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Forest Machine Depreciation Study

Assessing the value recovery of forestry machines in the New Zealand used machine market

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Executive Summary

Modern forest machinery are high cost capital items and expensive to operate, but are a requirement for modern safe and efficient harvesting operations. Depreciation of machinery is a significant component of operating cost and as such important for harvesting contractors and forestry companies. The are some rules of thumb; for example that a forestry machine is expected to be worth approximately 25% of its purchase value after 10,000 hours of operation, however little empirical data has been available to support such statements. This report evaluates the change in value of common forest harvesting machinery as machine hour's increase and investigates the factors that contribute to their depreciation.

Used machine price data and factors that influence price such as machine age and number of hours were retrieved from both online and print sources, with a total of 497 unique New Zealand entries. A survey of equipment dealers and harvest contractors was also conducted to ascertain their opinion of both used machine price factors and trends.

In addition to presenting average used price data and trends for a range of equipment, depreciation rates were calculated. It showed higher rates of depreciation for large (>150kW) tracked loaders and wheeled skidders than smaller models; and that on average, wheeled skidders had the highest rate of depreciation, losing $58.15 in value for every machine hour of use. In comparison, tracked loaders depreciate $37.90 in value for each hour worked, forwarders lose $48.40 while wheeled loaders had the lowest rate of depreciation, with $26.40 in value lost for each hour of use. Tracked loaders with a motorised attachment (i.e. felling/processing head) were approximately twice as valuable as those with basic attachments such as grapples and buckets.

When compared to data from a partner American study, both domestic markets have very similar relationships between used machine price and machine hours. However, every machine type is considerably more expensive in NZ than in the US. Forwarders and tracked skidders are approximately twice as expensive in NZ; while wheeled loaders and wheeled skidders, on average are $180,000 more expensive in the NZ market.

The survey indicated that contractors believe the biggest influences on used machine value are operator skill and the level of repairs and maintenance. Machine dealers believe that depreciation is heavily influenced by supply and demand trends and most dealers stated that there is a noticeable difference in the depreciation of forestry-specific machines such as wheeled skidders, in comparison to machines such as tracked loaders that can be used in other industries.

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1. Introduction

An essential consideration of any modern forest harvesting operation is the use of machinery to safely and economically fell, extract and process stems, whilst mitigating environmental impacts. Purchasing new forest machinery requires high capital expenditure and a high level of associated risk for a contractor. A concern for the purchaser is often the level of depreciation to be expected as the working hours of the machine increase. Although there are several 'rules of thumb' for the estimation of machine depreciation, there is currently little evidence to reinforce these estimates.

A pilot study into the effects of machine hours on used sale price was conducted in late 2018 (Visser and Fahey 2018). This study involved collecting a sample set of historical used machine sales data from the NZ used machine market. Similar data was also retrieved from the US used machine market. From this data, moderate statistical relationships were derived between machine hours and the used sale price for tracked and wheeled loaders (including harvesters and processors) in NZ. A strong relationship between machine hours and used sale price for forwarders was also found. The opportunity for an expanded study was highlighted to better understand both the trends and the factors that influence used machines.

This study evaluates the extent to which forest machinery in the New Zealand used machine market depreciates in value throughout its useful lifetime. The primary objective of the study is to determine the level of depreciation of each machine type commonly found in NZ harvesting operations. The secondary objectives of the study are to assess the influence of machine hours, machine size, the region of sale, and loader attachment on used machine price. Finally, the depreciation trends found within the NZ used machine market will be compared to trends within the United States (US) used machine market to determine whether there are similarities between domestic trends. The study includes a survey of both machine dealers and forestry contractors. The purpose of this report is to give all parties within the industry a clearer understanding of the salvage value of each forestry machine type, external factors that influence used machine value and the internal factors that lead to machine depreciation throughout its lifetime.

2. Background

Blackburne (2009) states that the decrease in machine value is maximum immediately after machine purchase and depreciation slows over time. The value of a used machine is not guaranteed, but rather it fluctuates with supply and demand trends. Some factors that Blackburne considers are that extra running costs are incurred with older machines, due to an increase in repairs and maintenance as the machine ages. A new machine will have repair and maintenance costs significantly lower than the average throughout its lifetime, whilst an older machine will have higher costs. New forestry machines are expected to have fewer breakdowns but present the contractor with high debt. This gives the contractor less tolerance for low production operations and constrains them to continue with contracts that may be costing them money.

Conversely, used machines have a higher rate of breakdowns, but represent a lesser financial burden for the contractor. According to Blackburne (2009), contractor considerations should be based on sensitivity analysis of their finances and the following questions:

- Will the budget still offer an acceptable profit margin if working days are decreased throughout the year?
- Will the business be profitable if costs increase by 10% and income is reduced by 10%?
- Is it possible to perform an engine overhaul on an old machine to extend its lifetime?

After these questions are answered, contractors must decide the likelihood of such an event occurring, to determine the risk to the company of each decision.

A common practice for calculating depreciation throughout the forest industry is to use the 'straight-line method', as it is simpler than alternative methods of calculation. This method states that:

$$Depreciation\ (\frac{\$}{hr}) = \frac{(Capital\ Cost - Tracks - Residual\ Value)}{Machine\ Life}$$

Where:

Capital Cost ($) = Purchase price of machine (less GST), including transport and attachments, bush-rigged (ready to work).

Tracks ($) = Cost of tracks (or Tyres), which his subtracted as they are accounted for in operating (variable) costs

Residual Value ($) = the amount the machine will be sold for at the end of its life.

Machine Life = the total 'lifetime' of the machine (hours).

If the expectation is that machines will perform similarly from year to year, the straight-line depreciation method should be adopted to give constant machine productivity. Ideally, the financial burden of capital purchases should be spread across the lifetime of the asset rather than being regarded as one-off purchases, with the benefits of ownership of these assets spread over their economic lifetime. Jensen (2002) states that machine depreciation should be calculated with consideration of the performance of the machine over its useful lifetime, rather than using a method of accelerated depreciation that provides tax benefits for the contractor. According to Blackburne (2009), depreciation of forestry machines decreases swiftly after 5 years, and the machine is worth approximately 25% of its purchase price after 10,000 hours of operation.

An alternative method for calculating inflation with respect to machine depreciation is to calculate the depreciation of the machine through each year of its life, but also include systems such as the ACRS depreciation schedules (Jones, 1986). This is conducted by analysing the cost of a similar machine in that year, as opposed to using the actual purchasing price or a theoretical future price. The change in the price of an asset over a period of time has two components, the first caused by depreciation, and the second due to inflation (Hulten, 1981; Blackburne 2009). This concept can be explained using Figure 1. The line 'ZZ' represents the specific price history of the asset in question. If this asset is worth a given price at point 'a', the price will decrease as time passes along the curve 'a-b' and at a certain time will reach 'b'; with this change representing the economic depreciation of this particular asset. At this hypothetical point 'b', the price increases, due to inflation, along the line 'b-d' and gives the new asset value as the point 'd'.

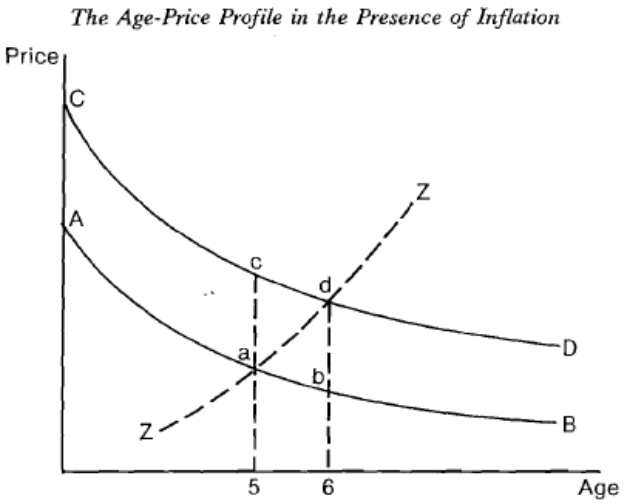

Figure 1: The combined effects of inflation and depreciation on asset value over time (Hulten, 1981)

Hulten (1981) also states that analysis of historical data of an asset, in the context of determining depreciation inevitably involves an element of variability, referred to as "censored sample bias". This variability arises from the fact that many of the assets may have been salvaged before the data was collected, effectively removing valid data points from the model. Censored sample bias occurs when machines are salvaged prior to reaching a given number of hours and are included in the machine data. This constrains the model, with the used price of the surviving machines being extrapolated across those machines which have since been salvaged. This censored sample bias was accounted for by multiplying each price with an estimate of the probability of survival. This depreciation was calculated for 32 different categories of equipment, including agricultural equipment (excluding tractors) and construction equipment. These two categories most closely resemble forest machinery and were calculated to have annual depreciation rates of 9.7% and 17.2% respectively.

According to Beidleman (1976), a concern of using historical data to identify the lifetimes and salvage values of assets is that the calculation "look(s) backward rather than forward." Another concern is that the historical model does not account for "prospective obsolescence", where a new model makes an older model redundant. Beidleman also states that this effect rarely happens uniformly and instead moves in "fits and starts."

Additionally, the use of historical records ignores the fact that these assets are frequently retained for longer than they are operating economically, due to the inability to finance a replacement asset. The value-age relationship was verified using econometric methods to establish a more accurate model for depreciation. In each test case, an inverse relationship between age and value was confirmed. The tests also indicated that depreciation of an asset was higher in the first few years of an assets lifetime, but decreased with age.

According to the New Zealand Inland Revenue Department, there are two methods for calculating depreciation which are suitable for tax purposes (Inland Revenue, 2019). These are the Straight Line (SL) Method and the Diminishing Value (DV) Method. The straight line method assumes that the asset depreciates at a constant rate each year until the end of its lifetime. The diminishing value method assumes that the asset initially has a high rate of depreciation, but this rate decreases over time. According to historical IRD data, the depreciation rates for industry machinery (default class), were as follows:

Table 1: Depreciation rates from the NZ Inland Revenue Department (Revenue, Historic Depreciation Rates, 2010) (Revenue, General Depreciation Rates, 2018)

	Est. Useful Life (Years)	DV Depreciation Rate (%)	SL Depreciation Rate (%)
1993-2005	15.5	12	8
2005-Current	15.5	13	8.5

Coen (1975) states that although there are models that predict asset depreciation, there is little empirical proof to reinforce these models. A common assumption is that the productivity of capital assets typically decreases geometrically at a rate which is twice the rate of straight line depreciation. This assumption suggests that replacement costs are a constant proportion of the capital owned at a certain point.

Table 2: Service lives of capital assets, showing lifespans used for tax purposes, and estimated actual service life. (Coen, 1975)

TABLE 3—SERVICE LIVES FOR TAX PURPOSES COMPARED WITH THOSE INDICATED BY INVESTMENT BEHAVIOR
(Years)

SIC Industry Code	Equipment Life for Tax Purposes			Excess of Tax Life Over Life Indicated by Investment Behavior Equipment			Structures All Years
	1947–61	1962–70	*ADR*[b]	1947–61	1962–70	*ADR*	
20	18	15	12	4	1	−2	3
21	18	15	12	6	3	0	−7
22	16	12	10	4	0	−2	−7
23	13	9	7	−1	−5	−7	−2
24	15	10	8	3	−2	−4	3
25	15	10	8	3	−2	−4	−27
26	19	14	11	1	−4	−7	−22
27	15	11	9	−3	−7	−9	−2
28	13	11	9	3	1	−1	−2
29	18	14	11	8	4	1	−22
30	15	13	10	−7	−9	−12	−17
31	14	11	9	4	1	−1	−2
32	23	17	14	5	−1	−4	−27
33	20	16	13	10	6	3	−7
34	16	12	10	6	2	0	−22
35	15	12	10	5	2	0	−17
36	15	11	9	−3	−7	−9	−22
37+19–371	16	12	10	4	0	−2	−7
371	15	12	10	7	4	2	−22
38	16	12	10	0	−4	−6	−27
39	14	12	10	−8	−10	−12	−22
All Industries[a]	16.5	12.9	10.5	3.6	0.0	−2.4	−12.4

[a] Weighted average, with weights proportional to equipment or structures expenditures in 1966.
[b] *Asset Depreciation Range (ADR) System.*

As can be seen from Table 2, the estimated lifespans of capital assets used for tax purposes are considerably different from the estimated actual lifespans of the assets, determined from investment behaviour. The bottom line shows the weighted averages of these estimates, with the ‘tax life' being approximately thirty-five per cent lower than the actual lifespan of the asset (Coen, 1975). This research shows that without suitable oversight, models can give misconstrued and inaccurate estimates of depreciation, which may be used to improve the outcome for one of the parties involved.

The sale price of a used forestry machine is dependent on many different variables, which adds to the uncertainty surrounding the true value of a given machine. Analysis of these factors will aid in understanding the factors affecting the market price for a used machine in the forest industry. As with any free market, the sale price of forest machinery is dependent on supply and demand, but there are

many other variables that affect the price of an individual machine. There are both internal and external factors that influence the resale value of a forestry machine. Internal variables that may affect machine resale value include:

- Age
- Machine hours
- Machine condition
- Previous working conditions
- Purpose
- Attachments
- Service history

External variables that may affect machine resale value include:

- Global market price
- Current log market
- The current market of complementary machine industries (e.g. civil works)
- International relationships with supplier countries

A study will be conducted into how forestry machines depreciate in value with respect to several dependent variables. The research will also analyse both external and internal factors that influence the depreciation of forestry machines. The study will focus solely on machines commonly used within production harvesting operations, namely tracked loaders, wheeled loaders, tracked skidders, wheeled skidders and forwarders. The study includes an analysis of relevant literature and historical data, and contractor and dealer evaluations to determine the considerations taken into account when purchasing and selling machines.

3. Methods

3.1 Used Machine Value

Used machine sales data will be required to undertake statistical analysis. This data will be collected from both online and print sources of New Zealand used forestry equipment that has the relevant data available. To be acceptable for analysis, the following information must be available for each machine.

- Machine Type (e.g. tracked loader, wheeled skidder)
- Machine Hours
- Used Sale Price

Ideally, these advertisements will show extra machine information which will strengthen the analysis. This information could include:

- Make
- Model
- Region of sale
- Year
- Attachments (for tracked loaders)

An example of a suitable classified for analysis is shown in Figure 2. This particular classified was retrieved from the May 2011 Edition of the New Zealand Logger magazine.

Figure 2: Example of an acceptable advertisement for analysis (Ellegard, 2011)

All used machine data collected will be entered into a spreadsheet format to categorically organise the useful information. The machines will be referenced according to the source, dealer, make, model and machine hours, should a unique identifier be unavailable for each classified.

Regression analysis will be conducted on the data to investigate possible relationships between the used machine price and several dependent variables. These variables are:

- Machine hours
- Region of sale
- Attachments (tracked loaders only)
- Machine size

The rate of depreciation of used machines will be calculated using the following formula:

$$Depreciation\left(\frac{\$}{hr}\right) = \frac{(New\ Price - Used\ Price)}{Machine\ Hours}$$

From this information, the effect of machine type on used machine depreciation will be investigated. The new price for each machine were retrieved from the INFORME 2017 Harvesting Survey and Daily Rate Estimates Report (FORME 2017). This data represents the most accurate new machine value information available at the time of publication. The used price was the price recorded from the source information, as with the machine hour information. The machines were split into small and large sizes, based on kilowatt ratings, to investigate whether size has any influence on machine depreciation, for a given machine type.

Machines were also be grouped in similar weight and power classes, to assess whether there are any differences in the depreciation trends between smaller and larger machines. The size classes were chosen based on available data for each machine type and the usefulness of the classification for operational decision making.

The data collated from the New Zealand used machine market will be compared to used machine data from the United States. The United States has a comparable forest industry, specifically in the South-Eastern United States, which allows for an evaluation to be made between the two countries. The equipment used in both countries is very analogous, with the US producing and using many of the common forestry machines found in the NZ forestry sector. Also, in temperate areas of the United States, many species of the Pinus genus are grown for production forestry, which requires similar harvesting techniques to the clearfell harvesting of Pinus radiata in New Zealand. Due to the proximity of NZ to the US, who manufacture and use much of the same equipment as is used in NZ, this analysis may also give an indication of the implication of international transport on used machine price.

3.2 Stakeholder Survey

Survey information was collected from both forestry contractors and used machine dealers to better understand industry perception of the used machine market. This information was used to ensure clarity between all parties within the forestry machine industry and may encourage more consistency within the used machine marketplace.

- What operational factor/s would you say have the largest effect on the depreciation of your machines? *E.g. slope, weather conditions, operator skill, piece size etc*.
- Are these operational factors the case for all of your machines, or do depreciation factors vary between different machines?
- To how many hours do you normally keep your machines?
- Do you have a preferred time of year to replace machines?
- How do you advertise a machine for sale?
- Do you normally sell loaders, processors or harvesters with their attachments? *E.g. grapple, processor, feller-director*

Several machinery dealers will also be surveyed to determine if their views on the depreciation of forestry machinery are aligned with contractors, or whether there are other factors that can affect the depreciation of machines, that may be unfamiliar to contractors. Dealers will be asked the following questions:

- What external factors affect the depreciation of machines? E.g. supply and demand, global machine market, inflation rates
- Are there any major differences in the depreciation of different forestry machines? E.g. A forwarder vs. a tracked loader
- Does the civil engineering machine market have an impact on the forestry machine market? If so, to what extent?
- Is there a noticeable change in the market for machines, due to changes in log prices?
- How would you describe machine depreciation? E.g. higher for the first 5000 hours then slows, worth 25% of the purchase price at 10,000 hours etc.

Contractors and dealers were chosen from different regions throughout the country, but responses were based on willingness to participate and the quality of the information provided.

4. Results

In total, 497 data samples were collected from various sources, comprising sales data of tracked and wheeled loaders, tracked and wheeled skidders and forwarders. Figure 3 below shows the number of used machine samples from the NZ market that were retrieved for data analysis.

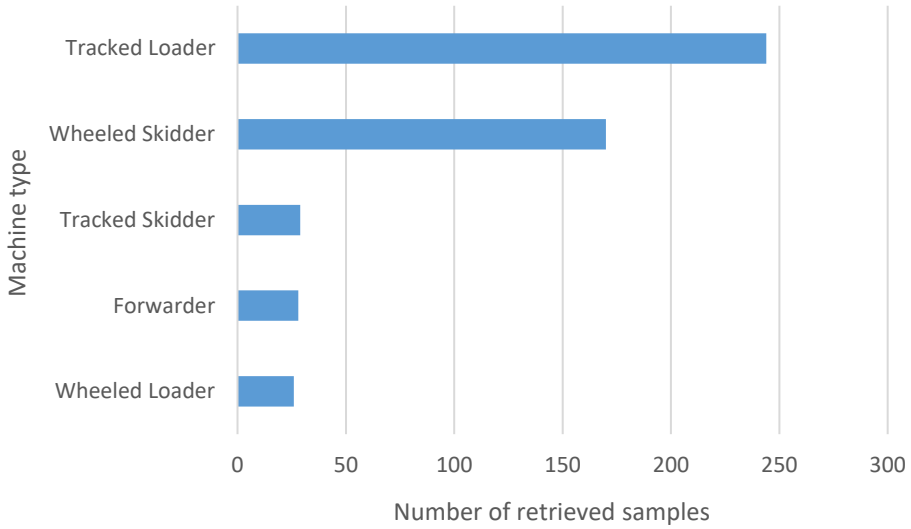

Figure 3: Number of retrieved NZ used forestry machine samples in the study

Tracked skidders and bulldozers were combined under the collective heading of tracked skidders. This is due to the ambiguity between these two machine types when advertised, and the similarity between their machine designs. As used price data was collected, it became clear that both of these machine types were much less common than other machine types, such as tracked loaders and wheeled skidders. This reinforced the decision to combine the two categories.

4.1 Used Machine Value

Figure 4 gives a summary of the used machine value of the different machine types in the study. Note that the used machine price of tracked loaders is heavily influenced by the fitted attachment. There is considerably more variation in used price for tracked loaders and wheeled skidders than the other machine types. Tracked loaders show higher variability due to the large variation in size between machines, the variation in attachments on these machines, and the number of retrieved samples in the study. Wheeled skidders show high variation due to the high price of these purpose-built machines when new, and the high rate of depreciation which sees them worth considerably less as their machine hours increase. The small sample size of the other machine types may contribute to the lack of variation in used machine price, and this could be investigated by increasing the sample size.

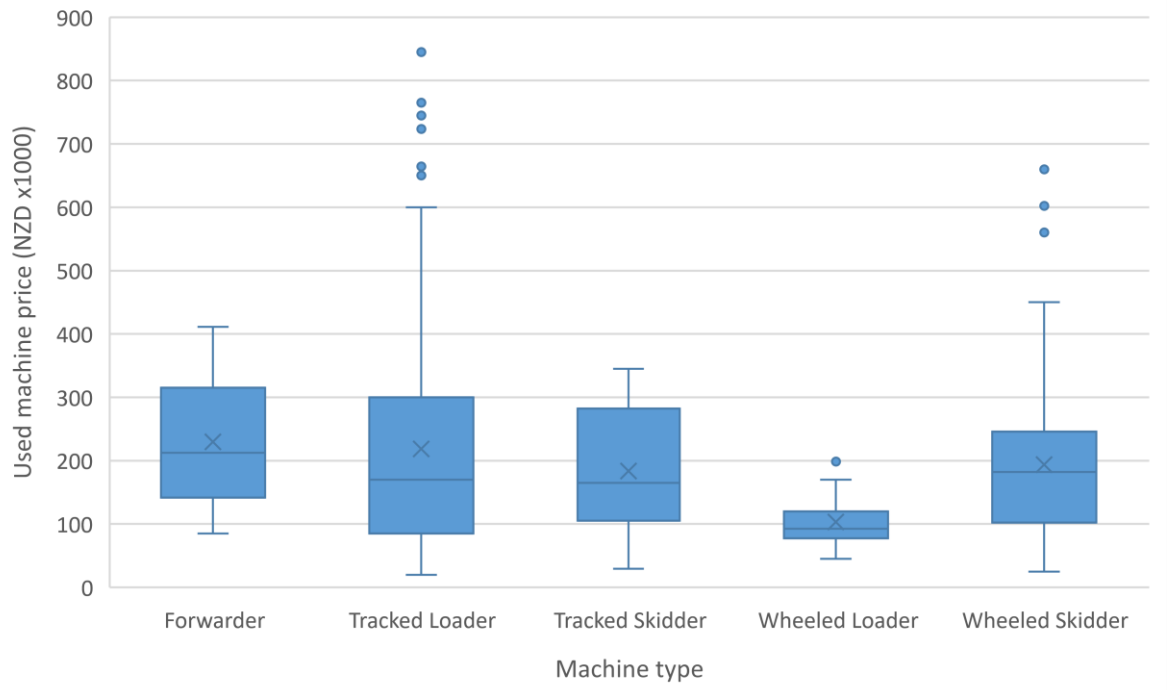

Figure 4: Summary of the used machine price of the retrieved sample data

Figure 5 gives a summary of the machine hours of each of the retrieved samples. The high variation in machine hours for tracked loaders is due to the variability of roles these machines may have within a harvesting operation, with older machines still capable of being productive when used within low-production harvesting operations, so these are sometimes kept to very high machine hours.

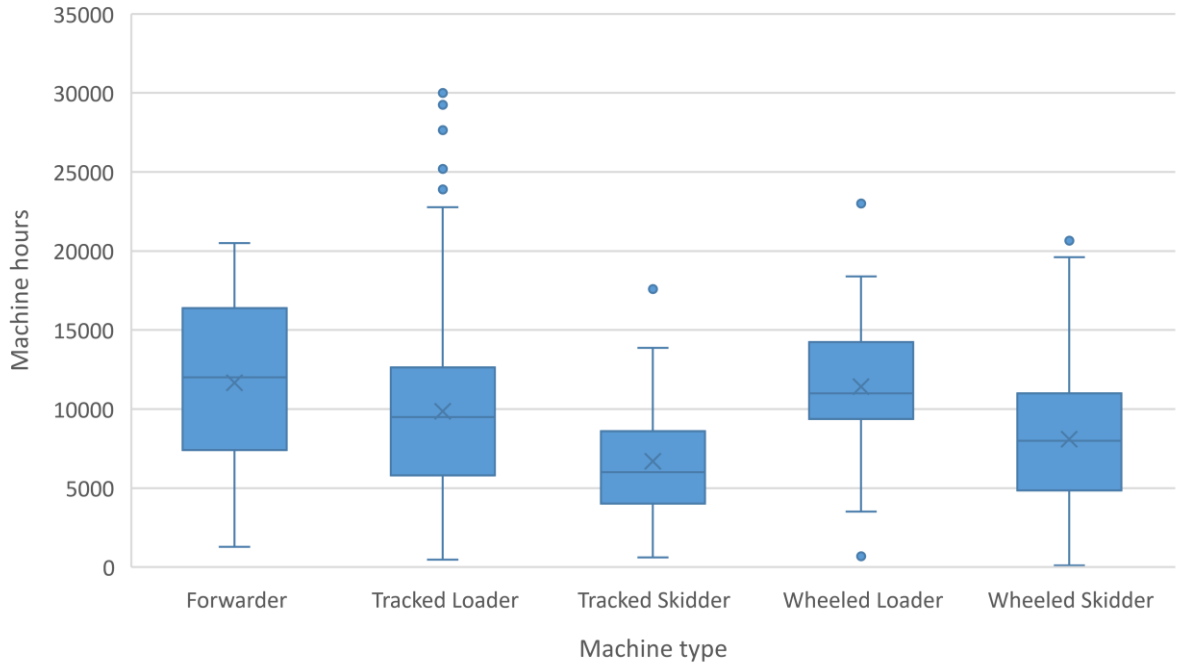

Figure 5: Summary of the machine hours for the retrieved sample data

Regression analysis was completed to determine whether there was a relationship between used price and machine hours for the five different machine types of interest, tracked and wheeled loaders, tracked and wheeled skidders and forwarders. The long-term trend for the used price of the five different machine types are shown below. Figures 6, 7 and 8 show the trends for, wheeled and tracked loaders, and wheeled and tracked skidders, and forwarders respectively.

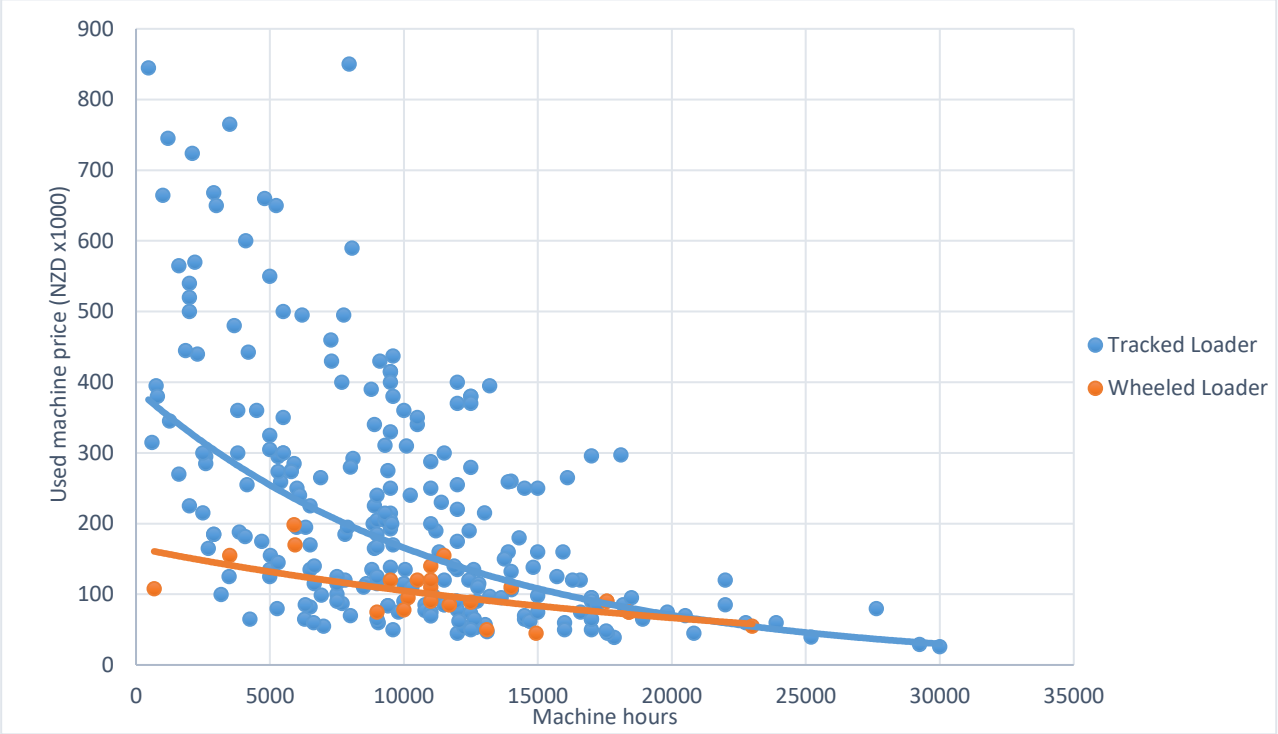

Figure 6: Used price of tracked and wheeled loaders in the NZ machine market

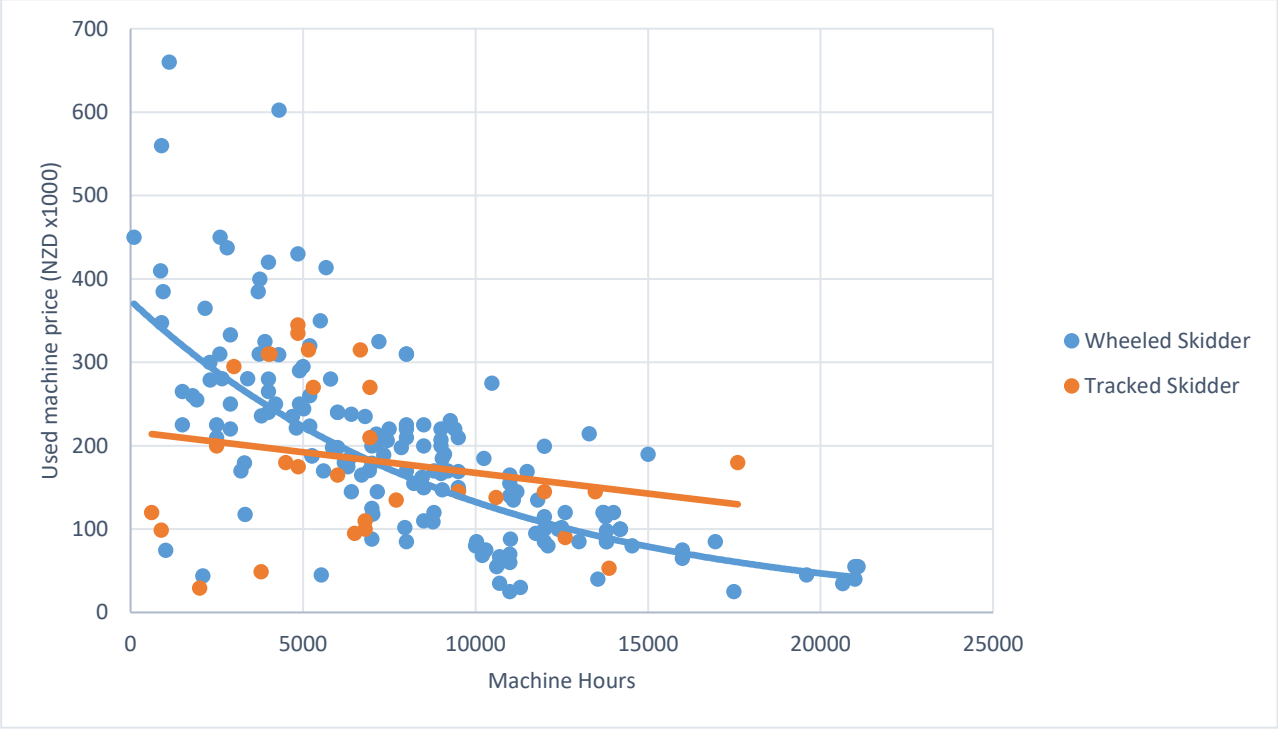

Figure 7: Used price of wheeled and tracked skidders in the NZ machine market

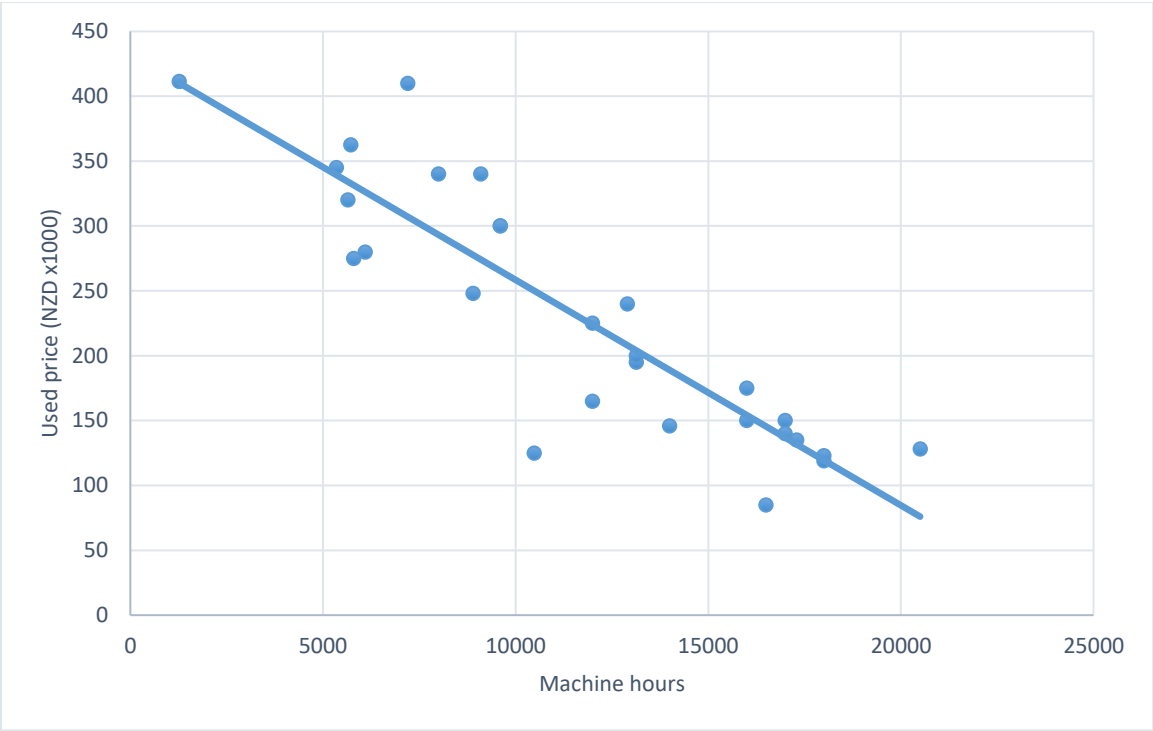

Figure 8: Used price of forwarders in the NZ machine market

The trends shown in Figures 6, 7 and 8 offer varying levels of statistical reliability with different coefficient of determination (R^2) values. The linear relationship for forwarder used price data has the strongest correlation between used machine price and machine hours with an R^2 value of 0.78. This means that 78% of the variability in used machine price can be explained by variability in machine hours. Wheeled skidders, tracked loaders and wheeled loaders show moderate negative exponential relationships between used machine and price and machine hours, with R^2 values of 0.51, 0.36 and 0.34 respectively. Tracked skidders show no significant relationship between used machine price and machine hours. The equations for wheeled skidder and tracked loaders (the two machine types that were considerably more prevalent in the sample data) are:

- Wheeled Skidders: $Used\ Price$ ($000) =375 e^(−0.0001 x $Machine\ hours$)
- Tracked Loaders: $Used\ Price$ ($000) =390 e^(−0.00009 x $Machine\ hours$)

While these equations should not be used to predict any specific used machine value with confidence, they can be used to understand value loss dependant on machine hours. For example, for the Wheeled Skidder, the average value loss over the first 5000 hours is $147,000, but only $33,000 between 15,000 and 20,000 hours. For the Tracked Loader, we can calculate that it will halve its purchase value at 7,700 hours, have a used value of 25% of its purchase price at 15,500 hours, but still retain 10% of the original value at 25,000 hours.

It can be deduced that this relationship may be present with the other machine types, should they have enough sample data points to generate a strong statistical relationship.

Figure 9 shows the used price value of different sized wheeled skidders and tracked loaders from the NZ used machine market.

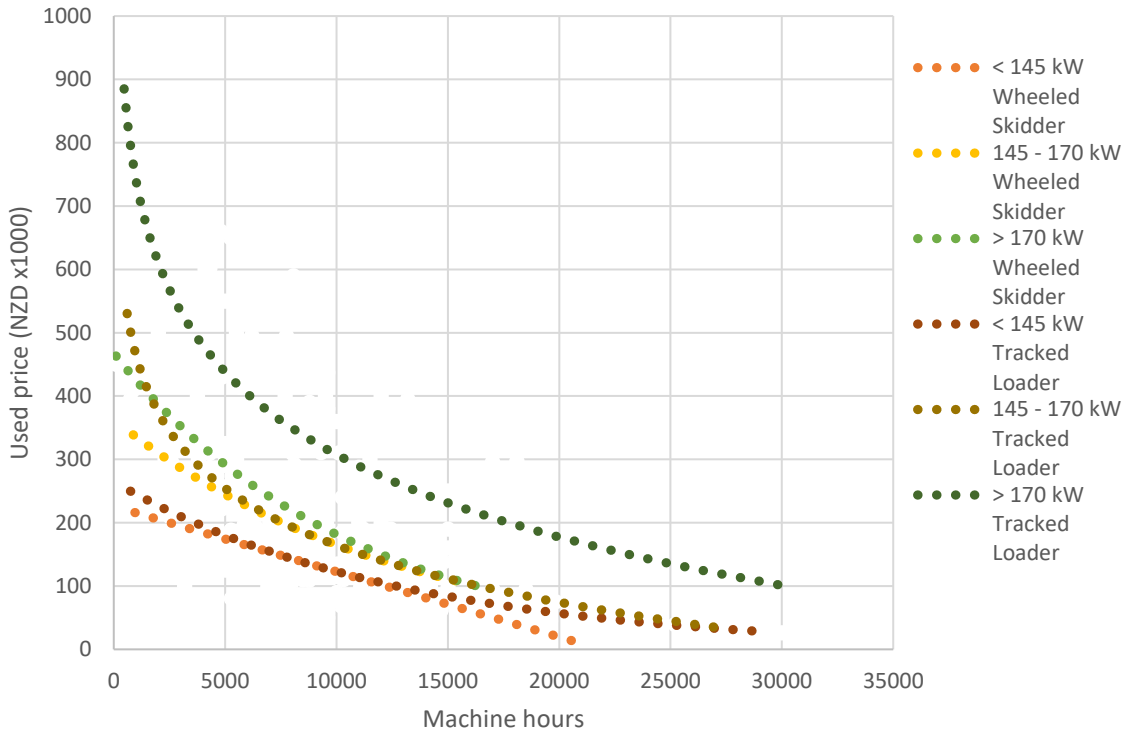

Figure 9: Used price value of wheeled skidders and tracked loaders based on machine size

The smallest wheeled skidders (<145 kW) show the most gradual trend, with the lowest incremental depreciation as machine hours increase. The relationship between used machine price and machine hours is deemed to be linear for these skidders. Conversely, for medium and large skidders, the line of best fit showed an exponentially decreasing relationship between used machine price and machine hours. All skidders show moderate coefficient of determination values, with the R^2 calculated to be 0.48, 0.57 and 0.58 for the small, medium and large skidders respectively.

Tracked loaders show similar trends to wheeled skidders, with high depreciation for the first 5,000 hours for both large and medium-sized tracked loaders and a rate of depreciation that slowly decreases as machine hours increase. Small tracked loaders show a gradually decreasing logarithmic relationship between used price and machine hours. The R^2 values for tracked loaders are 0.39, 0.63 and 0.55 for small, medium and large tracked loaders respectively.

4.2 Hourly Machine Depreciation

The average hourly depreciation for all the individual machine data each machine type is shown in Figure 10. Due to the large variation in machine sizes, conditions and original purchase prices, the averages shown may not offer a suitable estimate for machines with very high purchase prices, very low or very high machine hours, or excessive wear and tear. However, these averages give an estimate for most machines that are for sale on the used machine market in New Zealand. Tracked skidders are not shown due to the small sample size, the ambiguity between use as a skidder and use as a bulldozer, and vast size differences within the sample data giving unreliable and unrealistic results.

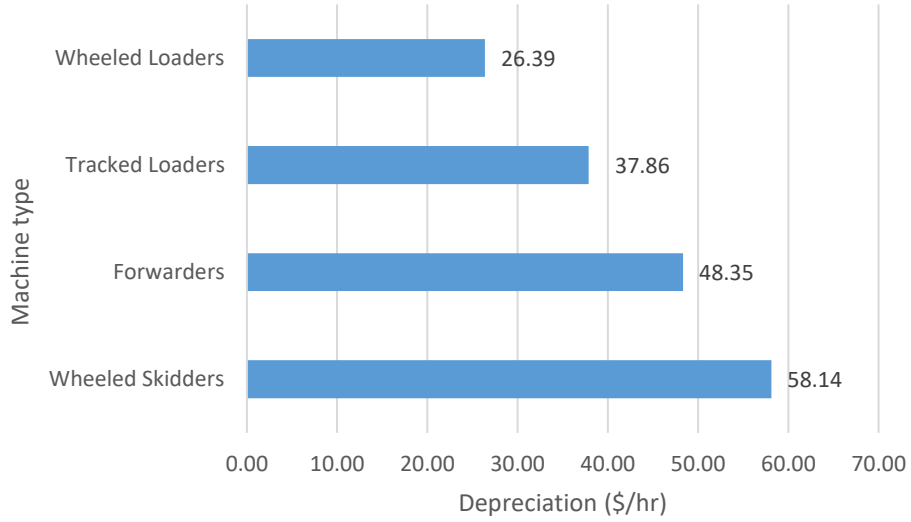

Figure 10: Average hourly depreciation by machine type

To further investigate the hourly machine depreciation, the two most common machine types in the NZ used machine market - tracked loaders and wheeled skidders - are separated into small and large categories to increase understanding of how machine size may affect depreciation. Small machines (both tracked loaders and wheeled skidders) were categorised as those with an engine output of fewer than 150 kilowatts, whilst large machines were defined as those with an engine output of 150 kilowatts or greater. The results of this analysis are shown in Figure 11.

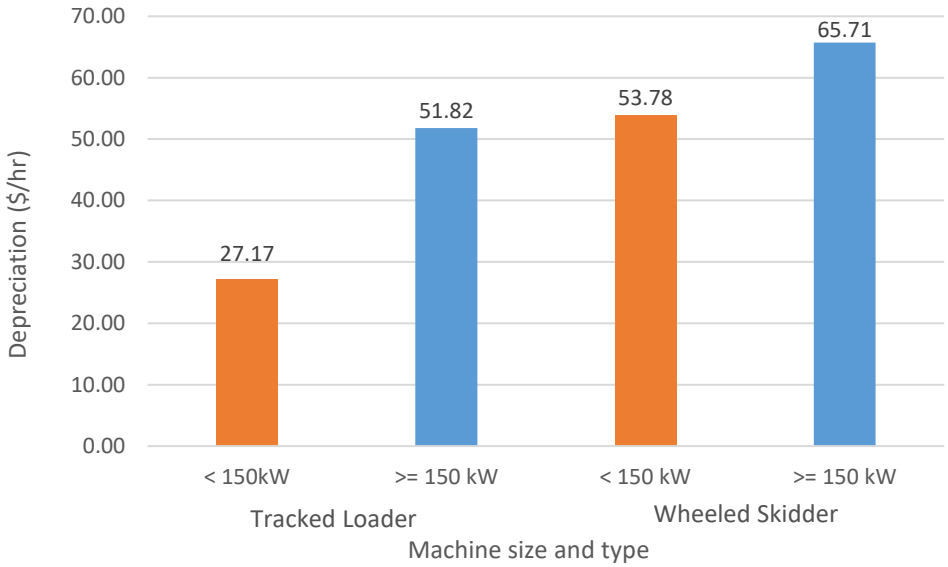

Figure 11: Hourly depreciation by machine size and type

As can be seen from Figure 11, there is a considerable difference in the hourly depreciation of small and large tracked loaders, with larger loaders depreciating at nearly twice the rate of smaller loaders. For wheeled skidders, the difference is much less pronounced, but larger wheeled skidders are seen to depreciate at a faster rate than smaller skidders.

4.3 Attachment Effects on Depreciation

Figure 12 shows the effect to which loader attachment affects the used price of tracked loaders. The averages have been calculated using a sample of used machine sales data points for each attachment. To ensure a level of consistency, all machines used in the sample had between 8000 and 12000 machine hours, and an engine output of between 125 and 150 kW. As can be seen from Figure 12, there is a sharp increase in the used price of motorised attachments, such as feller directors and processors/harvesters from simple attachments such as buckets and grapples. Machines fitted with buckets have an average used price of $89,000, while the average price for machines with grapples was calculated to be $122,600. Tracked loaders fitted with feller directors have an average used price of $220,000, while the average price for machines fitted with a processor or harvester was found to be $244,100.

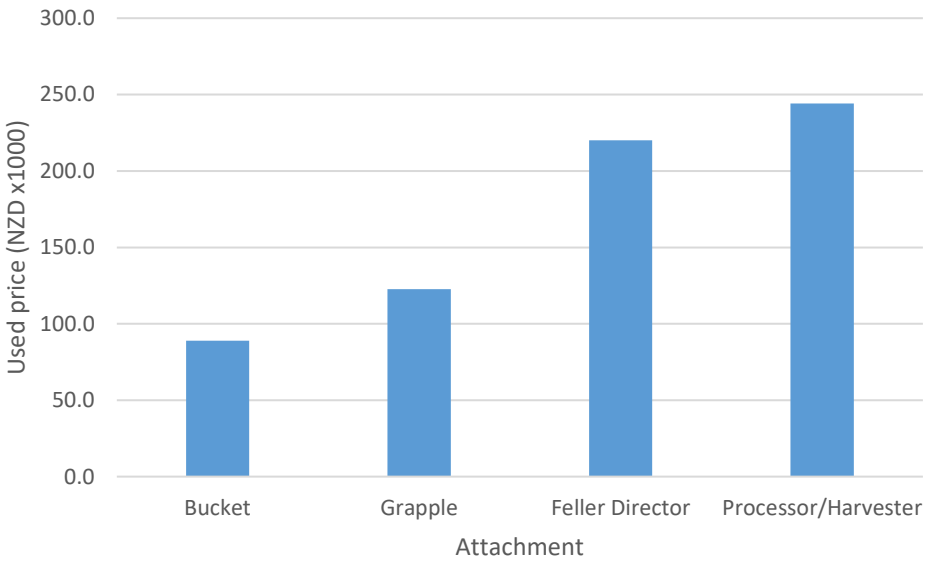

Figure 12: Extent to which loader attachment affects the used value

4.4 American Used Machine Market Comparison

To understand whether the trends seen in the New Zealand machine marketplace are unique to the country, comparison can be made to a similar study from the United States of America. The study to be used as a comparison is Used Forestry Machine Prices in the United States carried out at Virginia Tech under the supervision of Prof. Chad Bolding (Garren, Quistoff and Thompson 2018).

The United States has a comparable forest industry, particularly in the South-Eastern United States, which allows for an evaluation to be made between the two countries. The equipment used in both countries is very analogous, with the US producing and using many of the common forestry machines found in the NZ forestry sector. Also, in temperate areas of the United States, many species of the *Pinus* genus are grown for production forestry, which requires similar harvesting techniques to the clearfell harvesting of *Pinus radiata* in New Zealand.

The first comparison to be made is the difference in the number and type of machines retrieved for the survey. As with any statistical analysis, the quality of the results is heavily dependent on the number of data points within the analysis. There are several machine types within the American analysis not considered in the NZ study, primarily due to their frequency in the market and differences in logging practices between the two countries. For example, delimbers and trailer log loaders are uncommon in the

NZ machine market but are prevalent in the retrieved data within the US used machine market. The number of machines retrieved from each domestic market is shown in Table 3. In tracked loader, wheeled skidder and forwarder categories, the results from each study can be readily compared due to the similar number of samples. However, for the wheeled loader and tracked skidder categories, the differences in the number of samples make an accurate comparison more difficult.

Table 3: Numbers of retrieved samples from NZ and US used machine marketplaces

Machine Type	Number of New Zealand Used Machine Samples	Number of United States Used Machine Samples
Tracked Loader	244	230
Wheeled Loader	26	130
Wheeled Skidder	170	209
Tracked Skidder	29	9
Forwarder	28	30

Figure 13 shows the overall effect of machine hours have on used machine price in the US by region. There is a very similar relationship between used machine price and machine hours for the two countries. However, in general, the equipment is much more expensive in New Zealand than in the United States. There are many potential reasons for the increased price of forestry machinery in New Zealand. The most notable reason is the much bigger marketplace, and a higher number of suppliers in the US, which increases competition between manufacturers and dealers. The geographic isolation of NZ adds to the cost of importing forestry machines into the used machine market, which increases the price paid by consumers.

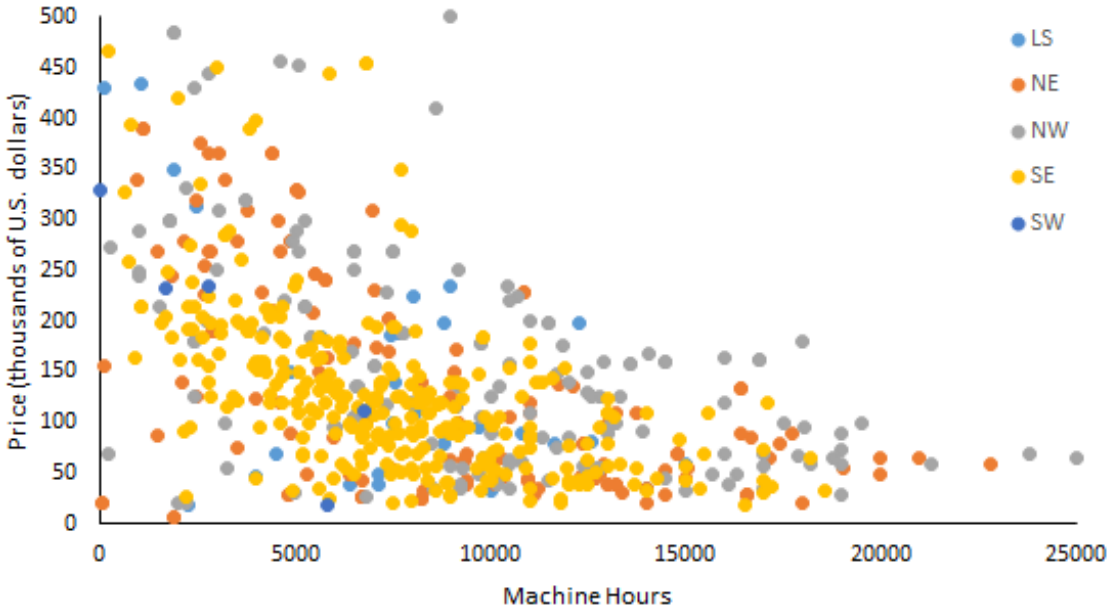

Figure 13: American used machine price by region

Figure 14 shows the average price for used machines in the US used machine market. The NZ data has again been converted to US dollars using the exchange rate at the time of publication of the American study. As can be seen from the graph, the average price for wheeled skidders is just over $100,000. In contrast, the average price for a wheeled skidder in New Zealand is approximately $280,000. The average

used price of wheeled loaders is slightly higher in the NZ marketplace than the US. However, as mentioned above, the sample size of wheeled loaders in NZ is comparably very small, which may affect the results. Forwarders are almost twice as expensive in NZ as they are in the US, on average. Tracked skidders are seen to be considerably more expensive in NZ than in the US, although this result may be impacted by the low sample size of these machines in the NZ market. Tracked loaders are difficult to compare directly, due to differences in the classification between the two studies, with the American study separating harvesters, processors, feller-bunchers and loaders, while the NZ data is in a single tracked loader category.

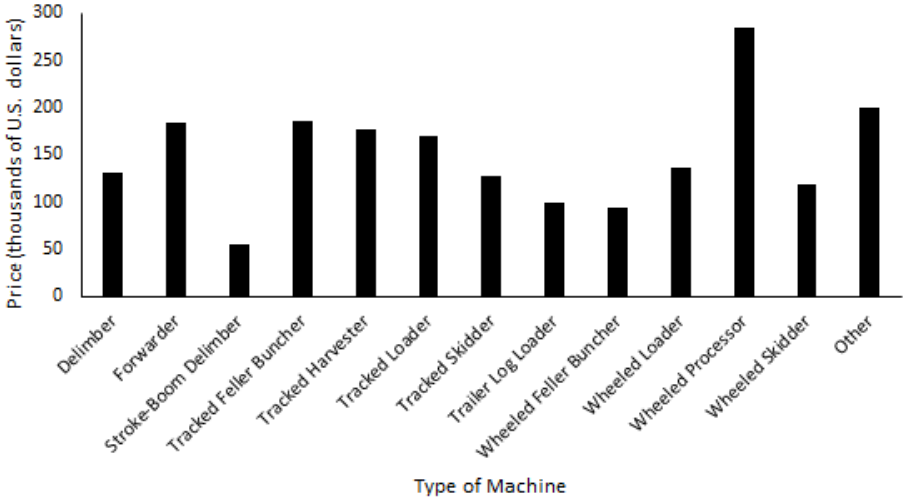

Figure 14: Average used price of American forestry machines, organised by machine type

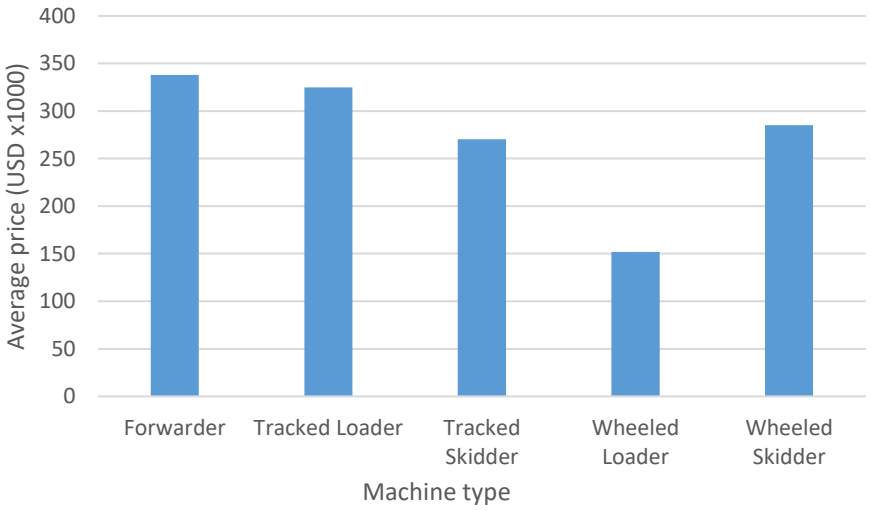

Figure 15: Average used machine price for NZ machines

4.5 Forestry Contractor Surveys

Forestry contractors were surveyed to determine consumer opinions of the used forestry machine market. From the eight contractors surveyed, the following information was gathered. The surveys for each of the participating contractors in the study are attached in Appendix 1.

Firstly, contractors were asked what operational factors they believed had the largest influence on the depreciation of their machines.

Figure 17: Main factors contractors regard as influential on machine depreciation

Figure 17 above shows the frequency of operational factors that contractors regarded as being the main causes of the depreciation of forestry machines. According to contractor feedback, repairs and maintenance (R & M) are closely related to operator skill, with the most skilled machine operators also being those that are the most consistent with machine maintenance. Regarding machine R & M, another issue that was raised was a lack of R & M not necessarily being the fault of operators, but the isolation of crews making it costly to receive adequate mechanical support. It was also suggested that many newer machine operators aren't as "mechanically-minded" as the older generation, and were less able to complete basic R & M themselves.

When asked about the number of machine hours to which contractors would keep their machines, there was some level of variation. This variation and the reasons behind their decision-making are shown in Table 4 below.

Table 4: Summary of explanations as to why machines are replaced after a particular number of machine hours

Contractor	Number of hours before machine is sold (hrs)	Reasons behind the decision
A	10,000	Most engines are designed for a 10,000 hour lifetime. After this point, an increase in breakdowns can be expected. Breakdowns have a big impact on company profits, so our machines are sold at this point.
B	10,000+	We'll normally keep our machines well over 10,000 hours. Due to the size of our operation, we're able to shift machines around. We can expect more frequent breakdowns in older machines, but as machines get higher hours, we'll move them to lower production crews where breakdowns are more tolerable. Also very dependent on the machine type. Machines that are bottlenecks of an operation are replaced more regularly than others.
C	10,000+	We don't really get rid of machines. Due to the variability of our operation, we're able to shift older machines to jobs with less demand for productivity to allow for an increase in the frequency of breakdowns.

D	12,000	Usually, all of our front line machines will be kept until about 12,000 hours. After we hit the 10,000 hour mark, we can expect that the machines will be slightly less reliable, but as long as R & M is up to date, these machines can still be productive.
E	10,000	We normally replace at 10,000 machine hours to avoid an increase in the frequency of breakdowns.
F	10,000	-
G	9,000-14,000	We normally try to replace our main machines between 9,000-10,000 hours to keep our fleet productive. However, some of our machines have been heavily invested in for specialist roles, so we'll try and keep these machines until about 14,000 hours where possible to get the most from our investment.
H	10,000	-

Contractors were asked whether they had a preferred time of year to replace forestry machines. With the exception of one contractor whose preferred time of year for machine replacement was 'between spring and summer', all contractors surveyed stated that time of year didn't factor into decision-making about machine replacement. One contractor did mention that rather than the time of year, a consideration made for decision-making on machine replacement was the condition of the "log market." When log prices were low, this contractor noted that machines tended to be cheaper, so this proved to be a good time to buy, should machine replacement be necessary. Another factor regarding machine replacement, mentioned by several contractors, are the long wait times that can be expected for many forestry machines and attachments. Wait times for new equipment were expected to be up to 12 months.

Contractors were also surveyed on the methods used for selling their machines. The results are shown in Table 5.

Table 5: Contractor used forestry machine advertising methods

Contractor	Method of advertising	Reasons behind the decision
A	Trade In / TradeMe	Will sometimes trade machines into a dealership when purchasing a new machine. Always get a lower price at a dealership but a simple process. Sometimes sell privately, but it takes time and sometimes risks machines being parked up, which impacts profitability.
B	Trade In / TradeMe / Word of Mouth	Have traded gear in, and sold gear on TradeMe, but due to long-standing relationships with contractors and a reputation for decent gear, most machines are sold by word of mouth.
C	TradeMe, if necessary.	Don't really sell machines, but we have sold gear on TradeMe before, so that would probably be what we'd choose.
D	Trade In	Although we lose some value due to the dealers cut, this takes all the hassle out of the process and means it is sorted immediately.
E	Trade In	-
F	Trade In	-
G	Turners / Trade In / Private Sale	Sell through Turners or trade in normally. Have sold by private sale, but takes a bit of organising, and also risks gear being parked up.
H	Word of Mouth	Have a few long-standing relationships with other contractors. Normally just enquire if people are interested and more often than not someone is keen to buy.

Contractors were then asked if they sold tracked loaders with or without attachment heads. The results of this question are shown in Table 6.

Table 6: Contractor decisions and reasoning on selling tracked loaders with attachments

Contractor	Do you sell with or without an attachment?	Reasons behind the decision
A	Yes	Buyers don't want to be paying for both a base machine and a head. Makes selling easier. The attachments are set up for the machines so would be a lot of work to remove anyway. Also, base machines and heads often have similar hours, so makes sense to keep them together, as old heads have increased problems, just like old machines.
B	Usually.	Harvesters and processors usually sold with the base machine. Sometimes digging bucket fitted to the machine to be used as an earthmoving machine. Decision made on a case by case basis.
C	Yes	-
D	Yes	-
E	Yes	-
F	Yes	-
G	Yes	Since we have a lot of gear, we'll normally sell a machine with an attachment we're looking to get rid of. Our fleet is set up so that most of the attachments are interchangeable.
H	Yes	Always get better value recovery when machines are sold with attachments.

4.6 Machine Dealer Surveys

Forestry machine dealers were surveyed to determine supplier opinions of the used forestry machine market. From the three dealers surveyed, the following information was gathered. When asked about the external factors influencing machine depreciation, supply and demand of machines were deemed to be the biggest influence on the used price of forestry machines. Supply and demand was heavily influenced by different 'tiers' of contractors, according to one machine dealer. The first tier of contractors would only buy new machines, so by introducing new machines into the market, older machines would slowly become cheaper. Second tier contractors buy used machines so the value of their machines would be heavily impacted by tier one contractors. Exchange rates were deemed to be the largest influencer of machine depreciation by one dealer. It was stated that the relationship between the NZ dollar and the US dollar was the primary exchange rate of concern, due to most heavy forestry machinery being traded in US dollars, regardless of the country of origin. In practical terms, this dealer stated that for every cent the NZ dollar decreases with respect to the US dollar, the price of a used machine can be expected to increase by ten thousand dollars.

It was also noted by two dealers that there are major differences in the depreciation of different used forestry machine types. The explanation for this is that purpose-built forestry machines such as wheeled skidders have no secondary purpose, whereas a tracked loader may be used as an earthmoving machine if a bucket is attached. For this reason, purpose-built forestry machines depreciate faster than those with a secondary purpose. One dealer stated that within their operation, all forestry machines were treated similarly, and all depreciated at a similar rate.

All machine dealers conclusively agreed that the market for civil engineering machines has little to no effect on the market for used forestry machinery, due to major differences in the design of the equipment for the different industries.

There is definitely an impact on the used price of forest machinery due to changes in log prices, according to each of the dealers surveyed. According to one dealer, used machine prices can be expected to dive dramatically if there is a considerable drop in used log prices, while another dealer stated that the biggest impact of a change in log prices is the effect it has on contractor confidence, which influences decisions into purchasing machinery.

Table 7 shows the description of machine deprecation trends, given by dealers in the survey.

Table 7: Dealer descriptions of depreciation trends

Contractor	Description of Depreciation Trends
A	Forestry machines depreciate very quickly in the first 2000 hours. After this period, depreciation begins to slow. Between 4000-7000 hours, there is very little machine depreciation. Warranties have a big effect on depreciation. If a machine is still under warranty, depreciation will be a lot less than if it is not under warranty.
B	Brand perception does play a part in the depreciation trends of most machines. However, in our experience, if the equipment is well maintained, used price values should remain relevant to their initial purchase price, in comparison to their competitors.
C	• In Year 1, we expect depreciation in value of 20% • In Year 2, we expect depreciation of 15% • In Year 3, also depreciation of 15% • Then depreciation is approximately 10% annually, for the rest of the machines lifetime

5. Discussion

When comparing the relationship between used price and machine hours for both tracked loaders and wheeled skidders was found to be exponentially decreasing, meaning the rate of depreciation is higher in the first few thousand machine hours of use and slowly decreases as the machine ages. Due to the high number of sample data points in these two categories, relative to the other machine type categories, this relationship is most likely to represent the true correlation between used machine price and machine hours for forestry machines. This relationship is reinforced by machine dealer survey data, with one dealer stating that “machines depreciate very quickly in the first 2000 hours. Between 4000-7000 hours, the rate of depreciation flattens out a lot.” This relationship is also reinforced by relevant literature, with (Blackburne, 2009) asserting that machine depreciation is highest immediately after purchase, and gradually slows over time.

In the analysis, machines were split into different size categories, based on the engine output of the machine. This was believed to be a more accurate measure for categorising machine size than weight, as true operational machine weight may be different between machines due to modifications and changes in the purpose of the machine throughout its lifetime. Also, the capabilities of a machine within a harvesting operation are heavily dependent on engine power, making this a suitable measure for categorisation of machine size. For some analyses, a small machine was defined as one with an engine output of fewer than 145 kilowatts, while for some analyses, a small machine was said to be a machine with less than 150 kilowatts of engine power. The difference between these two boundaries is insignificant for the results of the analysis and was done primarily to ensure a similar number of machines in each category to limit sample size bias.

As part of the analysis to determine the effect of loader attachment on used machine price, similar machines were chosen to limit the effect base machine had on the used price. For this analysis, similar machines were regarded as those with machine hours between 8,000-12,000 hours and an engine output between 125-150 kilowatts. Ideally, this analysis would be conducted with identical base machines to completely remove the influence of the base machine. However, due to the practical limits of the sample data, the categorisation mentioned above was deemed to be the best method to ensure there were enough data points to generate a representative average.

One limiting factor encountered early in the research stage was the ambiguity between bulldozers and tracked skidders when advertised. Although having slightly different design characteristics due to the different requirements for pushing and pulling, these machine types are very similar, and as such, were grouped together as tracked skidders for the statistical analysis. For the purposes of grouping machines in categories for analysis, power and weight data is required for each machine.

Another limitation is the amount of data available, and the quality of the data gathered. The amount of data within the study is directly related to the number of machines within the NZ used machine market, and is limited by the size of the market. The amount of retrieved data was also limited by the quality of the classifieds available. Although there were many more machines listed for sale in various sources, many did not include the information necessary for analysis to be conducted, so were excluded from the study. In addition to this, the used sale price used for the analysis was simply the price listed for each machine in their respective advertisements, so there is no guarantee this is the price the machine was sold for, with the potential for negotiations to change the final sale value. For the purposes of this study, however, these assumptions were necessary to produce the results above in a reasonable timeframe.

6. Conclusion

In order to determine the extent to which machinery depreciates in the New Zealand forest industry, an analysis was conducted on historical used price data, and industry professionals were consulted to better understand the drivers of this depreciation. Literature conclusively stated that there is an inverse relationship between used price and machine hours and discussed several methods for calculating depreciation, including assuming a constant annual depreciation, using a diminishing value method where depreciation decreases over time and factoring inflation into the calculation to offset some of the depreciation.

However, there was very little literature available specific to forest machinery, so these methods required further investigation. Statistical analysis concluded that there is an inverse relationship between machine hours and used machine price; depreciation is higher with larger machines, wheeled skidders had the highest rate of depreciation of any machine, and on average, tracked loaders with motorised attachments sold for approximately twice the price of tracked loaders with basic attachments such as buckets and grapples. The survey suggested that machine operators were regarded as the largest influence on machine depreciation by contractors, and supply and demand trends had the biggest influence on used machine price, according to machine dealers.

Limitations of the study included the availability and quality of used machine data in the NZ market and access to industry professionals. Although predicting the exact rate of depreciation for a given forest machine is unlikely, evaluations can be improved through an understanding of the variables involved in such an estimation, an important consideration for any party involved in modern forest harvesting.

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