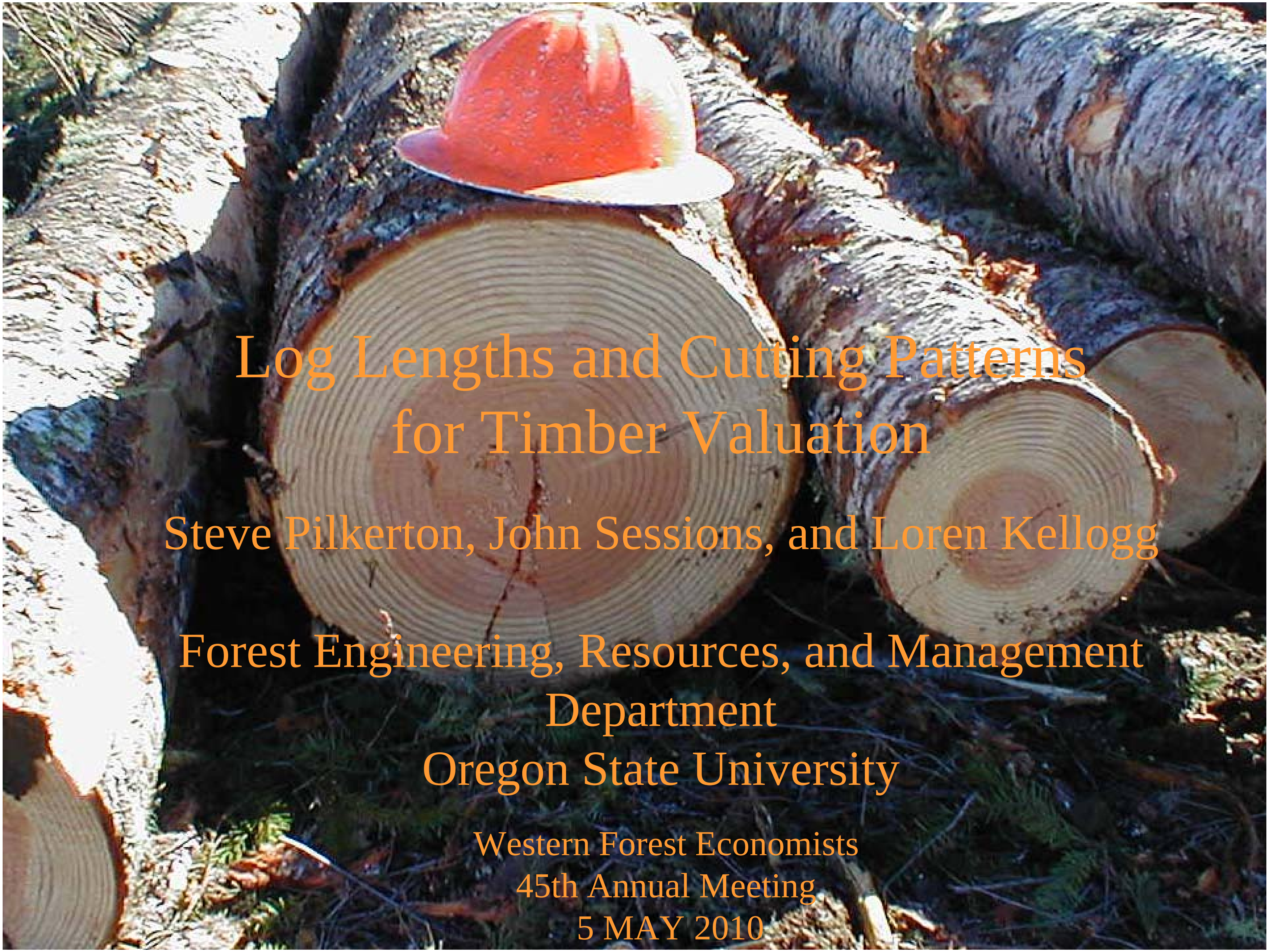

Log Lengths and Cutting Patterns for Timber Valuation

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Western Forest Economists
45th Annual Meeting
5 MAY 2010

Introduction

- Two important issues related to thinning harvests on steep slopes in Douglas-fir forests requiring log length bucking:
  - Log length influence on bucking values and revenue improvement
  - Bucking patterns, optimal value with log allocation constraint, and development of a simple bucking decision tool

Introduction

- Log length influence on bucking values and revenue improvement
  - Sue Willits, USFS-PNW Res. Station, Forest Inventory and Analysis
  - Question about 16 versus 20-foot length for valuing logs and standing timber
  - Recognized from previous bucking research alternative bucking patterns with equal or slightly lower values => OPTIONS
  - Potential for reduced set of allowable lengths to create woods-lengths logs of mill-length logs

Introduction

- Log length influence on bucking values and revenue improvement
  - Address improving bucking decisions with a new strategy of a reduced set of log lengths while producing acceptable woods-lengths and mill-lengths.
  - Quantify total value, unit values ($ per Ccf, 1 Ccf = 100 cubic feet), and resulting volume recovery for sample 45 and 65-year old stands.
  - Initiate development of a bucking pattern decision tool

Introduction

- Log length influence on bucking values and revenue improvement
  - Initiate development of a bucking pattern decision tool, a lookup table for length to a merchantable top, read off bucking pattern.
  - OSU-BUCK, single stem optimization, requires method to address delivery of a minimum percent long logs when pricing does not represent true values associated with preferred lengths.

Introduction

- Bucking patterns, optimal value with log allocation constraint, and development of a simple bucking decision tool
  - Handheld BUCK at the stump not implemented
    - Production focus
    - Cost minimization
  - Single stem optimization did not meet mill purchase order constraint for volume in preferred lengths

Objectives

- Provide knowledge of the effect on bucking values using a reduced set of log lengths.

- Develop a technique for optimizing value while meeting a log allocation constraint for developing an easy bucking decision tool .

AN EVALUATION OF LOG LENGTH ON TIMBER VALUES

- Bucking, or cross-cutting, is the process of sawing a felled tree length bole into shorter log segments. This initial process can create woods-length or mill-length (sawn-lumber length) logs. Woods-length logs are typically bucked into mill-length logs prior to the mill headrig.
- Resulting log lengths influence revenues and logging costs important to forest managers, contractors, and mill managers.

Introduction

- Bucking optimization:
  - Pearse and Sydneysmith, 1966
  - Sessions, 1988
  - Pickens, 1993
  - Garland, et al; 1989
- With Sawmill Optimization
  - Faaland and Briggs, 1984
  - Mendoza and Bare, 1986
  - Maness and Adams, 1991

Introduction

- Globally relevant topic:
  - Evanson, 1996
  - Herajarvi and Verkasalo, 2002
  - Wang et al, 2004
- PNW:
  - Raw log value optimization – OSU-BUCK
  - Finished lumber, veneer, etc – TREEVAL
  - Introduction of mechanized harvesters with “optimizers”

Introduction

- This study: Evaluate log bucking strategies to determine if a reduced set of log lengths return near optimal values and an acceptable log length distribution
- A positive outcome would allow for the creation of a bucking decision card to approach computer-aided value optimization in thinning harvests on steep slopes where whole tree and mechanized harvesting is not feasible (stand damage)

Introduction

- Preponderance of 16 and 20-foot lengths in the literature
- Higher product values for these lengths ($/unit volume)
- Cubic basis evaluation never performed previously with OSU-BUCK
- 16 and 20-foot lengths create 32, 36, & 40-foot woods-length logs

Objectives

- 1) Evaluate the value and volume differences for stems optimally bucked with a complete set of allowable log lengths and a reduced set of lengths for two sample sets of second-growth Douglas-fir (Pseudotsuga menziesii) trees to determine if a reduced set is economically viable for pursuing development of a simplified bucking decision tool.

Objectives

- 2) Evaluate the validity of using a board foot per cubic foot (BF/CF) ratio to convert log prices in dollars per one-thousand board feet ($/Mbf) to dollars per one-hundred cubic feet ($/Ccf) as an approach to developing cubic based pricing in the absence of mill provided values

Methods

- Stand 1: 45 year old, Cascade foothills near Oakridge, Oregon
- Stand 2: 65 year old, coast range near Alsea, Oregon
- 50 sample trees per stand

Stand Characteristics

	Butt Diameter (inside bark, inches) • 6 - 15 • 10 - 28		Height, Merch. Top (feet) 1) 50 - 95 2) 60 – 150		Top Diameter (inside bark, inches)		Volume (cubic ft.)
Stand	Average	Stand. Dev.	Average	Stand. Dev.	Average	Stand. Dev.	Average
1	9.9	2.1	73.4	9.7	2.1	n/a	23
2	18.4	5.0	101.8	19.6	8.6	n/a	123

Log Pricing Schedule

		Stand One	Stand Two
Scaling Length	**$ per Mbf**	**$ per Ccf**	**$ per Ccf**
38 – 40	650.00	236.60	315.25
30 – 36	620.00	225.70	300.70
24 – 28	575.00	209.30	278.88
16 – 22	500.00	182.00	242.50
12 – 14	400.00	145.60	194.00
8	200.00	72.80	97.00
Fiber logs			
12 - 40	150.00	54.60	72.75

Conversion Factors

- 5 BF to 1 CF
- 1 MBF = 2 CCF
- 1 CCF = 2.5 tons (at 50 # per CF)
- 1 CCF = 2.8 cubic meters (call 3)

Conversion Factors

- IF CCF in NUMERATOR (CCF / day):

- For MBF => DIVIDE BY 2
- For TONS => MULTIPLY BY 2.5
- For M^3 => MULTIPLY BY 3

Conversion Factors

- IF CCF in DENOMINATOR ($ / CCF):

- For MBF => MULTIPLY BY 2
- For TONS => DIVIDE BY 2.5
- For M^3 => DIVIDE BY 3

Methods

- Stand 1 - 9 Bucking Strategies:
  - 1) AS-BUCKED. log lengths (12 to 40 feet)
  - 2) BF OPTIMAL. Scribner BF, 40-foot scaling
  - 3) CF OPTIMAL. Smalian's CF,
  - 4) COMBO. 16, 20, 32, 36, and 40 feet, CF .
  - 5) (16). 16-foot log length only, 0.5 foot trim
  - 6) (20). 20-foot log length only, 0.5 foot trim
  - 7) (16&20).
  - 8) (16&40).
  - 9) (16,20,40).

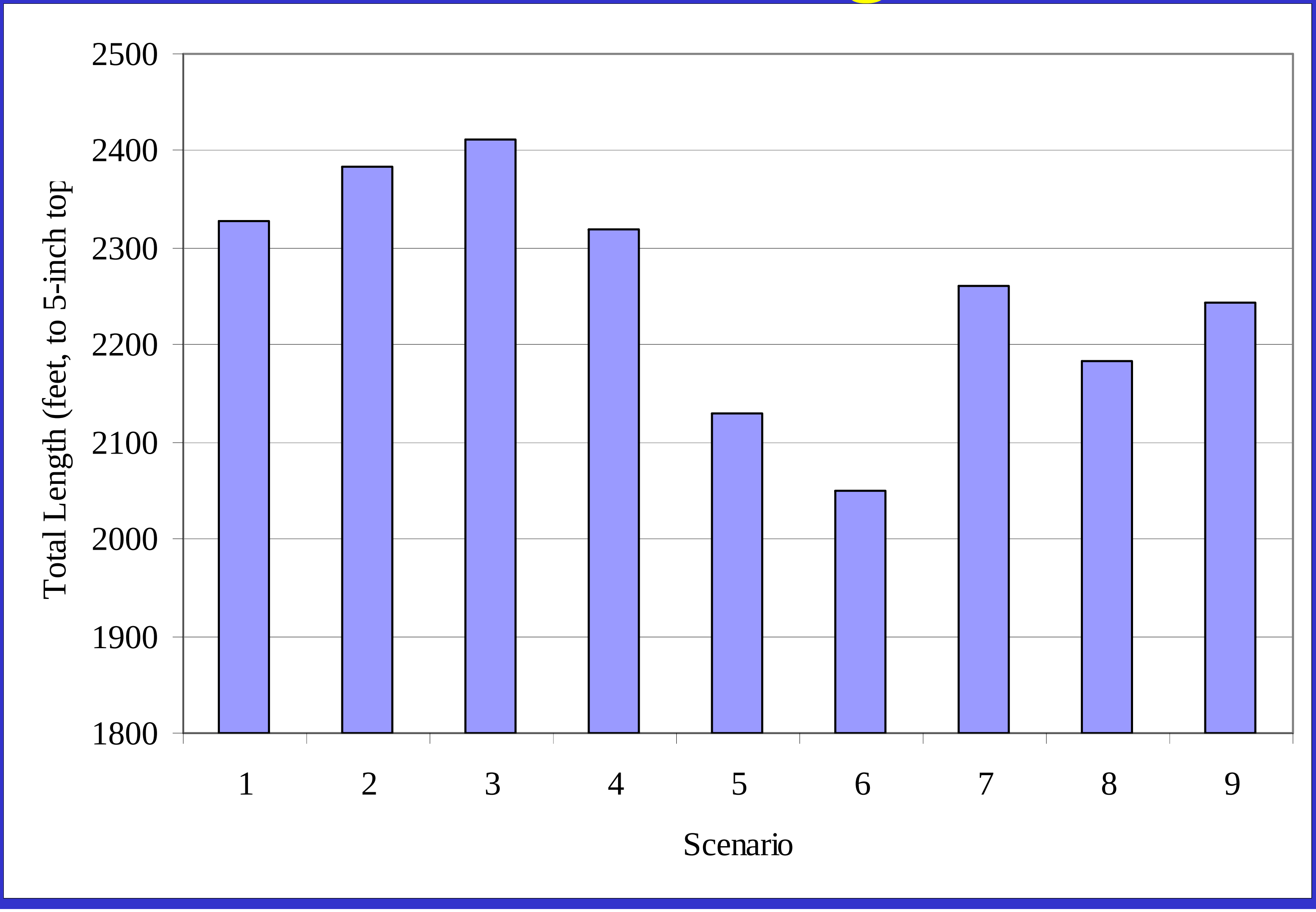
Methods

- Stand 2 - 4 Bucking Strategies:
  - 1) AS-BUCKED. As-Bucked log lengths (12 to 40 feet), BF and CF, 1 foot of trim
  - 2) BF OPTIMAL. 12 to 40 feet, 2 foot multiples, 1 foot of trim, Scribner Board Foot volume, 40-foot scaling segment basis.
  - 3) CF OPTIMAL. 12 to 40 feet, 2 foot multiples, 1 foot of trim, Smalian's cubic foot
  - 4) COMBO. Optimally bucked, log lengths limited to 16, 20, 32, 36, and 40 feet, 1 foot of trim, 40-foot cubic foot basis.

Results – Stand 1- Utilization of available length

	AS-BUCKED	BF OPTIMAL	CF OPTIMAL	CF (COMBOS)
	========	========	========	========
TOTAL SAWLOG VALUE	$2,214	$2,462	$2,336	$2,262
* BF basis *	*2228*	*2462*		
BOARD FOOT VOLUME	3610	4170	3710	3520
CUBIC FOOT VOLUME	986	1005	1023	994
MEAN BF/CF RATIO	3.73	4.24	3.71	3.65
TOTAL # OF SAWLOGS	76	92	73	71
TOTAL LENGTH OF SAWLOGS (FT)	2328	2384	2411	2319

Results – Stand 1- Utilization of available length



Results – Stand 1

	SCENARIOS		
	AS-BUCKED	CF (COMBOS)	
# of LOG LENGTHS	15	5	
TOTAL LENGTH OF SAWLOGS (Feet)	2328	2319	
CF SAWLOG VOLUME	986	994	
TOTAL # OF SAWLOGS	76	71	
LONG LOGS (>=36 feet, % by volume)	60	67	

Stand 2

	AS-BUCK	OPTIMAL	OPTIMAL	COMBOS
TOTAL SAWLOG VALUE	$18,594	$18,742	$19,042	$18,696
* BF basis *	*17,645*	*18,742*		
BOARD FOOT VOLUME	27970	30270	28900	28290
CUBIC FOOT VOLUME	6087	6196	6209	6119
AVG. BF/CF RATIO	4.36	4.59	4.39	4.42
TOTAL # OF SAWLOGS	152	158	150	148
TOTAL LENGTH OF SAWLOGS (FT)	5046	5013	5044	4980
LONG LOGS (>= 36') (PERCENT BY VOLUME)	80	49	69	75

Results – Stand 2

- COMBOS improve over unaided current bucking practices.
- Achieved 97 percent of ALL lengths optimal

Length	Percent Volume
36 – 40	75
32	17
16 – 20	7

Discussion

- COMBO improved over unaided bucker's solutions
- Stand 1 : $ 0.94 / tree, $ 4.09 / Ccf
- Stand 2 : $ 10.82 / tree, $ 8.80 / Ccf

Discussion

- Comparison of $ value needs to viewed with respect to percent long logs:
  - Stand 2 bucker cut 80 percent,
  - COMBO 75 percent,
  - CF Optimal 69 percent, and
  - BF Optimal 49 percent

BF to CF Pricing conversions can be achieved, with care

USFS sales on $/Ccf,

Ccf to Metric (international standard) straightforward

Discussion

- Bucker 80 percent vs. COMBO 75 percent
  - Can not revisit to perform comparative trial.
  - OSU-BUCK possible with price adjusters
  - Combinatorial heuristic is suited to this evaluation!

Discussion

Log bucking pattern as a function of merchantable length (trim requirement = 0, for example clarity).

Total Merchantable Length	Preferred Cutting Pattern (butt to top)		
========	====================================		
72	32-40,	40-32,	36-36
76	36-40,	40-36	
80	40-40,	32-32-16	
84	32-32-20,	32-20-32,	20-32-32
88	32-40-16,	40-32-16,	36-36-16, 16-36-36

Summary

- COMBO set of lengths creates near optimal values, with fewer logs, more volume in long logs than ALL lengths
- BF to CF pricing possible with conversion factors, possibly stand specific
- COMBO improves values over current bucking practices (with caveat)
- Heuristic approach needed to compare values while meeting log allocation constraint

DEVELOPMENT OF EFFICIENT CUTTING PATTERNS TO MAXIMIZE VALUE WITH A LOG ALLOCATION CONSTRAINT

Introduction

- Bucking-to-value is the segmenting of a tree into the most valuable combination of logs guided by the price table based on diameters, lengths, and surface quality.
- Assumes log prices explicitly reflect demand. PNW practices use price list and purchase order requirement of a minimum percent of preferred logs.
- This is bucking-to-value with constraint

Introduction

- As was demonstrated in previous discussion, value optimization alone may not achieve constraint.
- Approaches to solving this problem include:
  - Artificial price adjusters
  - Solve with Mixed Integer MP, match tree to closest tree and implement that pattern
  - Heuristic method, Tabu Search, pattern instructions based on priority list.

Introduction

- Limitations:
  - Handheld computer needed
  - Match a complex pattern to a large complex list
  - Difficulty in identifying priority list
- A reduced set of 5 lengths provided a better solution to current practices, but failed to meet log allocation constraint

Objective

- Develop a fourth approach to bucking-to-value with a length constraint that would:
  - (a) be operationally less expensive to implement in the field than price guided individual tree optimization at the tree stump,
  - (b) would markedly reduce the number of bucking patterns a faller would need to know, and
  - (c) would not rely on a priority list for implementation.

Approach

- The approach taken in this research is to develop a set of bucking prescriptions that a faller could use in the field through reference to a cutting card based upon tree height to a merchantable top diameter.
- To develop the cutting card, a sample of trees will be analyzed and the best bucking pattern determined for each tree using a set of bucking patterns will be restricted to combinations of preferred lengths

Patterns

- The pattern applied to the tree is the decision variable.
- Patterns increase exponentially with length – 814 patterns for a 56 foot tree using 8, 10, .. 20 foot logs

- A tree is randomly selected, a pattern generated and its value evaluated for contribution to the objective function

Heuristic Approach

- A modified Simulated Annealing heuristic was developed to deal with the bucking-to-value with log allocation constraint.
- A Goal Programming objective function is used to guide the search for the maximum total stand value subject to the constraint. The constraint is moved to the objective function.

Mathematical Model

Maximize:

$$\Sigma_{p,i}\ \pi_{pi}\ y_{pi}\ -\ \lambda(R^l - \Sigma_{p,i}\ v^l_{pi} y_{pi} / \Sigma_{p,i}\ v^t_{pi} y_{pi})^2$$

Subject to:

$$\Sigma_p\ y_{pi} = 1 \qquad \text{for all } i$$

$$y_{pi} = \{0,1\} \qquad \text{for all } p, i$$

where same as previous, and

λ = a penalty on the deviations from the volume length goal

Heuristic Approach

- The penalty function is used for quantifying, in dollar terms, a set of patterns degree of infeasibility.
- The exponent has been used to keep all deviations positive and so larger deviations from the length goal are to be exponentially penalized as compared to small deviations from the goal.
- It’s role is to help the search process converge to a good (optimal, near optimal) feasible solution by reducing the total stand value corresponding with the infeasible patterns.

Application

- The Modified SA was applied to the two stands previously described, using both ALL lengths and the COMBO set of lengths.
- Price table same as previous
- Probability function for accepting non-improving solutions: $P = e^{(Dobj / t)}$

where Dobj is the change in the objective function value associated with a trial change of bucking pattern *p* for tree *i* and *t* is the current temperature.

Results

- The Modified SA heuristic was able to find high quality solutions, matching the unconstrained values from OSU-BUCK.
- Achieved 100 percent of the value, excepting 1 case at 99.93 percent.

Results

Stand	Analysis Modeled	Total Value ($)	Logs (#)	Long Logs (#)	Patterns (#)
1	OSU-BUCK, BF, All	2466	92	16	n/a
1	SA, BF, All	2466	89	17	34
1	OSU-BUCK, CF, All	2346*	77	36	n/a
1	SA, CF, All	2339*	78	37	27
1	OSU-BUCK, CF, Combo	2262*	72	38	n/a
1	SA, CF, Combo	2259*	74	36	12
2	OSU-BUCK, BF, All	18768	157	60	n/a
2	SA, BF, All	18754	157	62	44
2	OSU-BUCK, CF, All	19134**	144	82	n/a
2	SA, CF, All	19135**	144	84	39
2	OSU-BUCK, CF, Combo	18776**	143	86	n/a
2	SA, CF, Combo	18777**	142	89	25

Results

		Total Value for 50 trees		
	CF - All Lengths		CF-Combo Lengths	
		Max $		Max $
Stand	Max $	80% Long	Max $	80% Long
1	2339	2328	2259	2242
2	19135	18884	18777	18762

Results

Stand	Percent Long Logs (by volume)		
	CF - All Lengths	CF-Combo Lengths	BF – All Lengths
1	63.3	62.3	26.3
2	72.3	77.0	51.0

Implementation

- Use of the COMBO set of lengths:
  - Decreased the number of logs
  - Maintained or increased the number of long logs
  - Reduced the number of patterns
  - Decreased value compared to ALL lengths from $1.72 to $2.44 per tree for the two stands respectively
  - This would require a handheld and expense of $4 to 6.00

Implementation

	Long Logs (% by Vol)	Total Value ($)	Value Increase (%)	Increase per tree ($)
As-Bucked	80	18594	-----	-----
COMBO	80	18762	0.9	3.36

Results

- Combo cutting card approach, developed from SA heuristic, meeting the 80 percent constraint would improve stand values:

- Stand 1 by $2.61 per Ccf
- Stand 2 by $2.73 per Ccf

- Approx. $5.00 per Mbf, $1.00 per M^3

Length Range (feet)	Length Pattern (log length with trim)	Results of COMBO analysis (#) = frequency pattern used
17 – 20	17	0*
21 – 32	21	5
33 – 36	33	1
37 – 40	37	4
41 – 49	41	19
50 – 53	33-17	2
54 – 57	37-17	2
58 – 61	41-17, 37-21	(6), (1)
62 – 65	41-21	8
66 – 69	33-33	0*
70 – 73	33-37, 37-33	(1), (0)
74 – 77	37-37, 41-33	0*
78 – 81	41-37	1
82 – 87	41-41	0*

0* indicates no trees required this pattern, included for completeness of the lookup table

Summary

- Modified SA heuristic :
  - Useful approach for bucking-to-value with log allocation constraint
  - Achieved 99.9 plus percent of value for unconstrained objective (MAX VALUE)
  - Found patterns for meeting optimal value while meeting mill preferred length constraint
  - COMBO set improves current values by over $2.50 per 100 cubic feet
  - Develops easy to use bucking decision aid

GLOBAL Summary

1. Log Lengths and Values:
   1. Analyzed a reduced set of log lengths for value, volume, and log assortment
   2. Improved value recovery over unaided current practices by $4.00 to $8.00 per Ccf for two D-fir stands, 45 and 65 years old, respectively
   3. Achieved 96-98 percent of optimal value when compared to ALL length solutions
   4. Developed a bucking decision tool approach for ease of implementation of resulting patterns
   5. Identified the need for a combinatorial heuristic approach to meet log allocation constraints.

GLOBAL Summary

1. Efficient Cutting Patterns and Log Allocation constraint:
    1. Developed a modified Simulated Annealing approach to analyze a reduced set of log lengths for value optimization with a log allocation constraint
    2. 99.9 plus percent attainment for unconstrained optimal values, compared to OSU-BUCK
    3. Confirmed COMBO reduced set of log lengths – 16, 20, 32, 36, and 40 are acceptable

GLOBAL Summary

1. Efficient Cutting Patterns and Log Allocation constraint:
    1. $2.73 per Ccf increased value over current unaided practices
    2. Identified patterns for bucking decision card approached for constrained optimization
    3. Developed a modified Simulated Annealing
    4. $2.73 per Ccf increased value >= to $1.50 to $2.60 per Ccf to cover mobilization costs or other expenses in thinning steep slope Douglas-fir stands.