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Montana Logging Costs: Resources for Continued Industry Viability

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MONTANA LOGGING COSTS: RESOURCES FOR CONTINUED INDUSTRY VIABILITY

By

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Abstract

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Montana's logging industry has changed significantly over the past two decades. Increased operating costs and subsequent diminishing returns, combined with a shifting paradigm in regards to active forest management have had significant impacts on the economic and demographic make-up of the industry. One way to address these changes and mitigate the associated challenges of continued viability is through analysis of the factors and constraints impacting routine operational costs. Two methods were employed to estimate regional logging costs and changes over time. First, to provide a resource for comparison between commonly-utilized logging equipment, the hourly owning and operating costs of select mechanical, ground-based machines were calculated using the machine rate method from data supplied by western Montana equipment dealers. Second, an expert opinion survey of Montana and Idaho loggers was conducted, asking respondents to provide a simulated bid for a harvest unit typical of this region. The results from each method were compared to historic cost data, and reasons for increased logging expense were studied and discussed for fixed and variable cost categories, as were the impacts of changing operating conditions on costs. Results from the machine rate analysis suggest that inflation-adjusted operating costs for ground-based equipment are 47-93% higher than 20 years ago. Expert opinion survey results suggest that though costs are increasing, loggers are bidding at levels lower than actual costs merely to stay in business. Research on the reasons for these increases showed that costs have increased across certain fixed and variable categories, namely in equipment purchase price, fuel, labor wages and benefits, and repair/maintenance expense. Further, the number of operational days per year has decreased, administrative costs have increased, and there is increasing concern over volatile market conditions and the uncertainty over guaranteed future work. Clearly, this situation should be of considerable concern to those interested in retaining this sector in Montana. Vigilant consideration of operating costs and productivity will become increasingly critical to maintaining current infrastructure and helping to ensure the future of active forest management in Montana.

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Introduction

Forestry has long been one of Montana's foremost industries and the state has played a significant role in the Northwest's important forest industry for well over a century. In 2012, Montana's forest products industry harvested 351 million board feet (MMBF) (Scribner scale), employed 6,650 workers, and produced an estimated 584 MMBF (lumber tally) of lumber with the majority of that activity occurring in the western part of the state (Figure 1) (Morgan et al. 2013).

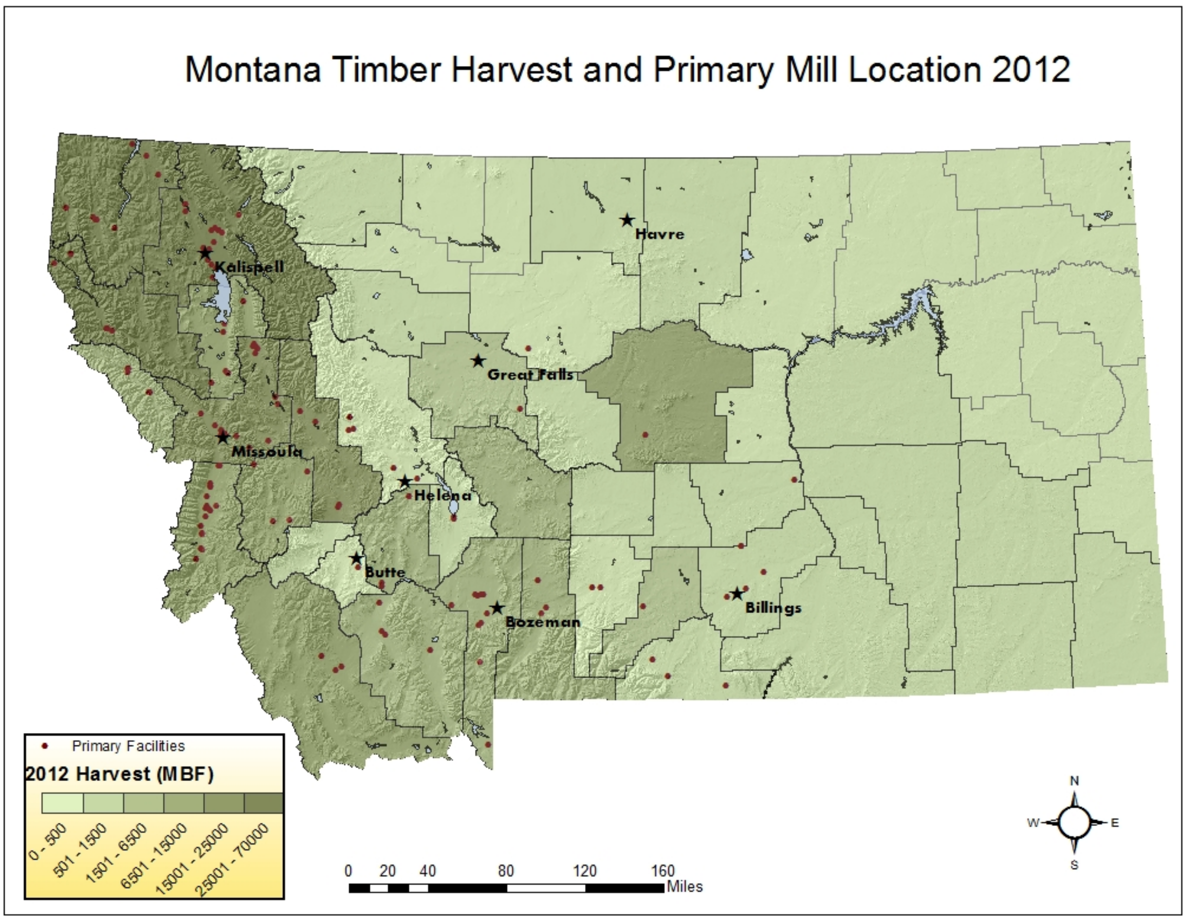

Figure 1- Montana timber harvest by county and primary mill location (source: Morgan et al. 2013)

The industry as a whole has changed significantly from its early days, and is much different now than it was even twenty years ago. Harvest volumes have decreased by 64% since 1993 and consequently, so too have employment numbers (44% decrease) and sales revenue from finished product (71% decrease) (Morgan et al. 2013). Despite this decline, the average wage in the forest products industry is 16% higher than the average across all sectors in Montana (DNRC 2013).

In addition to these economic changes, forestry in Montana is undergoing a significant paradigm shift. The emphasis on purely production-oriented forestry exists in a smaller capacity in 2013 than it did when log prices and annual harvest volumes were higher 20 years ago. As a result of changing ecological objectives and the challenges related to global climate change, more logging contractors are relying on restoration, salvage, and stewardship harvest projects with different ecological objectives. This brings a new set of challenges and the need for innovation and diversity within the industry. The demographic and economic changes occurring in the state, along with evolving ecological goals have significantly altered Montana's forest industry. To remain relevant, the industry must continually monitor itself and adapt to these constantly changing conditions.

While the forest industry across the United States has experienced similar trends, Montana's milling and logging industry faces a unique set of internal challenges. First, the state is far from major ports and markets, thus increasing the transportation distance of finished product and decreasing export opportunities. Second, Montana consists of rugged terrain and inclement weather, both of which contribute to increased operational logging costs in regards to fuel and repair/maintenance. Terrain and climate can also limit the number of productive, operational days which can impact a contractor's break-even point and consequent profit. Third, over 60% of Montana's forestland is Federally-managed, increasing bureaucratic gridlock and lowering the availability and consistency of work. Finally, Montana is considerably drier than other timber producing regions of the U.S., which contributes to slower tree growth and lower productivity forest types (DNRC 2013). Further, Montana has notoriously had a small, but active environmental community that is inclined towards litigation (Keele et al. 2006). These factors coupled with the economic recession of 2008 have created a challenging business environment for Montana's forest industry.

Montana's logging sector has experienced trends similar to the industry at large. In 2012, 575 people were employed in some aspect of logging in Montana, a decline of 96% from 10 years prior (BLS 2013). While employment has decreased, research suggests that the costs of operating a logging business have increased (Baker et al. 2013). Studies over the past 20 years have illustrated the impacts of increased logging costs, above inflation rates, across all component cost categories including the fixed and operational costs of running logging equipment as well as administrative, labor and benefits, and other associated costs (Cubbage et al. 1988, Hayes et al. 2011). Initial investment levels for new logging equipment have increased, as have fuel, oil, and maintenance costs. Increased concern over the environmental impact of equipment emissions have led to significant advances in engine technology, but have contributed to rising costs. This modern equipment is more powerful and efficient allowing for increased production, decreased fuel usage and emissions, and decreased need for human labor. However, the advances and benefits allowed by improved technology have been somewhat stifled by the economic situation that Montana's timber industry faces. Whether or not the improved efficiencies of modern machinery will offset the increased costs of purchasing new equipment is a concern of considerable measure for contemporary logging professionals (Carino et al. 1995).

The ability to find and purchase new equipment is easier now than ever before as a result of the internet. While purchasing used equipment might reduce the initial capital investment, maintenance costs, downtime, and subsequent diminished productivity might negate the intended savings. Yet investing in new equipment requires a significant capital investment, one that is questionably worthwhile without a reasonable guarantee of reliable and steady work. The variable nature of the industry, along with declining profits, makes this decision one with serious implications. However, with the typical age of equipment hovering between 11 to 15 years, Montana's logging business owners will be forced to upgrade this aging infrastructure at some point in the near future. There are a variety of factors pertinent to equipment replacement such as current and forecasted payments, maintenance costs, and fuel costs which must be balanced with the potential productivity gains of buying new versus retaining old equipment (Butler and Dykstra 1981). The consideration of operational needs and current equipment infrastructure will become increasingly important to business owners when considering investing in new equipment.

While total operating costs have largely increased over the past 20 years, delivered prices for logs have experienced wild volatility and have generally decreased since mid-1990s levels (Figure 2), thus continuing to decrease the already small profit margins for the logging contractor (Cubbage et al. 1988, BBER 2013). Logging costs not only affect a logging business, but also the landowner or agency relying on that contractor. As Roe et al. (1953, p.802) stated in one of Montana's early logging cost reports, "Increased logging costs result in reduced stumpage returns to the landowner or in lower profits to the logger". Increased operational costs are inevitably passed down from the producer to the consumer, and are thus an issue of concern throughout the whole supply chain.

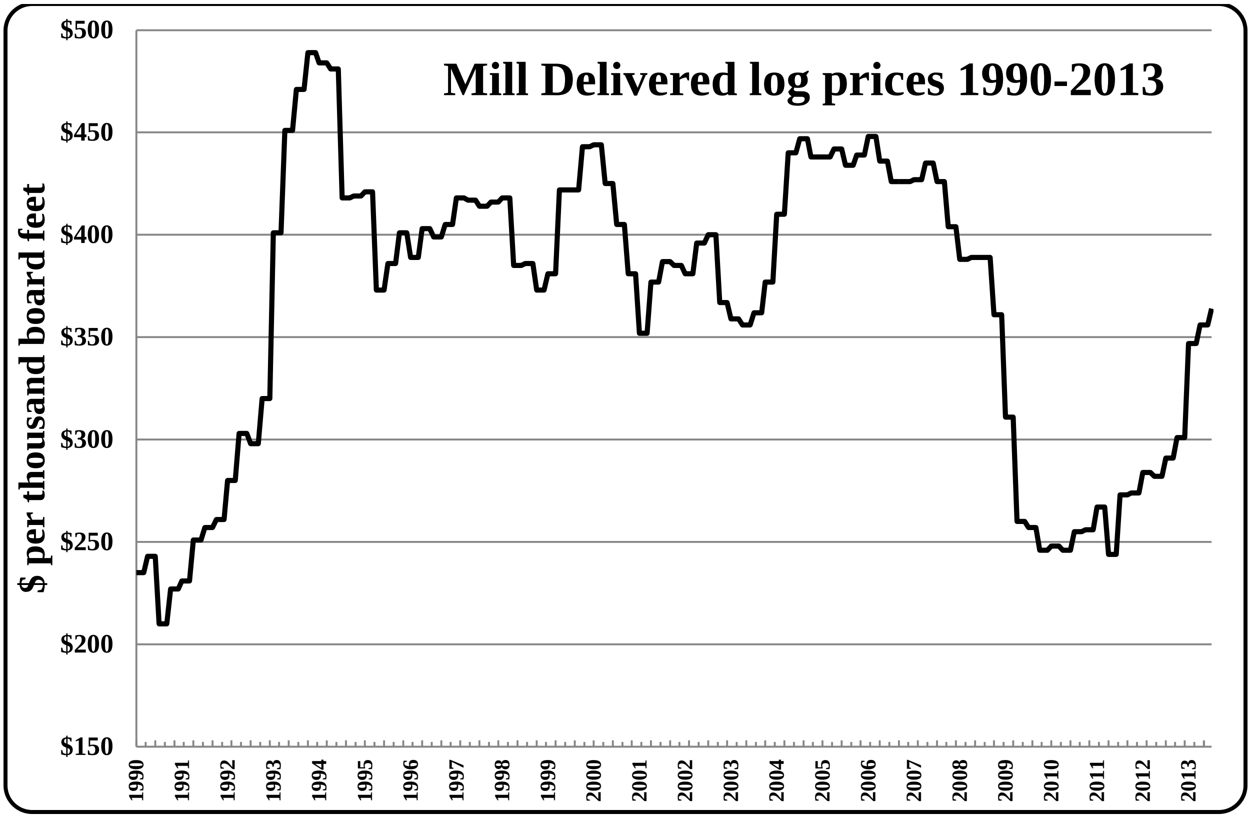

Figure 2- Mill delivered log prices in Montana for the period 1990-2013 (Source: Bureau of Business and Economic Research 2013).

A recent opinion piece in the Montana Logging Association newsletter (and the American Loggers Council newsletter before that) addressed this issue and ended with a rallying cry to the logging industry in America (Turner 2013). In identifying potential solutions, the author writes that loggers must know their costs and bid on jobs based on actual costs; loggers should work with mills and the larger forest industry; and should engage in training and education to improve financial literacy. These comments are a common thread in conversations with individuals involved in the various facets of Montana's forest industry. Consideration of the internal and external factors impacting a logging operation is one way to mitigate the challenges the industry faces. To remain competitive and informed on contemporary forestry issues, Montana's forestry practitioners must maintain and update their knowledge and data regarding operational parameters and subsequent continued viability.

Justification and Background

It is of utmost importance to any business to consider the factors that affect it and find ways to remain competitive (Bruner 2003). Constant consideration of production levels, operating costs and constraints, and ways to increase the former while minimizing the latter should be a main concern of any business owner, especially in the context of a slowly-recovering economy (Greene and Bolding 2013). While that is largely a matter of the personal motivation of the individual business, there are generalized resources available to serve as an estimator of start-up and operational costs, a means of comparison between equipment types and logging systems, or a base rate to negotiate from.

Specific to the forest products industry, extensive logging cost and production analyses have been produced formally since the early 1940’s and even before (Brandstrom 1933, Matthews 1942). Since then, costing research has been continually ongoing, though mostly in the southern region of the United States (Cubbage et al. 1986, Werblow and Cubbage 1986). This research has varied in scope and objective, and ranges from offering generalized logging equipment rates to specific costs and productivity rates for one piece of equipment studied in a particular setting.

The methodologies used to produce these estimates have remained largely unchanged and focus on either 1) the “machine rate analysis” developed by Matthews (1942), and refined by Miyata (1980) and others, or 2) the cash flow analysis utilized more frequently in the accounting or finance industries (Burgess and Cubbage 1989). The predominance of this costing research occurred mostly from 1942 through the 1990’s, and has lessened in recent years perhaps due in part to a decline in the industry and subsequent reduced need for this type of research, and/or increased complexity of costing more advanced equipment. Government agencies, research institutions such as universities or various research-oriented groups, along with major timber companies have continued to produce cost research into the 21st century, though in what seems considerably less volume. The practical consideration of operating costs is one way to improve the long-term survival of an individual operation and is an important facet of active forest management research.

Montana logging cost data has been publicly produced since at least the 1950s, and there is evidence that previously operating regional timber companies kept detailed records prior to that (Roe et al. 1953). Since then, it's likely that Montana's major timber companies have kept detailed cost records, most of which are not available publicly as they contain proprietary data. It is unknown, outside of the companies themselves, whether this type of logging cost analysis is on-going to ensure that contract rates reflect actual logging costs, a concept that has been studied in other parts of the country (Cutshall et al. 2000).

Fortunately a resource for publicly-available data does exist for the western United States. The manager of Montana's largest public land base, the US Forest Service (USFS) maintained logging cost records as part of their timber appraisal system until 1982 when the system was overhauled (Keegan et al. 1995). Filling the gap left by the loss of USFS data, the Bureau of Business and Economic Research at the University of Montana (BBER) (contracting through the USFS) has produced logging cost data based on an expert opinion survey conducted biennially and reported in a price per unit volume. These results are frequently requested by logging professionals, logging associations, management foresters, and research institutions. Further, the USFS uses this data to populate its sale appraisal system. The increasing challenges of economic viability and continued interest in logging cost work are two significant reasons for maintaining this type of research into the future.

Logging costs vary widely over time and between timber producing regions of the United States (which include the South, Northeast, Lake States, Inland Northwest, and West Coast). An examination of peer-reviewed literature identifies those major factors that influence costs among regions, but little has been produced in terms of a formalized comparison (Cubbage et al. 1988, Stuart 2003, Adebayo 2006, Leon and Benjamin 2012). Further, most of the logging cost research conducted in recent years has been produced in the South, and consequently, loggers in Montana might question the validity of utilizing these resources in a completely different operating environment. It is useful to consider these regional differences, and thus they are briefly included in the scope of this paper.

Objectives

There are several needs pertinent to maintaining the regional logging cost data provided by the BBER. First is the need to enhance and update knowledge on equipment and labor operating costs to act as a validation tool for the survey data used by the BBER. Acquiring and reporting valid data from a survey of this nature is notoriously challenging and producing machine cost data serves to validate responses received from the respondent population (Leon and Benjamin 2012, Baker 2013).

Second is a need to compile this data and offer it as a resource for cost estimation by loggers, forest managers, private landowners, and other interested parties. The high costs of operating logging equipment that may be familiar to the owner of a logging firm, may be less so to the mill, forester, or private landowner contracting with that firm. There has been an identified need (from discussions with various individuals from Montana mills, agencies, and loggers) to produce a set of baseline costs that might serve as a negotiating tool for logging professionals, as well as an informational resource for other interested parties to assess and understand the component parts of logging costs and how these components impact total expenditures. Further, offering a range of equipment costs might assist individuals or businesses that are considering purchasing new equipment in finding the right piece of equipment for their specific operation.

Logging equipment costing estimates and calculators have been produced in a variety of formats across the U.S. over the past 100 years (see Appendix 5) (Brinker et al. 2002, Bilek 2007, USDA n.d.). However, it has been many years since data was formally collected and reported specific to the Inland Northwest region; consequently, regional loggers and managers may question the applicability of using this cost data from other distinct locales. Anecdotal evidence suggests that the cost of logging has both increased rapidly over the past two decades, and that the Inland Northwest is one of the costliest places to operate. Thus there is a need to address these issues by updating region-explicit costing data and offering a formalized resource for historic and regional comparison.

The ultimate goals of this report are to 1) produce a resource for estimating owning and operating costs, independent of production, for the ground-based logging equipment typically encountered in Montana, 2) provide an updated price per unit volume resource based on local expert opinion, and finally 3) compare change in costs over a 20 year period and assess the factors impacting these expenditures.

Methods

Equipment Costing Methods

Logging cost estimation has historically relied on two accounting methods: the machine rate method and cash flow analysis (Burgess and Cubbage 1989). Arguably the most common method is the machine rate approach popularized by Matthews (1942) and further refined by others since then. The machine rate method compiles and averages fixed and variable costs over the entire lifespan of a piece of logging equipment so that costs may be calculated per scheduled or productive machine hour (SMH, PMH) (Burgess and Cubbage 1989). Fixed cost are those that occur even if the machine is not operating such as depreciation, principal repayment, interest, insurance, and taxes. Variable (or operating) costs are only incurred when the machine is actually operated, such as maintenance and repair, fuel, and lube and oil (Miyata 1980). Works done by Miyata (1980), Brinker et al. (2002), and others have described the machine rate approach as an easy-to-use and easy-to-apply method that also provides a standard format for comparison.

The machine rate method has proven to be a useful, albeit simple method of equipment cost estimation. The method relies heavily on general "rules of thumb" (ROT), which offer standardized ways to account for the unknown fixed and variable costs specific to logging machinery. For fixed costs, depreciation is accounted for using a straight line method, while interest, insurance, and taxes are calculated as a percentage of the "average value of investment" which is the value of the machine at the midpoint of the depreciation cycle (Greene and Bolding 2013). ROT are further utilized for assigning input values to fuel usage, lube and oil, maintenance, utilization rates, standard economic life, and others, though specific data could be utilized if known. These ROT have been further studied over the period of the machine rate method's popularity and refinements have been made in various published literature (Brinker et al. 2002, Smidt and Gallagher 2013). The simplicity of this method has made it popular for comparison between types of equipment over the years, though it does have obvious limitations. For example, fixed costs will be higher when the equipment is new, and lower as it ages. Conversely, operating costs will be lower when new, and generally higher as the equipment ages (Werblow and Cubbage 1986). The machine rate method doesn't allow for this sort of analysis, and doesn't take into account various investment credits, realistic equipment lifespans, and other Federal and State tax laws (Werblow and Cubbage 1986).

The machine rate analysis' limitations negate it from being a useful tool for individual, specific cost estimation and tracking. Individual loggers with solid record-keeping might instead choose to employ a second method of cost estimation, cash flow analysis, which utilizes an approach more common to the finance and accounting industries (Burgess and Cubbage 1989, Cutshall et al. 2000). This approach periodically tracks the in-flows and out-flows of cash from a business on a monthly, quarterly, or yearly basis. It takes into account the time-value of money, or the fact that an amount of money today has different buying power tomorrow based on interest and inflation. For an individual logging contractor with detailed cost records and an understanding of accounting, this method will prove more intuitive and accurate for cost tracking and will account for changes in costs over the life of equipment. Comparisons of the two methods of cost accounting have found the cash flow analysis to be more accurate, though a more cumbersome method based on the amount of detailed input data required, constantly changing Federal tax laws, and the complexity of calculations (Burgess and Cubbage 1989). In this same comparison, Burgess and Cubbage (1989) also found that the machine rate method generally underestimates actual costs, and that the cash flow analysis was more true to actual costs reported by logging contractors.

There are pros and cons to both methods depending on user literacy, quantity and quality of data, and intended objective. The cash flow analysis is likely more accurate and relevant to an actual contractor with an interest in maintaining detailed cost records. However, for the sake of academic comparison and standardization, this report produces equipment costs that were computed using the standard machine rate method.

Machine Rate Analysis

The equipment costing aspect of this report relies primarily on local equipment dealers and data in the form of equipment specification and cost sheets, as well as ROT data widely accepted from published sources (Matthews 1942, Brinker et al. 2002). There are five dealerships in the Missoula, Montana area that sell new logging equipment that combined have distribution rights to all major equipment brands commonly utilized in the region. The individual in charge of forestry equipment sales at each dealership was contacted; four out of the five dealerships agreed to furnish data. Direct interviews were conducted and each dealer was asked to provide data for what they see as most frequently sold ground-based logging equipment, including feller-bunchers, skidders, processors, and log loaders. Ultimately, a Manufacturer's Suggested Retail Price (MSRP) (prior to any discounting, delivery, and other associated charges) and specification data was provided for 6-11 pieces of equipment in each category of a ground-based operation, with the exception of tracked skidders. The fifth dealership (not participating in an interview) offers an online tool allowing users to build and price a piece of equipment (with associated features such as engine type, cab type, hydraulic package, attachments, etc…), and was accounted for in this way (Caterpillar Tractor Company 2013).

Specific costing aspects for each piece of equipment were then broken out individually into fixed and variable costs to produce daily and hourly scheduled/productive rates as per established machine rate equations (Matthews 1942, Caterpillar Tractor Company 2001). Equipment depreciation was calculated using the straight-line method and an assumed economic life of five years for all equipment. Other fixed cost data including interest, insurance, and taxes were collected from Federal, State, City, and private agencies. Labor costs were assembled using Montana-specific wage data from the Bureau of Labor Statistics (BLS) (Bureau of Labor

Statistics 2013) and were based on a 9.5 hour working day. Worker's Compensation, Federal unemployment, Social Security, and benefit costs were acquired from Federal, State, and City agencies, local insurance dealers, and the Montana Logging Association. Operating costs were based on a scheduled 180 working days per year (1710 scheduled hours). Appendices 1-4 illustrate the machine rate parameters and assumptions utilized, and rates produced for each fixed and operating cost category for every piece of equipment. Mobilization, road building/maintenance, and other contracted services such as slash disposal costs were not included in this estimate. It should also be noted that production rates have no influence on hourly cost estimates beyond utilization rates. After compilation of cost data, six local loggers (acting as experts) were contacted and interviewed to validate these costs and make adjustments as applicable.

To identify changes in logging cost over time, current estimates were compared to data produced 20 years ago (1993) by Champion International Timberlands, one of Montana's former major timber companies and landowners. This data had costs broken down through typical machine rate methods for individual pieces of equipment across different logging systems (ground and cable) and split between fixed and variable costs. These historic costs were then adjusted to 2013 dollars using the Consumer Price Index inflator provided by the BLS (2013). Production estimates were not included in the historic data, and consequently are not included in this report.

Expert Opinion Survey

While the machine rate method provides an impartial and cross-regionally consistent way to compare the costs of purchasing and operating new logging equipment, there is also a need to produce an average price per unit volume for harvest systems as a whole that summarize costs in an accurate and inexpensive way. To achieve this goal, the BBER has utilized an expert opinion survey since the 1980s, which is updated biennially in Montana and Idaho.

The latest survey in this series went out in September of 2013 and of those that responded, 95% were collected by the end of October. To populate the initial mailing list, group membership lists were acquired from the Montana Logging Association and the Associated Logging Contractors in Idaho. The survey was sent to 231 Montana loggers, mills, and associated individuals and 26 were returned for a response rate of 11%. Two hundred and thirty five Idaho loggers were sent surveys and 15 responses were received for a response rate of 6%. Despite the low response rate, survey respondents in Montana accounted for 87 million board feet (MMBF) of the total 351 MMBF 2012 harvest or 25% of total (Morgan et al. 2013). Idaho respondents accounted for 411 MMBF of the total 1090 MMBF 2012 harvest or 38% of total (Morgan et al. 2013). Further, the membership lists consisted of loggers, mills, log haulers, and other associated individuals, not all of which actually logged in 2012, possibly contributing to the low response rates. Responses were collected primarily from operational loggers, with several mills with company logging crews responding as well.

In this survey, contractors were asked to prepare simulated bids for a "typical" Inland Northwest harvest unit based on three logging systems commonly utilized in this region: ground-based, cable, and cut-to-length. A detailed harvest scenario was presented with a list of relevant variables needed to prepare a bid (Table 1). A suggested cost per ton was offered as a starting point to be adjusted and commented on if applicable. Each logger was asked to provide current per-ton and/or per-MBF cost estimates for the following cost components of the logging systems based on this unit: planning and administration, felling, skidding or yarding, limbing and bucking, and loading. Survey results were compiled across cost categories and averaged for each system, and reported in dollars per ton and dollars per MBF. A conversion factor of 6.2 green tons per thousand board feet was used to convert values from tons to MBF. Not unlike other efforts, survey response rates in this study were low and precluded the opportunity for statistical testing.

Table 1- Factors and value assignments used to comprise simulated logging systems. Does not include mobilization costs.

Variables Used in Expert Opinion Survey Treatment	
Average skidding distance	600 feet
Average yarding distance	800 feet
Average forwarding distance	1000 feet
Average DBH removed	13 inches
Trees per acre removed	42 (partial cut)
Cubic foot volume of average tree	24
Volume removed per acre	1,000 ft^3 (30 green tons)
Overall harvest acres treated	40-80 acres

To provide additional anecdotal context, associated demographic information were collected as well, including: average daily and yearly production; logging capacity; yearly operational days; type, age, and initial purchase price of logging equipment; and employment data. The survey also included a comments section, providing an opportunity for respondents to provide feedback on perceived operating trends, issues, concerns, or any other relevant information.

Results

Machine Rate Analysis

The results of the machine rate calculations using regionally-specific data are provided in Table 2, along with a demonstration of the potential cost to invest in and operate a total ground-based system (Table 3). As evidenced, the cost of purchasing and operating a new piece of logging equipment is significant and for a prospective new logging business, the initial investment of approximately $1.5 million dollars might preclude entry into the field for many individuals. For established loggers looking to replace one piece of equipment, careful consideration of operational needs is required to match the right equipment to the right job. For instance, horsepower (HP) needs should be of concern based on the calculated price difference between equipment HP ranges in Table 2. For example, the average purchase price for a feller-buncher with more than 285 HP is 9% (roughly $42,000) more than a feller-buncher with less than 285 HP. The cost of operating different log processor types ranges from $1,524 per day for a slide-boom delimber to $1,440 per day for a dangle-head processor, a difference of 6% or $84 per day. Over the course of a 180 day operating year, this difference equals approximately $15,000. Between equipment and labor, a business owner might expect daily costs to equal roughly $4,800 per day if all new equipment was being utilized. These costs do not include other necessary costs such as support vehicles to transport the crew or overhead costs such as bookkeeping and sale administration. Whether or not this expenditure is viable when considering the expected return from delivered logs is the question a business owner must consider when purchasing new equipment or entering the logging business.

The costs in Tables 2 and 3 are averaged across a range of equipment, and specific makes and models of equipment will undoubtedly show varying costs (see Appendices 3 through 6 for specific details). Regardless, this data should provide a resource for generalized comparison when actual costs are unknown. As noted by Werblow and Cubbage (1986), this type of general data provides a useful means of comparison, as well as a tool for managers when considering an investment or contract negotiation.

Table 2- Average estimated costs (dollars) for select ground-based equipment in Montana based on a 9.5 hour day

Equipment Type	***Purchase Price***	***Total Cost Per SMH***	***Unoperated Total Cost Per Day***	***Operated Total Cost Per day***
Feller Buncher <285 HP	443,444	114	1,086	1,355
Feller Buncher >286 HP	485,502	126	1,198	1,468
Slide-Boom Delimber	474,477	134	1,270	1,540
Standard Processor	437,282	125	1,186	1,456
Grapple Processor	398,000	116	1,106	1,376
Loader <185 HP	299,812	72	683	953
Loader >186 HP	379,417	91	863	1,133
Track Skidder	405,218	107	1,015	1,285
Rubber-Tire Skidder <185 HP	292,562	82	775	1,045
Rubber-Tire Skidder >185 HP	326,533	95	904	1,174

Table 3- Average estimated cost (dollars) of running a complete ground-based logging system based on a 9.5 hour day

Equipment Type	***Purchase Price***	***Unoperated Total Cost Per Day***	***Operated Total Cost Per day***
Feller Buncher <285 HP	443,444	1,086	1,355
Slide Boom Delimber	474,477	1,270	1,540
Loader <185 HP	299,812	683	953
Rubber-Tire Skidder <185 HP	292,562	775	1,045
Total	**1,510,295**	**3,814**	**4,893**

Table 4 illustrates cost data from Champion International (1993 total values have been adjusted to 2013 dollars) and data from the updated costing exercise utilizing local information for one complete ground-based logging side including operator wages specific to Montana. In regards to the contemporary data, costs were averaged across machines of comparable size, horsepower, and attachment type to produce a singular cost. As demonstrated, costs have risen significantly over the past 20 years.

Table 4- Logging Cost Comparison between 1993 using Champion International Data adjusted for inflation (2013 dollars) and 2013 machine rate data

Operation	***1993 Total ($/Day)***	***2013 Total ($/Day)***	***Change ($/Day)***	***Change (%)***
Rubber-Tire Skidder-<185 HP	538	1,045	+507	+94
Rubber-Tire Skidder->186 HP	632	1,174	+543	+86
Track Skidder	734	1,285	+551	+75
Slide-Boom Delimber	945	1,540	+595	+63
Loader	706	1,132	+427	+60
Feller-Buncher	1,001	1,468	+466	+47

Expert Opinion Survey

Tables 5-7 illustrate reported costs from the updated 2013 survey, along with results from the past three iterations of the survey in real dollars. The "Total" row was calculated using the base skidding, yarding, or forwarding distance; other distance costs were included to show the impact of longer skid distance on cost. Prices include a measure of both profit and production on the logging end, unlike the machine rate data in Table 2. The different values reflect the difference between "cost" and "price".

As evidenced in Tables 5-7, in some cases reported prices have actually declined. This apparent phenomenon may be accounted for by the fact that contractors are generally reporting what they were paid for these years, including a steadily declining profit margin, and not what it cost them to operate. Another potential explanation is that many logging contractors have gone out of business as a result of the economic downturn beginning in 2008. Those that survived might either be more efficient and able to operate for a lower cost, or may be large enough with enough capital to continue to operate at a lower cost until economic conditions improve.

Table 5-Ground based system costs from expert opinion survey in 2013 dollars (2006-2011 data courtesy of the BBER)

	$/Green Ton				*$/MBF*	
	2006	*2009*	*2011*	*2013*	*2011*	*2013*
Feller-buncher	7.55	7.06	6.64	6.92	41.14	42.90
Skidding 600’	5.41	5.71	5.01	5.39	31.04	33.42
Skidding 1,200’		7.74	6.18	6.80	38.30	42.16
Skidding 1,800’		9.75	7.32	8.45	45.37	52.39
Processing	7.10	6.79	6.17	6.57	38.24	40.73
Loading	4.06	3.40	3.46	3.43	21.45	21.27
Administration	1.47	1.42	1.31	1.64	8.14	10.17
Total	**25.59**	**24.38**	**22.58**	**23.95**	**140.02**	**148.49**

Table 6-Cable system costs from expert opinion survey in 2013 dollars (2006-2011 data courtesy of the BBER)

	$/Green Ton				*$/MBF*	
	2006	*2009*	*2011*	*2013*	*2011*	*2013*
Hand-Felling	4.85	5.01	4.67	4.53	28.96	28.09
Yarding 800’	23.45	22.40	22.29	20.41	138.19	126.54
Yarding 1,600’		27.42	27.51	24.06	170.56	149.17
Yarding 2,000’		32.02	31.42	27.05	194.79	167.71
Processing	6.99	7.10	6.56	6.89	40.70	42.72
Loading	3.49	3.54	3.34	3.25	20.70	20.15
Administration	2.03	1.90	1.63	1.65	10.10	10.23
Total	**40.81**	**39.95**	**38.49**	**36.73**	**238.64**	**227.73**

Table 7- Cut-to-length system costs from expert opinion survey in 2013 dollars (2006-2011 data courtesy of the BBER)

	$/Green Ton				*$/MBF*	
	2006	*2009*	*2011*	*2013*	*2011*	*2013*
Harvester	14.66	14.08	12.48	14.42	77.36	89.40
Forwarding 1,000’	10.69	10.21	8.82	10.63	54.71	65.91
Forwarding 2,000’		15.30	11.21	14.50	69.47	89.90
Forwarding 3,000’		18.92	14.95	17.00	92.69	105.40
Loading	3.95	3.72	3.66	3.79	22.72	23.50
Administration	1.69	1.59	1.30	1.68	8.08	10.42
Total	**30.98**	**29.60**	**26.27**	**30.52**	**162.86**	**189.22**

Expert Opinion Survey Respondent Demographic Results

Summary demographic data was compiled to make basic assumptions about the respondent population as illustrated in Figure 3. Of the 41 total respondents, 62% provided ground-based data, 20% provided cable system data, and 18% provided cut to length data. The mode of survey respondents had 1-5 employees, worked 9-10 months per year, operated equipment that is 11-15 years old, and produced more than 250 tons per day on average. Those contractors that produced more than 200 tons per day had the highest percentage of newer equipment than others, potentially illustrating the benefits of newer machinery over older. It also might reflect the type and size of jobs certain contractors are able to bid on and the type of equipment that is required, or the other business characteristics and resources that a large contractor might have and the subsequent buying power that could be used to purchase new equipment.

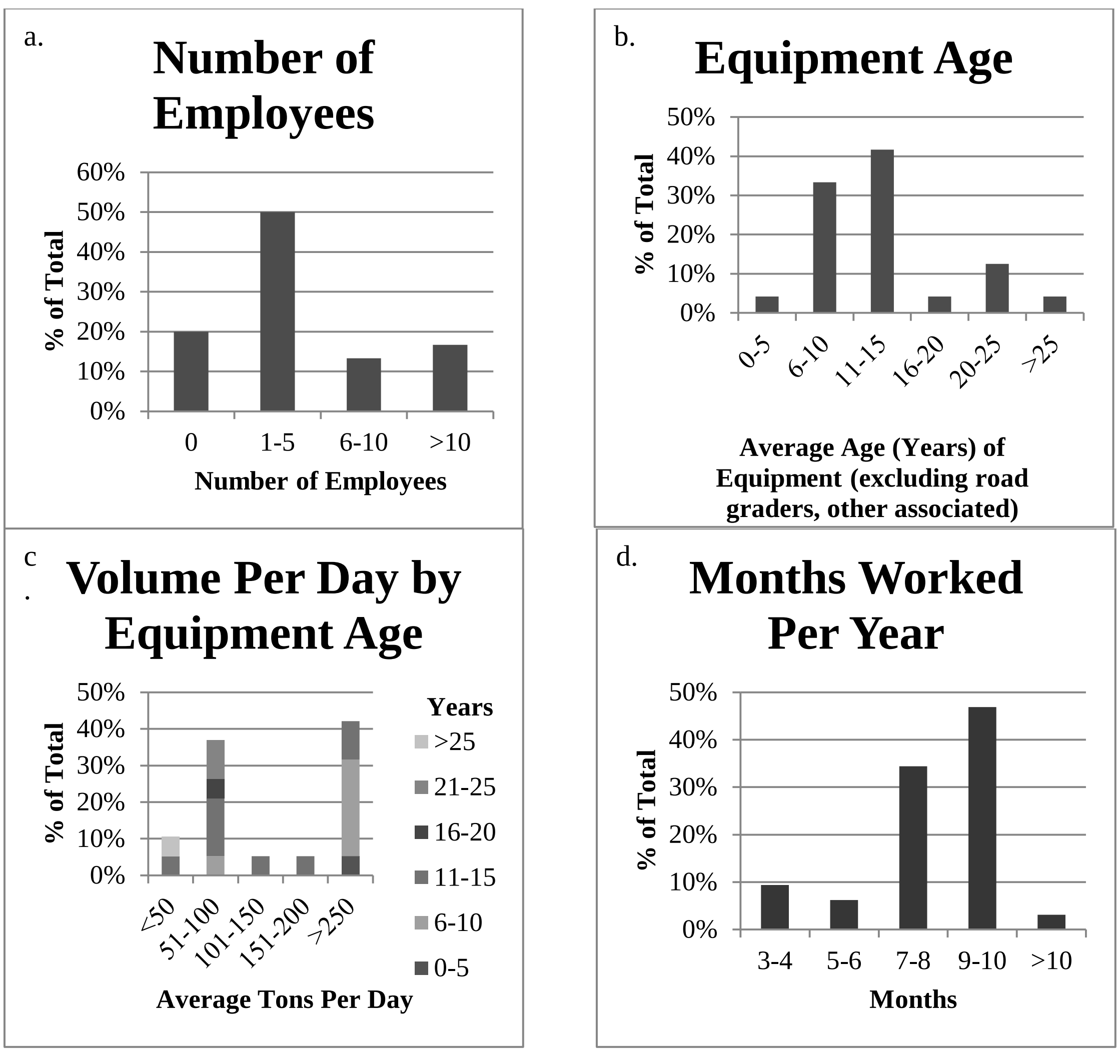

Figure 3-Averages of respondent demographic data from the expert opinion survey

Sixty percent of survey respondents provided an equipment list with year of purchase and initial purchase price. Each purchase price was adjusted to 2013 dollars and Figure 4 illustrates, by equipment type, how this cost has increased over the years as reported by logging professionals. The purchase prices shown below are for when the equipment was new; any supplied data for used equipment was excluded.

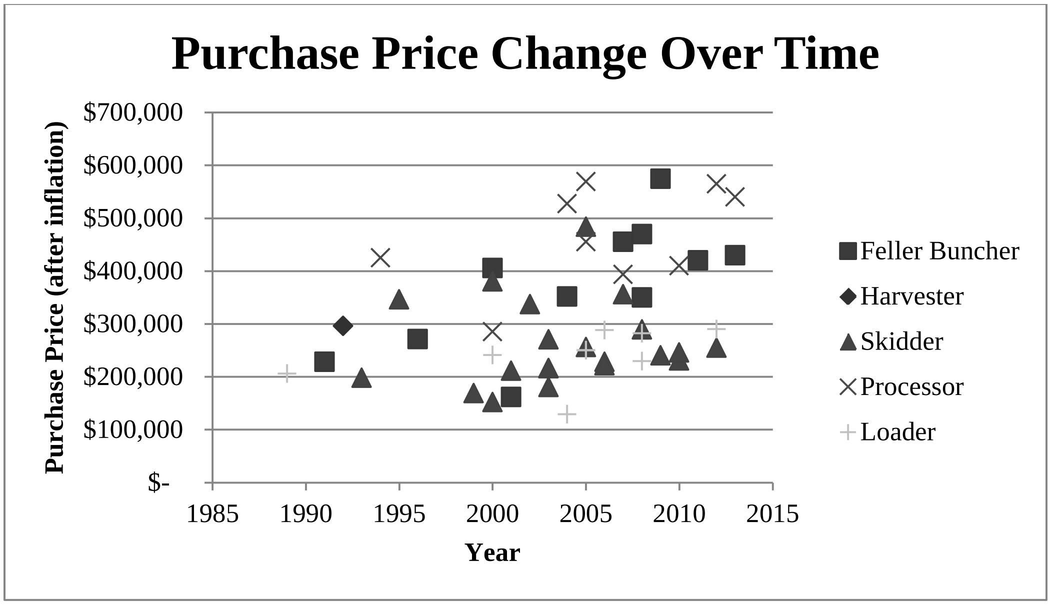

Figure 4-Adjusted purchase price data (in 2013 dollars) supplied by loggers in the expert opinion survey for equipment currently in operation

Table 8 shows a select set of comments provided by survey respondents and contains anecdotal summations of the logging industry and the specific problems that it faces. Three primary themes emerged. First, Montana and Idaho loggers believe that costs are too high, profits too low, and that they are doing all they can to merely survive, let alone profit. It appears for most of the respondents, purchasing new equipment is unlikely and illogical in the face of diminished profit margins. A second common theme is the frustration, and increased cost of, dealing with the U.S. Forest Service and the associated administrative challenges. Respondents expressed concern about the availability and continuity of timber from Federal land, and the serious effects this has on the likelihood of continued financial success. A third theme was the need to improve relationships with mills and to establish long-term contracts beneficial to both parties. This might be a step in establishing more security for the industry. Ultimately, these comments are reflective of respondent opinion on the current state of the forest industry and demonstrate the need for change if the industry is going to survive in Montana.

Table 8- Select comments provided by loggers from the 2013 expert opinion survey

"Local price to log is too cheap to allow any profit. Your (survey) prices are about what it should be but local mills won't pay that much."
"The cost of trucking and availability of trucks has really hurt our industry. I have had to change the way I log because of the trucking problem and it has hurt my production. I cannot hot log anymore. Logs might sit in decks for a month before they get hauled. All the trucks went to the oilfields".
"Some Forest Service sales require stump treatments, more packing trees with FB to achieve skid trail spacing etc…Some of the other costs with a FS sale are log branding, skid trail layout and landing lay out and approval or modification per FS admin. There are typically more operational delays on FS projects than other projects and it is very difficult to come up with a $ per ton cost for those delays. Since we do a lot of stewardship and fuels reduction projects our daily production is extremely variable. Since we have quite a bit more equipment than employees we could probably produce 400+ tons per day if we had the work and extra employees."
"Our costs are way up; these (ground based) prices are not usually what they should be".
"Payroll and health insurance for our employees and fuel are taking all what we make; really hard to afford to buy new equipment. Cost of new equipment and fuel and repairs is a killer; can't log for any less."
"The problem with logging is the cost of equipment and parts have doubled in the last 4-5 years and the pay to contract log has stayed at a low level. There are very few equip operators left that can do the job right and that care about what they do and that most of the jobs you're logging dead wood so you put at least a 1/3 more logs on per load as you would in green logs and you get paid the same price. So with cost of fuel, parts, labor, insurance, and work comp you barely break even at the current logging prices. If you put in new equipment payment you would go broke."

Discussion

Machine Rate Analysis Limitations

It is generally accepted that logging costs are inherently variable due to a multitude of internal and external factors. However, being able to offer at least a baseline of average costs is a useful tool for estimation, as well as comparison between types of equipment. Offering an average cost goes back to Matthew's (1942, p.7) quintessential work where he writes "It is submitted that there should be no such thing as a predetermined current operating cost or fixed per acre cost for an entire logging change *except as an average*" (emphasis added). Most, if not all, costing research identifies these costs as an average, and not an exact measure. It's likely that individual machine rates could vary significantly from this average when using standard estimation techniques as well as when using individually-specific operational costs (Matthews 1942). For individual logging contractors or foresters with detailed cost records, there are other resources for compiling and summarizing this data (see Appendix 5).

There are both formal and anecdotal records of the most significant variables influencing the cost of running a logging operation. To compile and compare these factors between regions, an informal questionnaire was sent to professors of forestry, forest management, forest engineering, and forest operations at major universities around the country that have Society of American Foresters (SAF)-accredited forestry programs. Several questions were posed as to how they think their region's costs compare to the others and what factors have the most significant impact on cost. The combined responses from each regional university outlined the same set of factors though with differing impact on total cost. The most commonly referenced factors from this survey are: fuel and labor costs, volume harvested per acre, tree size, skid distance, topography, harvest type, and logging system. The costs presented in the "Results" section are subject to change based on these variables. Consideration of the importance of these variables on cost is important to Montana's loggers, especially when comparing regional costs and utilizing cost estimation tools from other regions of the United States. While some estimation tools and calculators attempt to modify a base cost using these factors, it's unlikely that these "cost modifiers" are applicable to Montana logging costs, hence loggers should attempt to find and utilize regional data where applicable. Insurance, interest, and tax rates can be found locally to address fixed costs, as can fuel and labor rates for variable costs. There are resources that exist that quantify how to account for these variables for personal cost estimation that are specific to the Inland Northwest that should minimize regional differences (found in Appendix 5).

Comparison to Historic Cost Data

As illustrated by Table 4, the cost of running a total ground-based system in Montana has significantly increased over the past 20 years beyond inflation. Similar results have been found in other regions, dating back to the 1980s where researchers found that "…the costs of logging equipment have increased at rates considerably greater than the prices received by loggers (Cubbage et al. 1988, p.9)." Based on comparison to past data as well as anecdotal interviews with logging professionals, the biggest increase in equipment costs purportedly has been in the purchase price of new equipment (and price of steel), diesel fuel prices, and labor costs (Brinker et al. 2002, Hampton 2004, Smidt and Gallagher 2013). Though largely uncontrollable, it is interesting to observe how these factors have influenced fixed and variable costs over the past two decades.

Factors Affecting Fixed Cost Changes Over Time

New equipment might come with added efficiency, power, and consequent productivity, but also with substantial fixed and variable costs. It has been noted that the mere initial investment in a mechanized logging operation can constitute 40%-50% of the delivered cost of wood, let alone all other intervening factors (Ashton et al. 2007). This cost is significant and purportedly has been rising over the past 20 years as seen in Figure 4, begging the question of what factors are contributing to escalating purchase prices. While this is largely uncontrollable (in contrast to operating costs), it might be of interest and concern to the logging industry to understand the underlying reasons for this trend.

Comparison between equipment purchase price from our historic data and contemporary data proved challenging based on several factors. Most notably, equipment utilized today is mechanically and technologically much different than 20 years ago. Based on equipment specification data provided by equipment dealers there were observable differences in both weight and horsepower between data sets, with modern equipment having a range of 12-122% more horsepower, thus contributing to increased fuel usage, lube and oil, maintenance, and initial purchase price. Ideally this increase in power would equate to an increase in productivity or a reduction in complete system bottleneck, a concept validated by research around the country, though the increase in purchase price might offset the production benefits of purchasing new equipment (Cubbage et al. 1986). Ultimately, "…the replacement should be able to generate additional income from increased production (in terms of quantity and/or quality) to offset the additional costs associated with it" (Carino et al. 1995, p.62).

In addition to increased engine power, changing emission standards have influenced the initial purchase of logging equipment. Federal emission standards have been in place since 1994, with several planned changes occurring since by means of changing generations or "tiers" of standards that new vehicles must meet (EPA 2013). This tiered system implemented a plan to reduce particulate matter and nitrogen oxide from off-road heavy equipment by 50-96% of the current equipment generation in several steps. Essentially, machine manufacturers are charged with adding emission control technology to the exhaust system; this will occur through either exhaust gas recirculation (EGR) or selective catalytic reduction (SCR) (Diesel Technology Forum 2012). The latter option (SCR) will require the use of diesel exhaust fluid (DEF) that is periodically sprayed into the exhaust/muffler system to interact with nitrogen oxide and reduce tailpipe emissions (EPA 2013). While all vehicles in the U.S. are subject to these tiers, heavy equipment will enter Tier 4 standards in 2014, though many manufacturers are already producing and selling Tier 4 equipment in the U.S. (Doosan 2013). These required engine alterations along with the addition of the DEF system (fluid replenishment) will undoubtedly impact both initial purchase price and operating costs, though the exact impact is unknown and likely manufacturer-dependent. This range is from a 1% increase (Dieselnet 2013) up to 30% based on our interviews with local equipment dealers and published resources. All new equipment is subject to Tier 4 standards, but older equipment will not require retrofitting, a consideration for deciding between purchasing new versus used equipment (Diesel Technology Forum 2012). At some point in the near future Montana's logging professionals will be faced with the decision between continuing to maintain older and potentially cheaper equipment or purchasing new, "greener" equipment. This is a decision that individual business owners must make alone, but one that will have significant cumulative effects on the industry and environment.

While the mechanical side of logging equipment has changed significantly, there has also been substantial improvement in on-board technology. Most modern equipment has advanced computer systems capable of determining and processing different cut log specifications, and then storing production data for future use. For instance, John Deere offers an optional program called "JD Link" that wirelessly enables mill operators to adjust cutting specifications from the mill without having to implement any changes on the machine. This program also monitors how the machine is operating mechanically and when maintenance is required. Other companies offer similar services, thus ideally enabling loggers and mill operators to interact more seamlessly and improving overall efficiency. Yet, similar to cost changes resulting from mechanical advances, there is an underlying cost associated with this improved technology that may be of further consideration when purchasing new equipment.

Another explanation for rising purchase prices is that the price of steel has increased from $175 per ton (adjusted for inflation) in 1993 to $216 in 2011 (an increase of over 23%), as a result of restricted supply and increased demand overseas (Bleiwas et al. 2013). The cost of steel as a raw material can constitute 60% of the total cost to produce a piece of equipment and a number of equipment manufacturers have stated that as a result of this issue, consumers might see a rise in purchase price if there is a continued upward swing in steel prices (Hampton 2004, Holden-Moss 2012). It was reported that this purchase price increase would range from 3%-5% (Hampton 2004, Electrical Contractor Magazine 2008). The increased costs on the manufacturing end will undoubtedly be passed to the consumer, and logging contractors looking to buy new equipment should be prepared for this.

Changes to the fixed cost categories of logging equipment are entirely susceptible to forces outside of the owner of a business or operator of a piece of equipment, and thus are personally uncontrollable. Remaining aware of the internal changes impacting fixed cost is crucial, but the one opportunity a business owner does have in this regard is to carefully match specific equipment to personal operational need and capital availability/outlay to assist in continued operational viability.

Factors Affecting Variable Cost Changes Over Time

In addition to increased fixed costs, there has been a notable rise in the variable cost of operation. Volatile fuel costs are an especially influential factor on operational costs, and are a cost that is unlikely to level out in the near future. Debate continues over how Tier 4 standards will impact fuel usage, though from conversations with equipment dealers it appears that with increasing engine sophistication might come increased fuel efficiency. This is especially important to the logging industry, as fuel costs can increase an operation's break-even point and erode profit margins as suggested by respondents to our logging cost survey. Estimated fuel costs (See Appendix 4) were based on the current average price for off-road diesel in Montana and fuel usage relied on value assumptions produced by Plummer and Stokes (1983); a range of 5-8 gallons per hour was calculated based on the horsepower of the machines. This range was validated as "typical" from our interviews with dealers and contractors, though fuel usage is subject to vary by topography, operator skill, weather, and other factors. Research is ongoing to update these fuel usage estimators to reflect modern equipment and operating conditions (Smidt and Gallagher 2013).

Daily operation requires a large amount of fuel. To illustrate the impacts of fuel prices on total daily operating cost, a sensitivity analysis was conducted for the complete ground-based system listed in Table 3. Using machine rate calculations, this equipment combination would use roughly 138 gallons of fuel per day. At $3.50 per gallon, daily fuel expenditures would equal $483; if diesel prices increased to $4.00 per gallon this daily expense would be $552, a difference of $69 or 14%. Contrasted with the average fuel price in 1993 at $1.44/gallon (Champion International data) adjusted to 2013 dollars, daily fuel expense would only be $199. Varying fuel prices have an impact on daily fuel expenditures and when these prices are extrapolated further, the difference in daily cost becomes increasingly significant as seen in Table 9. Similar to the issues inherent to the fixed cost categories, changing fuel prices can't be directly controlled, though fuel usage and subsequent expenses can be mitigated by operator skill and consideration of fuel use during downtimes such as breaks or other delays.

Table 5-Price per gallon impacts on total fuel expenditures daily, yearly, and over the economic life (5 years) of the equipment

Fuel $/Gallon	Daily Fuel Cost $/day	Yearly Fuel Cost $/year	Economic Life Fuel Cost $/5 years
1.44	199	35,769	178,848
3.50	483	86,940	434,700
4.00	552	99,360	496,800

The cost of repairs and maintenance for logging equipment is another influential expense though is one that is notoriously difficult to track with reliability (Werblow and Cubbage 1986). These costs exist as both routine, expected maintenance and as unplanned, potentially catastrophic breakdowns that can have a significant impact on an operation's monetary situation both in lost productivity and return, as well as in the actual repair cost. Repair and maintenance costs vary depending on the type and make/model of machine, operator skill and usage, topography, and planned maintenance routine. This study employed the typical machine rate method of accounting for maintenance as a percentage of depreciation. However, it was attempted to acquire local ROTs from the equipment dealers that were surveyed for comparison and verification of established ROT. Unsurprisingly, those dealers agreed that average repair and maintenance rates are hard to predict; an estimated range of $35-$50 per operated hour was given anecdotally. Utilizing the machine rate ROT produced a range of $24-$72 per operated hour varying with the type of machine. The calculated average rate was highest for feller-bunchers at $58/PMH, similar for processors and skidders at $46/PMH, and lowest for loaders at $37/PMH. Using the machine rate ROT likely overestimates repair and maintenance costs early in a machine's life, and underestimates them later on. However, assuming a straight-line repair and maintenance cost might allow a business owner to "accumulate a reserve fund in early years to cover the higher costs incurred later in the equipment's life" as noted by Werblow and Cubbage (1986, p.13).

In our interviews with loggers, foresters, and equipment dealers, maintenance costs were frequently highlighted as a cost that has increased over the past 20 years. Local equipment dealers acknowledged that the price of lubricant and oil, hydraulic hoses, and other parts has increased in recent years though no contemporary research has attempted to quantify this change.

To assess the applicability of machine rate ROT, we focused closely on repair and maintenance data acquired from a local logger for one feller-buncher of well-known make and model over the course of years 2007-2012. It was found that repair and maintenance costs did not increase linearly over the life of this machine, but fluctuated widely as seen in Figure 5. Average yearly costs for this piece of equipment were $13,660 with an hourly rate of $15.93 based on an average 1,295 operated hours per year. The average operated hours per year does not deviate greatly from yearly operated hours calculated using ROT utilization rates developed in the machine rate method, which was 1,111 for a feller-buncher.

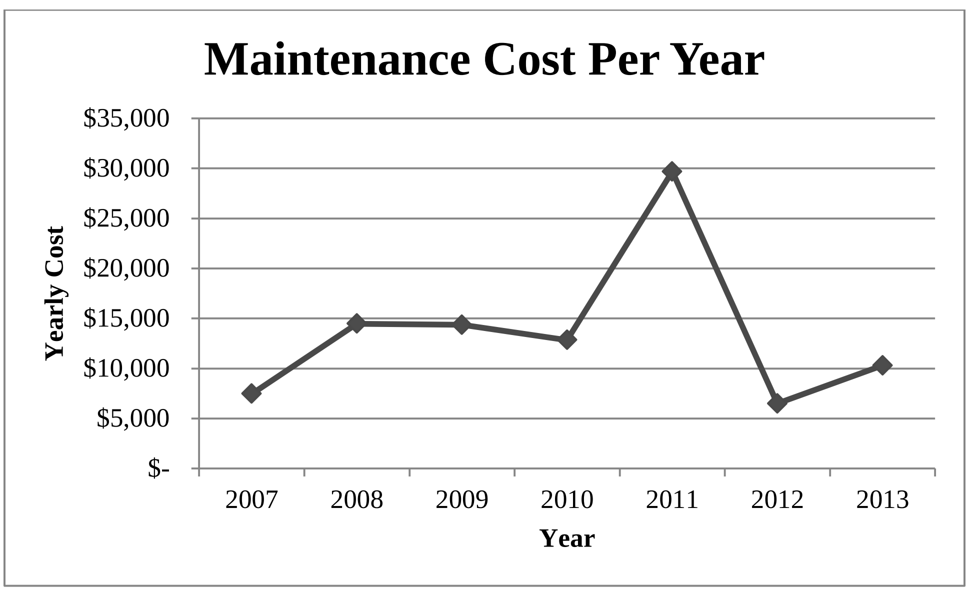

Figure 5- Actual yearly maintenance costs of one feller-buncher

Ultimately, calculating an average repair and maintenance cost to suit the range of equipment and conditions experienced is challenging and assumed values are virtually meaningless themselves as the variability between costs is so great. Instead, logging contractors should remain aware of the range of values they can expect over the lifespan of a piece of equipment and should save accordingly.

Though the variable costs of a logging operation are significant, they are also more pliable to change than fixed costs, largely based on operator skill and judgment, mitigation of equipment wear from harsh operating conditions, and the type and condition of the equipment itself. There are ways to reduce these daily expenditures, but it will again require thoughtful consideration of operating parameters and conditions to do so.

Other Factors Affecting Operational Costs

The mechanical (fixed and variable) costs of running a logging operation account for a large portion of overall cost difference between our historic and contemporary cost data. However, other more general factors exist that routinely impact operational costs. First, the number of annual days a logger works appears to have decreased over the past 20 years. Survey results reveal that the majority of Montana loggers work, on average, between 9 and 10 months a year. This range is due to a variety of factors, most notably market influences on consumer need and the availability of a consistent supply of timber. Yearly weather patterns also influence the amount of operable days with closed forest access due to spring break-up, high amounts of snow, or extreme fire danger. A shorter working year can decrease profit margins by increasing total operational costs and decreasing the amount of timber being produced daily. Based on our machine rate calculations and example from Table 3, a 10 day difference per operating year changes daily cost by 3% or about $140 per day. Per year this difference would be over $25,000.

Total yearly expenses are spread over fewer days and less return from production, thus increasing daily operating rates. Further, it puts added strain on an operation to maintain consistent production over the days that are available, thus increasing stress from machine breakdowns, laborer recruitment and retention, and other issues. Consistent production is key to minimizing costs, a point that is especially salient for loggers with aging equipment, restricted wood supplies, and increasingly expensive labor costs (Baker et al. 2012). Our interviews with local logging professionals indicated that the shorter work year combined with the inability to depend on a consistent wood supply, are the two most significant changes that they have seen over the past 20 years, and are a reason that many loggers have gone out of business.

Another influence on general operating cost is the increased driving distance to get to a job site. A consequence of decreased logging employment and mill facilities means the same area is covered by fewer contractors, thus those remaining must travel further. This results in increased fuel usage, vehicle maintenance, and mobilization costs and becomes more prevalent on overall operational costs.

A final influence is in regards to the changing demographics of the logging contractor workforce. It's been noted in several recent publications that the average age of the logging sector workforce is increasing. In a 2004 survey of the Inland Northwest, Allen et al. (2008) found that 58% of respondents were over the age of 40, with an average age of 51 years. This is affecting all associated labor costs including hourly wages, worker's compensation (WC) rates, social security, and other personnel costs. According to Bureau of Labor Statistics (2013) data, Montana's average wage for logging equipment operators is $16.75 per hour, and $19.53 per hour for timber fallers. For the machine rate analysis portion of this paper, benefit costs including WC, Social Security, Federal and State unemployment, and Medicare rates were compiled from respective Federal and State agencies. We found that excluding WC rates, fringe benefits constitute 23% of the base wage; with WC included that percentage can rise to 30%-50%. While the forest industry sector still commands higher wages than other sectors in Montana, survey respondents reported diminishing wages and revenue each year. Base wage rates are controllable; however business owners should expect rising fringe benefit costs to be of increasing significance on total operating expenses.

Worker's compensation rates are increasingly important to operational viability. According to a recent article in the Forest Operations Review, "The logging profession ranks number one among the most hazardous occupations in terms of fatalities per 100 workers and logging and hauling rank as the top two areas for high severity claims among insurance companies that provide Worker's Compensation" (Lemire 2013, p.31). In Montana, as in most states, specific WC rates are based on a logging contractors work experience and history of accidents (Montana State Fund 2012). These rates can vary from $4.00-$6.00 per hour on average, to upwards of $9.00 per hour. Some loggers in Montana and Idaho reported upwards of 78% of the base wage paid in worker's compensation insurance. In a ranking of state-level WC rates, Montana ranks eighth highest in the nation (Dotter and Manly 2012). This operating cost is highly influential and has led to an interesting workforce dynamic of subcontracting out work to avoid paying this insurance. There are signs that the situation is improving based on declining rates over the past 10 years, a decline that is based largely on increased safety measures in logging equipment such as enclosed cabs and seatbelt usage and a transition from conventional to mechanized operations. Further, there has been a notable shift in the "safety culture" of the logging industry with greater use of hard hats, saw chaps, radios and cellphones, as well as the addition of the formalized Montana Logging Association Safety Ranger program. Though WC rates have decreased on average, they still remain a significant cost and are costs that can be mitigated at the business level.

Imminent changes in Federal health care policies, via the Affordable Care Act (ACA), might further increase labor benefit costs though the exact impacts are currently unknown. Logging business owners in Montana will likely avoid having to pay health insurance for their employees as most employ fewer than 50 people, thus waiving the ACA requirement to provide health insurance. Regardless of the number of employees, a business that does offer insurance might find ways to minimize health care costs by trimming employees, raising deductibles, or taking other cost-saving measures. Individuals currently without insurance will be required to purchase their own insurance, thus reducing immediate personal profits. While health care costs are both significant and unknown, there might be a non-monetary benefit to offering health insurance by way of maintaining employee loyalty.

Ultimately, there isn't a business sector that exists that doesn't experience cost and price volatility as a result of market conditions, resource and labor availability, and the myriad of other variables inherent to remaining in operation. Yet for Montana's logging sector this inherent volatility does appear to be increasing. This creates a challenge, and an opportunity, to remain educated, innovative, and productive in the face of economic uncertainty. Close examination of the important influences and factors that affect the industry will become all the more necessary for the industry's viability, both within the state and from other timber producing regions of the U.S.

Conclusion

Montana's logging industry is still crucial to the state's economy and plays a pivotal role in mitigating forest health issues, assisting in wildland fire suppression, and providing sustainable wood products despite numerous challenges and changes. Continued industry viability depends on the hard work, innovation, and vigilance of logging contractors in the face of decreasing profit margins, increasing costs, and uncertainties of a changing forest management paradigm. The goals of this research were to provide estimated machine costs for commonly-utilized ground-based logging equipment in Montana, to provide an estimated price per unit volume based on expert opinion, and to investigate the reasons for change in costs over a twenty year period. Each of these objectives was intended to meet the ultimate objective of providing a resource to Montana's logging industry to assist in continued viability by offering a tool to inform bidding or pricing, a way to compare fixed and variable costs when considering purchasing new logging equipment, a tool for those without specific cost data (such as foresters, mills, and/or newcomers to the field looking at entry costs), and an explanation for increased costs. Ultimately, Montana's logging industry has survived through economic ups-and-downs on its own merit. Constant consideration of operating costs and productivity will become increasingly critical to maintaining current infrastructure and helping to ensure that this vital industry is retained in the state.

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Appendix 1-Machine Data and Specifications

Machine Number	Equip. Type	Brand	Model	Track or Tire	Weight (lbs)	HP	Diesel gal/hour	Purchase Price
1	Feller-Buncher	John Deere	759J	Track	60060	241	6.35	$ 583,736
2	Feller-Buncher	Cat	511	Track	53710	247	6.50	$ 320,270
3	Feller-Buncher	Cat	521	Track	59710	284	7.48	$ 482,660
4	Feller-Buncher	Cat	522B	Track	67040	284	7.48	$ 387,110
5	Feller-Buncher	Timbco	XT445L-2	Track	67055	300	7.90	$ 532,341
6	Feller-Buncher	Timbco	XT430L-2	Track	61035	300	7.90	$ 470,091
7	Feller-Buncher	TimberPro	TL735B	Track	59680	300	7.90	$ 503,443
8	Feller-Buncher	Cat	541	Track	66560	305	8.03	$ 414,000
9	Feller-Buncher	Cat	552	Track	78660	305	8.03	$ 513,530
10	Feller-Buncher	Cat	551	Track	68468	308	8.11	$ 465,110
11	Feller-Buncher	Tigercat	LX 830	Track	80000	300	7.90	$ 500,000
12	Skidder	Cat	535C	Tire	39780	152	4.43	$ 292,562
13	Skidder	Cat	545C	Tire	42325	219	6.39	$ 325,155
14	Skidder	John Deere	848H Grapple	Tire		200	5.83	$ 369,444
15	Skidder	Tigercat	620D	Tire		220	6.42	$ 285,000
16	Skidder	Cat	527 GR	Track		150	4.38	$ 405,218
17	Processor	Timbco					5.5	$ 435,000
18	Processor	John Deere	2454D Logger	Track	31218	194	5.66	$ 428,179
19	Processor	Komatsu	PC210LC-10	Track	51419	160	4.67	$ 417,000
20	Processor	Pierce	Titan 22	Track	31218	194	5.66	$ 393,000
21	Processor	Pierce	Titan 23	Track	31218	194	5.66	$ 410,514
22	Processor	Komatsu	PC290LC-1	Track		213	6.21	$ 540,000
23	Slide Boom Delimber	Denharco	DT 4150	Track	31218	194	5.66	$ 459,364
24	Slide Boom Delimber	Denharco	DM 4150	Track	31218	194	5.66	$ 442,853
25	Slide Boom Delimber	Pierce	PTD2856	Track	31218	194	5.66	$ 521,214
26	Grapple Processor	Pierce	GP	Track	31218	194	5.66	$ 398,000
27	Loader	Timbco					5.2	$ 326,000
28	Loader	John Deere	2154D Logger	Track	26660	159	3.44	$ 371,766
29	Loader	Doosan	DX 225 LL	Track	65035	155	3.36	$ 218,998
30	Loader	Komatsu	PC210LC-10	Track	51419	160	3.47	$ 325,000
31	Loader	Cat	320D FM	Track	59315	157	3.40	$ 257,294
32	Loader	Cat	325D FM	Track	73478	204	4.42	$ 351,055
33	Loader	Cat	330D FM	Track	91344	268	5.80	$ 392,310
34	Loader	Cat	324D	Track	68853	188	4.07	$ 394,885

Appendix 2-Machine Rate Input Parameters

Machine Number	Equip. Type	Brand	Model	Life (Year)	Salvage Value	Utilization	Repair and Maint.	Interest Rate	Insurance Rate	Taxes	Fuel Use Rate	Fuel $/Gal.	Lube & Oil Rate
1	Feller-Buncher	John Deere	759J	5	15%	60%	75%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
2	Feller-Buncher	Cat	511	5	15%	60%	75%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
3	Feller-Buncher	Cat	521	5	15%	60%	75%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
4	Feller-Buncher	Cat	522B	5	15%	60%	75%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
5	Feller-Buncher	Timbco	XT445L-2	5	15%	60%	75%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
6	Feller-Buncher	Timbco	XT430L-2	5	15%	60%	75%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
7	Feller-Buncher	TimberPro	TL735B	5	15%	60%	75%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
8	Feller-Buncher	Cat	541	5	15%	60%	75%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
9	Feller-Buncher	Cat	552	5	15%	60%	75%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
10	Feller-Buncher	Cat	551	5	15%	60%	75%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
11	Feller-Buncher	Tigercat	LX 830	5	15%	60%	75%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
12	Skidder	Cat	535C	5	15%	65%	90%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
13	Skidder	Cat	545C	5	15%	65%	90%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
14	Skidder	John Deere	848H Grapple	5	15%	65%	90%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
15	Skidder	Tigercat	620D	5	15%	65%	90%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
16	Skidder	Cat	527 GR	5	15%	65%	90%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
17	Processor	Timbco		5	20%	90%	100%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
18	Processor	John Deere	2454D Logger	5	20%	90%	100%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
19	Processor	Komatsu	PC210LC-10	5	20%	90%	100%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
20	Processor	Pierce	Titan 22	5	20%	90%	100%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
21	Processor	Pierce	Titan 23	5	20%	90%	100%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
22	Processor	Komatsu	PC290LC-1	5	20%	90%	100%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
23	Slide Boom Delimber	Denharco	DT 4150	5	20%	90%	100%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
24	Slide Boom Delimber	Denharco	DM 4150	5	20%	90%	100%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
25	Slide Boom Delimber	Pierce	PTD2856	5	20%	90%	100%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%

26	Grapple Processor	Pierce	GP	5	20%	90%	100%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
27	Loader	Timbco		5	30%	65%	90%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
28	Loader	John Deere	2154D Logger	5	30%	65%	90%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
29	Loader	Doosan	DX 225 LL	5	30%	65%	90%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
30	Loader	Komatsu	PC210LC-10	5	30%	65%	90%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
31	Loader	Cat	320D FM	5	30%	65%	90%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
32	Loader	Cat	325D FM	5	30%	65%	90%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
33	Loader	Cat	330D Fm	5	30%	65%	90%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%
34	Loader	Cat	324D	5	30%	65%	90%	6.5%	1.3%	2%	2.633%	$ 3.50	36.8%

Appendix 3-Fixed Costs

Machine Number	Equip. Type	Brand	Model	Salvage Value	Annual Depreciation	Annual Interest	Annual Taxes	Annual Equipment Insurance	Annual Loggers Broad Form Insurance	Fixed Cost/Year	Fixed Cost/SMH	Fixed Cost/PMH
							$					
1	Feller-Buncher	John Deere	759J	87560	99235	25042	7705	4553	1000	137536	80.43	134.05
2	Feller-Buncher	Cat	511	48041	54446	13740	4228	2498	1000	75911	44.39	71.55
3	Feller-Buncher	Cat	521	72399	82052	20706	6371	3765	1000	113894	66.60	107.34
4	Feller-Buncher	Cat	522B	58067	65809	16607	5110	3019	1000	91545	53.54	86.28
5	Feller-Buncher	Timbco	XT445L-2	79851	90498	22837	7027	4152	1000	125515	73.40	118.29
6	Feller-Buncher	Timbco	XT430L-2	70514	79915	20167	6205	3667	1000	110954	64.89	104.57
7	Feller-Buncher	TimberPro	TL735B	75516	85585	21598	6645	3927	1000	118755	69.45	111.92
8	Feller-Buncher	Cat	541	62100	70380	17761	5465	3229	1000	97835	57.21	92.21
9	Feller-Buncher	Cat	552	77030	87300	22030	6779	4006	1000	121115	70.83	114.14
10	Feller-Buncher	Cat	551	69767	79069	19953	6139	3628	1000	109789	64.20	103.47
11	Feller-Buncher	Tigercat	LX 830	75000	85000	21450	6600	3900	1000	117950	68.98	111.16
12	Skidder	Cat	535C	43884	49736	12551	3862	2282	1000	69430	40.60	62.47
13	Skidder	Cat	545C	48773	55276	13949	4292	2536	1000	77054	45.06	69.32
14	Skidder	John Deere	848H Grapple	55417	62805	15849	4877	2882	1000	87413	51.12	78.64
15	Skidder	Tigercat	620D	42750	48450	12227	3762	2223	1000	67662	39.57	60.87
16	Skidder	Cat	527 GR	60783	68887	17384	5349	3161	1000	95780	56.01	86.17
17	Processor	Timbco		87000	69600	19227	5916	3393	1000	99136	57.97	64.42
18	Processor	John Deere	2454D Logger	85636	68509	18926	5823	3340	1000	97597	57.07	63.42
19	Processor	Komatsu	PC210LC-10	83400	66720	18431	5671	3253	1000	95075	55.60	61.78
20	Processor	Pierce	Titan 22	78600	62880	17371	5345	3065	1000	89661	52.43	58.26
21	Processor	Pierce	Titan 23	82103	65682	18145	5583	3202	1000	93612	54.74	60.83
22	Processor	Komatsu	PC290LC-1	108000	86400	23868	7344	4212	1000	122824	71.83	79.81
23	Slide Boom Delimber	Denharco	DT 4150	91873	73498	20304	6247	3583	1000	104633	61.19	67.99
24	Slide Boom Delimber	Denharco	DM 4150	88571	70856	19574	6023	3454	1000	100908	59.01	65.57
25	Slide Boom Delimber	Pierce	PTD2856	104243	83394	23038	7089	4065	1000	118586	69.35	77.05

							$					
26	Grapple Processor	Pierce	GP	79600	63680	17592	5413	3104	1000	90789	53.09	58.99
27	Loader	Timbco		97800	45640	15257	4694	2543	1000	69134	40.43	62.20
28	Loader	John Deere	2154D Logger	111530	52047	17399	5353	2900	1000	78699	46.02	70.80
29	Loader	Doosan	DX 225 LL	65699	30660	10249	3154	1708	1000	46771	27.35	42.08
30	Loader	Komatsu	PC210LC-10	97500	45500	15210	4680	2535	1000	68925	40.31	62.01
31	Loader	Cat	320D FM	77188	36021	12041	3705	2007	1000	54774	32.03	49.28
32	Loader	Cat	325D FM	105317	49148	16429	5055	2738	1000	74370	43.49	66.91
33	Loader	Cat	330D Fm	117693	54923	18360	5649	3060	1000	82993	48.53	74.67
34	Loader	Cat	324D	118466	55284	18481	5686	3080	1000	83531	48.85	75.15

Appendix 4-Variable Costs

Machine Number	Equip. Type	Brand	Model	Fuel $/PMH	L&O $/PMH	R&M $/PMH	Variable Cost/PMH	Variable Cost/SMH
						$		
1	Feller-Buncher	John Deere	759J	22.21	8.17	72.54	102.92	61.75
2	Feller-Buncher	Cat	511	22.76	8.37	39.80	70.93	42.56
3	Feller-Buncher	Cat	521	26.17	9.62	59.98	95.78	57.47
4	Feller-Buncher	Cat	522B	26.17	9.62	48.11	83.90	50.34
5	Feller-Buncher	Timbco	XT445L-2	27.65	10.17	66.15	103.97	62.38
6	Feller-Buncher	Timbco	XT430L-2	27.65	10.17	58.42	96.23	57.74
7	Feller-Buncher	TimberPro	TL735B	27.65	10.17	62.56	100.37	60.22
8	Feller-Buncher	Cat	541	28.11	10.34	51.45	89.89	53.93
9	Feller-Buncher	Cat	552	28.11	10.34	63.82	102.26	61.35
10	Feller-Buncher	Cat	551	28.38	10.44	57.80	96.62	57.97
11	Feller-Buncher	Tigercat	LX 830	27.65	10.17	62.13	99.95	59.97
12	Skidder	Cat	535C	15.52	5.71	40.27	61.50	39.97
13	Skidder	Cat	545C	22.36	8.22	44.76	75.34	48.97
14	Skidder	John Deere	848H Grapple	20.42	7.51	50.85	78.78	51.21
15	Skidder	Tigercat	620D	22.46	8.26	39.23	69.95	45.47
16	Skidder	Cat	527 GR	15.31	5.63	55.78	76.72	49.87
17	Processor	Timbco		19.25	7.08	45.22	71.55	64.40
18	Processor	John Deere	2454D Logger	19.81	7.28	44.52	71.60	64.44
19	Processor	Komatsu	PC210LC-10	16.34	6.01	43.35	65.69	59.13
20	Processor	Pierce	Titan 22	19.81	7.28	40.86	67.95	61.15
21	Processor	Pierce	Titan 23	19.81	7.28	42.68	69.77	62.79
22	Processor	Komatsu	PC290LC-1	21.75	8.00	56.14	85.88	77.29
23	Slide Boom Delimber	Denharco	DT 4150	19.81	7.28	47.76	74.85	67.36
24	Slide Boom Delimber	Denharco	DM 4150	19.81	7.28	46.04	73.13	65.82
25	Slide Boom Delimber	Pierce	PTD2856	19.81	7.28	54.19	81.28	73.15
26	Grapple Processor	Pierce	GP	19.81	7.28	41.38	68.47	61.62
27	Loader	Timbco		18.20	6.69	36.96	61.85	40.20
28	Loader	John Deere	2154D Logger	12.05	4.43	42.14	58.63	38.11
29	Loader	Doosan	DX 225 LL	11.75	4.32	24.83	40.90	26.58
30	Loader	Komatsu	PC210LC-10	12.13	4.46	36.84	53.43	34.73
31	Loader	Cat	320D FM	11.90	4.38	29.17	45.45	29.54
32	Loader	Cat	325D FM	15.47	5.69	39.80	60.95	39.62
33	Loader	Cat	330D Fm	20.32	7.47	44.47	72.26	46.97
34	Loader	Cat	324D	14.25	5.24	44.76	64.26	41.77

Appendix 5-Logging Cost Estimation Resources

- WSRI Stump to Mill Cost Program: https://fp.auburn.edu/auforestops/stomp/
- Virginia Tech-Logging Cost Analyses: http://web1.cnre.vt.edu/harvestingsystems/Costing.htm
    - Includes Auburn Harvest Analyzer
- US Forest Service-Region 6 Logging Cost Tools: ftp://ftp2.fs.fed.us/incoming/r6/ro/toupin/Programs/
- Mitch Lansky-Northeastern US Logging Cost Calculator: www.meepi.org/lif/costs.doc
- Harry Lee and Leonard Johnson-"Cost of Timber Removal under Ecosystem Management" (contains cost modifiers for slope, volume per acre, tree size etc… specific to the Inland Northwest)