An Applied Hardwood Value Recovery Study in the Appalachian Region of Virginia and West Virginia

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ABSTRACT

An analysis of log-making (bucking) performance for five logging crews in southern Appalachian mixed-hardwood stands of Virginia and West Virginia was conducted. Cutting accuracy and value recovery were analyzed and compared to an optimal solution that was determined through the use of the *HW-BUCK* computer software. In total 148 trees were bucked into 510 logs and only 11 percent were cut accurately. Fifteen percent were under cut and 74 percent were over length. The crew with the best performance in length cutting accuracy also recorded the lowest value recovery loss. An average value loss of 20.7 percent was calculated for all five crews.

Keywords: *Value recovery, merchandizing, log making, bucking, southern Appalachian mixed hardwoods, logging, Quercus, Acer, Prunus, Liriodendron, Tilia, United States.*

INTRODUCTION

Value recovery in forestry operations implies maximizing the value of the raw materials through the production chain. An area with potential for minimizing value loss in the stump to mill supply chain is log manufacturing [2, 3]. Value can be recovered through the optimal bucking of trees; the stem is cut into logs that maximize the total tree value according to the decision-makers objectives [11]. The optimization of log value is dependent on numerous factors; however the bucker's ability to determine the optimal cut and his precision in making the cut influences value loss within the industrial forest supply chain.

Studies on softwood bucking practices in the US Pacific Northwest and New Zealand determined value loss ranged between 5 to 26 percent [5, 12, and 13]. Similar studies on hardwood bucking practices in the Upper Peninsula of Michigan revealed that value loss ranged between 39 to 55 percent [9].

The objective of this case study was to determine the value lost due to poor bucking decisions in southern Appalachian hardwood stands. For privacy reasons the company selected will remain anonymous; the five independent harvesting contractors has been labeled A through E.

METHODS

During the months of June and July of 2002 value recovery data was collected from five independent logging contractor crews in the Appalachian region of Virginia and West Virginia. All crews used a hydraulic saw-bunk for bucking. The operator of the trailer-mounted loader placed the stem in the saw-bunk and determined the intended log length using a metal rack indicating either 0.6 or 1.2 meter [2 or 4 foot] spacing intervals (Figure 1). All operators studied were experienced and one crew manually pre-marked the stems prior to bucking. Crews A and B supplied the same mill, crews C and D supplied another and crew E supplied a third mill (Table 1).

Descriptive data was collected for 148 trees. The trees sampled included American Basswood (*Tilia americana*), Black Cherry (*Prunus serotina*), Chestnut Oak (*Quercus prinus*), Red (Soft) Maple (*Acer rubrum*), Northern Red Oak (*Quercus rubra*), Sugar (Hard) Maple (*Acer saccharum*), White Oak (*Quercus alba*), and Yellow Poplar (*Liriodendron tulipifera*). Only trees with potential to produce veneer or sawlogs were included in the sample. Stem shape and defect data were collected before the trees were bucked, and the bucking decisions (cuts) made by the bucker were recorded. Post-bucking data was collected at the landing once the log-maker had completed merchandizing the tree. No attempt was made to grade, scale or value the bucker-produced logs in the field. Instead the bucker solutions were assessed according to the *HW-BUCK* optimization procedure.

Shape Data

Shape data were collected simultaneously with defect data. Under normal operational conditions the entire tree would have been skidded to the landing, where it would have been topped and bucked into logs. Due to the quantitative nature of the data, and the need to determine the sweep of the more valuable timber, the trees were topped at 250 – 300 mm [10-12 in.] so offset templates could be attached to both ends of the stem.

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Figure 1. Loader with saw-bunk and measuring rack.

Table 1: Bucker operator description.

Bucker	Mill	Experience (years)	Loader operated hydraulic bucking saw system	Rack spacing m [ft.]	Premarking
A	1	10-15	✓	1.2 [4]	
B	1	5-10	✓	0.6 [2]	
C	2	15-20	✓	1.2 [4]	
D	2	15-20	✓	1.2 [4]	✓

Diameter and sweep measurements were taken along the tree length. Measurements were taken where one or both of these features abruptly changed, or at 0.9 - 1.2 m [3 - 4 ft.] intervals, whichever was less. Sweep was measured relative to a straight line running from the center of the ends of the tree. Using both the vertical and horizontal offset reference lines, deviations of the tree's central axis from this line was measured. Sweep data points were measured at the same point as diameter measurements. The diameter at each interval was measured twice using a caliper, including both large and small diameter measurements where possible.

The method used to collect the shape data did not include bark thickness measurements. To remedy the situation, inside bark is determined as [6]:

$$D_{ib} = D_{ob} * (DBH_{ib}/DBH_{ob}) \quad (1)$$

Where: D_{ib} = diameter inside bark
D_{ob} = diameter outside bark
DBH_{ib} = diameter at breast height inside bark
DBH_{ob} = diameter at breast height outside bark

The average DBH_{ib}/ DBH_{ob} ratios for Appalachian hardwood species [6] was used to calculate the estimated diameter inside bark. Bark thickness was determined as:

$$\text{Bark thickness} = (\text{Observed } D_{ob} - \text{Estimated } D_{ib})/2 \quad (2)$$

Defect Data

The parameters used to describe the individual defects are summarized (Table 2) and the data was recorded manually. A fixed reference point (butt-end) was used when determining the orientation of a defect; the clockwise angle was relative to the data recorder working from the butt-end towards the top-end of the tree.

Table 2: Data parameters for individual defects.

Defect	Parameters	Units
Knot, burl, scar	• Distance of defect from tree butt;	feet
	• Clockwise angle of defect center from the upper surface of the stem;	degrees
	• Defect length;	inches
	• Defect width.	inches
Seam, split	• Distance of start of defect from tree butt;	feet
	• Clockwise angle of start of defect from the upper surface of the stem;	degrees
	• Distance of end of defect from tree butt;	feet
	• Clockwise angle of end of defect from upper surface of the stem.	degrees
Fork, bulge	• Distance of start of defect from tree butt;	feet
	• Distance of end of defect from tree butt.	feet
Decay, stain, heart	• Distance of start of defect from tree butt;	feet
	• Distance of end of defect from tree butt;	feet
	• Defect diameter at start;	inches
	• Defect diameter at end.	inches

Post-Bucking Data

Post-bucking data included collecting the length and small-end diameter of each log. The position of the log in relation to the tree was noted. Co-operation of the bucker during this final phase was critical for the accurate and safe collection of information.

Optimization

A one-stage decision simulator designed to maximize the value of an individual tree, *HW-BUCK*, was used in this analysis. *HW-BUCK*, primarily developed for northern hardwoods, is limited to evaluating stems not longer than 15 m [50 ft.] with a maximum large end diameter of 75 cm [30 in.]. It uses a bucking optimization model that does not include demand-constraints [8]. The general absence of demand-constraints for particular northern hardwood log grades, and the sensitivity of northern hardwood grades to the spatial arrangement of defects, were the main reasons why the one-stage modeling approach was applied.

HW-BUCK uses dynamic programming to select the optimal sequence of the bucking decision. Optimization is a process whereby all possible combinations of logs and cull sections are evaluated. This evaluation determines the sequence of cuts that produces the highest monetary value [9].

HW-BUCK is useful not only from a research perspective [9], where the amount of value recovered from the tree can be optimized, but also from an educational perspective. It can be used as a training tool to develop operator heuristics so that bucking skills can be improved [10].

VALUE ESTIMATION

Two *HW-BUCK* limitations have a direct influence on the value ascribed to manufactured logs. It has only been designed to accommodate International ¼ inch and Scribner Decimal C Log Rules, and secondly there is capacity for only three saw-log grades. To overcome these limitations, the US dollar per thousand board feet (MBF) Doyle Log Rule price used by the mills was modified so a more realistic log value could be analyzed.

Scribner Decimal C Value Estimation

Doyle and Scribner Decimal C are log rules that estimates the sawn outturn from a log based on its small-end diameter and length. Doyle [14] and Scribner Decimal C [15] Log Rule tables were used to develop conversion factors for average volumes so that prices per Doyle MBF could be adjusted to realistic price per Scribner Decimal C MBF. A ratio (Doyle: Scribner Decimal C) for each expected log diameter and log length class was developed. This ratio was then multiplied by the price per Doyle MBF value as presented by the Company. The above-mentioned formula is based on the assumption that the Scribner Decimal C overestimates volume in logs with a diameter inside bark of 254 to 635 mm [10 – 25 in.] [1]. This methodology makes intuitive sense, because using this formula, the price per Doyle Log Rule MBF is higher than the price per Scribner Decimal C (Tables 3-5).

In order to present the data in a universal measurement unit Scribner Decimal C log rule has been further converted to cubic meters [4] (Table 3-5).

Saw-log Grade Value Estimation

All three mills had more than three saw-log grades; however these grades were based on length and diameter of the log rather than the quality of the logs. In order to simplify the pricing matrix of these three mills, the average price for each major grade per species: Prime grade,

Table 3. Mill 1's modified Open Market Log Prices. Prices in US dollars per cubic meter [dollars per MBF, Scribner] (March 17, 2002).

Species	Veneer 1	Veneer 2	Prime Grade	Clear Grade	Select and Mill Grade
Am. Basswood	-	-	57 [293]	43 [259]	16 [117]
Cherry	597 [2700]	497 [2250]	211 [1075]	158 [945]	52 [391]
Chestnut Oak	-	-	64 [325]	41 [248]	17 [124]
Red Maple	-	-	100 [453]	67 [405]	21 [154]
Red Oak	212 [960]	-	147 [665]	102 [608]	25 [184]
Sugar Maple	354 [1600]	265 [1200]	139 [710]	113 [675]	27 [204]
White Oak	-	-	80 [410]	45 [270]	17 [124]
Yellow Poplar	-	-	59 [303]	43 [259]	18 [134]

Table 4. Mill 2's modified Open Market Log Prices. All prices in US dollars per cubic meter [dollars per MBF, Scribner] (March 26, 2001).

Species	Veneer 1	Veneer 2	Prime Grade 14'-16'	Prime Grade 8'-12'	Clear Grade 14'16'	Clear Grade 8'-12'	Select and Mill Grade
Am. Basswood	-	-	82 [420]	73 [374]	54 [324]	45 [267]	16 [123]
Cherry	895 [4050]	696 [3150]	347 [1769]	313 [1599]	230 [1380]	204 [1219]	86 [641]
Chestnut Oak	-	-	61 [310]	53 [268]	32 [193]	26 [155]	12 [86]
White Oak	199 [900]	124 [560]	70 [355]	57 [290]	39 [231]	31 [183]	13 [99]
Red Oak	230 [1040]	194 [880]	153 [779]	138 [704]	100 [596]	89 [533]	40 [301]
Red Maple	-	-	92 [470]	75 [385]	57 [343]	48 [285]	27 [200]
Sugar Maple	318 [1440]	248 [1120]	234 [1195]	201 [1025]	147 [888]	127 [758]	57 [429]
Yellow Poplar	-	-	58 [262]	40 [204]	28 [167]	20 [119]	72 [54]

Table 5. Mill 3's modified Open Market Log Prices. All prices in US dollars per cubic meter [dollars per MBF, Scribner] (May 29, 2001).

	Veneer 1	Prime Grade 14'-16'	Prime Grade 8'-12'	Clear Grade 14'-16'	Clear Grade 8'-12'	Select and Mill Grade
Am. Basswood	-	82 [420]	73 [374]	54 [324]	45 [267]	17 [126]
Cherry	646 [2925]	351 [1790]	318 [1620]	244 [1461]	224 [1343]	113 [841]
Chestnut Oak	-	61 [310]	53 [268]	32 [193]	26 [155]	12 [86]
Red Maple	-	92 [470]	75 [385]	57 [343]	47.6 [285]	30 [221]
Red Oak	212 [960]	159 [810]	144 [735]	107 [639]	96 [575]	50 [373]
Sugar Maple	309 [1440]	234 [1195]	201 [1025]	147 [888]	127 [758]	63 [469]
White Oak	199 [900]	70 [355]	57 [290]	39 [231]	31 [183]	13 [99]
Yellow Poplar	-	71 [364]	59 [300]	44 [265]	35 [208]	134 [113]

Clear Grade and Mill/Select grade were determined. This manipulation of the price information allowed for the use of *HW-BUCK*, despite its limitation, and allows a more realistic pricing outcome once the optimization values are generated (Table 3-5).

The Company sawmills specification sheets clearly state that logs with less than four inches trim will be reduced to the next lower acceptable length. For this study a tolerance of 38 mm [1.5 in.] above the trimming allowance was set. All logs cuts below the trimming allowance were defined as 'under cut' logs, all logs cut between the trim allowance and the tolerance limit of 38 mm [1.5 in.] were defined as 'perfect' and logs cut above this tolerance limit were defined as 'over cut'. All bucking cuts for the 148 stems were measured to within 3 mm [1/8 in.]. Out of those 148 trees, 510 logs were manufactured.

RESULTS AND DISCUSSION

Cutting Accuracy

Accurate cutting is critical for optimal performance of the logger. Accurate cutting directly impacts the value recovered from the timber being harvested and directly impacts the value recovered by the sawmill and the company as a whole. Table 6 indicates that an average of 15 percent of the logs manufactured by the five logging companies studied were under cut. The value of the under cut logs is not fully realized because under-cut logs are sold in the next lower log length category and paid for according to that reduced length. In addition, 74 percent of the logs were over cut and opportunity was lost.

Table 6 shows the summary statistics for the bucking length accuracy part of this study. Bucker C and bucker E had the lowest under cut percentages and performed to a higher standard of bucking accuracy. Their standard deviation from the absolute target was 91mm [3.6 in.]. This means that 68 percent of the time they were within 91mm [3.6 in.] of the absolute target cut – defined as a cut with a trim allowance of 102 mm [4 in.] for every log. Bucker B had the highest under cut percentage at 23%, and the largest standard deviation for accuracy, 142 mm [5.6 in.].

Value Recovery

To estimate the value loss from the five logging crews a comparison was made between the observed buckers decision and the *HW-BUCK* optimal solutions. Of the 148 trees measured only 145 met the dimension and shape requirements of the *HW-BUCK* optimizer. The three trees that could not be optimized by *HW-BUCK* were all Yellow Poplar trees that had large end diameters that exceeded the maximum allowable 75 cm [30 in.].

The net-volume distribution of the bucker-produced logs and *HW-BUCK* generated optimal logs (Table 7) indicates the optimizer captures more utilizable volume, and shifts the volume distribution toward high value log classes (veneer and prime logs). *HW-BUCK* identified 22.9 m^3 [4.4 MBF] more utilizable higher value timber than the buckers. Fifty-one percent more veneer log volume (which is the most valuable log class) is produced by the optimizer,. In the prime log class, there is a 36 percent volume increase over the bucker-produced logs. In the clear log class there was an 8 percent increase in volume by the optimal solution. It is interesting to note that there was a critical shift in the volume allocation that occurred in this log class. The optimal solution allocated more volume to the higher valued longwood (Clear no. 1) with an increase of 60 percent and a 32 percent decrease in volume for the shortwood (Clear no. 2). The optimizer also had 32 percent [44% using MBF scale] less volume allocated to the lowest valued saw lumber (select and mill).

Table 6. Summary statistics for the five buckers that were investigated.

Summary Statistics	Bucker A	Bucker B	Bucker C	Bucker D	Bucker E
No. of trees bucked	30	29	28	28	33
No. of logs made	87	91	109	110	113
Avg. no. of logs/tree	2.9	3.1	3.9	3.9	3.4
Minimum (mm [in.])	-302 [-11.9]	-257 [-10.1]	-267 [-10.5]	-292 [-11.5]	-279 [-11.0]
Maximum (mm [in.])	299 [11.8]	290 [11.4]	257 [10.1]	191 [7.5]	262 [10.3]
Range (mm [in.])	599 [23.6]	546 [21.5]	523 [20.6]	483 [19.0]	541 [21.3]
Std. Deviation	119 [4.7]	142 [5.6]	91 [3.6]	102 [4.0]	91 [3.6]
% perfect logs	9	5	19	10	10
% under cut logs	17	23	12	20	5
% over cut logs	74	72	69	70	85

Table 7. Net volume distribution of bucker and optimal solutions -- cubic meter {Scribner Decimal C log board feet = 10 bf].

Log Length	Solution	Veneer 1	Veneer 2	Prime 1	Prime 2	Clear 1	Clear 2	Select & Mill	Grand Total
8' (2.4m)	*Bucker*	6.6 [144]			2.9 [58]		14.9 [310]	13.4 [267]	37.8 [779]
	Optimal	10.9 [236]			8.3 [172]		27.4 [571]	14.9 [286]	61.5 [1265]
10' (3m)	*Bucker*	10.9 [237]	0.4 [7]		2.8 [58]		16.8 [351]	12.5 [251]	43.4 [904]
	Optimal	24.1 [518]	2.1 [41]		2.9 [58]		7.6 [160]	17.9 [337]	54.6 [1114]
12' (3.6m)	*Bucker*	2.2 [48]			4.0 [82]		39.0 [826]	16.7 [330]	61.9 [1286]
	Optimal	4.2 [92]			5.2 [108]		18.6 [382]	3.7 [75]	31.7 [657]
14' (4.3m)	*Bucker*			1.8 [38]		7.9 [164]		7.5 [147]	17.2 [349]
	Optimal			2.1 [44]		17.3 [355]		2.8 [54]	22.2 [453]
16' (4.9m)	*Bucker*			0.6 [11]		8.7 [174]		11.2 [210]	20.5 [395]
	Optimal			0.5 [10]		24.2 [497]		9.0 [158]	33.7 [665]
Grand Total	*Bucker*	19.7 [429]	0.4 [7]	2.4 [49]	9.7 [198]	16.6 [338]	70.7 [1487]	61.3 [1205]	180.8 [3713]
	Optimal	39.2 [846]	2.1 [41]	2.6 [54]	16.4 [338]	41.5 [852]	53.6 [1113]	48.3 [910]	203.7 [4154]
Share (%)	*Bucker*	10.9 [11.6]	0.2 [0.2]	1.3 [1.3]	5.4 [5.3]	9.2 [9.1]	39.1 [40.0]	34.0 [32.5]	100
	Optimal	19.3 [20.4]	0.8 [1.0]	1.3 [1.3]	8.1 [8.1]	20.4 [20.5]	26.1 [26.8]	23.7 [21.9]	100

The actual absolute value lost ranged from $410 for the crew B bucking primarily Yellow Poplar, up to $3300 for crew E working primarily with Cherry, based on the sample of 29 and 33 stems respectively. A more useful way of presenting and comparing this is in terms of overall percent value lost. This value loss is calculated as [7]:

$$\frac{100 * (\text{optimal solution (\$)} - \text{buckers' solution (\$)})}{\text{optimal solution (\$)}} \quad (3)$$

The value lost by the buckers' investigated in this study ranged between 17 to 35 percent (Figure 2). The average value loss for all five logging crews of 20.7 percent.

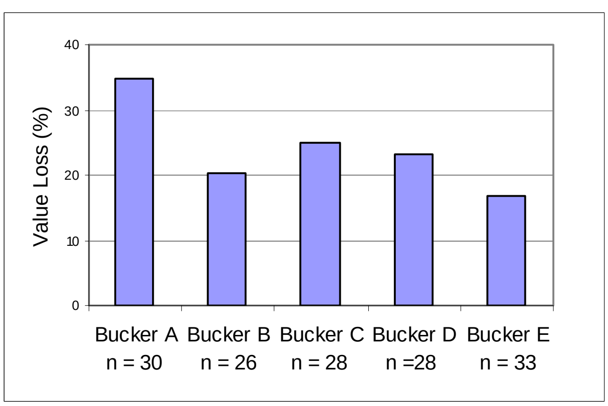

Figure 2. Average bucker value loss based on current open market log prices presented in Tables 3, 4, and 5.

In comparison, studies on hardwood bucking practices in the Upper Peninsula of Michigan showed value loss ranged between 39 to 55 percent [9]. Studies on softwood bucking practices in the US Pacific Northwest and New Zealand determined value loss ranged between 5 to 26 percent [5, 12, and 13].

Crew E, which had the highest absolute value loss also had the lowest percent value loss. Crew E bucked 29 out of 30 black cherry stems and black cherry is the most valuable species in the region. The value loss distribution among the tree species bucked was calculated (Table 8).

Table 8. Average value loss based on current open market log prices presented in Tables 3, 4 and 5.

Species	N	Optimal ($)	Bucker ($)	Loss (%)
Am. Basswood	4	342	266	22.3
Black Cherry	30	17933	14914	16.8
Chest. Oak	9	357	226	36.5
Red Maple	6	500	391	21.8
Red oak	42	8989	6653	26.0
Sugar Maple	21	4329	3394	21.6
White Oak	9	607	431	29.0
Yellow Poplar	24	1217	911	25.1
Grand Total	145	34273	27185	20.7

CONCLUSION

The opportunity for improvement in value recovery in the southern Appalachian hardwood logging industry is similar to the opportunity that exists in the hardwood logging operations of the Upper Peninsula of Michigan. A case study on hardwood bucking practices in this region revealed that the value loss ranged between 39 to 55 percent [9]. The value loss percentages of the buckers investigated in this study showed a range of 17 percent to 35 percent (Figure 2).

Further research should be conducted to determine and test methods of value recovery performance improvement in industrial Appalachian mountain hardwood harvesting operations. This could include studying the benefits of operator training or having a dedicated trained logmaker on deck.

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