions it might be applied.

Table 1 Example for basic requirements for harvesting cost calculation (for the examples the currency US$ is used)

Item	Unit	Value
Productivity	m^3/month (or hour, day, shift)	–
Effective harvesting costs	US$/$m^3$	–
Current harvesting costs per year	US$/year	–
Annual taxes	%/year	–
Fuel costs	US/h	–
Currency exchange rate (if applicable)	Currency/U$	–
Labor/operator costs	%	–
Social costs	US$/month	–
Taxes	%	–

Machine and Equipment Information

If the basic requirements are available, the next step consists in calculating the operational costs of the chosen system. Detailed information about machines or equipment to be used are necessary to get reliable costs in the calculation (Table 2).

According to the items listed in Table 1, the most important value to determine is the productivity of each machine under predetermined conditions. An adequate estimation for the productivity is absolutely necessary for a reliable cost calculation. The calculation is the base for a cost analysis of different harvesting systems that possibly could be used under given circumstances. Size and power of the machines might be adapted to the natural conditions found in the forest intended to be harvested (Malinovski et al. 2006). An important issue for cost calculation of a harvesting system is to consider the labor force and machine operators necessary to make the system working. The salaries and social costs linked with the activities in some cases may exceed costs for machines and equipment. These costs are under constant modification and adaption, specifically in emerging countries like those often found in the tropical regions of the world. Since harvesting costing in general is based on medium- to long-term planning, changes in labor and social costs may have significant impact on the costs per unit produced. It is recommendable to consider yearly increases of these costs when estimating the overall harvesting costs.

Costs

For planning, execution, and controlling of harvesting processes, the costs for machines and labor have to be well known (Stöhr 1977). The FAO/ECE system considers three different types of costs: fixed costs, semifixed costs, and variable costs. Other systems only work with fixed and variable costs.

Fixed Costs

The fixed costs are costs that do not change with an increase or decrease in the amount of goods or services produced. Fixed costs are expenses that have to be paid independent of any operational activity (Pacheco 2000; FAO 1992). In the case of forest harvesting, this means that a chainsaw, a tractor, or a harvester generates costs, if they are working or if they are parked in the machine yard. The same is true for the staff hired, regardless if it is a motor-manual harvesting system based on chainsaw felling or a fully mechanized one with harvesters, forwarders, or other machines. In the fix costs, costs for depreciation allowance, the costs for purchasing the machines, and insurance and taxes also are included. The equation for calculation of fixed costs is the following:

Table 2 Example for information necessary for cost calculation of a mechanized harvesting system consisting of feller buncher, skidder, and processor (based on costs in 2014 in Brazil)

Item	Unit	Feller	Skidder	Processor
Activity	Type	Felling	Skidding	Processing
Purchase costs of basic machine	US$/unit	490,000	470,000	275,000
Accessory	Type	Disk saw head	Grapple	Processor head
Purchase costs of accessory	US$	100,000	23,000	135,000
Residual value	%	20	20	20
Costs for tires	US$	25,000	29,000	18,000
Life span of the machine	Hours	20,000	20,000	20,000
Life span of accessories	Hours	20,000	20,000	10,000
Life span of tires	Hours	10,000	5,000	10,000
Percentage of lubricants in relation to fuel consumption	%	15	15	15
Fuel consumption	L/h	28	27	20
Operational availability	%	85	85	85
Average mechanical availability	%	85.4	85.4	85.4
Mechanical availability year 1	%	91	91	91
Mechanical availability year 2	%	88	88	88
Mechanical availability year 3	%	85	85	85
Mechanical availability year 4	%	83	83	83
Mechanical availability year 5	%	80	80	80
Surplus for maintenance (total of purchase value = PV))	% PV	100	100	100
Surplus for maintenance (up to 20 % of life span)	% PV	10	10	10
Surplus for maintenance (up to 40 % of life span)	% PV	15	15	15
Surplus for maintenance (up to 60 % of life span)	% PV	20	20	20
Surplus for maintenance (up to 80 % of life span)	% PV	25	25	25
Surplus for maintenance (up to 100 % of life span)	% PV	30	30	30
Insurance (in %/year of purchase value)	%/year	1.5	1.5	1.5
Annual interest rates for financing basic machine	%/year	6	6	6
Annual interest rates for financing accessories	%/year	6	6	6
Advance payment basic machine	US$	490,000	470,000	275,000
Period of grace for basic machine	Month	0	0	0
Financing period for basic machine	Month	0	0	0
Advance payment accessories	US$	100,000	23,000	135,000
Period of grace for accessories	Month	0	0	0
Financing period for accessories	Month	0	0	0

Calculation of Fixed Costs

$$FC = PC + DPC + CCa + IC + LC + OV \quad (1)$$

where:

FC = fixed costs (US$/year)
PC = purchase costs (US$)
DPC = depreciation costs (US$/year)
CCa = capital costs (US$/year)
IC = insurance costs (US$/year)
LC = labor costs (US$/year)
OV = general overheads (US$/year)

Property Costs

Property costs refer to the costs generated by purchasing equipment or machine and the subsequent utilization of it (Borinelli 2003). The property costs show a broader approach including more costs than the price for purchasing, considering the total consumption of the good or the scrapping of a machine (Ellram and Siferd 1998; Soutes 2007).

Purchase Costs

The price of a machine in the factory is different from the price the client has to pay for it. There are costs for taxes, transport, and commission that have to be added (Stöhr 1977).

Calculation of Costs for Machines

$$PC = (PC_{BM} + PC_{AC}) * QM \quad (2)$$

where:

PC = purchasing costs (US$)
PC_{BM} = purchase costs for basic machine (US$/machine)
PC_{AC} = purchase costs for accessory (US$/accessory)
QM = quantity of machines to be purchased

A harvesting system in general consists of several processing steps, where different machines and equipment are used. Harvesting costing refers to the overall costs generated by this operation, including all machines, equipment, or vehicles necessary. This includes from mobile modules for coordinating harvesting operations maintenance trucks, storage for spare parts, low-loading trucks for transporting the oversized harvesting machines, hiring the staff up to the chemical toilets in the field, etc. It is noteworthy that the costs for the harvesting equipment in general are computed before the harvesting operation is executed; having the investment this way has a significant impact on the internal rate of return of the overall project.

Depreciation Allowance

The depreciation refers to the loss of value of a machine due to aging and utilization. The difference between both is that the loss of value by wearing in general is linked with productivity, with a financial return (PACHECO 2000). Including the value of depreciation in the operational costs allows creating a capital reserve for the purchasing of a new machine when the end of the life span of the machine is reached (OLIVEIRA et al. 2006).

Calculation of Depreciation Costs

$$DPC = (DPC_{BM} + DPC_{Ac}) * 12 * QM \quad (3)$$

where:

DPC = depreciation costs (US$/year).
DPC_{BM} = depreciation costs of the basic machine (US$/month)
DPC_{AC} = depreciation costs of the accessories (US$/month)
QM = quantity of machines

The annual rate of depreciation is applied to calculate the residual value of the machine or the accessory, if the machine is sold after a given period. The amortization costs that may be used in the tax declaration in general are given by the respective governments for the different machines and equipment. A flat rate of 0 %–20 % over the purchasing value of the new machine is very common for an estimation of the residual value. In practice, it is not very common to use the residual value for the accessories used with the basic machine. For manual tools like axes, saws, and other equipment used in harvesting operations, also an annual depreciation allowance of 20 % is common.

For calculating the depreciation cost, the period of analysis of the harvesting system should be used subtracting the purchasing costs of tires and tracks, because they are already considered as variable costs.

- If the span of property of the basic machine is less than or equal to the period of analysis:

Calculation for Depreciation Costs for Less Than the Period of Analysis

$$DPC_{BM} = \frac{(PC_{BM} - PC_{TR}) * (1 - PRV_{BM})}{PP_{BM} * 12} \quad DPC_{Ac} = \frac{PC_{AC} * (1 - AD_{AC})}{PP_{AC} * 12} \quad (4)$$

- If the span of property of the basic machine is more than the period of analysis:

Calculation for Depreciation Costs for More Than the Period of Analysis

$$DPC_{BM} = \frac{(PC_{BM} - PC_{TR}) * (1 - PRV_{BM})}{PA * 12} \; DPC_{AC} = \frac{PC_{AC}\,(1 - AD_{AC})}{PA * 12} \quad (5)$$

where:

DPC_{BM} = depreciation costs of the basic machine (US$/month)
DPC_{AC} = depreciation costs of the accessories (US$/month)
PC_{BM} = purchase costs of basic machine (US$)
PC_{AC} = purchase costs of accessory (US$)
PC_{TR} = purchasing costs of tires (US$)
AD_{BM} = annual depreciation of the basic machine (%)
AD_{AC} = annual depreciation of the accessory (%)
PP_{BM} = period of properties of the basic machine (years)
PP_{AC} = period of property of the accessory (years)
PRV_{BM} = residual value of the machine (in % of PC_{BM})
PA = period of analysis (years)

Capital Costs

The capital costs are the return an investor would expect investing the money in a project of the same risk class. It indicates how much it costs the enterprise to finance its activities using its own or committed assets.

Calculation of Capital Costs

$$\begin{aligned} CC_{BM} &= \left\langle AP_{BM} * \left\{ \left[(1+i)^{1/12} \right] - 1 \right\} \right\rangle * 12 * QM \\ CC_{AC} &= \left\langle AP_{AC} * \left\{ \left[(1+i)^{1/12} \right] - 1 \right\} \right\rangle * 12 * QM \\ CC_{a} &= CC_{BM} + CC_{AC} \end{aligned} \quad (6)$$

where:

CC_{BM} = capital costs of the basic machine (US$/year)
CC_{AC} = capital costs of the accessory (US$/year)
CC_{a} = capital costs (U$/year)
AP_{BM} = advance payment for the basic machine (US$/year)
AP_{AC} = advance payment for the accessory (US$/year)
i = annual interest rate (%/year)
QM = quantity of machines

Insurance Costs

Harvesting machines and equipment are used in zones and under working conditions of high risk; therefore it is recommendable to contract a partial or full insurance (Stöhr 1977). The risks are manifold. Harvesting operations under tropical conditions are dangerous for all machines with combustion engines. Heat, fuel, lubricants, and dust in combination with crown slash increase the risk of fires. Falling trees or big branches may cause damages to machines as well as injuries of personnel. The insurance costs may cover the full or partial value in case of an accident or unforeseen event (Pacheco 2000). It is very common to use a certain percentage of the purchasing costs for estimating the insurance costs, as indicated in the following equation:

Calculation of Insurance Costs

$$IC = IR * (PC_{BM} + PC_{AC}) \tag{7}$$

where:

IC = insurance costs (US$/year)
IR = insurance rate (%/year of PC)
PC_{BM} = purchase costs of basic machine (US$)
PC_{AC} = purchase costs of accessory (US$)

Labor Costs

Labor costs are all salaries paid to employees, as well as the cost for benefits and payroll taxes that have to be paid by an employer. It can be distinguished between direct and indirect costs. Direct costs include salaries for the employees physically making a product, like the operators of a harvesting machine or a chainsaw. Indirect costs are associated with labor that support the production of goods, such as the maintenance crew of harvesting machines or the administration staff that hires workers for the harvesting operation (Rocha 1992). The labor costs can be calculated with the following equation:

Calculation of the Labor Costs

$$LC = SA + OTH \tag{8}$$

where:

LC = labor costs (US$/year)
SA = salaries and social costs of the employees (US$/year)
OTH = overtime hours and extras (US$/year)

The costs for different groups can be summarized by multiplying the salary calculated by the number of employees. Typical groups in harvesting operations would be machine operators, chainsaw operators, maintenance crew, or supervisors. Extras like overtime, nightshifts, or premiums for high productivity may be estimated in a separated way. In many countries, the daily, weekly, or monthly working time of each employee is restricted by law. Any calculation of the number of employees should consider these restrictions, and absence periods of workers should be taken into account. In the case of machine operators, a sufficient buffer has to be planned, especially when it is intended to work in two or three shifts a day. In many emerging countries of the tropical regions, the social costs for employees increased significantly in the last decade. Especially for forest work, mainly classified as dangerous, the costs for health and life insurance, as well as limitations for maximum working hours, training requirements, and ban of outer-most hard physical work, contributed in raising the costs. The local working legislation should be taken into account when calculating the labor costs for harvesting operations.

Variable Costs

In the case of harvesting operations, the volumes or weights of wood assortments provided for transport and further processing are directly linked to the variable costs. The following equation expresses the variable costs:

Calculation of Variable Costs

$$VC = CMF + FC + LC + TRY + CCY \tag{9}$$

where:

VC = variable costs (US$/year)
CMF = costs for maintenance fund (US$/year)
FC = fuel costs (US$/year)
LC = lubricants costs (including hydraulic oil and other fluids) (US$/year)
TRY = costs for tires and tracks (US$/year)
CCY = costs of consumables (US$/year)

Costs for Maintenance and Repair

This category includes every maintenance activity, from a simple oil level checkup to a periodic revision of the engine, brakes, clutch, transmission, and other components of a harvesting machine. The same is true for a chainsaw. Even if the costs for this working tool might be lower, the time spent to tensioning the chain or to clean the air filter reduces productivity because it reduces the time spent in processing wood (FAO 1992).

Maintenance might be classified as (a) preventive maintenance and (b) corrective maintenance. The preventive maintenance is applied on equipment, machines, or systems before a fault occurs. It can be subdivided into planned maintenance and condition-based maintenance. Corrective maintenance on the other hand may also be called repair. It is conducted to get a machine working again when it is broken or with a defect (Pacheco 2000). These costs may be estimated with information provided in the user manual of the producer or by own or third-party experiences. An indirect method would be by using the percentage depreciation allowance (FAO 1992).

In the examples given below, another methodology is applied. The owner has to decide whether the utilization rate of the machine is below or above/equal 20 %. That value commonly is accepted as a break-even value for maintenance cost calculation in the practice.

- If the machine is operating (percentage of the utilization – PU) below 20 % multiplied by the year of reference:

Calculation of Maintenance Fund Costs (Less Than 20 % of Usage of Total Machine Capacity Multiplied by the Reference Year)

$$\text{If } \left(\frac{\text{OH}}{\text{LS}}\right) * 100 < 20\% * \text{A}, \text{ then}: \ \text{CMF} = (\text{WHY} * \text{CM}_n) * \text{QM} \tag{10}$$

where:

OH = total operating hours (hours)
LS = life span of the machine (hours; see manufacturer indications)
A = year of reference (1, 2, 3...)
CMF = costs for maintenance fund (US$/year)
WHY = working hours per year (hours/year)
CM_A = costs for maintenance in the respective year (US$/h)
QM = quantity of machines (unit)

- If the machine is operating (percentage of the utilization – PU) above or equal to 20 % multiplied by the year of reference:

Calculation of Reserve Fund Costs (Equal or More Than 20 % of Usage of Total Machine Capacity Multiplied by the Reference Year)

$$\begin{aligned} &\text{If } \left(\frac{\text{OH}}{\text{LS}}\right) * 100 \geq 20\% * \text{A}, \\ \text{then}: \quad &\text{CMF} = \left\{(\text{WHY} * \text{CM}_\text{A}) + \left[\text{WHY} - \left(\frac{\text{WHY} * \text{LS} * 0,2}{\text{OH}}\right)\right] * (\text{CM}_{\text{A}+1} - \text{CM}_\text{A})\right\} * \text{QM} \end{aligned} \tag{11}$$

where:

CMF = costs for maintenance fund (US$/year)
WHY = working hours per year (hours/year)
CM_A = costs per hour for maintenance in the respective year (US$/h)
LS = life span of the machine (hours; see manufacturer indications)

OH = total operating hours (hours)
A = year of reference (1, 2, 3...)
QM = quantity of machines (unit)

The percentage of the utilization of the machine is corresponding to the working hours already spent in relation to its life span. This value is calculated with the following equation:

Calculation of the Working Hours Already Spent by the Machine in Relation to Its Total Life Span

$$PU = \frac{OH}{LS} \tag{12}$$

where:

PU = utilization of the machine up to the year of reference (%)
OH = total operating hours (hours)
LS = life span of the machine (hours)

For calculating the costs for the maintenance fund for every working hour of the machine or equipment, the following equation has to be applied:

Calculation of the Maintenance Fund Costs per Working Hour

$$CM_A = \left(\frac{PC_{BM} + PC_{AC} - PC_{TR}}{LS}\right) * (1 + PRM) \tag{13}$$

where:

CM_A = costs per hour for maintenance in the respective year (US$/h)
PC_{BM} = purchasing costs of basic machine (US$)
PC_{AC} = purchasing costs of accessory (US$)
PC_{TR} = purchasing costs of tires (US$)
LS = life span of the machine (hours)
PRM = percentage reserved for maintenance (%)

Example 1: Repair and Maintenance Costs
A *feller buncher* that works 3,041 h in the first year and 2,941 h in the second year. Life span of the machine is estimated with 20,000 h. For calculation of the costs, it has to be verified:

$$\left[\frac{(3,041 + 2,941)}{20,000}\right] * 100 < 20\% * 2.$$

The cost for one maintenance hour in the reference year (year 2) is about US$ 38.61. The calculated cost is

$\text{CMF} = (2,941 * 38.61) * 1$ $\text{CMF} = \text{US\$ } 113{,}55$.

The annual working hours of a machine or equipment depend on the number of working days, the hours worked each day, and the effective use of the equipment.

Calculation of Working Hours of an Equipment per Year

$$\text{WHY} = \text{WHD} * \text{WDY} * \text{EU} \quad (14)$$

where:

WHY = working hours per year (h/year)
WHD = working hours per day (h/day)
WDY = working days per year (days/year)
EU = effective use (%)

The total operating hours correspond to the product of the programmed working hours per day, number of working days in 1 year, and the effective use of the machine or equipment, the latter being the result of the multiplication of the mechanical availability, the operational availability, and the rate of utilization.

Accumulated Working Hours During the Period of Analysis (Hours)

$$\text{OH} = \sum_{j}^{n} \left(\text{PWHY}_j * \text{WDY}_j * \text{EU}_j\right) \quad (15)$$

where:

OH = total operating hours (hours)
PWHY_j = programmed working hours per day in the year "j" (hours)
WDY_j = working days considered in the year "j" (days)
EU_j = effective use in the year "j" (%)
n = number of analyzed years

The effective use of the machine takes into account the utilization rate and the operational efficiency. The latter is the product of the multiplication of the mechanical and operational availability of the machine.

Calculation of the Effective Use of the Equipment

$$\text{EU} = \text{UR} * \text{OEE} \quad (16)$$

where:

EU = effective use of the equipment (%)
UR = utilization rate (%)
OEE = overall equipment effectiveness (%)

The machine or equipment efficiency is defined as the percentage of the effective working time in relation to the scheduled hours for the service (OLIVEIRA et al. 2006). It can also be defined as the product of the mechanical availability and operational availability.

Calculation of the Overall Equipment Efficiency

$$OEE = \left(\frac{WHM}{AHM}\right) * 100 \text{ or } OEE = MA * AO \quad (17)$$

where:

OEE = overall equipment effectiveness (%)
WHM = working hours per month (hours/month)
AHM = available hours per month (hours/month)
MA = mechanical availability (%)
AO = operational availability (%)

The mechanical availability refers to the time frame the machine is programmed to work in harvesting operations, not being in preventive or corrective maintenance. The operational availability on the other hand is the time the machine is really operating, compared to the total time where it is scheduled for work.

Fuel Costs

It is difficult to obtain reliable fuel consumption values for machines used in harvesting operations, since the overall consumption depends on the workload of the machine at a given activity (Pacheco 2000). If there is no experience or manufacturer information about fuel consumption available, in literature it is recommended to calculate with 0.2 up to 0.3 l per hour of diesel oil per HP (horse power) put on the power train. Another source refers to a value of 0.14 l of diesel oil per working hour and HP. In case the consumption of the manufacturer is available, it is recommendable to add a surplus of 10–20 % (Stöhr 1977).

Calculation of the Fuel Cost

$$FC = FCS * FP * WHY * QM \quad (18)$$

where:

FC = fuel costs (US$/year)
FCS = fuel consumption (l/h)
FP = fuel price (US$/l)
WHY = working hours per year (hours/year)
QM = quantity of machines (unit)

Lubricants, Hydraulic Oils, and Other Fluids

Even more difficult to estimate is the quantity of lubricants consumed by different machine types. The most reliable source in case of missing experience values are the user manuals provided by the manufacturers. The size of the reservoirs, intervals for changing lubricants, and other useful information are available there. Stöhr (1977) comments that in case of missing information, the lubricants can be estimated by using a value of 15–20 % of the fuel costs (except for chainsaws).

Calculation of the Costs for Lubricants

$$LC = FC * LO \tag{19}$$

where:

LC = lubricant costs (including hydraulic oil and other fluids) (US$/year)
FC = fuel costs (US$/year)
LO = percentage of lubricants and oils in relation to the fuel consumption (%)

Some basic rules for changing intervals are given here (Pacheco 2000):

- Engine oils = > 200 h
- Gearbox oil and differential = > 750 h
- Hydraulic transmission = > 750 h
- Hydraulic oil = > 750 a 1,000 h
- Box of hydraulic steering = > 500 h

The consumption of grease is difficult to estimate without experience. Some basic rules are (Pacheco 2000):

- 0.5 kg/10 h for tractors
- 0.3 kg/10 h for accessories

Costs for Tires and Tracks

The costs for tires include costs for tracks and other accessories of the machines for keeping them mobile, not only for maintenance but also for replacement. These costs are influenced by terrain conditions, environment, maintenance, and capacity of the operators (Oliveira et al. 2006). Even if the track-based machines used in harvesting operations are built for heavy duty applications, the costs for replacing the tracks correspond to 50 % of the overall maintenance costs. Already when purchasing the basic machine, the tracks are about 20 % of the price of the new machine (ELO 2010).

Calculation of the Costs for Tires and Track Maintenance

$$TRY = TRH * WHY * QM \tag{20}$$

where:

TRY = costs for tires and tracks per year (US$/year)
TRH = costs for tires and tracks per hour (US$/h)
WHY = working hours per year (hours/year)
QM = quantity of machines

Other Consumables

Many machines use parts that have to be replaced periodically, causing additional variable costs. Some examples are saws and chains for felling in harvester heads, disks or shears in feller heads, knives in chippers, hydraulic hose, or steel cables for wood extraction. The calculation of such costs, the costs per hour, and year of the consumable should be known. It can be calculated with the following equation:

Calculation of the Costs of Consumables

$$CCY = CCH * WHY * QM \tag{21}$$

where:

CCY = costs of consumables per year (US$/year)
CCH = costs of consumables per hour (US$/h)
WHY = working hours per year (hours/year)
QM = quantity of machines

Total Costs

The total costs are calculated by summing up the fixed costs and the variable costs described in the subchapters, by using the following equation:

$$TC = FC + VC$$

where:

TC = total costs (US$/year)
FC = fixed costs (US$/year)
VC = variable costs (US$/year)

Assets to Be Considered

Harvesting operations make part of a company's cash flow over a given accounting period. The accounting entries can be separated into three sections like operating activities, investing activities, and financing activities.

Residual Values of Machines and Equipment

When completing the life span after a given number of working hours or technical aging, a machine or equipment in many cases still can be used for the same or other activities for a certain period. In this case there is a potential residual value that may enter in the overall cost analysis, reducing the costs per working hour and at least the cost for the depreciation allowance (Stöhr 1977).

Calculating Residual Value of a Machine or Equipment

$$RV_{BM} = \{[PC_{BM} - (PC_{BM} * PRV_{BM})] * (1 - PU)\} + (PC_{BM} * PRV_{BM}) * QM \quad (22)$$

where:

RV_{BM} = residual value of the basic machine (US$)
PC_{BM} = purchase costs of the basic machine (US$)
PRV_{BM} = residual value of the machine (in % of PC_{BM})
PU = percentage of utilization (absolute value) (OH/LS)
QM = quantity of machines in operation

Example 2: Residual Value of Equipment and Machines
Calculating the residual value of a *feller buncher* knowing the purchase cost of the machine: US$ 591,680. The life span is estimated with 20,000 h. The company works with the *feller* 13.7 h per day for 23.9 days per month (average). The utilization rate of the machine is 100 %, the average mechanical availabilities is reducing from 91% in year 1 to 80% in year 5 while the operational efficiency remains constant with 85%, and the operational efficiency is 85 %. The percentage of the residual value of the machine is estimated in 20 % of the purchasing costs.

$$\text{WHY year 1} = 13.7 * 23.9 * (100\% * 91\% * 85\%) = 3{,}041\ \text{h}$$

$$\text{WHY year 2} = 13.7 * 23.9 * (100\% * 88\% * 85\%) = 2{,}941\ \text{h}$$

$$\text{WHY year 3} = 13.7 * 23.9 * (100\% * 85\% * 85\%) = 2{,}841\ \text{h}$$

$$\text{WHY year 4} \quad = 13.7 * 23.9 * (100\% * 83\% * 85\%) \ = \ 2,774 \text{ h}$$

$$\text{WHY year 5} \quad = 13.7 * 23.9 * (100\% * 80\% * 85\%) \ = \ 2,674 \text{ h}$$

$$\text{OH} = \ 14271 \text{ h}$$

$$\text{PU} = \left(\frac{14,271}{20,000}\right) * 100 = \ 71.36\%$$

$$\text{RV}_{\text{BM}} = \quad \{[591,680 - (591,680 * 20\%)] * (1 - 0.7136)\} + \ (591,680 * 20\%)$$

$$\text{RV}_{\text{BM}} \ = \text{US\$ } 253,900$$

Expenses with Outsourced Services

Harvesting can be done under own administration and execution or a service provider can be hired. In the first case, harvesting costing is treated as an internal investment of the company. In many cases, harvesting operations are outsourced to a service provider, causing this way a cash outflow to a third party.

Economic Analysis

Like the cash flow evaluation, the economic analysis is an important tool for decision taking in investments. Harvesting operation is one of the most cost intensive cost position in forest management activities. An economic analysis of such operation points out the pros and cons of the investment in the present and future. For an economic analysis of an investment, three methods may be applied: internal rate of return (IRR), net present value (NPV), and payback (PB).

Internal Rate of Return (IRR)

The internal rate of return (IRR) (or economic rate of return (ERR)) is used to measure and compare the profitability of investments. It is also called the discounted cash flow rate of return. The calculation does not incorporate business environmental factors like the interest rate or inflation (Oliveira 1979). The internal rate of return follows from the net present value as a function of the rate of return for a given collection of pairs of time and cash flow (see equation below).

Calculation of the Internal Rate of Return

$$0 = CF_0 + \frac{CF_1}{(1 + IRR)^1} + \frac{CF_2}{(1 + IRR)^2} + \ldots + \frac{CF_n}{(1 + IRR)^n} \quad (23)$$

where:

CF_n = cash flow of the evaluated period (US$)
IRR = internal rate of return (%)
n = analyzed period in the year of reference

Example 3: Internal Rate of Return (IRR)
A forest plantation company wants to invest in new harvesting machines. They want to know if the interest rate of the investment is higher than the cost for the capital to be invested. This way the internal rate of return (IRR) is calculated knowing that:

- Investment for year 0: US$ 3,626,340
- Cash flow considered for 5 years:

Year 1	Year 2	Year 3	Year 4	Year 5
US$ 897,581	US$ 900,744	US$ 905,868	US$ 901,047	US$ 2,696,320

$$0 = 3,626,340 + \frac{897,581}{(1 + IRR)^1} + \frac{900,744}{(1 + IRR)^2} + \frac{905,868}{(1 + IRR)^3} + \frac{R\$ 901,047}{(1 + IRR)^4} + \frac{R\$ 2,696,320}{(1 + IRR)^5}$$

IRR = 17.8 % per annum (if the IRR is higher than the cost of the capital, the investment would be acceptable).

Net Present Value (NPV)

The net present value (NPV) (also called net present worth) of a time series of incoming and outgoing cash flow is defined as the sum of the present values of the individual cash flows. It compares the present value of money today to the present value of money in the future, taking inflation and returns into account (Lapponi 1996; Afonso Júnior et al. 2006).

Calculation of the Net Present Value (NPV)

$$NPV = CF_0 + \frac{CF_1}{(1 + i)^1} + \frac{CF_2}{(1 + i)^2} + \ldots + \frac{CF_n}{(1 + i)^n} \quad (24)$$

where:

NPV = net present value (US$)
CF_n = cash flow of the evaluated period (US$, "n" can be month or years)
i = capital costs (% per month or per year)
n = analyzed period

If the NPV is positive, then the investment aggregates value to the enterprise because the IRR is higher than the capital costs (i).

If the NPV is negative, then the investment doesn't aggregate value to the enterprise because the IRR is lower than the capital costs (i).

If the NPV is equal to zero, the investment generates an IRR at the same amount as the capital costs (i).

Example 4: Net Present Value (NPV)
Using the data of the IRR sample, the calculation shows that the investment generates a profit of 904, 277 US$ in the following years. In the fifth year, the machines are sold. If an interest rate of 10 % per annum is assumed, the NPV is

YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
US$ 3,626,340	US$ 897,581	US$ 900,744	US$ 905,868	US$ 901,047	US$ 2,696,320

$$\begin{aligned} \text{NPV} = \quad & -3,626,340 + \frac{897,581}{(1+0.1)^1} + \frac{900,744}{(1+0.1)^2} \\ & + \frac{905,868}{(1+0.1)^3} + \frac{\text{R\$ } 901,047}{(1+0.1)^4} + \frac{\text{R\$ } 2,696,320}{(1+0.1)^5} \end{aligned}$$

$$\text{NPV} = \text{US } 904,277$$

Financial and Cost Accounting

Financial and cost accounting are tools in order to have a better control of costs. As already mentioned, harvesting operations in general are expensive as compared to other activities of forest management. Financial accounting is focused on the reference year and reports the loss or profit in the form of a balance sheet. Cost accounting aims at computing production costs in order to facilitate cost control and cost reduction.

Machine and Equipment Costs (Present Value)

The cost for each machine can be calculated by using the following equation:

Calculation of the Cost per Machine

$$\text{CPM} = \text{PV} + [(\text{LC} * \text{PLC}) + (\text{COH} * \text{PDG})] \quad (25)$$

where:

CPM = cost per machine (US$)
PV = present value (US$)
LC = labor costs (US$)
PLC = percentage of other labor costs linked to the operation (%)
COH = costs overheads (US$)
PDG = % of overheads linked to harvesting operation (%)

The present value or present discounted value is a future amount of money that has been discounted to reflect its current value, as if it existed today. The term was created because money has a potential of "interest earning" in the future, i.e., the value of a dollar today is less than the value of a dollar tomorrow.

The future value measures the nominal future sum of money that a given amount is "worth" at a specified time in the future. For that purpose, a certain interest rate or rate of return has to be specified.

Calculation of the Present Value

$$\text{PV} = \frac{\text{FV}}{(1+\text{i})^{\text{n}}} \quad (26)$$

where:

PV = present value (US$/year)
FV = future value (US$/year)
i = annual interest rate (%/year)
n = analyzed period (year)

Example 5: Costs by Machine and Year
Costs for a feller buncher operating at the second year:

Account	Year 2 (in US$)
Purchase costs	–
Depreciation allowance	96,800
Insurance	8,700
Maintenance costs	60,961
Fuel	48,052
Lubricants, oils, filters, etc.	7,208
Tires (tracks)	4,576
Overheads	11,085

(*continued*)

Account	Year 2 (in US$)
Labor costs	25,050
General costs	40,000
Tax refunds	67.122
Percentage of labor costs dedicated to harvesting operations	10 %
Percentage of general costs dedicated to harvesting operations	10 %

For the calculation of present value, it is sufficient to sum the expenses of year 2 discounted to reflect the value in year 0, considering interest rates of 10 % p.a.

$$PV = \frac{(0 + 96.800 + 8,700 + 60,961 + 48,052 + 7,208 + 4,576 + 11,085)}{(1 + 0,1)^2}$$

$$US = 267,503$$

Costs related to the machine/equipment are
CPM = 267,503 + [(25,050 * 0,1) + (11,085 * 0,1) + (67,122)]
CPM = US$ 338,238.50

In the case of the operational cost, expenses related to the purchase cost of machines or equipment, depreciation allowance, insurance, maintenance fund, fuel and lubricant costs, tires, and overheads have to be registered as future cost.

Costs by Operation

In some cases, one machine is not enough to realize a harvesting operation, but a combination of machines or a system. For wood extraction, it may be necessary to use a shovel logger and a skidder. Under these conditions, it is necessary to sum up the costs of both machines used in the process.

Example 6: Harvesting Costs by Operation
Combination of a skidder and a shovel logger in an operation of wood extraction. The costs for both machines in year 2 are US$ 306,948 and US$ 349,281, respectively.

The total costs of both machines are US$ 656,229.

Costs per Unit Produced in a Respective Period (US$/m^3)

The average costs per unit of goods produced, in the case of harvesting operations, for instance, a cubic meter of wood, are equivalent to the ratio of the total costs and the production per month in a reference period.

Average Costs per Produced Unit in a Reference Period

$$\mathrm{ACU} = \frac{\mathrm{CO}}{\mathrm{PDM} * 12 * \mathrm{P}} \tag{27}$$

where:

ACU = average costs per unit produced in the period of reference (US$/m^3)
CO = costs per operation in the period of reference (US$)
PDM = planned production per month (m^3/month)
P = analyzed period (year)

Example 7: Average Costs per Unit Produced in a Reference Period
A forest enterprise has a demand of 13.195 m^3 of wood in their mill yard every month. From experience, it is known that costs are variable for each year analyzed, according to the table below:

Operation	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Total/ average
Extraction (US$)	0	699,930	656,229	616,364	582,672	477,522	3,032,716
Working hours (h)	0	2,700	2,611	2,522	2,463	2,374	12,699
Overall equipment effectiveness (OEE)	0	77,4 %	74,8 %	72,3 %	70,6 %	68 %	74,8 %
Mechanical availability	0	91,0 %	88,0 %	85,0 %	83,0 %	80,0 %	88,0 %

The costs for wood extraction in the example are reduced by every year, even the harvesting volume remaining constant. This is due to the changes in operational efficiency and mechanical availability which are influencing on the variable costs like fuel consumption, lubricants, tires, and other consumables. The working hours are reduced because the effective use of the machines diminished too (multiplication operational efficiency × utilization rate). The result is that the same volume of wood is extracted in less working hours.

This way the average costs per unit produced would be:

$$\mathrm{ACU} = \frac{3,032,716}{(13,195 * 12 * 5)} \quad \mathrm{ACU} = \mathrm{US\$}\ 3.83/\mathrm{m}^3$$

Operational Costs on a Yearly Base

The operational costs on a yearly base refer to the real costs of a produced unit in a given year of reference.

Calculation of Costs per Unit and Operation

$$\mathrm{CUO} = \frac{\mathrm{CO}}{\mathrm{PDM} * 12} \tag{28}$$

where:

CUO = costs per unit and operation (US$/$m^3$)
CO = costs per operation (US$/year)
PDM = production demand per month (m^3/month)

Example 8: Operational Costs per Unit
For the 5-year period considered in the former example, the average costs per cubic meter and year were of US$ 3.83. But on a yearly base, the costs show a different value:

$$\text{CUO(year 1)} = \frac{1.738.940,98}{13.195*12} \text{ CUO (year 1)} = \text{US\$ } 3.83/\text{m}^3$$

Operation	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Wood extraction (m^3)	0	697,529	653,978	614,250	580,674	475,884
CUO (US$/$m^3$)	0	4.40	4.13	3.88	3.67	3.00

Operational Costs on a Monthly Base

Under some conditions it might be necessary to have the real costs on a monthly base. In this case, the monthly costs have to be multiplied by the wood units to be produced in the respective month.

Example: Costs for a Monthly Operation
Knowing that the costs per cubic meter of wood produced in year 2 are US$ 3.83 and in each month a volume of 13,185 m^3, the operational costs would be

$$\text{CMO} = 3.83 * 13,185 \quad \text{CMO} = \text{US } 54.498/\text{month}$$

Operational Costs per Hour

For calculating the costs on an hourly base, the quantity of effective working hours of each machine or equipment has to be known.

Calculation of Operational Costs per Working Hour

$$\text{OCH} = \frac{\text{OCM}}{\text{OA} * \text{MA} * \text{UR} * \text{AHM}} \tag{29}$$

where:

OCH = operational costs per hour (US$/h)
OCM = operational costs per month (US$/month)
OA = operational availability of the machine (%)
MA = mechanical availability of the machine (%)
UR = utilization rate of the machine (%)
AHM = available hours per month (hours/month)

Example 9: Costs per Hour of Operation
In a forest company, the working schedule is 5.5 days per week; the machines used for the operation of "wood extraction" are a skidder and a shovel logger, both working in a two-shift system of 7.7 and 8 h, respectively, including a 1-h rest in each shift. One month in average has 4.35 weeks.

AHM = (7.7 + 8 − 2) * 5.5 * 4.35 = 327.77 h available for working each month.

OBS: In case of overtime hours, these have to be considered in the calculations.

Considering that the skidder as well as the shovel logger has an operational availability of 85 % and a mechanical availability of 85.4 %, the machines are used at 100 % of their availability; the operational cost per hour is

$$OCH = \frac{54,389}{0,85*0,854*1*327,77} \quad OCH = 229 \text{ US\$/h}$$

The mechanical availability is defined as the percentage of the time the machine is mechanically able to realize productive service. This excludes all the time the machine is out of order for repair or maintenance.

Case Study: Harvesting Costing

The case study is based upon an example of a Brazilian company operating in a tropical region. The example includes local taxes at federal, state, and municipality level. The conversion rate is given in US$ to Brazilian real.

A Brazilian forest enterprise wants to revise their harvesting system. The company produces eucalypt for pulping in a tropical region and has a daily demand of 9,000 m^3 of pulpwood. The assortment to be produced is of 3.60 m in length; the individual volume per tree is of 0.25 m^3. The current harvesting costs are 32.30 R$/$m^3$ using a system that consists of a harvester (felling, debarking, delimbing, and cutting to length) and a forwarder to transport and pile the wood at forest roadside.

The company hired a consultant to support the internal process of evaluation of the current harvesting system. The objective is to evaluate an alternative harvesting system and to elaborate a cost report. The company is providing the information about the 5-year period to be analyzed.

Information About the Area

For selecting a harvesting system, it is necessary to have sufficient information about the area where the operations should take place.

- Total area
- Forest road density
- Average wood extraction distance
- Inclination of the terrain

Table 3 General information for cost calculation

Item	Unit	Value
Monthly production/wood demand	m^3/month	9,000
Current harvesting costs	R$/$m^3$	32.30
Harvesting costs	R$/year	3,488,400
Interest rate (p.a.)	% per year	10
Conversion rate	US$/R$	1: 2.498
Fuel cost	R$/l	2.32
PIS/COFINS (specific Brazilian taxes)	%	9,25
Value added tax	%	18
Profit tax	% over profit	34
Social benefits offered	–	–
Medical assistance (optional)	R$/month and employee	356.70
Food basket (optional)	R$/month and employee	174.00
Monthly food assistance (mandatory)	R$/month and employee	258.00
Transport to company (mandatory)	R$/month and employee	258.00
Medicine (optional)	R$/month and employee	50.00
Transport to working place (mandatory)	R$/month and employee	477.05
Lunches and meals at workplace (mandatory)	R$/month and employee	300.00
13th salary (mandatory)	% over salary	8.93
Life insurance for forest workers (mandatory)	% over salary	0.3
Expenses for overtime work	% overnormal working hours	50
Additional spending for overtime hours	%	17
Additional spending for night work	%	20
Social costs over salary	%	18

- Homogeneity of the forest
- Operational conditions (rocks, soil type, etc.)

General Preconditions

Besides the information necessary about costs and productivity of the system, also the data about employee costs, overheads, taxes, and so on have to be considered (Table 3).

Listing of the Machines for an Alternative Harvesting System

Based upon information of the area, the volume to be harvested, and the climate conditions, a set of machines is listed to cope with the demand of the company:

- Felling: feller buncher (track-based basic machine and felling head)
- Skidding: clambunk skidder
- Processing (delimbing, debarking, cutting to length): processor (track-based basic machine and processing head)

Table 4 Information about machine and labor costs

Item	Unit	Feller	Skidder	Processor
Activity	Type	Felling	Skidding	Processing
Purchase costs of basic machine (including taxes)	R$	1,200,000	1,150,000	680,000
Accessories	Type	Head with disk saw	Grapple and clambunk	Felling head
Purchasing costs accessories (including taxes)	R$	R$ 250,000	R$ 57,500	R$ 330,000
Residual value of basic machine	%	20 %	20 %	20 %
Value of tires and tracks (including taxes)	R$	R$ 60,000	R$ 72,00	R$ 45,000
Life span of the machines	Hours	20,000	20,000	20,000
Life span of accessories	Hours	20,000	20,000	10,000
Life span of tires/tracks	Hours	10,000	5,000	10,000
% of lubricants in relation to fuel Consumption	%	15.0 %	15.0 %	15.0 %
Fuel consumption	l/h	28.0	27.0	20.0
Operational availability	%	85.0 %	85.0 %	85.0 %
Average mechanical availability	%	85.4 %	85.4 %	85.4 %
Mechanical availability in year 1	%	91.0 %	91.0 %	91.0 %
Mechanical availability in year 2	%	88.0 %	88.0 %	88.0 %
Mechanical availability in year 3	%	85.0 %	85.0 %	85.0 %
Mechanical availability in year 4	%	83.0 %	83.0 %	83.0 %
Mechanical availability in year 5	%	80.0 %	80.0 %	80.0 %
Reserve fund (total) (PC = purchase costs)	% PC	100.0 %	100.0 %	100.0 %
Reserve fund (until 20 % of life span)	% PC	10.0 %	10.0 %	10.0 %
Reserve fund (until 40 % of life span)	% PC	15.0 %	15.0 %	15.0 %
Reserve fund (until 60 % of life span)	% PC	20.0 %	20.0 %	20.0 %
Reserve fund (until 80 % of life span)	% PC	25.0 %	25.0 %	25.0 %
Reserve fund (until 100 % of life span)	% PC	30.0 %	30.0 %	30.0 %
Insurance (percentage of purchasing value))	% p.a.	1.50 %	1.50 %	1.50 %
Interest rate for financing basic machines	% p.a.	6.0 %	6.0 %	6.0 %
Interest rate for financing accessories	% p.a.	6.0 %	6.0 %	6.0 %
Cash down basic machine (without financing)	R$	R$ 1,200,000	R$ 1,150,000	R$ 680,000
Period allowed for payment	Month	0	0	0
Period for financing basic machine	Month	0	0	0
Cash down for accessories	R$	R$ 250,000	R$ 57,500	R$ 330,000
Period allowed for payment	Month	0	0	0
Period for financing the accessories	Month	0	0	0
Financing of national machines by government	–	None	None	None

Table 5 Example of a table for data collection about working hours and productivity of machines

Operation		Felling	Extraction	Processing
Machine	Unit	Feller buncher	Clambunk skidder	Processor
Estimated productivity				
Individual volume of the tree	m^3/tree	0.25	0.25	0.25
Average skidding distance	Meter	–	75	–
Assortment	Meter	–	–	3,6
Machine productivity	m^3/h	87.5	45	25
Machine productivity	Trees/h	350	–	100
Machines and Employees				
Quantity of machines	n	1	1	1
Operator in shift 1	n	1	1	1
Operator in shift 2	n	1	1	1
Operator in shift 3	n	–	–	1
Operators in reserve (vacation/ illness)	n	–	–	2
Working hours				
Working hours shift 1	Hours	7.7	7.7	8
Working hours shift 2	Hours	8	8	8
Working hours shift 3	Hours	–	–	8
Meals/day	Hours	−2	−2	−3
Programmed hours per day	Hours	13.7	13.7	21
Working days per week	Days	5.5	5.5	5.5
Working days per month	Days	23.9	23.9	23.9
Hours available per month	Hours	326.8	326.8	502.2
Overtime hours per month	Hours	0	0	0
Night shift hours per month	Hours	23.9	23.9	23.9
Utilization and production				
Operational availability	%	85 %	85 %	85 %
Mechanical availability	%	85.4 %	85.4 %	85.4 %
Utilization rate	%	65 %	95 %	100 %
Utilization hours per day	Hours	154.2	225.4	364.6
Life span of the machine	Year	10.8	7.4	5.0
Average productivity	m^3/month	13,493.15	10,143.10	9,114.01
Wood demand	m^3/month	9,000	9,000	9,000
Difference	***m^3/month***	***4,493.15***	***1,142.10***	***114.01***

The next step is to get information about the costs of the new machines, the accessories necessary, and the labor costs to get the machines working (Table 4).

The company decided not to finance the purchase costs for the machines and pay cash for it. Therefore the period for financing the costs is equal to 0. Since the machines are not of national production, the government does not finance the purchasing with a low interest rate.

Table 6 Example for a table for working hours and employees

Function	Shift 1	Shift 2	shift 3	Reserve	Number of employees	Wages	R$/h
Machine operator	3	3	1	2	9	2,400.00	12.54
Supervisor	1				1	3,780.00	19.76
Operator maintenance truck	1				1	1,800.00	9.41
Operator fuel truck	1	1			2	1,800.00	9.41
Supervisor mechanics	1	1			2	1,500.00	7.84
Mechanic assistant	1				1	2,500.00	13.07
Total	***8***	***5***	***1***	***2***	**16**	**Mean value**	**11.85**

Operational Data

In a next step, the information about the workload per month, productivity of machines, number of operators and employees necessary to get the system working, and the machine availability are necessary for further cost calculation (Tables 5 and 6).

Cash Flow

For generating the cash flow, all the data presented in the tables of Chap. 7 have to be considered for the calculation of the costs of the processes of the harvesting system to be evaluated (Table 7).

Cost Reporting

The cost reporting consists of the general presentation of the aggregated costs of the harvesting system for each accounting. It contains detailed information about the costs of the evaluated system per unit produced (m^3) and related to different production periods (day, week, month, and year). The economic analysis uses an internal rate of return (IRR) of 22.4 % and a net present value (NPV) of 1,453,910.73 R$ (Table 8).

The cost reporting reveals that the change from the system harvester and forwarder to feller buncher, skidder, and processor under the conditions described above reduces the average costs per cubic meter of wood produced from 32.30 R$ to 29.54 R$. This means a cost reduction of 8.5 % for the harvesting operation if the new system is introduced.

Table 7 Cash flow

Annual cash flow	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
1. Fixed costs						
(a) Property costs						
Net purchase costs (without taxes or subsidies)	3,835,343.63	0.00	0.00	0.00	0.00	0.00
Depreciation allowance	0.00	799,534.40	799,534.40	799,534.40	799,534.40	799,534.40
Other initial investments	0.00	202,640.00	202,640.00	202,640.00	202,640.00	202,640.00
Capital costs	0.00	0.00	0.00	0.00	0.00	0.00
Other initial investments	0.00	0.00	0.00	0.00	0.00	0.00
Insurance	0.00	63,881.25	63,881.25	63,881.25	63,881.25	63,881.25
(b) Labor costs	0.00	897,558.79	897,558.79	897,558.79	897,558.79	897,558.79
(c) General expenses	0.00	412,918.40	412,918.40	412,918.40	412,918.40	412,918.40
Total fixed costs	**3,835,343.63**	**2,376,532.84**	**2,376,532.84**	**2,376,532.84**	**2,376,532.84**	**2,376,532.84**
2. Variable costs						
(a) Maintenance	0.00	652,681.60	659,853.92	665,070.16	676,480.68	678,110.75
(b) Fuel costs	0.00	442,705.90	428,111.20	413,516.50	403,786.70	389,192.00
(c) Lubricants, hydraulic oils, etc.	0.00	66,405.88	64,216.68	62,027.47	60,568.00	58,378.80
(d) Tires and tracks	0.00	41,463.04	40,096.12	38,729.21	37,817.93	36,451.02
(e) Other consumables	0.00	55,228.38	53,407.67	51,586.95	50,373.14	48,552.43
Total variable costs	**0.00**	**1,258,484.80**	**1,245,685.59**	**1,230,930.29**	**1,229,026.45**	**1,210,684.99**
Total costs without depreciation allowance and capital costs	**3,835,343.63**	**2,653,003.32**	**2,649,101.81**	**2,642,930.51**	**2,649,506.17**	**2,639,225.86**
3. Assets to be considered						
(a) Residual value of machines	0.00	0.00	0.00	0.00	0.00	1,615,641.69
(b) Expenses if the service is hired by third parties	0.00	3,477,600.00	3,477,600.00	3,477,600.00	3,477,600.00	3,477,600.00
(c) Tax refunds (in Brazil PIS/COFINS/ICMS for 48 months)	0.00	359,151.59	359,151.59	359,151.59	359,151.59	0.00
Total of assets (R$)	**0.00**	**3,836,751.59**	**3,836,751.59**	**3,836,751.59**	**3,836,751.59**	**5,093,241.69**
Gross margin without depreciation allowance and capital costs (R$)	**−3,835,343.63**	**1,183,748.27**	**1,187,649.78**	**1,193,821.09**	**1,187,245.43**	**2,454,015.83**

Table 8 Cost reporting

Cost reporting						
Annual costs for harvesting (R$/year)	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Felling	0.00	914,523.26	861,488.32	813,264.97	772,109.42	652,316.72
Extraction	0.00	881,670.99	832,264.39	787,228.56	748,955.67	631,626.80
Processing	0.00	1,802,434.93	1,718,934.95	1,642,648.36	1,577,729.81	1,314,386.99
Annual costs by operation (R$/year)	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Felling	0.00	914,523.26	861,488.32	813,264.97	772,109.42	652,316.72
Extraction	0.00	881,670.99	832,264.39	787,228.56	748,955.67	631,626.80
Processing	0.00	1,802,434.93	1,718,934.95	1,642,648.36	1,577,729.81	1,314,386.99
Average costs by unit produced and period	*R$/m*^{3}					
Felling	7.43					
Extraction	7.19					
Processing	14.92					
Total	29.54					
Annual cost per unit produced (R$/m^3)	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Felling	0.00	8.47	7.98	7.53	7.15	6.04
Extraction	0.00	8.16	7.71	7.29	6.93	5.85
Processing	0.00	16.69	15.92	15.21	14.61	12.17
Total	0.00	33.32	31.60	30.03	28.69	24.06
Monthly costs per operation (R$/month)	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Felling	0.00	76,210.27	71,790.69	67,772.08	64,342.45	54,359.73
Extraction	0.00	73,472.58	69,355.37	65,602.38	62,412.97	52,635.57
Processing	0.00	150,202.91	143,244.58	136,887.36	131,477.48	109,532.25
Total	0.00	299,885.77	284,390.64	270,261.82	258,232.91	216,527.54
Operational cost per hour (R$/h)	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Felling	0.00	494.21	465.55	439.49	417.25	352.51
Extraction	0.00	201.54	190.24	179.95	171.20	144.38
Processing	0.00	412.01	392.92	375.49	360.65	300.45
Total	0.00	1,107.75	1,048.71	994.92	949.09	797.34

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