Advantage

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Contents



# Repair and maintenance costs of timber harvesting equipment

**Abstract**

The Forest Engineering Research Institute of Canada (FERIC) collected repair and maintenance cost information on common timber harvesting equipment from the financial records of several companies in British Columbia and Alberta. The machines were classified by size and type, regression equations relating cost to equipment usage were developed for each class, and the average repair and maintenance cost for each class was calculated using the regression equations.

**Keywords**

Costs, Repairs, Maintenance, Harvesting equipment, Regression analysis.

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## Executive summary

Many companies lack detailed knowledge about the repair and maintenance costs of equipment. To address this information gap, FERIC performed a survey of nearly 400 timber-harvesting machines from nine company and contractor operations in British Columbia and Alberta to establish their average repair and maintenance costs.

Costs and operating hours for each machine were collected and used to calculate the repair and maintenance costs in 27 classes based on machine size and type. Costs were categorized under parts, labour, tires, or other, and assigned to a usage class based on operating time. The average cost of the sample points was calculated for each machine class, but was susceptible to uneven distributions of new or old machines. Therefore, linear regression equations for repair and maintenance costs were developed for certain usage classes, and these handled the uneven distributions of machine usage better than the simple average cost. Extraordinary repairs such as engine or undercarriage replacements were separated from the more conventional repairs, and amortized over the full analysis period rather than allocated to the usage class when they occurred.

The results showed that costs were affected by usage for some machine classes but not for others. However, statistical analysis showed that the correlation between costs and usage was generally weak. The variation within a usage class was often greater than between classes.

Further information, including primary machine task, geographical location, ownership (company or contractor), and labour costing method, were recorded to determine influence on repair and maintenance costs. None of these factors were able to adequately explain the large variation in cost between machines. However, only the excavator classes had sufficient data to perform this analysis, so it is unclear if this trend applies to other machine classes.

The average values developed from the survey could be a useful starting point for estimating repair and maintenance costs in various costing models, but they should be used with caution because of the large variability between sample points. Adding more machines to the analysis may reduce the variation and improve the confidence in the regression equations, but a limited number of machines with sufficiently detailed records exist as few companies track costs for individual machines.

## Introduction

Fewer forest companies in western Canada than ever before operate their own timber harvesting equipment and employ their own crews, with most companies relying on contractors to carry out their timber harvesting activities. Without their own equipment to use as a basis for comparison, many FERIC member companies lack detailed knowledge about the ownership, repair, and operating costs of equipment. This lack of knowledge can cause difficulties when their employees are required to confirm the costs of rented or contracted equipment.

To address this information gap, FERIC was asked by its member companies to undertake a study of the operating costs of timber harvesting equipment. FERIC concentrated on the repair and maintenance costs since its member companies felt that sufficient information about the ownership, operating, and labour costs already existed. This report summarizes the findings.

The project was directed by a steering committee consisting of representatives from FERIC's member companies and their contractors.

Figure 1. Monthly or annual cost statements were the typical source of cost information from co-operators.

## Objectives

The objectives of this study were to:

- Survey a sample of equipment to obtain the as-experienced costs of repairing and maintaining equipment as related to actual usage.
- Derive the average repair and maintenance costs for each machine type.
- Transfer the results to FERIC members and their contractors.

## Data collection and processing methods

### Sources

Cost data were collected from nine forestry enterprises from their month-end and year-end cost statements (Figure 1). Since the study's purpose was to correlate repair and maintenance costs with the actual usage for individual machines, only companies that routinely recorded costs and usage on individual machines were surveyed. FERIC recorded the costs onsite into spreadsheets, using the same cost categories as the co-operating company. Subsequently, FERIC standardized cost figures into the following categories, then imported them into a database for analysis:

- Parts and Supplies
- Repair Labour
- Tires
- Other

Repair Labour was derived from each company's financial statements, and represented either wages plus benefits or a shop rate that included shop overhead. The Other category included such items as minor supplies, fixed-rate third-party service plans, or invoiced third-party costs that consisted of both parts and supplies.

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## Data classification

Each database record represented one entry from monthly or annual cost statements, as determined by the co-operating company's practices. In addition to the repair cost, each database entry included the machine that was repaired, the date of occurrence, and the number of hours the machine was operated during the costing period. Machine usage was calculated by summing the operating hours for the study period.

Approximately half the machines in the survey had records from when the machine was new. For the remainder, either the machines had no records (because the company purchased the machines used or the company only recently employed a detailed cost-tracking system), or FERIC chose not to record the oldest information because of its age. The usage for these machines without lifetime records was calculated using the accumulated operating hours when record-keeping commenced.

Each cost record was subsequently assigned to a 1 000-hour "usage class" based on the machine usage at the time of repair. For example, all costs incurred on a machine that had between 4 500 and 5 500 hours of usage were assigned to usage class 5.

Costs from different years were adjusted to current values by applying a cost trend factor (Appendix I) derived from the Machinery and Equipment Price Index (Statistics Canada 2002).

Costs and operating hours within each usage class were totalled for each machine. The average repair and maintenance cost for each machine in each usage class was calculated by dividing the total cost incurred during the period by the total operating hours in the period. These calculations resulted in a series of sample points of machine usage versus repair and maintenance costs.

Some sample points represented more or less than the targeted 1 000 operating hours for a machine depending on how the original data were reported. For example, some co-operators recorded costs on an annual basis, which resulted in samples of more than 2 500 hours of usage instead of the desired 1 000 hours. No attempt was made to subdivide these costs into smaller usage classes.

The make and model of each machine was noted (Figure 2), and each machine was assigned to a style and size class ("machine class"). The makes and models in each machine class are shown in Appendix II. The sample points for each machine class were combined and then analyzed using linear regression.

## Cost analysis

Up to five regression lines were fitted to each set of cost data. First, costs up to 5 000 hours of usage were calculated by selecting all the sample points with usage class 5 or less, then computing the regression line through those sample points.[1] The average cost for the period was calculated on the regression line at half the analysis period, or 2 500 hours. This calculation is referred to as the "regression average." This process was repeated for usage classes 10, 15, 20, and 25 when sufficient data were available.

Expensive repairs such as engine or undercarriage replacements complicated the calculations because allocating their costs to the usage class in which they occurred would have distorted the costs for that class. Instead, the costs for large repairs were separated from the typical repairs and their costs were

[1] For the purpose of discussion in this report, the analysis periods are referred to as 1000 hours, 2000 hours, 3000 hours, etc., even though usage class 1 was 500–1500 hours, class 2 was 1500–2500 hours, class 3 was 2500–3500 hours, etc.


Figure 2. Each machine was assigned to a machine class. These machines are in the 20-tonne excavator/loader class.

amortized over the full analysis period (5 000 hours, 10 000 hours, etc.).

## Results

### Summary of all survey data

Table 1 shows a summary of the survey population and the average repair and maintenance costs for each machine class.

The operating machine hours is the time the machines were operated that had corresponding repair records. The machines may have additional operating hours without cost records. The minimum and maximum usage classes show the range that were surveyed in each machine class.

The last column shows the mean of all the sample points up to usage class 25. Since this average cost calculation does not account for differences in machine usage, uneven data distributions may generate misleading results. For example, the maximum usage class for 30-tonne excavators was 13, while the maximum usage class for 40-tonne excavators was 20. Ignoring any fundamental differences between the machine classes, it is reasonable to expect different costs simply because the machine classes have different usage class ranges. Likewise, a large proportion of new or old machines in the sample will skew the class average. Furthermore, the average cost from Table 1 is up to usage class 25, but some machine classes do not include machines that old. Simply calculating the mean of the survey data is insufficient to accurately represent the average cost for a machine's entire life.

**Table 1. Population of surveyed machines**

| Machine class | Machines (no.) | Operating machine hours (OMH) | Minimum usage class (1000-h) | Maximum usage class (1000-h) | Average cumulative R&M cost up to and including usage class 25 ($/OMH) |
|---|---|---|---|---|---|
| Clambunk skidder: 25 000–35 000 kg | 4 | 19 019 | 1 | 13 | 40.69 |
| Crawler tractor: D-6 size | 6 | 29 375 | 1 | 20 | 27.04 |
| Crawler tractor: D-7 size | 11 | 51 093 | 2 | 21 | 31.58 |
| Crawler tractor: D-8 size | 6 | 17 329 | 1 | 16 | 28.92 |
| Excavator/loader: 20-tonne (15 000–25 000 kg) | 39 | 159 371 | 1 | 13 | 18.18 |
| Excavator/loader: 30-tonne (25 000–35 000 kg) | 16 | 63 827 | 0 | 13 | 19.30 |
| Excavator/loader: 40-tonne (35 000–45 000 kg) | 33 | 201 773 | 0 | 20 | 24.99 |
| Excavator/loader: 50+ tonne (45 000 kg+) | 30 | 172 369 | 0 | 26 | 26.58 |
| Feller-buncher: flat (25 000+ kg) | 20 | 108 126 | 0 | 19 | 31.42 |
| Feller-buncher: tilt (<25 000 kg) | 6 | 38 226 | 2 | 14 | 29.73 |
| Feller-buncher: tilt (25 000+ kg) | 7 | 21 773 | 1 | 11 | 32.07 |
| Line loader: unspecified | 6 | 40 917 | 3 | 23 | 45.91 |
| Processor: boom-mount - large 65 cm plus opening | 10 | 65 261 | 1 | 23 | 16.84 |
| Processor: boom-mount - small 65 cm minus opening | 14 | 78 456 | 1 | 17 | 19.43 |
| Processor: dangle - large 60 cm plus butt | 6 | 46 551 | 2 | 18 | 31.61 |
| Processor: dangle - small 60 cm minus butt | 7 | 48 658 | 1 | 14 | 19.71 |
| Skidder: tracked - D5 size (15 000–25 000 kg) | 8 | 34 391 | 0 | 13 | 27.61 |
| Skidder: grapple - large (>16 000 kg) | 19 | 74 055 | 0 | 19 | 19.91 |
| Skidder: grapple - medium (12 000–16 000 kg) | 19 | 116 394 | 0 | 18 | 32.62 |
| Skidder: grapple - small (<12 000 kg) | 4 | 19 086 | 1 | 13 | 27.98 |
| Truck: highway - B-train | 5 | 28 965 | 1 | 11 | 12.95 |
| Truck: highway - hayrack | 6 | 51 311 | 1 | 16 | 20.83 |
| Truck: highway - pole trailer | 11 | 92 573 | 1 | 26 | 18.81 |
| Truck: highway - tridem-tridem | 59 | 151 144 | 0 | 12 | 21.19 |
| Wheeled loader: medium 3300–3600 mm wheelbase | 11 | 35 381 | 1 | 20 | 18.64 |
| Wheeled loader: small <3300 mm wheelbase | 5 | 17 710 | 0 | 18 | 25.36 |
| Yarding crane: large | 12 | 66 907 | 0 | 35 | 66.13 |
| Total | 380 | 1 850 041 | - | - | - |

## Costs by usage class

To address the deficiencies in using simple averages, values were calculated at usage classes 5, 10, 15, 20, and 25 using regression analysis (Table 2).

Values in Table 2 are the averages for repair and maintenance costs for all repairs that occurred from zero up to the specified usage class, calculated using the regression equations. These averages properly account for uneven distributions of new or old machines in the survey samples.

However, these costs are derived from small samples from diverse populations, and must be used with caution. To help visualize the variability and reliability of the data, additional detail about the survey data was developed and shown for all machines in Appendix III. Figure 3, Figure 4, and Table 3 explain how to interpret the information from Appendix III, using the 20-tonne excavators as examples.

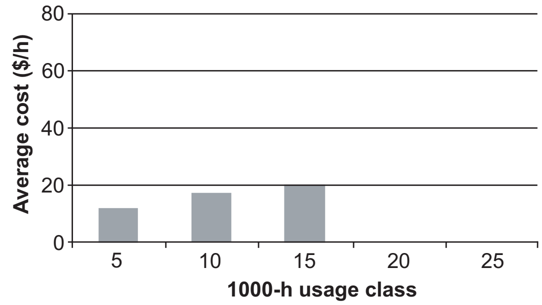


Figure 3. Typical bar chart: average costs for 20-tonne excavators at three usage classes calculated from the regression equations.

First, the regression average costs for each machine class and usage class are shown as a bar chart. These bar charts clearly illustrate those machine classes for which costs remain stable with usage, and those machine classes for which costs increase with usage, such as with the 20-tonne excavators (Figure 3). However, the bar charts mask whether the cost trend is based on a few or many sample points, tightly clustered or highly variable data, or well-distributed or poorly distributed data. That information can be found in the scatter charts such as Figure 4. Points above usage class 20 were omitted from the scatter

**Table 2. Average repair and maintenance costs ($/h) calculated at various cumulative usage classes using linear regression**

| Machine class | 1000 h cumulative usage class | | | | |
|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 25 |
| Clambunk skidder: 25 000–35 000 kg | 29.94 | 37.31 | 44.43 | - | - |
| Crawler tractor: D-6 size | 24.42 | 30.37 | 31.06 | 27.34 | - |
| Crawler tractor: D-7 size | 33.29 | 32.01 | 31.41 | 31.78 | - |
| Crawler tractor: D-8 size | 6.91 | 17.22 | 25.28 | - | - |
| Excavator/loader: 20-tonne (15 000–25 000 kg) | 11.02 | 16.37 | 19.71 | - | - |
| Excavator/loader: 30-tonne (25 000–35 000 kg) | 13.73 | 20.52 | 22.16 | - | - |
| Excavator/loader: 40-tonne (35 000–45 000 kg) | 21.40 | 24.38 | 24.86 | 26.39 | - |
| Excavator/loader: 50+ tonne (45 000+ kg) | 24.13 | 25.27 | 28.88 | 28.36 | 27.55 |
| Feller-buncher: flat (25 000+ kg) | 21.59 | 31.37 | 39.36 | 43.08 | - |
| Feller-buncher: tilt (<25 000 kg) | 15.65 | 32.15 | 31.13 | - | - |
| Feller-buncher: tilt (25 000+ kg) | 32.29 | - | - | - | - |
| Line loader: unspecified | 43.25 | 39.96 | 42.65 | 45.55 | 47.80 |
| Processor: boom-mount - large 65 cm plus opening | 21.94 | 18.31 | 19.03 | 18.40 | 17.37 |
| Processor: boom-mount - small 65 cm minus opening | 14.81 | 17.71 | 20.51 | - | - |
| Processor: dangle - large 60 cm plus butt | 28.77 | 32.71 | 31.72 | 31.25 | - |
| Processor: dangle - small 60 cm minus butt | 22.37 | 19.27 | 20.39 | - | - |
| Skidder: tracked - D5 size (15 000–25 000 kg) | 18.52 | 31.28 | 37.30 | - | - |
| Skidder: grapple - large (>16 000 kg) | 14.37 | 20.68 | 24.39 | 27.86 | - |
| Skidder: grapple - medium (12 000–16 000 kg) | 33.44 | 32.70 | 33.40 | 34.11 | - |
| Skidder: grapple - small (<12 000 kg) | 10.38 | 24.14 | 35.73 | - | - |
| Truck: highway - B-train | 16.10 | 13.83 | - | - | - |
| Truck: highway - hayrack | 21.06 | 21.56 | - | - | - |
| Truck: highway - pole trailer | 15.76 | 17.44 | 16.90 | 18.11 | 18.70 |
| Truck: highway - tridem-tridem | 23.43 | - | - | - | - |
| Wheeled loader: medium 3300–3600 mm wheelbase | 16.91 | 19.22 | 17.82 | 17.55 | - |
| Wheeled loader: small <3300 mm wheelbase | 33.94 | - | 29.17 | 25.73 | - |
| Yarding crane: large | 40.36 | 43.63 | - | 59.46 | 65.04 |

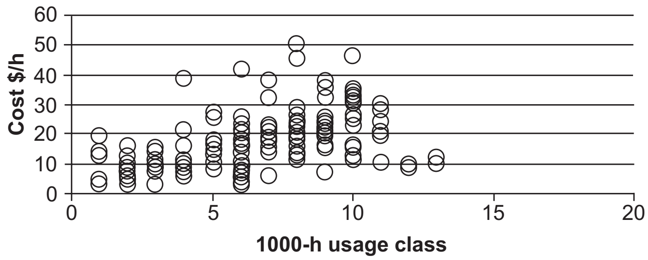


Figure 4. Typical cost data: cost per hour for 20-tonne excavators.

charts to make the charts easier to read. Note that the scale of the scatter charts' vertical axes changes depending on the range of the data. Be sure to account for the variable scale when comparing the charts of different machine classes.

With the 20-tonne excavators, even though there is a general upward trend with usage, the costs are highly variable, and the variability within a given usage class may be greater than the variability between the usage classes.

The third component of Appendix III is a table that shows the sample size and how well the regression line fits the sample points. Table 3 illustrates this information for the 20-tonne excavators. Each table has one row for each 5 000-h class, and each row shows the minimum and maximum usage class of the sample data, the number of machines, the number of sample points, and the total operating hours for the class. For example, the class 5 cost for the 20-tonne excavators was derived from 22 machines when they had between 1 000 and 5 000 hours of accumulated operating time, and the 58 577 operating hours during this period was from 43 sample points. Similarly, the cost for usage class 15 was derived from 119 points that represent 159 371 hours on 39 machines between 1 000 and 13 000 hours. The last three columns show the regression $r^2$, the regression average (Table 2), and sample average (Table 1). [2]

Clearly, regression equations derived from many machines, many sample points, many operating hours, and a wide range of usage classes can be used with the most confidence. FERIC considers regressions based on fewer than four machines, eight sample points, or 15 000 operating hours to be unusable in this survey.

In comparison to other machine classes in this survey, the $r^2$ for 20-tonne excavators was relatively high, but it is not high enough to suggest that a strong relationship exists between usage and repair costs. The low value suggests that most of the cost variation was caused by other, unmeasured factors. When viewed in conjunction with the plotted data, the regression statistics suggest there is a relationship between usage and cost, but it is a relatively weak relationship.

Given a weak relationship, the best statistic to use is the sample average. The last columns in Table 3 and Appendix III are the simple average of all the sample points up to the specified usage class. These averages are susceptible to the errors caused by uneven data distribution.

Values were omitted from the table and charts in Appendix III if the survey did not include machines at least at the specified usage class minus two. For example, the

[2] $r^2$ is a standard statistical measure that shows how well the regression equations fit the sample data. For this analysis, an $r^2$ value of .3 indicates that 30% of the difference in average cost is attributed to machine usage, while the remaining 70% of variability is caused by other, unmeasured factors.

**Table 3. Typical statistical summary: regressions for 20-tonne excavators**

| Class | Minimum | Maximum | Machines (no.) | Points (no.) | Operating hours | $r^2$ | Average cost ($/h) Regr. | Average cost ($/h) Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 5 | 22 | 43 | 58 577 | .14 | 11.02 | 12.30 |
| 10 | 1 | 10 | 39 | 108 | 143 674 | .32 | 16.37 | 18.57 |
| 15 | 1 | 13 | 39 | 119 | 159 371 | .19 | 19.71 | 18.29 |
| 20 | 1 | 13 | 39 | 119 | 159 371 | | | |
| 25 | 1 | 13 | 39 | 119 | 159 371 | | | |

oldest 20-tonne excavators were usage class 13 (13 500 hours), so the table and charts were included up to usage class 15. On the other hand, 50-tonne excavators were surveyed up to 25 000 hours usage, so costs for all usage classes were shown.

## Discussion

The survey average costs in Table 1 depend on the usage of the equipment and the distribution of sample points. For example, surveying mostly new or mostly old machines is expected to skew the costs lower or higher. As an alternative, the costs shown in Table 2 are based on regression analysis, and provide estimates that better account for machine usage. However, the costs for each machine class retain a large amount of variation, so FERIC recorded additional items about each machine or co-operating company. Specifically, the cost records show the machine's primary task, whether it was used in a company or contractor operation, whether the labour costs were based on wages or shop rate, and whether the machine was from the coastal or interior/Alberta regions. Although each machine's make and model were recorded in the survey, FERIC chose not to calculate or report costs by manufacturer.

### Subdividing machine classes

Defining the machine classes presented some challenges. Small classes are required to avoid grouping machines that logically don't belong together, but conversely, too-specific classes result in so few class members that the averages simply reflect the costs of individual machines. For example, feller bunchers can be characterized based on undercarriage size, but the survey has too few feller bunchers to allow this distinction. The result is that some classes contain machines with different features that might be expected to have widely ranging repair and maintenance costs, but that had to be combined for practicality.

The excavator classes were the only ones with sufficient numbers of machines to subdivide by these additional factors. FERIC calculated and compared regression lines for 20-, 30-, 40-, and 50-tonne excavators for each factor, and found that:

- Costs were slightly higher for integrated companies than contractors for 20-tonne excavators, and slightly lower for 40-tonne excavators. Costs for 30-tonne excavators were substantially higher for integrated companies than for contractors.
- Costs were higher for operations that used wage rates to calculate maintenance labour costs as compared to operations where labour costs were calculated using a shop rate.
- Costs were higher for coastal operations than for interior/Alberta operations.
- Costs for loader forwarding were usually higher than the group average, but loader forwarding was not always the most expensive task.
- The effect on regression quality by differentiating the machines by these factors was inconsistent. In some cases, the regression lines for each new subcategory had higher $r^2$ values than the whole-group regression, while in other cases, there was no improvement. In other words, no drastic improvements were evident that would make it imperative to use these factors.

As mentioned, these comparisons were made only for the excavator classes because of their larger populations. It is unclear whether the same trends would apply to the other machine classes.

### Distribution between parts, labour, other, and tires

Where supported by the underlying bookkeeping data, FERIC distinguished between four cost types: parts, labour, other, and tires (Appendix IV). Some bookkeeping systems combined parts and labour into a single category, and these records were omitted from the following analysis. Machine classes with less than 10 000 operating hours were also omitted. The cost distribution between categories was highly variable; the parts category represented between 40% and

60% of the total cost for less than half the machine classes.

Tire repair and replacement costs comprised a substantial proportion of operating costs for log trucks. Appendix V shows the tire costs and operating hours at various usage classes for all the trucks from the survey, together with the number of operating hours accumulated for all the trucks in the class. The tire percentage shows the proportion of all parts and labour costs that is represented by the tire cost.

### Cost trends with usage

Table 2 and Appendix III allowed comparisons to be made between some repair costs. FERIC found that different machine classes had different cost trends. For example, the costs for D-8 sized bulldozers, flat bunchers, clambunks, small and medium excavators, large and small grapple skidders, D-5 sized track skidders, and yarding cranes increased as the machines aged. On the other hand, D-6 and D-7 sized bulldozers, tilt bunchers, large excavators, line loaders, processors (except small boom-mounted processors), medium grapple skidders, trucks, and wheeled loaders had more constant costs as the machines aged.

These patterns may have implications for managing equipment fleets. When costs increase as the machines get older, the repair and maintenance costs should play a significant part in replacement decisions. On the other hand, other factors become more critical in replacement decisions if the repair costs remain stable as the machines get older.

In addition, and owing to the highly variable nature of costs within some classes, managing for repair and maintenance costs on a fleet basis may be difficult. Instead, the owner should monitor the costs on an individual machine basis and make replacement decisions accordingly.

### Actual machine usage versus reported machine usage

The hourly costs generated for this report were derived using the machine hours as reported in the co-operators' monthly or annual cost statements. Moreover, some co-operators reported the time as operator hours, in which case FERIC estimated the machine hours from the operators' hours. However, the reported machine hours were never guaranteed to be the productive operating time for the machines, nor were there any guarantees that consistent practices were used for all co-operators in reporting the machine time. They were simply the best estimate available of operating time given the data sources that were available.

FERIC's recent experience with computerized dataloggers to record actual machine activity has suggested that the proportion of time spent doing productive work can vary substantially between operations and between machines on a single operation. This variation in productive operating time may explain some of the variation in hourly repair and maintenance costs if different machines were operated under different regimes. Knowing the actual productive operating time for each machine, which can be measured using a computerized datalogger, may help towards establishing a more reliable cost estimate of repair and maintenance costs.

### Future possibilities for cost survey

Over the long term, the reliability of these costs can be improved only if more data are added to the database, but obstacles that were encountered during the survey and analysis must be addressed before achieving that goal. FERIC found that many companies keep their cost records based on machine groups, and thus were unable to participate in the survey. Furthermore, each site where FERIC obtained data used a different bookkeeping system, or even used different bookkeeping systems during different time periods covered by the survey. This meant that the data required much manipulation before they could be entered into the database. Finally, peculiarities such as swapping components between different carriers or missing data for used machines complicated the record keeping process, and eliminated some machines from the survey. The net result is that the pool of machines with sufficiently detailed records to include in the analysis is limited.

If the FERIC member companies and their contractors want to expand this database with additional information, then these issues must be addressed to increase the efficiency of the survey and analytic processes. A standardized cost-tracking system would help, but several potential co-operators indicated they could not afford to double their data entry effort by adding a separate cost tracking system to their existing general ledger system. Developing a standardized cost-tracking system that could integrate with different general ledger systems would be beneficial, but would also pose a significant challenge.

## Conclusions

This project surveyed the actual repair and maintenance costs of almost 400 forest harvesting machines with almost two million operating hours from nine company and contractor sites in British Columbia and Alberta. Average repair and maintenance costs were developed for 27 machine classes. The average costs were developed into costs for machines with 5 000, 10 000, 15 000, 20 000, and 25 000 hours of operating time.

The costs from this report could be used as a starting point for estimating repair and maintenance costs in different cost models; however, FERIC urges that these costs be used with caution because of their highly variable nature. The reader is advised to consider these costs in combination with other information sources that may already be employed.

Not all owners keep their equipment for the same length of time. Calculating the repair costs over different lifetimes, as was done in this survey, allows costs to be estimated for different ownership periods. The analysis showed that the costs for some machine classes increase throughout their lifetime, while the costs for other machine classes remain constant as the machines get older. These different aging characteristics can affect the decision whether to replace an older machine with a new one. For example, if repair costs increase with usage, then they should be factored more heavily into the replacement decision than if the repair costs remain relatively stable over time.

The highly variable costs within classes imply that managing costs on a machine-class or fleet basis may be impractical. Instead, managing the costs for individual machines may be required. The project was unable to establish whether the variability within a class was the result of limited sample sizes or if the costs are intrinsically variable.

One weakness of using the financial statements to find the total costs is that it was based on labour costs, rather than labour hours. Accordingly, any differences between costing methods from different sites caused systematic differences in the total cost that cannot be attributed to the machines themselves. For example, some labour costs were based on wages plus benefits, while others were based on a shop rate. Also, different wage rates would result in different repair costs, even if the machines themselves had similar repair histories. Recording the repair time instead of the cost, then applying a standard wage rate, would address this weakness. However, it would be impractical to derive this information from typical bookkeeping systems.

The analysis showed that repair costs were highly variable within some machine classes, and that the variability could not be explained by using the traditional information from financial statements. It may be possible to develop a more detailed model using more site-specific factors, but such a model would be applicable only to a narrow range of sites. Furthermore, the time requirements to record the additional information on an ongoing basis may make it impractical to keep current. FERIC believes that future cost-tracking projects will continue to be based on general information to be applicable to the widest possible range of sites.

## Reference

Statistics Canada. 2002. Machinery and equipment price indexes. Accessed through website at http://www.statcan.ca/english/sdds/2312.htm.

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# Appendix I

## Machinery and equipment price index

| Year | Cumulative cost trend factor |
|---|---|
| 1990 | 1.223 |
| 1991 | 1.364 |
| 1992 | 1.272 |
| 1993 | 1.218 |
| 1994 | 1.196 |
| 1995 | 1.182 |
| 1996 | 1.173 |
| 1997 | 1.132 |
| 1998 | 1.060 |
| 1999 | 1.071 |
| 2000 | 1.013 |
| 2001 | 1.000 |
| 2002 | 1.000 |

All comparisons were done as if the repair incidents occurred in 2002. As-recorded costs from each specified year were multiplied by the cumulative cost trend factor from this table to estimate the costs in 2002.

# Appendix II

## Make and model by machine class

All machines that were surveyed are shown in this table. Some classes had insufficient machines or number of operating hours to be included in the analysis, but they are included here for completeness.

Clambunk skidder: 25 000–35 000 kg
- Timberjack 933

Crawler tractor: D-3 size
- Komatsu D 31

Crawler tractor: D-5 size
- Komatsu D 65

Crawler tractor: D-6 size
- Caterpillar D6
- Komatsu D 85

Crawler tractor: D-7 size
- Caterpillar D7
- International TD20
- Komatsu D155

Crawler Tractor: D-8 size
- Caterpillar D8

Excavator/loader: 20-tonne (15 000–25 000 kg)
- Caterpillar 315
- Caterpillar 320
- Hyundai 220
- John Deere 200
- John Deere 230
- John Deere 270
- John Deere 690
- John Deere 790
- Kobelco SK150
- Komatsu PC150
- Link Belt 2650
- Link Belt 2700

Excavator/loader: 30-tonne (25 000–35 000 kg)
- Caterpillar 300
- Hitachi 250
- John Deere 330
- Kobelco SK330
- Komatsu PC250
- Link Belt 3400

Excavator/loader: 40-tonne (35 000–45 000 kg)
- Barko 475
- Caterpillar 235
- Caterpillar 325
- Caterpillar 330
- John Deere 892
- Kobelco SK300
- Kobelco SK350
- Kobelco SK370
- Kobelco SK375
- Komatsu PC300
- Link Belt 4300
- Madill 3800

Excavator/loader: 50+ tonne (45 000+ kg)
- Hitachi 480
- John Deere 450
- John Deere 992
- Kobelco SK400
- Kobelco SK475
- Komatsu PC400
- Madill 4800

Feller-buncher: flat (<25 000 kg)
- Komatsu PC200(fb)

Feller-buncher: flat (25 000+ kg)
- Caterpillar TK921
- John Deere 853
- Tigercat 860
- Timberjack 618
- Timberjack 850
- Timberjack 950

Feller-buncher: tilt (<25 000 kg)
- Timbco T425

Feller-buncher: tilt (25 000+ kg)
- Caterpillar TK923
- John Deere 753 tilt
- Madill 2200
- Timbco 445
- Timberjack 2628

- Line loader: unspecified
  - American 7220
  - Madill 075
- Processor: boom-mount - large 65 cm plus opening
  - Denharco 4400
  - Denis 30
  - Limmit 2200
  - Quadco ForestPro
- Processor: boom-mount - small 65 cm minus opening
  - Denharco 3000
  - Limmit 2000
  - Limmit 2100
- Processor: dangle - large 60 cm plus butt
  - Keto 500
  - Valmet 965
- Processor: dangle - small 60 cm minus butt
  - Denharco DH550
  - Pierce 20
  - Target
  - Valmet 960
- Rock drill: hydraulic - excavator mount
  - Atlas Copco
- Rock drill: hydraulic - tank mount
  - Chapman Roc Champ
  - Rotair Drill King
- Rock drill: tank
  - Finning M40
- Rock truck: off road - unspecified
  - Caterpillar 250
  - Caterpillar 300 truck
- Skidder: grapple - large (>16 000 kg)
  - John Deere 748
  - Tigercat 635
  - Timberjack 660
- Skidder: grapple - medium (12 000–16 000 kg)
  - Caterpillar 525
  - John Deere 648
  - Tigercat 630
  - Timberjack 450
  - Timberjack 460
  - Timberjack 480
  - Timberjack 560
- Skidder: grapple - small (<12 000 kg)
  - Timberjack 240
- Skidder: small-line
  - Caterpillar 518
- Skidder: tracked - D4 size (<15 000 kg)
  - Caterpillar D4H
- Skidder: tracked - D5 size (15 000–25 000 kg)
  - Caterpillar 527/D5
- Tower yarder: large
  - Madill 3-450
  - Madill 3-500
  - Madill S-90
- Tower yarder: oversize
  - Washington 217
- Truck: highway - B-train
  - Western Star 4986 - B-train
- Truck: highway - hayrack
  - Kenworth T800 - hayrack
  - Western Star 4986 - hayrack
- Truck: highway - pole trailer
  - Kenworth T800 - pole
  - Kenworth T800 - pole – self-load
  - Kenworth T800 - jeep
  - Western Star 4986S – jeep
  - Western Star 4986S – pole
- Truck: highway - tridem-tridem
  - Kenworth T800 - tridrive
- Truck: off-highway - pole trailer
  - Western Star 6964
- Wheeled loader: large 3600–3800 mm wheelbase
  - Kawasaki 115
- Wheeled loader: medium 3300–3600 mm wheelbase
  - Caterpillar 966
  - John Deere 744
  - Kawasaki 95
  - Samsung 250
- Wheeled loader: small <3300 mm wheelbase
  - Caterpillar 950
  - Caterpillar 966C
  - Komatsu WA250
- Yarding crane: large
  - Cypress 7280
  - Madill 124
  - Madill 144

# Appendix III

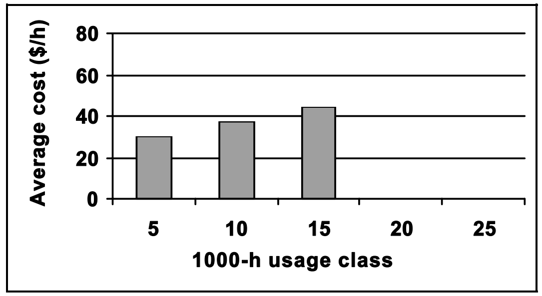
## Sample points and regression coefficients of determination for each machine class

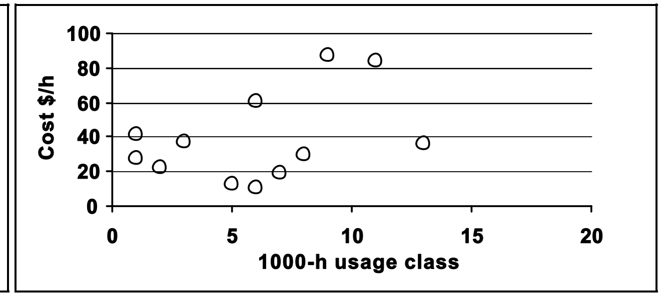
The following pages contain detail about the survey data.

- The bar charts show the average costs for each machine class and usage class.
- The scatter charts show the quantity and distribution of the survey data for each class. The scale of the scatter charts' vertical axes are variable depending on the range of the data. When comparing the charts of different machine classes, the variable scales must be taken into consideration.
- The tables show the sample sizes and how well the regression line fits the sample points.
- Machine classes with fewer than four machines, eight sample points, or 15 000 operating hours have been omitted.

## Clambunk skidder: 25000 - 35000 kg

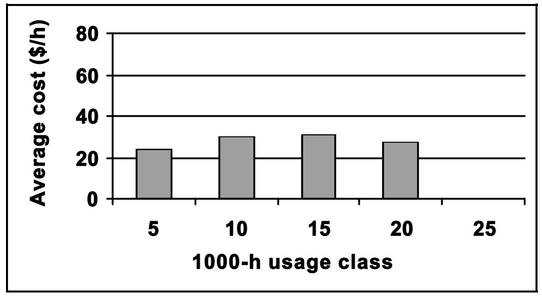
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | $r^2$ | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 5 | 4 | 5 | 7,405 | 0.46 | 29.94 | 30.48 |
| 10 | 1 | 9 | 4 | 10 | 15,492 | 0.08 | 37.31 | 36.84 |
| 15 | 1 | 13 | 4 | 12 | 19,019 | 0.14 | 44.43 | 40.69 |
| 20 | 1 | 13 | 4 | 12 | 19,019 | | | |
| 25 | 1 | 13 | 4 | 12 | 19,019 | | | |

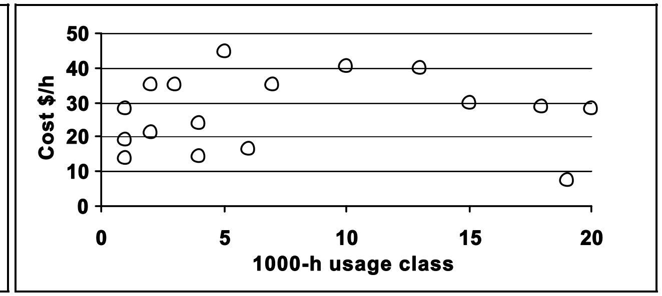



## Crawler tractor: D-6 size

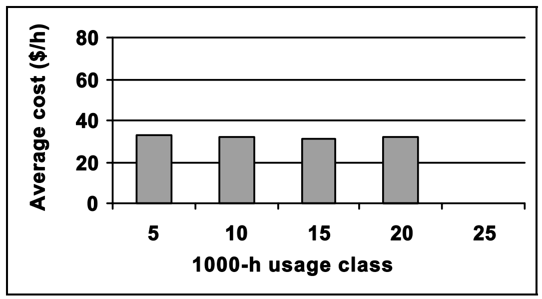
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | $r^2$ | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 5 | 4 | 10 | 14,160 | 0.05 | 24.42 | 24.63 |
| 10 | 1 | 10 | 5 | 12 | 21,742 | 0.22 | 30.37 | 27.08 |
| 15 | 1 | 15 | 5 | 14 | 25,435 | 0.18 | 31.06 | 28.19 |
| 20 | 1 | 20 | 6 | 17 | 29,375 | 0.00 | 27.34 | 27.04 |
| 25 | 1 | 20 | 6 | 17 | 29,375 | | | |

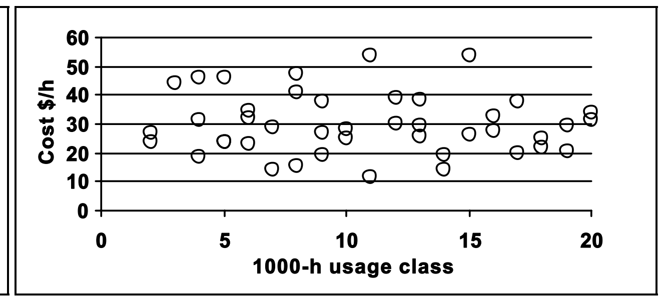



## Crawler tractor: D-7 size

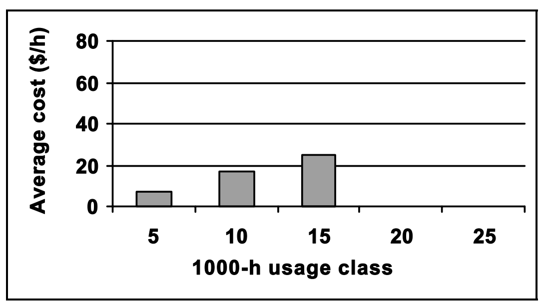
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | $r^2$ | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 2 | 5 | 4 | 9 | 10,590 | 0.00 | 33.29 | 33.03 |
| 10 | 2 | 10 | 7 | 22 | 26,865 | 0.01 | 32.01 | 31.43 |
| 15 | 2 | 15 | 11 | 33 | 39,506 | 0.00 | 31.41 | 31.51 |
| 20 | 2 | 20 | 11 | 43 | 49,567 | 0.00 | 31.78 | 31.86 |
| 25 | 2 | 21 | 11 | 44 | 51,093 | | | |

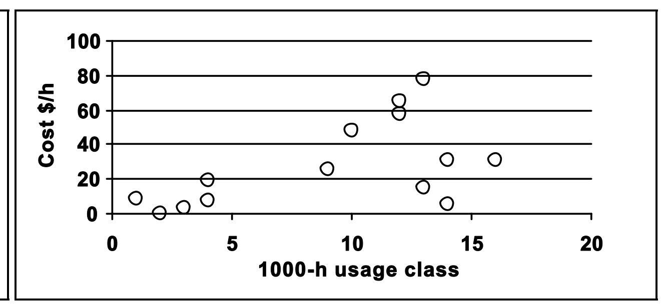



## Crawler tractor: D-8 size

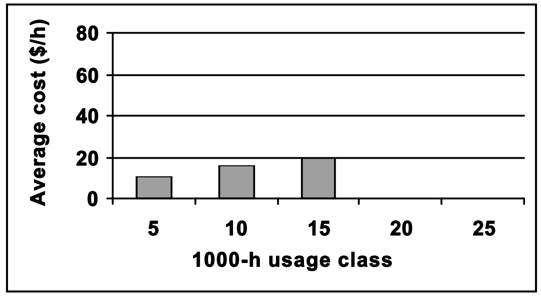
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | $r^2$ | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 4 | 2 | 5 | 6,013 | 0.19 | 6.91 | 7.65 |
| 10 | 1 | 10 | 3 | 7 | 8,579 | 0.78 | 17.22 | 15.99 |
| 15 | 1 | 14 | 6 | 13 | 16,093 | 0.36 | 25.28 | 28.59 |
| 20 | 1 | 16 | 6 | 14 | 17,329 | | | |
| 25 | 1 | 16 | 6 | 14 | 17,329 | | | |

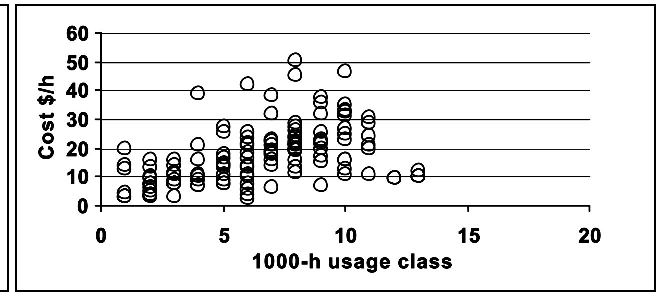


## Excavator/loader: 20-tonne (15 000 - 25 000 kg)

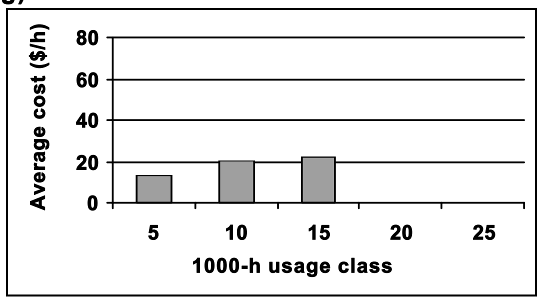
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 5 | 22 | 43 | 58,577 | 0.14 | 11.02 | 12.30 |
| 10 | 1 | 10 | 39 | 108 | 143,674 | 0.32 | 16.37 | 18.57 |
| 15 | 1 | 13 | 39 | 119 | 159,371 | 0.19 | 19.71 | 18.29 |
| 20 | 1 | 13 | 39 | 119 | 159,371 | | | |
| 25 | 1 | 13 | 39 | 119 | 159,371 | | | |

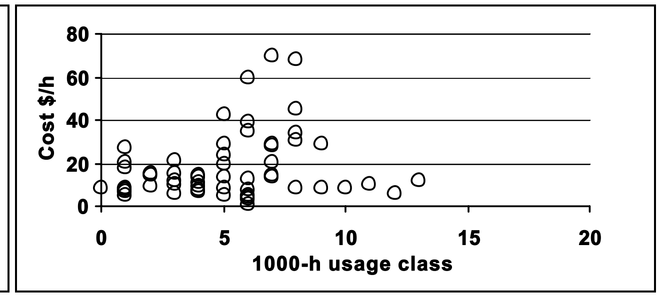



## Excavator/loader: 30-tonne (25 000 - 35 000 kg)

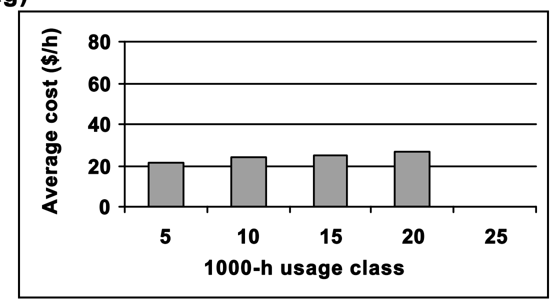
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 0 | 5 | 11 | 29 | 35,628 | 0.07 | 13.73 | 14.41 |
| 10 | 0 | 10 | 16 | 51 | 60,846 | 0.14 | 20.52 | 20.04 |
| 15 | 0 | 13 | 16 | 54 | 63,827 | 0.05 | 22.16 | 19.37 |
| 20 | 0 | 13 | 16 | 54 | 63,827 | | | |
| 25 | 0 | 13 | 16 | 54 | 63,827 | | | |

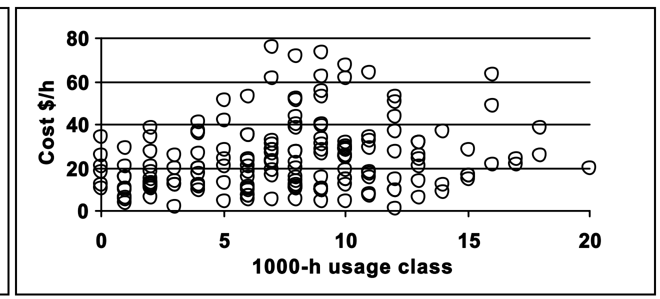



## Excavator/loader: 40-tonne (35 000 - 45 000 kg)

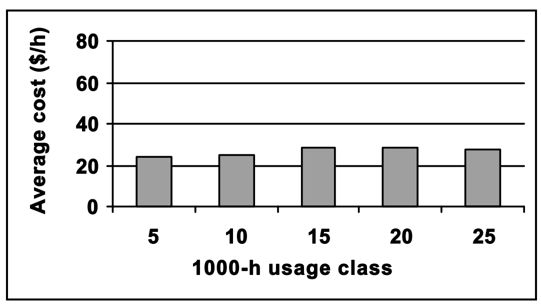
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 0 | 5 | 21 | 51 | 65,837 | 0.06 | 21.40 | 21.66 |
| 10 | 0 | 10 | 32 | 124 | 152,876 | 0.07 | 24.38 | 25.64 |
| 15 | 0 | 15 | 33 | 159 | 192,506 | 0.01 | 24.86 | 24.78 |
| 20 | 0 | 20 | 33 | 167 | 201,773 | 0.02 | 26.39 | 25.18 |
| 25 | 0 | 20 | 33 | 167 | 201,773 | | | |

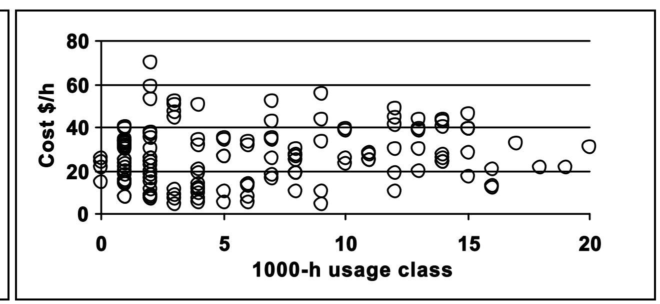



## Excavator/loader: 50+ tonne (45 000+ kg)

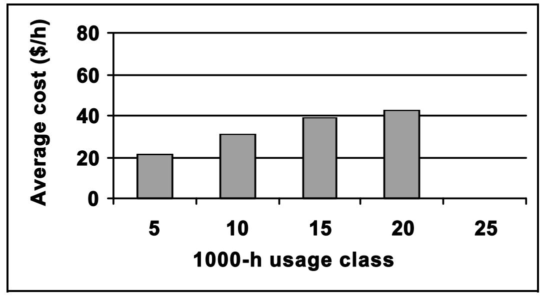
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 0 | 5 | 26 | 69 | 95,831 | 0.01 | 24.13 | 24.31 |
| 10 | 0 | 10 | 27 | 99 | 127,725 | 0.00 | 25.27 | 25.08 |
| 15 | 0 | 15 | 30 | 126 | 158,200 | 0.04 | 28.88 | 27.85 |
| 20 | 0 | 20 | 30 | 133 | 165,951 | 0.02 | 28.36 | 27.13 |
| 25 | 0 | 25 | 30 | 138 | 171,078 | 0.01 | 27.55 | 26.58 |

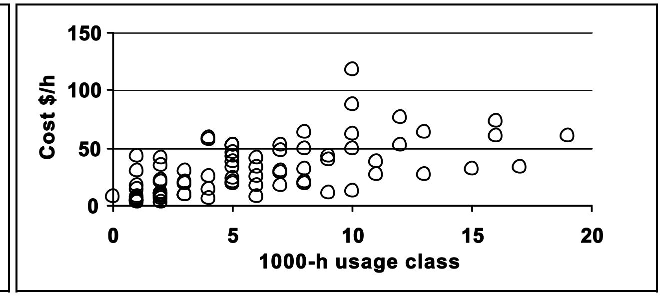


## Feller buncher: flat (25 000+ kg)

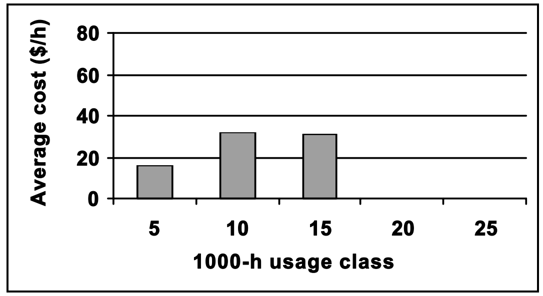
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 0 | 5 | 18 | 39 | 61,468 | 0.34 | 21.59 | 22.79 |
| 10 | 0 | 10 | 20 | 62 | 90,293 | 0.28 | 31.37 | 29.81 |
| 15 | 0 | 15 | 20 | 69 | 100,607 | 0.30 | 39.36 | 32.09 |
| 20 | 0 | 19 | 20 | 73 | 108,126 | 0.29 | 43.08 | 32.18 |
| 25 | 0 | 19 | 20 | 73 | 108,126 | | | |

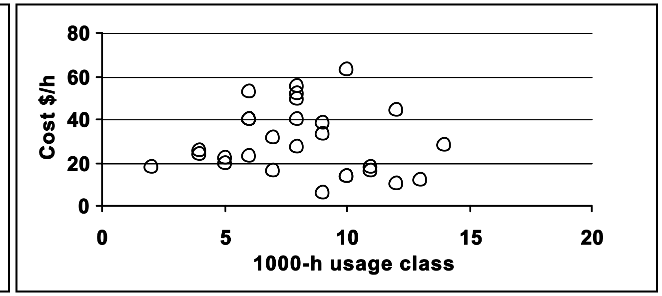



## Feller buncher: tilt (<25 000 kg)

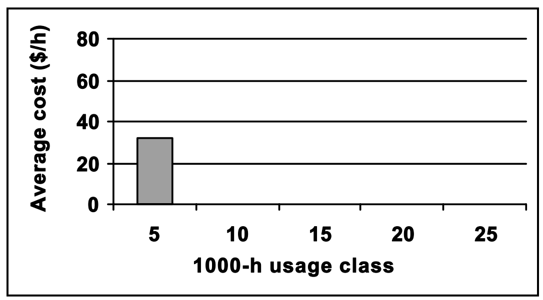
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 2 | 5 | 3 | 5 | 7,742 | 0.63 | 15.65 | 20.62 |
| 10 | 2 | 10 | 6 | 22 | 32,176 | 0.02 | 32.15 | 34.56 |
| 15 | 2 | 14 | 6 | 28 | 38,226 | 0.01 | 31.13 | 30.73 |
| 20 | 2 | 14 | 6 | 28 | 38,226 | | | |
| 25 | 2 | 14 | 6 | 28 | 38,226 | | | |

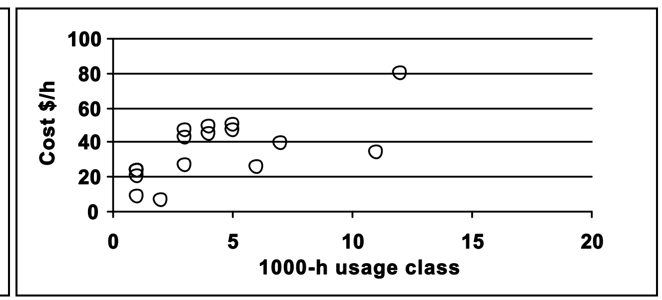



## Feller buncher: tilt (25 000+ kg)

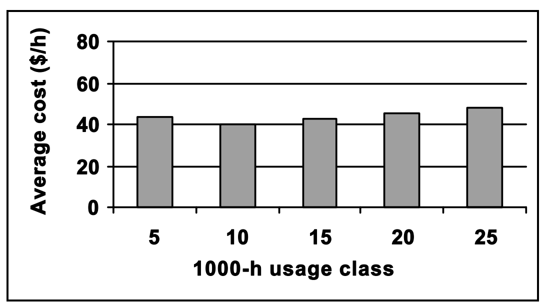
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 5 | 6 | 13 | 17,955 | 0.65 | 32.29 | 33.32 |
| 10 | 1 | 7 | 6 | 15 | 20,017 | | | |
| 15 | 1 | 11 | 7 | 16 | 21,773 | | | |
| 20 | 1 | 11 | 7 | 16 | 21,773 | | | |
| 25 | 1 | 11 | 7 | 16 | 21,773 | | | |

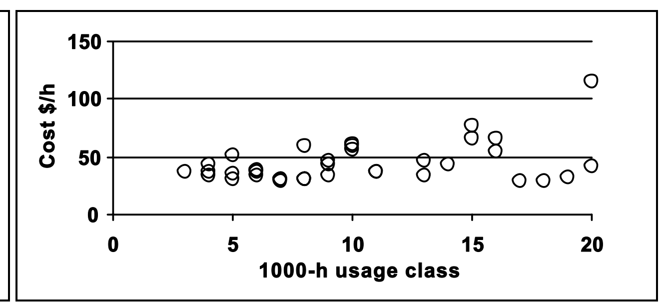



## Line loader: unspecified

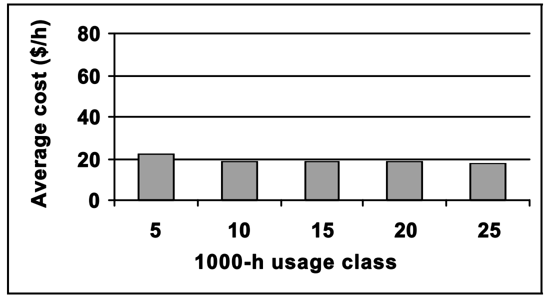
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 3 | 5 | 3 | 7 | 6,659 | 0.02 | 43.25 | 40.69 |
| 10 | 3 | 10 | 3 | 22 | 22,245 | 0.11 | 39.96 | 42.78 |
| 15 | 3 | 15 | 5 | 29 | 30,468 | 0.24 | 42.65 | 44.15 |
| 20 | 3 | 20 | 6 | 36 | 37,820 | 0.14 | 45.55 | 45.87 |
| 25 | 3 | 23 | 6 | 38 | 40,917 | 0.13 | 47.80 | 45.91 |

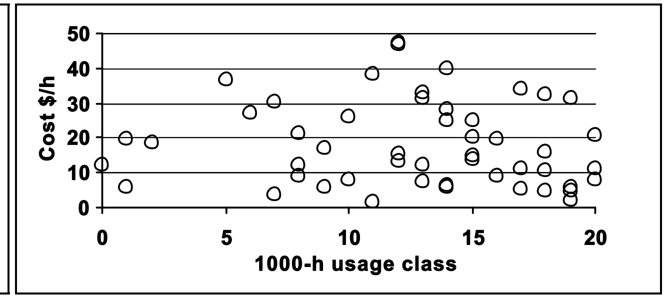


## Processor: boom-mount - large 65 cm plus opening

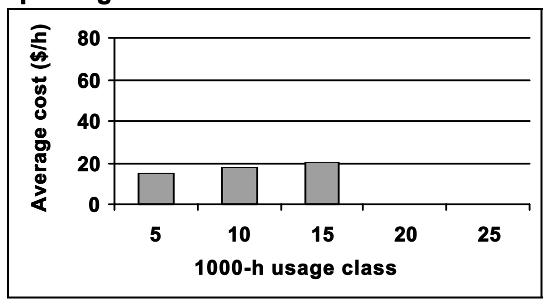
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 5 | 4 | 4 | 8,318 | 0.80 | 21.94 | 20.44 |
| 10 | 1 | 10 | 6 | 14 | 20,671 | 0.00 | 18.31 | 18.00 |
| 15 | 1 | 15 | 9 | 32 | 40,613 | 0.01 | 19.03 | 19.81 |
| 20 | 1 | 20 | 10 | 49 | 59,615 | 0.02 | 18.40 | 17.43 |
| 25 | 1 | 23 | 10 | 54 | 65,261 | 0.03 | 17.37 | 16.84 |

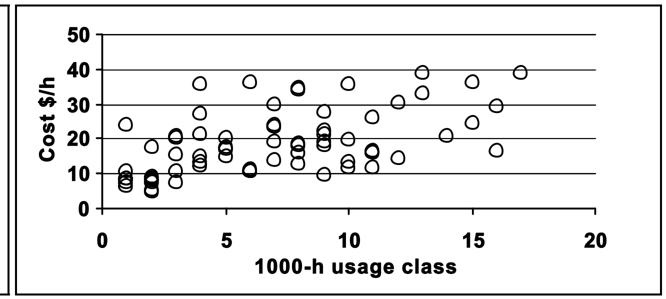



## Processor: boom-mount - small 65 cm minus opening

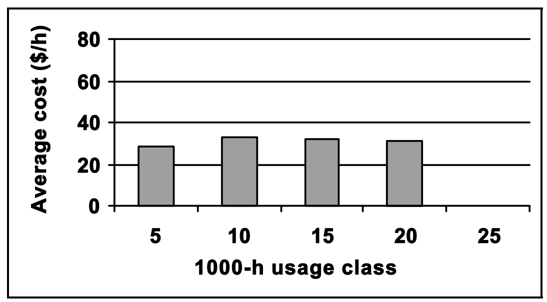
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 5 | 10 | 29 | 36,679 | 0.15 | 14.81 | 15.70 |
| 10 | 1 | 10 | 13 | 54 | 63,357 | 0.17 | 17.71 | 18.01 |
| 15 | 1 | 15 | 14 | 65 | 75,102 | 0.22 | 20.51 | 19.34 |
| 20 | 1 | 17 | 14 | 68 | 78,456 | | | |
| 25 | 1 | 17 | 14 | 68 | 78,456 | | | |

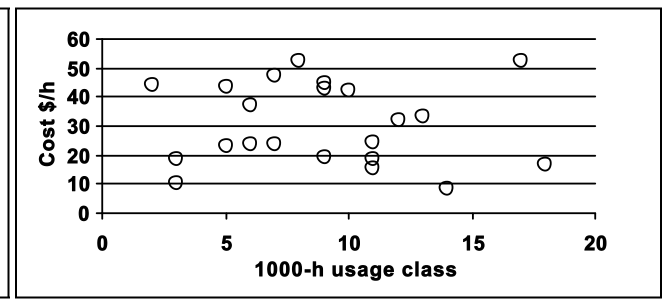



## Processor: dangle - large 60 cm plus butt

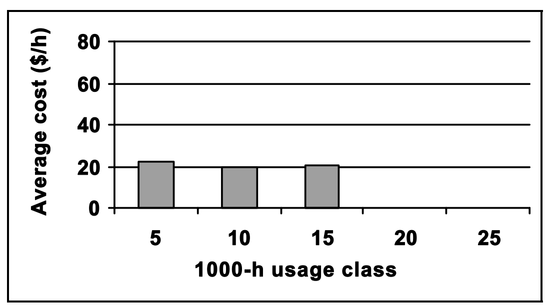
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 2 | 5 | 4 | 5 | 11,039 | 0.00 | 28.77 | 29.64 |
| 10 | 2 | 10 | 5 | 14 | 32,192 | 0.12 | 32.71 | 35.32 |
| 15 | 2 | 14 | 5 | 20 | 44,221 | 0.03 | 31.72 | 31.31 |
| 20 | 2 | 18 | 6 | 22 | 46,551 | 0.01 | 31.25 | 31.61 |
| 25 | 2 | 18 | 6 | 22 | 46,551 | | | |

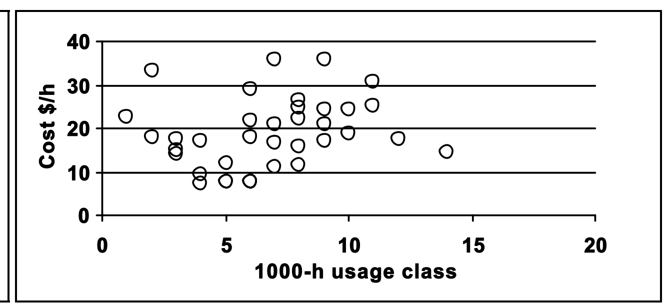



## Processor: dangle - small 60 cm minus butt

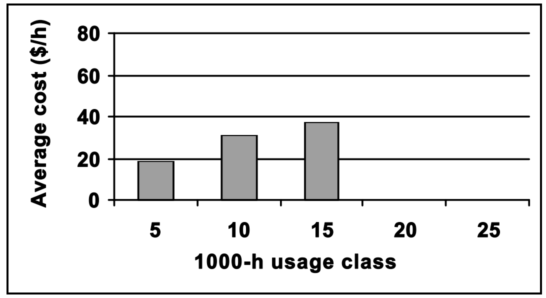
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 5 | 4 | 12 | 13,728 | 0.64 | 22.37 | 17.25 |
| 10 | 1 | 10 | 7 | 32 | 41,833 | 0.04 | 19.27 | 19.96 |
| 15 | 1 | 14 | 7 | 36 | 48,658 | 0.03 | 20.39 | 20.03 |
| 20 | 1 | 14 | 7 | 36 | 48,658 | | | |
| 25 | 1 | 14 | 7 | 36 | 48,658 | | | |

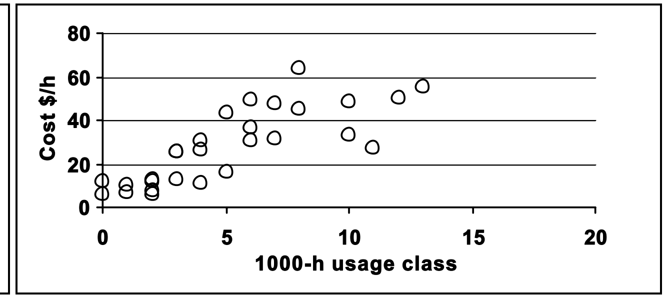


## Skidder - tracked: D5 size (15 000 - 25 000 kg)

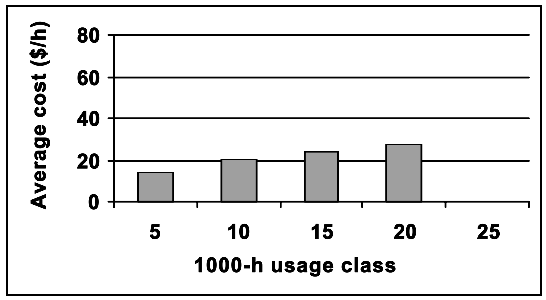
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 0 | 5 | 5 | 15 | 18,108 | 0.30 | 18.52 | 19.61 |
| 10 | 0 | 10 | 8 | 24 | 30,788 | 0.63 | 31.28 | 29.16 |
| 15 | 0 | 13 | 8 | 27 | 34,391 | 0.62 | 37.30 | 29.19 |
| 20 | 0 | 13 | 8 | 27 | 34,391 | | | |
| 25 | 0 | 13 | 8 | 27 | 34,391 | | | |

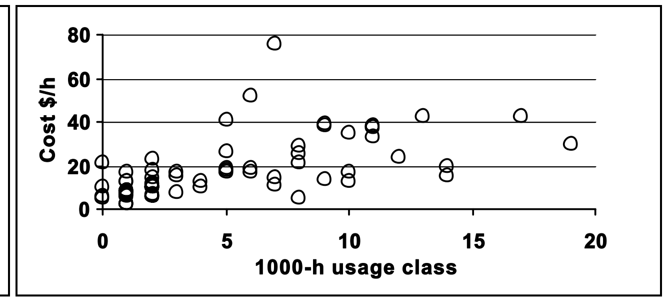



## Skidder: grapple - large (>16 000 kg)

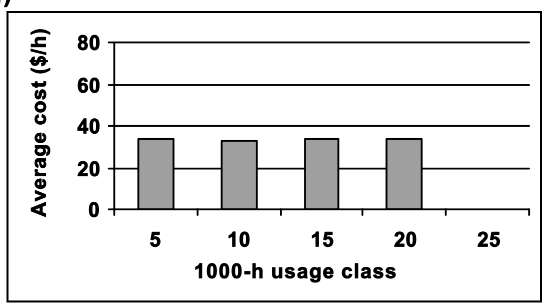
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 0 | 5 | 16 | 34 | 42,021 | 0.32 | 14.37 | 13.37 |
| 10 | 0 | 10 | 18 | 50 | 59,659 | 0.27 | 20.68 | 18.30 |
| 15 | 0 | 14 | 19 | 57 | 70,260 | 0.28 | 24.39 | 19.65 |
| 20 | 0 | 19 | 19 | 59 | 74,055 | 0.29 | 27.86 | 20.03 |
| 25 | 0 | 19 | 19 | 59 | 74,055 | | | |

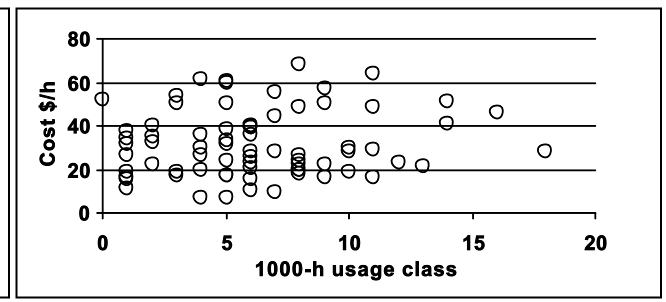



## Skidder: grapple - medium (12 000 - 16 000 kg)

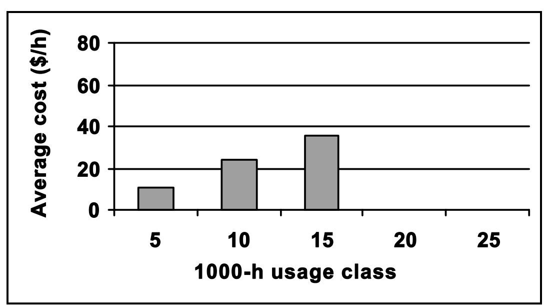
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 0 | 5 | 16 | 33 | 49,684 | 0.00 | 33.44 | 33.80 |
| 10 | 0 | 10 | 19 | 63 | 98,683 | 0.00 | 32.70 | 32.70 |
| 15 | 0 | 14 | 19 | 71 | 111,086 | 0.01 | 33.40 | 32.86 |
| 20 | 0 | 18 | 19 | 73 | 116,394 | 0.01 | 34.11 | 32.76 |
| 25 | 0 | 18 | 19 | 73 | 116,394 | | | |

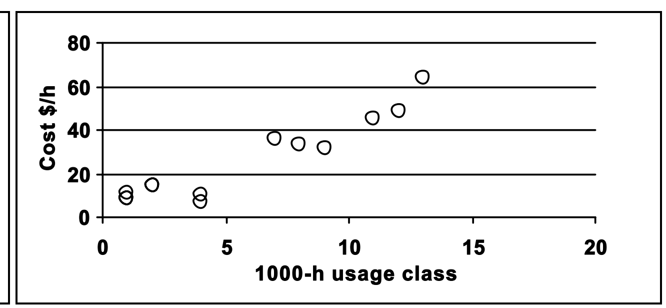



## Skidder: grapple - small (<12 000 kg)

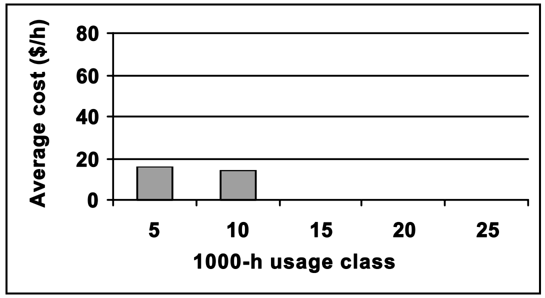
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 4 | 3 | 7 | 12,285 | 0.06 | 10.38 | 10.58 |
| 10 | 1 | 9 | 4 | 10 | 15,229 | 0.75 | 24.14 | 19.56 |
| 15 | 1 | 13 | 4 | 13 | 19,086 | 0.89 | 35.73 | 28.12 |
| 20 | 1 | 13 | 4 | 13 | 19,086 | | | |
| 25 | 1 | 13 | 4 | 13 | 19,086 | | | |

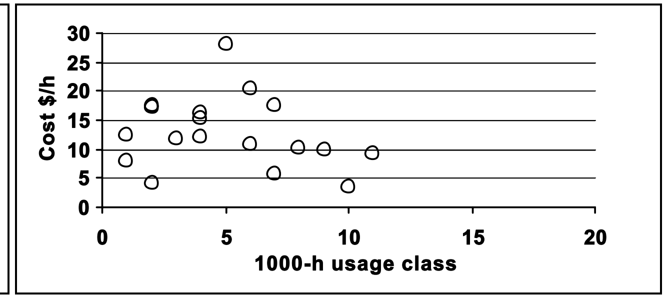


## Truck - highway: B-train

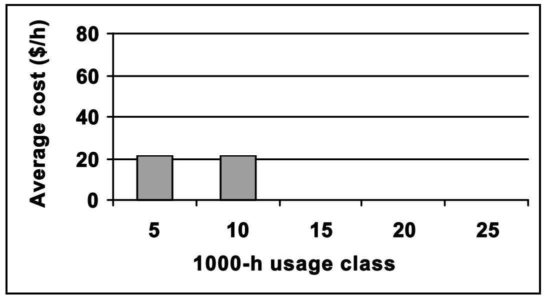
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 5 | 4 | 10 | 19,823 | 0.31 | 16.10 | 17.11 |
| 10 | 1 | 10 | 5 | 17 | 28,226 | 0.03 | 13.83 | 13.94 |
| 15 | 1 | 11 | 5 | 18 | 28,965 | | | |
| 20 | 1 | 11 | 5 | 18 | 28,965 | | | |
| 25 | 1 | 11 | 5 | 18 | 28,965 | | | |

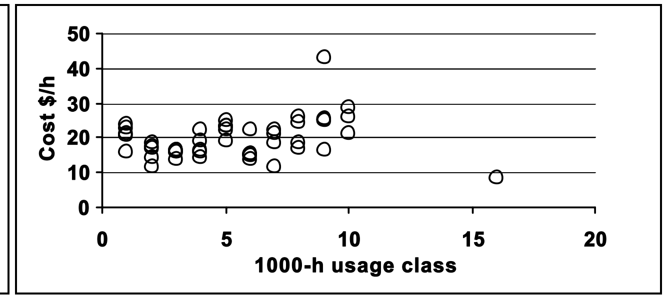



## Truck - highway: hayrack

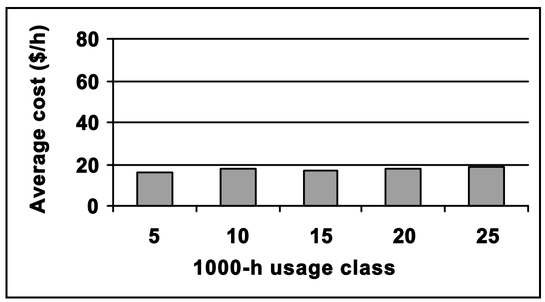
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 5 | 5 | 25 | 27,434 | 0.00 | 21.06 | 21.14 |
| 10 | 1 | 10 | 5 | 45 | 50,011 | 0.09 | 21.56 | 21.65 |
| 15 | 1 | 10 | 5 | 45 | 50,011 | | | |
| 20 | 1 | 16 | 6 | 46 | 51,311 | | | |
| 25 | 1 | 16 | 6 | 46 | 51,311 | | | |

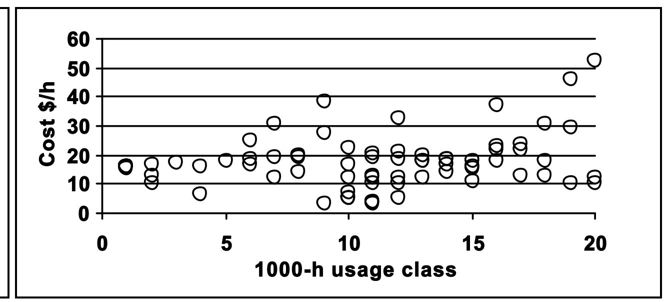



## Truck - highway: pole trailer

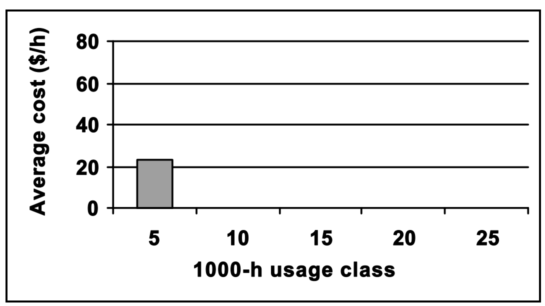
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 5 | 3 | 10 | 13,628 | 0.00 | 15.76 | 15.76 |
| 10 | 1 | 10 | 9 | 28 | 33,366 | 0.00 | 17.44 | 17.49 |
| 15 | 1 | 15 | 11 | 53 | 59,891 | 0.00 | 16.90 | 16.75 |
| 20 | 1 | 20 | 11 | 69 | 76,040 | 0.06 | 18.11 | 18.67 |
| 25 | 1 | 25 | 11 | 83 | 91,266 | 0.04 | 18.70 | 18.93 |

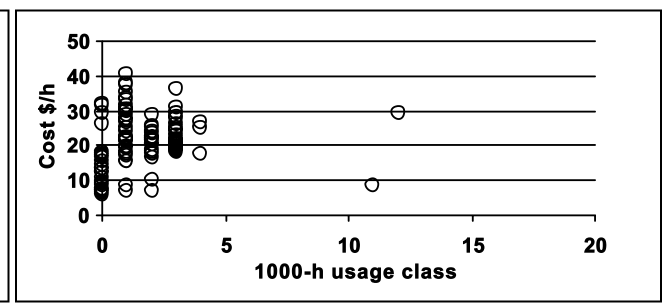



## Truck - highway: tridem-tridem

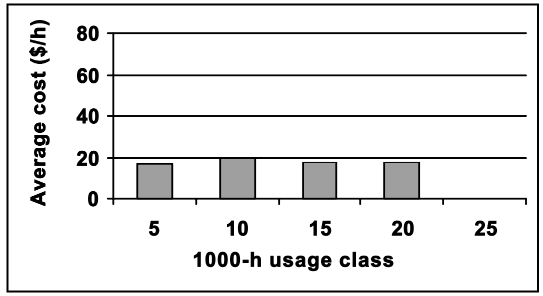
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 0 | 4 | 58 | 99 | 149,725 | 0.11 | 23.43 | 21.23 |
| 10 | 0 | 4 | 58 | 99 | 149,725 | | | |
| 15 | 0 | 12 | 59 | 100 | 151,144 | | | |
| 20 | 0 | 12 | 59 | 100 | 151,144 | | | |
| 25 | 0 | 12 | 59 | 100 | 151,144 | | | |

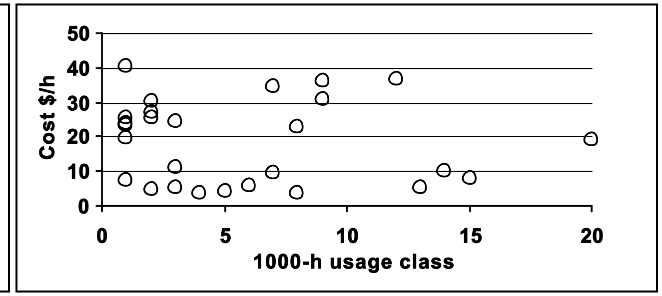


### Wheeled loader: medium 3300 - 3600 mm wheelbase

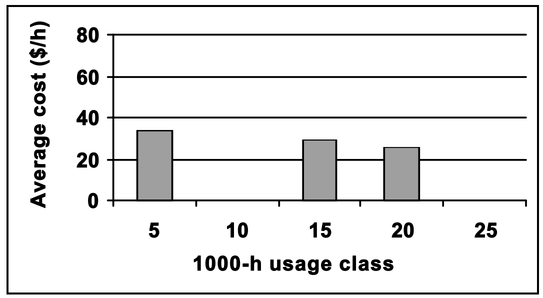
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 5 | 7 | 15 | 21,465 | 0.33 | 16.91 | 18.94 |
| 10 | 1 | 9 | 9 | 22 | 29,920 | 0.00 | 19.22 | 19.36 |
| 15 | 1 | 15 | 10 | 26 | 33,992 | 0.02 | 17.82 | 18.67 |
| 20 | 1 | 20 | 11 | 27 | 35,381 | 0.01 | 17.55 | 18.66 |
| 25 | 1 | 20 | 11 | 27 | 35,381 | | | |

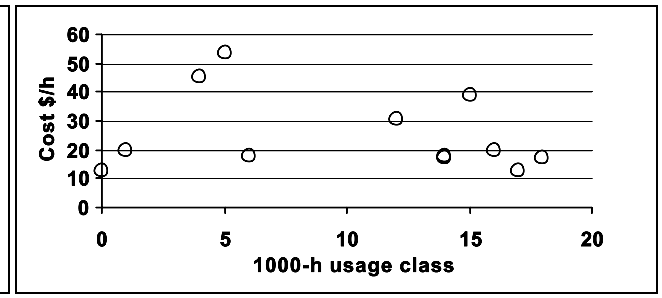



### Wheeled loader: small <3300 mm wheelbase

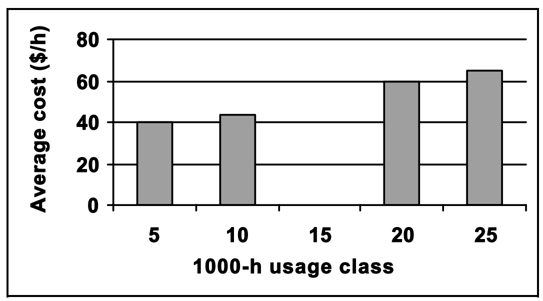
| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 0 | 5 | 3 | 4 | 4,019 | 1.00 | 33.94 | 33.94 |
| 10 | 0 | 6 | 3 | 5 | 4,865 | | | |
| 15 | 0 | 15 | 5 | 9 | 12,054 | 0.00 | 29.17 | 29.20 |
| 20 | 0 | 18 | 5 | 12 | 17,710 | 0.06 | 25.73 | 25.63 |
| 25 | 0 | 18 | 5 | 12 | 17,710 | | | |

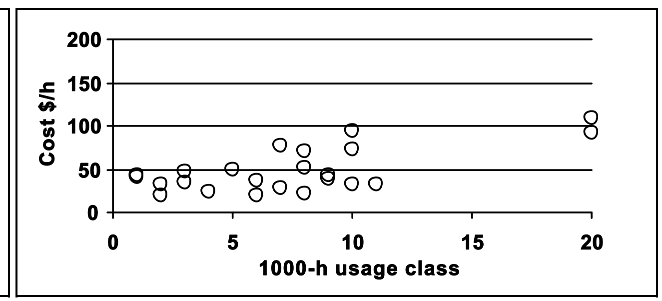



### Yarding crane: large

| Class | Min | Max | Mach. (no.) | Pts (no.) | Usage (h) | r² | Average cost ($/h) Regr. | Mean |
|---|---|---|---|---|---|---|---|---|
| 5 | 0 | 5 | 3 | 9 | 10,208 | 0.16 | 40.36 | 41.04 |
| 10 | 0 | 10 | 6 | 21 | 23,987 | 0.08 | 43.63 | 44.81 |
| 15 | 0 | 11 | 6 | 22 | 25,589 | | | |
| 20 | 0 | 20 | 8 | 24 | 28,614 | 0.41 | 59.46 | 49.48 |
| 25 | 0 | 25 | 10 | 38 | 44,789 | 0.49 | 65.04 | 66.13 |



# Appendix IV

## Distribution between cost categories

| Machine class | Hours | Parts (%) | Labour (%) | Other (%) | Tire (%) | Total costs ($) |
|---|---|---|---|---|---|---|
| Clambunk skidder: 25 000–35 000 kg | 19 019 | 33 | 67 | 0 | 0 | 904 318 |
| Crawler tractor: D-6 size | 27 393 | 59 | 41 | 0 | 0 | 788 820 |
| Crawler tractor: D-7 size | 34 063 | 66 | 34 | 0 | 0 | 1 268 514 |
| Crawler tractor: D-8 size | 15 493 | 46 | 54 | 0 | 0 | 393 231 |
| Excavator/loader: 20-tonne (15 000–25 000 kg) | 41 913 | 57 | 42 | 0 | 1 | 670 465 |
| Excavator/loader: 30-tonne (25 000–35 000 kg) | 50 740 | 59 | 41 | 0 | 0 | 1 016 166 |
| Excavator/loader: 40-tonne (35 000–45 000 kg) | 152 910 | 55 | 44 | 0 | 1 | 3 904 456 |
| Excavator/loader: 50+ tonne (45 000+ kg) | 123 524 | 53 | 46 | 1 | 0 | 3 001 662 |
| Feller-buncher: flat (25 000+ kg) | 102 195 | 48 | 52 | 0 | 0 | 3 815 212 |
| Feller-buncher: tilt (<25 000 kg) | 16 596 | 85 | 15 | 0 | 0 | 378 759 |
| Feller-buncher: tilt (25 000+ kg) | 21 305 | 56 | 44 | 0 | 0 | 787 767 |
| Line loader: unspecified | 31 854 | 53 | 42 | 4 | 1 | 1 636 060 |
| Processor: boom-mount - large 65 cm plus opening | 58 150 | 71 | 29 | 0 | 0 | 961 800 |
| Processor: boom-mount - small 65 cm minus opening | 75 147 | 68 | 32 | 0 | 0 | 1 453 066 |
| Processor: dangle - small 60 cm minus butt | 38 194 | 62 | 38 | 0 | 0 | 823 015 |
| Skidder: grapple - large (>16 000 kg) | 61 127 | 62 | 38 | 0 | 0 | 1 157 007 |
| Skidder: grapple - medium (12 000–16 000 kg) | 94 068 | 30 | 68 | 0 | 2 | 3 407 130 |
| Skidder: grapple - small (<12 000 kg) | 19 086 | 30 | 70 | 0 | 0 | 425 952 |
| Skidder : tracked - D5 size (15 000–25 000 kg) | 25 883 | 55 | 45 | 0 | 0 | 865 783 |
| Truck : highway - pole trailer | 87 709 | 37 | 50 | 0 | 13 | 1 583 772 |
| Truck : highway - tridem-tridem | 147 647 | 39 | 45 | 0 | 16 | 3 302 957 |
| Wheeled loader: medium 3300–3600 mm wheelbase | 23 017 | 48 | 49 | 2 | 1 | 369 412 |
| Yarding crane: large | 42 570 | 66 | 30 | 4 | 0 | 3 174 455 |

# Appendix V

## Tire costs for trucks

| Machine class | Usage class | All costs ($) | Tire cost ($) | Operating hours (h) | Tire percentage (%) |
|---|---|---|---|---|---|
| Truck - highway: B-train | 5 | 329 234 | 11 551 | 19 823 | 4 |
| | 10 | 429 816 | 15 335 | 28 226 | 4 |
| Truck - highway: hayrack | 5 | 531 539 | 48 766 | 27 434 | 9 |
| | 10 | 1 020 876 | 65 546 | 50 011 | 6 |
| Truck - highway: pole trailer | 10 | 180 053 | 48 707 | 12 890 | 27 |
| | 15 | 582 065 | 86 708 | 39 759 | 15 |
| | 20 | 976 535 | 127 115 | 55 908 | 13 |
| | 25 | 1 264 497 | 137 346 | 71 134 | 11 |
| Truck - highway: pole trailer | 5 | 196 711 | 60 800 | 13 628 | 31 |
| | 10 | 546 267 | 122 853 | 33 543 | 22 |
| | 15 | 948 279 | 160 854 | 60 412 | 17 |
| | 20 | 1 342 749 | 201 261 | 76 561 | 15 |
| | 25 | 1 630 711 | 211 492 | 91 787 | 13 |
| Truck - highway: tridem-tridem | 5 | 3 312 129 | 531 625 | 150 031 | 16 |