

**An Analysis of the Process and Attributes used in the Transaction Evidence
Appraisal method for Forest Service timber sales in the US Southwest**

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April 2025

*A Professional Paper Submitted in Partial Fulfillment
of the Requirements for the Degree of Master of Forestry*

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Acknowledgements

I cannot thank my advisor, Dr. Han-Sup Han, enough for his incredible motivation, encouragement, and invaluable advice throughout my graduate school endeavors. From first encouraging me to return to school after a long hiatus to consistently supporting and guiding this project and our exploration of the Transaction Evidence Appraisal (TEA) together, even from thousands of miles away in South Korea during his sabbatical. I also want to express my sincere appreciation to the amazing staff and support team at the Ecological Restoration Institute (ERI), and especially my Forest Operations & Biomass Utilization counterpart, Dr. Dipita Ghosh, for constantly checking in and collaborating with me on projects and field visits over the past two years. Dr. Mathew Smidt with the U.S. Department of Agriculture Forest Service (USFS) Southern Research Station, Eric Olson at Northern Arizona University (NAU) School of Forestry, and Dr. Nate Anderson from the USFS Rocky Mountain Research Station all provided technical expertise, valuable feedback, and countless helpful suggestions that guided the overall direction of the project. This effort could not have been completed without their assistance. This study was developed through a close collaboration between the ERI at NAU and the USFS. I'd like to thank everyone who assisted with the development and data collection for this study, with special thanks to USFS TEA Specialists Matthew Etzenhouser (USFS Region 2), Marc Estrada (USFS Region 3), and Ashton Hargrave (USFS Washington Office) for providing access to TEA data and offering their thorough and insightful review and feedback on the TEA process. Finally, I would not have made it through this journey without the never-ending love, encouragement, and support of my mom and dad, brother and sister, close friends, and my amazing partner. The gratitude I feel is simply too great to express; I could not have done this without them.

Abstract

Evaluating the cost of fuel treatment operations is essential for mitigating elevated wildfire risks across western US landscapes. The United States Forest Service (USFS) currently uses a transaction evidence-based system to appraise stumpage in fuel treatment contracts. The Transaction Evidence Appraisal (TEA) method incorporates key factors such as slash disposal, transportation, stump-to-truck processing, timber markets, and adjustments such as bidder competition. This study aims to improve our understanding of the total costs involved in fuel treatment operations. TEA data from USFS Regions 2 and 3 were analyzed to identify key variables impacting final advertised rates. Stump-to-truck processing and timber transportation to mills represented the greatest share of TEA costs, comprising 96% of sale estimates in Region 2 and 94% in Region 3. These costs are significantly influenced by factors such as volume per acre, skidding distance, and proximity to processing facilities. Region 3 faces higher haul costs due to limited mill infrastructure near treatment sites. Additionally, regression analysis examining bidding behaviors identified total sawtimber sale volumes and travel time as key factors influencing bid amounts that were higher than advertised rates. Refining TEA cost estimation methods and strategically structuring future sales could optimize the effectiveness and scalability of mechanical thinning treatments.

Keywords: Transaction Evidence Appraisal (TEA), mechanical thinning treatment, logging costs, bidding behavior, stumpage prices

Abbreviations:

TEA – Transaction Evidence Appraisal
NF – National Forest
WCS – Wildfire Crisis Strategy
BPP – Base Period Price
CCF – Hundred Cubic Feet

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1. Introduction

A number of key factors have altered fire regimes and created conditions in western United States (US) forests conducive to increasing the spread of frequent, large-scale, high-severity catastrophic wildfires (Wasserman and Mueller 2023; Reinhardt et al. 2008). The increase in scale and destruction from wildfires is predominantly a result of years of effective fire suppression policies (Dombeck et al. 2004; Rummer 2008), climate change induced fuel aridity (Abatzoglou and Williams 2016), and an expansion of the wildland-urban interface (WUI) (Schoennagel et al. 2017). These changes have created favorable forest conditions for ongoing, devastating wildfires. Together, they significantly increase the risk of larger, more destructive fires, which can negatively impact both human and ecological communities alike (Allen et al. 2002).

In response, forest managers are increasingly turning to mechanical forest thinning treatments to restore western forests to more natural conditions and reduce the risk of unnatural, stand-replacing crown fires. Thinning treatment planning and implementation must account for various cost and logistical complexities such as spatial (acres treated) and location considerations, property and administrative boundaries, site access (e.g., temporary roads), funding limitations, operational factors (e.g., slope and skid distances), and WUI proximity (Stephens et al. 2021). It is important to consider that a large proportion of the extracted products from treatments available to regional markets consist of small-diameter, low-grade, and low-value timber (Townsend et al. 2019). Since the overall cost of timber removal and transport presents a financial barrier for most logging contractors, understanding how these thinning treatment costs are assessed is essential for meeting the growing demand for large-scale implementation in the western

US (Rummer 2008). To address the growing wildfire threat and expedite landscape-scale fuel reduction efforts, the United States Forest Service (USFS) launched the Wildfire Crisis Strategy (WCS) in January of 2022, with the ambitious goal of treating approximately 50 million acres across ten western states over the course of the next 10 years (Woolsey et al. 2024).

Rummer (2008) identifies four main approaches that have been utilized to establish a cost-benefit analysis of forest restoration treatment: expert opinion, transaction evidence, accounting, and engineering cost analysis. The transaction evidence method, which captures and documents the post-treatment price paid by contractors for stumpage, provides insight into the total bid cost for proposed thinning treatments while also reflecting the impact of competition and local market price fluctuations. While other treatment cost-analysis studies have focused on separate managerial, operational, or physical cost factors (Barry and Hesseln 2004), the transaction evidence method can be useful in combining all three. In some cases, a combination of treatment cost analysis approaches can be utilized to determine the estimated cost for a particular treatment (Rummer 2008). To understand how timber sales and restoration thinning treatments have traditionally been assessed on public lands in the western US, it's helpful to examine the USFS method for appraising timber sales offered for public auction.

As early as 1902, the US Secretary of the Interior recognized the need to appraise USFS timber based on its relevant quality, logging difficulty, and distance to nearby markets or mills (Craig 1983). By 1983, driven by rising timber values, the USFS began implementing use of the Transaction Evidence Appraisal (TEA) method to set prices for new timber sale offerings in the West. This method relied on recent bid stumpage rates

for timber of similar quality to establish base period prices. Prior to the implementation of TEA, federal law, dating back to 1897, mandated that timber sold from US forest reserves must be sold “for not less than the appraised value.” (Craig 1983). The current TEA method used by the USFS is based on the Code of Federal Regulations (CFR) mandate stating that “The objective of Forest Service timber appraisals is to determine fair market value.” (36 CFR 223.60, 2025). A TEA advertised rate represents the Forest Service’s estimate of fair market value and serves as the starting point for negotiating a mutually agreeable timber value.

As the primary appraisal process for all USFS regions except Region 10 (Alaska), the TEA method encompasses planning, appraisal, bids, operations, and closeout. In the Southwest and Colorado Front Range, the TEA method uses prior sales data to establish advertised rates that reflect a range of operational, transportation, competition, and market cost adjustments. It is designed to: (1) estimate the fair market value for stumpage (i.e., timber) offered for sale; (2) set advertised rates that encourage competition in bidding; (3) close the gap between bid values and advertised rates; and (4) generate appraisals that account for fluctuations and changes in the market for forest products (Haynes et al. 2016). In theory, TEA combines the transaction evidence and engineering cost analysis methods. Transaction evidence is used to establish the Base Period Price (BPP) from prior sale high bid prices, while an engineering cost analysis estimates skid-yard (stump-to-truck), slash management, road maintenance, and haul costs.

Haynes et al. (2016) conducted an in-depth report on the current USFS TEA process using timber sale data from FY 2010-2014 across eight different USFS Regions, highlighting potential shortcomings in the current appraisal process. The report noted that

a low number of sale offerings, combined with use of a rollback factor in an appraisal zone with limited competition, could result in BPP's and advertised rates dropping over time, even when the market price for stumpage could be increasing. Market values for timber can fluctuate unexpectedly, and with most sale contracts in the 2–4-year range, developing a financially feasible bid for stumpage based on current conditions can be difficult to estimate. Also, the use of average winning high bids prices to establish BPPs introduces risk in the process, such as intentional underpricing in competitive markets (Rummer 2008), preclusive bidding (Brown et al. 2012), the potential for “no-bids”, and the practice of intentionally skewing bids on species believed to be overestimated (Athey and Levin 2001). These factors pose challenges in estimating a fair market price in a transaction evidence appraisal.

Sale characteristics that influence trends in bid behavior can be divided into several categories, including operational and stand-specific variables, site conditions, regional and seasonal considerations, and management objectives. Silvicultural prescriptions, forest management plans, and fuel treatment goals often dictate the timing, volume, timber quality, and species composition of a planned sale (Soman et al. 2019). However, forest managers can still evaluate specific factors that influence bid behavior to strategically design future timber sales that encourage higher bids and competition, while maintaining alignment with management objectives (Brown et al. 2012). By observing and analyzing bidding behavior trends, forest managers can identify optimal sale characteristics that not only attract higher stumpage bids and help potential bidders predict operational costs (Kilgore and Blinn 2005) while also accounting for potential

impacts on the long-term sustainability of the logging industry and timber markets (Brown et al. 2012).

Stump-to-truck timber harvesting and transportation costs for moving material to processing facilities are key factors in determining the economic feasibility of mechanical thinning treatments (Louis et al. 2022). Transportation costs alone can represent as much as one-third of the entire stump-to-mill cost for a given treatment (Han et al. 2004), with longer distance transportation of sale material on temporary, spur, or unpaved (off-highway) roads contributing significantly to high hauling costs (Pan et al. 2008). Understanding the sale characteristics and market conditions that drive higher transportation costs is crucial for strategically developing plans to reduce those costs. Harvest productivity and cost are key factors in reducing stump-to-truck processing expenses and ensuring the feasibility of treatments for contractors and forest managers. Volume per acre, skidding distance, tree size, and machine system configuration all influence total treatment costs. Generally, harvesting larger trees increases overall productivity and lowers treatment costs (Louis et al. 2022), but consideration is also given to the social and environmental dimensions of responsible restoration, such as setting diameter caps on most sales in the Southwest (Hjerpe et al. 2009). Stand density and total timber volume in a treatment also impact productivity and cost. When sale volume is low, contractor costs increase due to greater travel distances between trees for feller-bunchers, reducing production rates and raising operational costs (Parajuli et al. 2020). Together, these key production and transportation factors influence fundamental financial considerations for treatments.

The TEA method has been in use for nearly 40 years, but its ability to capture the true cost of thinning treatments could benefit from reassessment due to recent changes in timber markets and cost estimation techniques. This study aims to evaluate the current appraisal process for sale cost centers and examine how various sale characteristics and competition influence bid behavior. Specifically, trends in TEA cost center estimates and stumpage bidding habits were analyzed to address the following three study objectives: (1) examine the impact of key operational variables (such as tree size, volume per acre, and skid distance) on overall harvest productivity, and explore how these factors could be more effectively integrated into TEA skid-yard calculations to improve cost estimation, with a particular emphasis on regional differences between Regions 2 and 3; (2) analyze trends in TEA stumpage bidding behavior to understand the influence of competition, stand characteristics, and operational variables on high bid amounts, explore how these factors vary regionally, and assess how adjustments to sale design or appraisal methods could impact bid outcomes; (3) identify opportunities to improve the consistency and accuracy of TEA procedures across regions, ensuring that timber sale estimates better reflect current operational and logging industry conditions, especially with regard to limited market availability and transportation cost challenges.

2. Data and Methods

2.1. TEA method

Establishment of a BPP for each appraisal group (i.e., product, species, and condition) is the starting point for all TEA sales. The BPP, based on the volume-weighted average winning high bid price from sales in the previous four calendar quarters (the “base period”), is listed in a USFS regional appraisal bulletin, issued monthly (or until

superseded), and applied to all new appraisals for upcoming sales. An overview of the definitions and variables used in the TEA method is provided in Table 1.

Table 1. Primary variables used in the USFS TEA method.

TEA Attribute	Description
Base Period Price (BPP)	The value representing the appraisal group's volume-weighted average winning bid price of competitively sold timber sales from the previous base period. Starting point for the TEA process prior to adjustments.
Base Rates	The lowest rates of payment for timber authorized within a federal contract. Usually the same as minimum rates but can be raised if the collection of essential K-V and/or timber property requires the additional funds.
Market Adjustment	An adjustment that reflects changes in the lumber market between the base period and the most recent quarter within that period.
Cost Centers	The primary estimation of sale specific costs adjusted against the average base period costs from prior sales. Adjustments can be positive or negative.
Haul Cost	The cost to transport sale timber products to the nearest estimated processing facility.
Road Maintenance Cost	The cost to operate and maintain existing roads to access the timber sale cutting unit(s).
Temporary Road Cost	The cost of constructing a road for timber removal from sale units, used only for initial access and not needed thereafter.
Slash	The cost associated with burning landing slash piles or any other extraordinary logging operation slash management.
Skid-Yard	The stump-to-truck (felling, skidding, processing) operational logging cost for removal of sale material.
Unusual Adjustments	Made for special sale characteristics not reflected in other market, quality, risk or cost adjustments (e.g., seasonal restrictions, sorting and handling)
Quality Adjustments	An appraisal adjustment to reflect differences in timber quality (e.g., excessive taper) between the base period and current sale.
Predicted Bid Rate	The highest anticipated bid if the timber sale attracts average competition.
Competition Factor	A rollback factor (either 10% or 5%) applied to account for market changes, risk, and slack in bidding.
Adjustment to Base Rate	Adjustment made to raise timber rates when they fall below the required minimum authorized "base" rate during the appraisal process
Advertised Rate	The final step in the TEA process. Designates the final rate at which each product and species in the sale will be advertised at.
Timber Property Value	The total cost of manufacture from the standing tree to its sale-ready form, including felling, bucking, skidding, decking, overhead, and depreciation.
Specified Road Cost	The estimated cost of constructing permanent roads for future use that is included in the timber sale contract.

Once the BPP is established, the TEA process (Figure 1) applies adjustments to account for factors such as market conditions, competition, timber quality, and sale-specific cost centers. A market adjustment, based on the current WWPA lumber price index (as listed in the appraisal bulletin), is first applied to the BPP to account for market changes between base periods, resulting in an adjusted BPP. Next, calculations for sale-specific cost centers in Regions 2 and 3 (e.g., haul, road maintenance, slash management, skid-yard, and temporary road construction) are then adjusted (either positively or negatively) according to base costs found in the appraisal bulletin. Any applicable quality or unusual adjustments for special sale characteristics are applied next. After totaling all adjustments, the predicted bid rate (PBR) for each appraisal group is determined, followed by a competition or 'rollback' factor, based on whether the sale occurs in a competitive (10% rollback) or non-competitive (5% rollback) National Forest (NF).

To finalize the process, the indicated advertised rate, representing the estimated value of timber products in a sale after all adjustments are accounted for, is set. If this value falls below the base rate (listed in the bulletin), an adjustment to the base rate is required. Finally, the advertised rate, representing the fair market value for each appraisal group, is established. The total sale value is calculated by multiplying the advertised rate for each product and species group by its corresponding volume (in hundred cubic feet, or CCF).

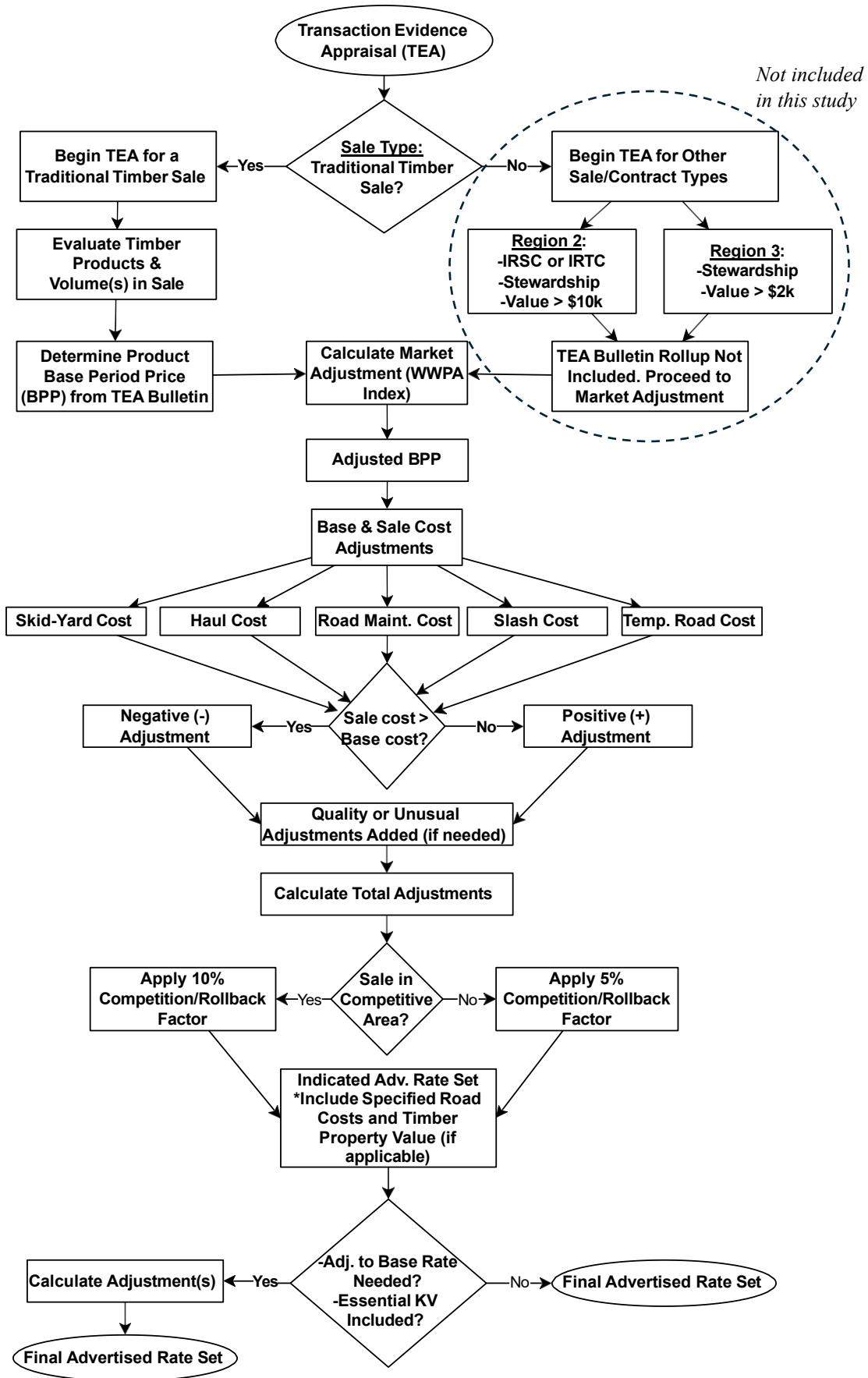


Figure 1. Flowchart illustrating the USFS TEA process, from establishing the base period price (BBP) to determining the final advertised rate. Key abbreviations: Western Woods Product Association (WWPA) Index, Integrated Resource Timber Contract (IRTC), and Integrated Resource Service Contract (IRSC).

2.2. Forest Service Regions

USFS WCS priority landscapes analyzed in this study include the Four Forest Restoration Initiative (4FRI) in northern Arizona, the Enchanted Circle in northern New Mexico, and the Colorado Front Range (Figure 2). The study included TEA data from four western states (AZ, NM, CO, WY) and a total of twelve different National Forests (NFs) across the USFS’s Region 2 (Rocky Mountain) and Region 3 (Southwestern) from 2020 to 2024.

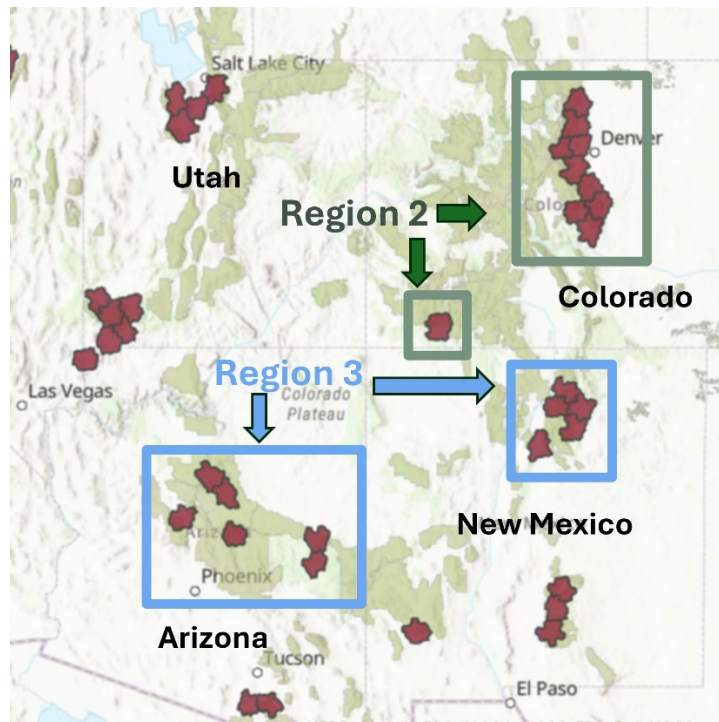


Figure 2. Map of USFS Wildfire Crisis Strategy (WCS) high-risk firesheds in Regions 2 and 3. Firesheds are located in the Colorado Front Range, Four Forest Restoration Initiative (4FRI), and the Enchanted Circle WCS priority landscapes. Note: Not all WCS landscapes and National Forests in Regions 2 and 3 were represented in this TEA study. Adapted from *Confronting the Wildfire Crisis: A Strategy for Protecting Communities and Improving Resilience in America’s Forests* (US Forest Service, 2022).

In Region 2, TEA data from the Arapaho and Roosevelt, Medicine Bow-Routt, Grand Mesa, Uncompahgre, and Gunnison (GMUG), Pike-San Isabel, San Juan, Rio Grande, and White River NFs were analyzed. Colorado Front Range WCS priority landscapes include portions of the Arapaho, Roosevelt, and Pike NFs. TEA data from Region 3 included timber sales from the Coconino, Apache-Sitgreaves, Carson, Gila, Kaibab, and Santa Fe NFs.

In the TEA process, appraisal zones typically define geographic areas with similarities in timber sale characteristics, such as haul distances, species composition, timber quality, or market competition. An appraisal zone could encompass an entire USFS Region, multiple NFs within a particular region, or several Ranger Districts.

Region 3, covering 11 NFs across New Mexico and Arizona, is currently one continuous appraisal zone. Region 2, encompassing 17 NFs across Wyoming, Colorado, South Dakota, Nebraska, and Kansas, is divided into 3 distinct appraisal zones. For this study, TEA data from Appraisal Zone 1 (NW Intermountain) and Zone 3 (SW Intermountain) was analyzed. TEA data from Region 2, Zone 2 (Black Hills) was excluded from the analysis because it included sales from Wyoming, which is outside the study region.

2.3. Collection of TEA timber sale data from Regions 2 and 3

TEA timber sale data from 2020 to 2024 was selected for analysis to capture recent sale characteristics and market conditions. The study analyzed a total of 28 timber sales from Region 3 and 63 timber sales from Region 2. TEA sales associated with stewardship or service contracts, and simple, small, or deck sales were excluded from analysis. While still subject to the USFS TEA process, these contract types were not

dependable for analysis due to being awarded on best value (past performance, work quality, benefit to local community) and not solely on highest bid, making it incompatible with the creation of accurate base period prices from TEA bulletin rollup reports.

Access and permission to utilize data from the TEA 234 Microsoft Access Database was provided in collaboration with USFS Appraisal Specialists from Regions 2 and 3. An Access Database query was devised and run to extract key TEA data variables to Microsoft Excel for sorting, cleaning, and organizing by individual NF within the two regions. Data variables not included in the initial query (e.g., volume per acre, species, average DBH) were identified and manually added to spreadsheets.

TEA products appraised in Region 3 (SW) include: 01 – Sawtimber, 07 – Fuelwood, 08 – Non-sawtimber, and 20-Biomass. Region 3 timber species included Ponderosa pine (*Pinus Ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), and White fir (*Abies concolor*). Region 2 (Rocky Mtn) TEA products 01 – Sawtimber, and 03 – Poles (0-4.9”) were included in the analysis. Species in Region 2 covered a larger variety, including Ponderosa pine, Douglas-fir, White fir, Lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), Quaking aspen (*Populus tremuloides*), and True fir (*Abies*).

2.4. Statistical analysis

TEA data summary statistics were run in Microsoft Excel to determine a percentage breakdown of cost characteristics for timber sales across Region 2 and Region 3. Mean and standard errors for regional NF breakdowns of haul and skid-yard costs were calculated for each available product type. To calculate cost center averages for a comprehensive view of TEA trends over the past 3-4 years, data for Product 01

(sawtimber) was selected for analysis, as it is the only product appraised consistently across both regions. The average percentage of each sawtimber product cost center was calculated per sale, averaged across each individual NF, and then summed to obtain the final total for the entire region.

Timber sale competition and the impact of sale characteristics on bidding behavior were further evaluated using several statistical methods designed to identify regional trends and differences within the TEA dataset. To assess the impact of an increase in the total number of bids a timber sale appraisal received on the dollar amount (expressed as a %) above the advertised rate that a bidder was willing to submit, a one-way analysis of covariance (ANCOVA) was conducted in R v4.4.2 (R Core Team 2024). The ANCOVA analysis used the number of bids received per sale (ranging from 1-5) and the log-transformed, volume-weighted percentage increase from the advertised rate to the highest bid to assess how an increase in bid quantity affected the percentage increase in payment above the advertised rate for sawtimber, non-sawtimber, and biomass appraised sale products in Regions 2 and 3. The percentage increase in payment from the advertised rate to the high bid was log-transformed to correct for the heavy right skew in the data, ensuring normality and constant variance assumptions for ANCOVA.

A multiple linear regression with backward variable selection was used to explore how various TEA timber sale characteristics such as volume, skid distance, number of bids per sale, average sale diameter at breast height (DBH) and round-trip minutes (RTM), influence stumpage bidding behavior for the sawtimber product across the two regions. The high bid amount (i.e., the winning bid) was used as the response variable in the model and log-transformed to enhance model fit by meeting normality and constant

variance assumptions while also mitigating the impact of potential outliers. Although the TEA advertised rates for sawtimber are not a physical sale characteristic, they were included as a predictor variable to capture additional variability in the high bid amount, thus improving overall model fit. To avoid duplication, timber sales in which the sawtimber product included multiple tree species with varying advertised rates and high bids were volume-weighted into a single data point for analysis, and data points from both regions were combined for the comparative analysis. To determine the inclusion of final model variables, a correlation matrix was used to detect multicollinearity between highly correlated predictors and avoid overfitting. The final model was assessed using the adjusted coefficient of determination (R^2) and root mean squared error (RMSE).

2.5. Calculating percentage increases in payment from advertised rates

The analysis used the total number of bids as the covariate and the percentage increase in payment from the advertised rate to the high bid as the dependent variable. To prevent infinite values in the log-transformed percentage increase in payment when the submitted bid for a sale product equaled the advertised rate, a small value of 0.01 was added. To calculate the percentage increase in payment from the advertised rate to the high bid for each timber sale, the following steps were performed. First, the total volume-weighted appraised sale value was calculated using the following equation:

$$TSV = (AR_1 * V_1) + (AR_2 * V_2)$$

where:

TSV = Total Sale Value (\$/CCF)

AR_i = Advertised rate for product i , $i = 1, 2$

V_i = Volume (CCF) for product i , $i = 1, 2$

Next, the volume-weighted total bid value for each timber sale is calculated using the following equation based on the dataset:

$$TBV = (B_1 * V_1) + (B_2 * V_2)$$

where:

TBV = Total Bid Value (\$/CCF)

B_i = High Bid for product i , $i = 1, 2$

V_i = Volume (CCF) for product i , $i = 1, 2$

Finally, the percentage increase in payment (ΔP) between the total bid value and total sale value was calculated. The equation is expressed as:

$$\Delta P = (TBV - TSV)/TSV$$

3. Results

3.1. TEA cost attributes and their effect on a final advertised rate

TEA data for the sawtimber product (01), based on sale-specific cost adjustments from 63 timber sales in the Rocky Mountain region (R2) and 28 timber sales in the Southwestern region (R3), was analyzed to identify which estimated cost center (e.g., skid-yard, slash, temporary road, haul, road maintenance, quality, and unusual adjustments) constitutes the largest percentage of a completed appraisal. Across both regions (Figure 3), skid-yard and haul cost expenditure estimates represent the largest portion of the cost centers appraisals over the past 3-4 years. Skid-yard cost, a calculation of the stump-to-truck harvest operating cost for felling, skidding, and processing the sawtimber (sawlog) product, represents the highest proportion of sale cost center appraisals, comprising 67.2% of the total estimate in Region 2 and 56.3% in Region 3. Haul cost, a transportation-based calculation, is determined from a round-trip minutes

(RTM) estimate derived from local studies measuring minutes per mile on various road segments classified by class and grade for delivering sawlogs to the mill. It was the second-largest component of the TEA process in Region 2 (28.9%) and Region 3 (38%). An RTM factor (e.g., 0.1130) used to calculate haul costs varies slightly between regions. The remaining sale cost centers, including estimates for road maintenance, slash management, temporary road construction, and quality or unusual adjustments, made up a small fraction (<6%) of the total appraisals, with similar percentages across both regions.

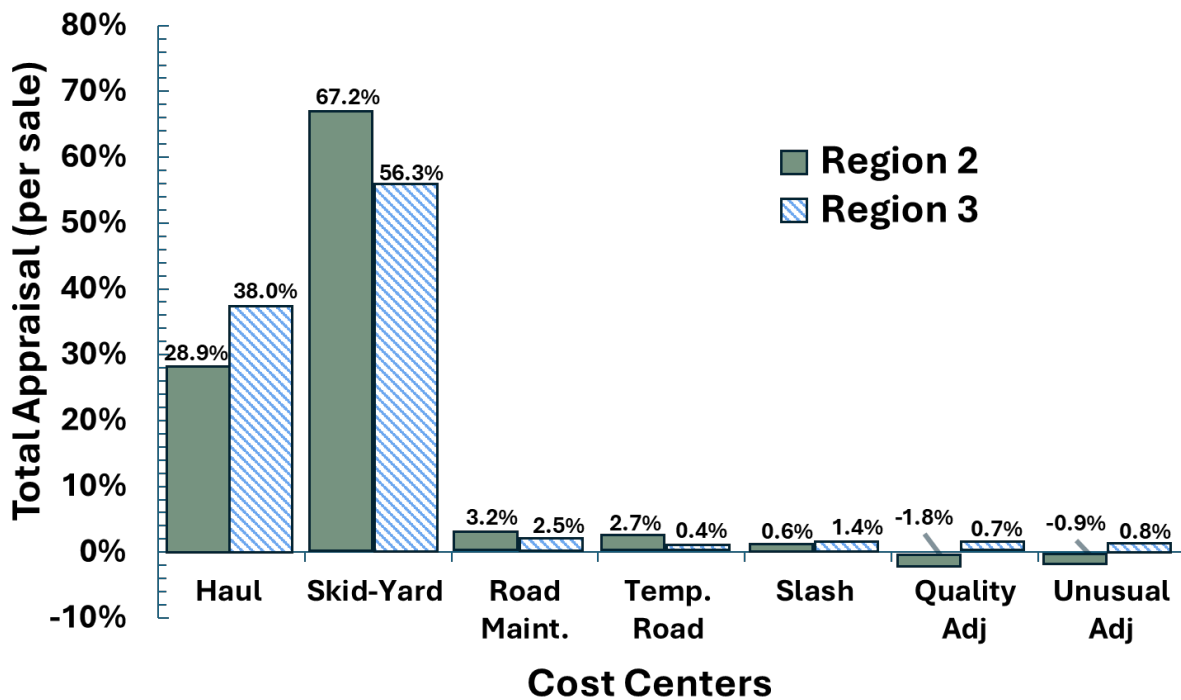


Figure 3. Percentage breakdowns of TEA sale cost centers for timber sales in Regions 2 and 3 from 2020-2024. Primary cost centers, including quality and unusual adjustments, are shown.

In Region 3, the sawtimber product accounted for the highest average estimated haul cost (\$78.81/CCF), while biomass was slightly lower at \$70.46/CCF. Of the five

National Forest's (NFs) analyzed, the Kaibab NF in northern Arizona (AZ), located farthest from lumber processing facilities, estimated an average transport distance of 192 miles and 426 round-trip minutes (RTM) to deliver sawtimber to mills (Table 2). As part of an engineering cost analysis, skid-yard cost estimates in Region 3 use volume per acre (CCF/acre), volume per tree (CF/tree), and average skid distance as the key operational variables. As skid distance increases, skid-yard cost estimates rise accordingly. However, as CCF/acre and CF tree estimates-compiled from cruise reports-increase, skid-yard costs decrease. In Region 3, the Apache-Sitgreaves NF in Arizona had the lowest estimated average total sale volume (3,036 CCF) and the highest average skid distances (660 ft) among NFs with similar timber sale sample sizes, such as the Coconino and Kaibab NFs, resulting in the highest estimated average skid-yard cost at \$115.35/CCF (Table 3).

Table 2. Means and standard errors (in parentheses) of Regions 2 and 3 haul cost, miles, and round-trip minutes (RTM) for sawtimber, non-sawtimber, biomass, and poles TEA products.

Region 2 (Rocky Mountain)					
Product	National Forest	n	Haul Cost (\$/CCF)	Miles (mi)	RTM (min)
Sawtimber	Arapaho.Roosevelt	5	33.29	65	294
	Grand Mesa.Uncompahgre.Gunnison	15	37.55	85	347
	Medicine Bow.Routt	26	24.7	48	219
	Pike.San Isabel	1	63.05	129	558
	San Juan.Rio Grande	9	65.17	135	574
	White River	5	61.84	125	535
	Sub-Total		61	38.21 (2.5)	79 (5.6)
Poles	Arapaho.Roosevelt	2	-4.17	28	187
	Grand Mesa.Uncompahgre.Gunnison	2	7.23	95	285
	Medicine Bow.Routt	16	2.94	69	220
	San Juan.Rio Grande	6	9.59	108	547
	Sub-Total		26	4.26 (1.5)	77 (8.5)
Total		87			
Region 3 (Southwestern)					
Product	National Forest	n	Haul Cost (\$/CCF)	Miles (mi)	RTM (min)
Sawtimber	Apache-Sitgreaves	6	38.46	37	173
	Carson	2	66.16	87	304
	Coconino	6	88.56	159	373
	Gila	3	84.62	127	370
	Kaibab	8	87.13	192	426
	Sub-Total		25	73.81 (5.7)	128 (14.7)
Non-sawtimber	Apache-Sitgreaves	5	41.57	44	184
	Carson	2	66.16	87	304
	Coconino	9	51.31	109	241
	Gila	3	41.33	49	198
	Kaibab	6	70.73	158	360
	Santa Fe	1	61.42	56	240
Sub-Total		26	54.30 (3.8)	94 (12.4)	254 (20.1)
Biomass	Apache-Sitgreaves	4	40.93	42	183
	Coconino	6	87.78	144	370
	Kaibab	4	74.02	170	364
	Sub-Total		14	70.46 (5.8)	122 (14.8)
Total		65			

n = number of timber sale transactions analyzed for individual products

Table 3. Means and standard errors (in parenthesis) of Region 3 skid-yard cost, volume, and average skid distance for sawtimber, non-sawtimber, and biomass TEA products.

Product	National Forest	n	Skid-Yard Cost (\$/CCF)	Volume (CCF)	Skid Distance (ft)
Sawtimber	Apache-Sitgreaves	6	115.35	3036	660
	Carson	2	74.10	317	131
	Coconino	6	101.86	8040	573
	Gila	3	95.28	1235	467
	Kaibab	8	92.59	5197	576
	Sub-Total		25	99.12 (2.8)	4495 (771.7)
Non-sawtimber	Apache-Sitgreaves	5	114.34	1790	585
	Carson	2	74.10	142	131
	Coconino	8	100.29	11030	555
	Gila	3	95.28	1008	467
	Kaibab	6	97.30	2625	627
	Santa Fe	1	95.66	1512	400
Sub-Total		25	99.50 (2.4)	4710 (1232.4)	527 (36.9)
Biomass	Apache-Sitgreaves	4	118.85	1703	655
	Coconino	6	101.86	2910	573
	Kaibab	4	97.08	783	721
	Sub-Total		14	105.35 (2.9)	1957 (438.3)
Total		64			

n = number of timber sale transactions analyzed for individual products

The Pike-San Isabel and San Juan/Rio Grande NFs in Colorado (CO) had the highest average haul costs for sawtimber in Region 2, at \$63.05/CCF and \$65.17/CCF respectively (Table 2). The Medicine Bow-Routt NF, with the largest number (26) of analyzed timber sales over the past 3-4 years, appears to be closest to several nearby lumber processing facilities (i.e., appraisal points) with an average of 48 miles and 219 RTM. In comparison, the San Juan/Rio Grande NF in southwest CO has an average haul estimate of 574 RTM and 135 miles. To calculate skid-yard timber processing costs in Region 2, the sale cruise report estimates for sawtimber, including average DBH and volume per acre (CCF/acre), are balanced against averages from a TEA bulletin to determine the adjustment. As the sale DBH increases, the estimated skid-yard cost

decreases with the same correlation holding true for increases in volume per acre. With the lowest estimated average sale sawtimber DBH (9.3 in), the Arapaho-Roosevelt NF had the highest average skid-yard cost at \$136.35/CCF (Table 4). Due to higher volume and average DBH estimates for their timber sales, the San Juan/Rio Grande and White River NFs had the lowest estimated skid-yard cost at \$89.24/CCF and \$88.85/CCF, respectively.

Table 4. Means and standard errors (in parenthesis) of Region 2 skid-yard cost, volume, and the timber sale average diameter at breast height (DBH) for sawtimber, and poles TEA products.

Product	National Forest	n	Skid-Yard Cost (\$/CCF)	Volume (CCF)	Avg. DBH (in.)
Sawtimber	Arapaho.Roosevelt Grand Mesa.	5	136.35	5225	9.3
	Uncompahgre.Gunnison	15	89.38	5492	13.1
	Medicine Bow.Routt	26	130.46	6337	9.7
	Pike.San Isabel	1	106.81	4740	11.6
	San Juan.Rio Grande	9	89.24	7019	12.9
	White River	5	88.85	7874	12.8
	Sub-Total		61	110.96 (3.4)	6239 (533.5)
Poles	Arapaho.Roosevelt Grand Mesa.	2	128.20	1917	9.1
	Uncompahgre.Gunnison	2	89.23	631	12.6
	Medicine Bow.Routt	16	129.82	857	9.3
	San Juan.Rio Grande	3	103.33	405	11.6
	Sub-Total		23	122.69 (3.5)	871 (112.9)
Total		84			

n = number of timber sale transactions analyzed for individual products

3.2. TEA bidding

Competition for timber sale offerings on TEA sales from Regions 2 and 3 can be measured by evaluating the bidding behavior of timber contractors, logging companies or sawmills. This study analyzed the bidding behavior of logging contractors on USFS TEA sales in Regions 2 (n = 63 sales) and 3 (n = 28 sales) from 2020 to 2024 to understand how sale-specific factors and regional competition influenced the additional payments

bidders made above advertised rates to secure timber sale contracts. To gain a more comprehensive understanding of recent bidding behavior, the total number of bids received per sale (between 1-5 bids) was analyzed and compared between the two regions (Figure 4). In Region 2, a large proportion (65%) of the 63 total timber sales received only one bid. Of the 15 timber sales from the Grand Mesa, Uncompahgre, and Gunnison NFs in Colorado, 86.7% received just one bid. In comparison, approximately 40% of the 28 timber sales analyzed from the Southwestern Region (R3) received one bid. The percentage of timber sales in Region 3 receiving three to five bids, indicating increased competition, was significantly higher than in Region 2, at 40%. In contrast, only 5% of the 63 timber sales in Region 2 received three to five bids. Additionally, 7% of Region 3 sales received a total of five bids, while none of the sales across six NFs in Region 2 reached that number.

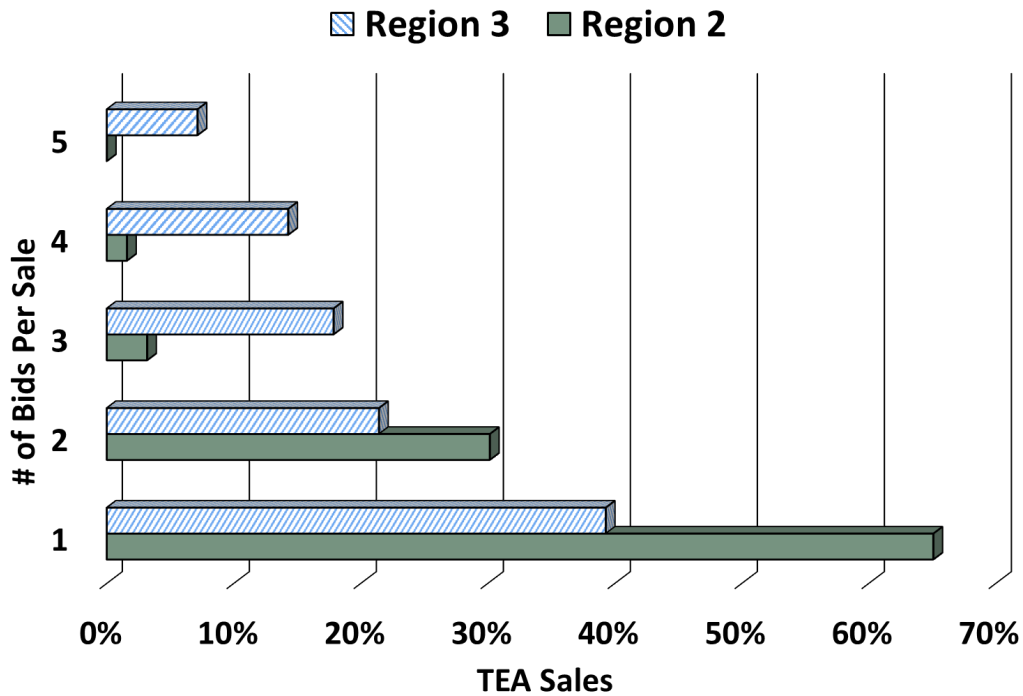


Figure 4. General TEA bidding attributes showing the percentage of sales receiving between 1 to 5 bids from USFS Regions 2 (Rocky Mountain) and 3 (Southwestern).

To further assess competition and the effect of an increase in the total number of bids received per sale (across all products and volumes) on the percentage increase in payment above advertised rates, a one-way analysis of covariance (ANCOVA) was conducted. The estimated mean difference in the log-transformed volume-adjusted percentage increase in payment above the advertised rate between Regions 2 and 3 was -0.3905, with Region 3 showing a lower mean than Region 2. However, with a p-value of 0.43, this difference was not statistically significant. The estimated slope parameter in the ANCOVA was 1.2181, indicating that for every additional bid per sale, the percentage increase in payment above the advertised rate tended to increase by an average of 238% (i.e., $e^{1.2181} - 1 = 2.38$) across both regions (Figure 5). With a p-value close to 0 ($p < 0.0001$), this result suggests that the number of bids received per timber sale is significantly associated with the percentage by which the winning bid exceeds the advertised rate.

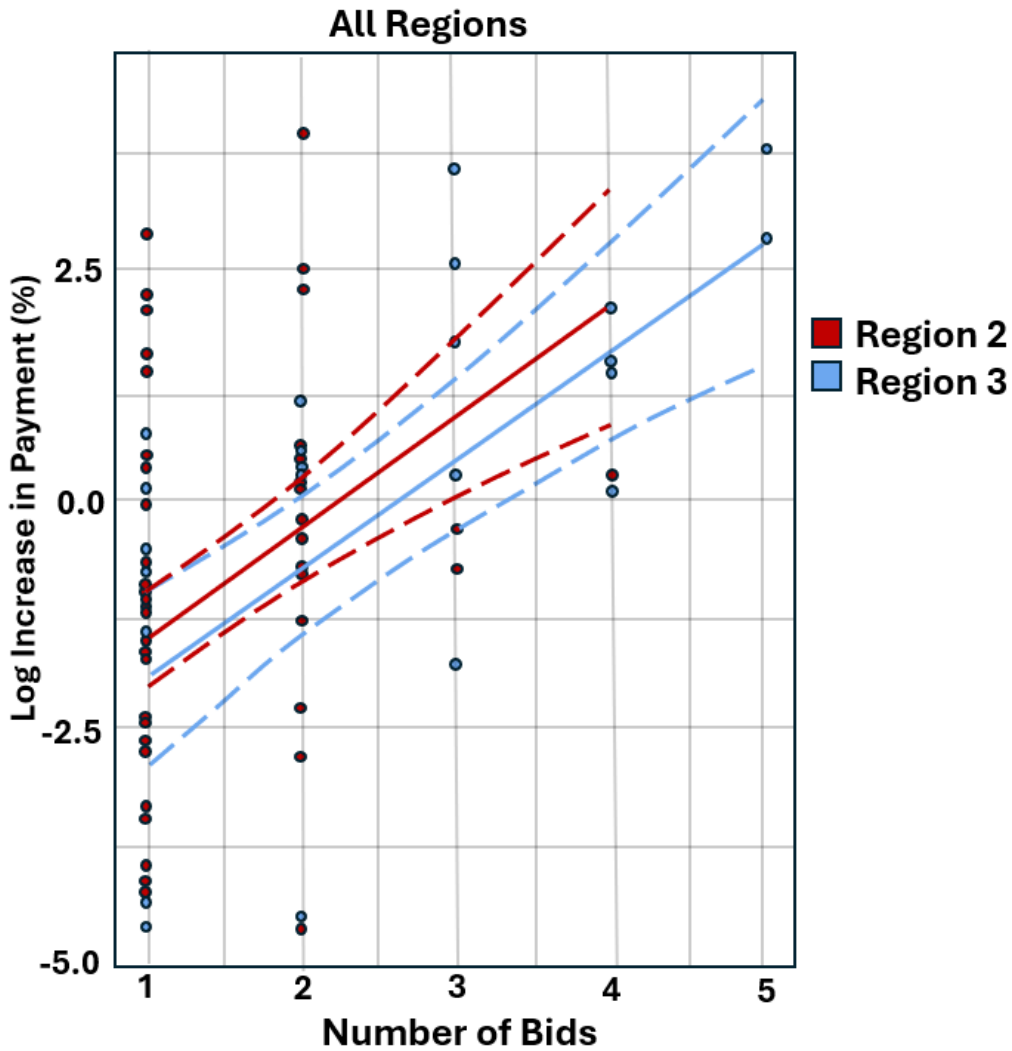


Figure 5. Log-transformed percentage increase in payment above the TEA advertised rate versus total number of bids received per sale, based on ANCOVA analysis. Solid lines represent the estimated means of the log-transformed percentage increase for each region. Dashed lines indicate the confidence intervals for each region.

To gain a deeper understanding of trends in TEA bidding behavior based on the influence of various timber sale characteristics, specifically those affecting sawtimber product high bid amounts, we fitted a multiple regression model to the combined data from Regions 2 and 3 as illustrated in Section 2.4. After backward variable selection, the fitted model produced an adjusted R^2 of 0.78 and a residual standard error (RSE) of 0.55. Five sawtimber product sale characteristics were assessed for their impact on log-

transformed high bid amounts for sales in Regions 2 and 3. The regression results, presented in Table 6, illustrate the relationship between high bid amounts (the response variable) and predictor variables (sale characteristics). A correlation matrix revealed strong correlations between RTM and haul miles (0.92 in Region 2 and 0.95 in Regions 3, respectively), with RTM providing a slightly better model fit. Volume (in CCF) and harvest acres also showed strong correlations (0.64 in Region 2 and 0.83 in Region 3, respectively), which led to the inclusion of volume over harvest acres in the backward variable selection. Variables with high p-values were removed through backward selection, resulting in a simplified model that retained *volume*, *number of bids*, *RTM*, and *skid distance* without significantly compromising model fit. Although important in other harvest productivity models (Louis et al. 2022), the *average sale DBH* did not significantly affect high bid amounts when accounting for other variables and was thus removed during the backward selection process.

Table 6. Sale characteristics, parameter estimates^a, and p-values from TEA sawtimber high bid amount model, displayed by USDA Forest Service Region. n = 75 (56, Region 2; 19, Region 3)

Region 2 (Rocky Mountain)		
Sale Characteristic (Variable)	Parameter estimates	p-value
Intercept	0.6924	0.0913
Log-transformed sawtimber TEA advertised rate	0.7204	<0.0001
Number of bids per timber sale	0.1622	0.1581
Sawtimber volume (in 100 CCF)	-0.0056	0.0029
Round-trip transportation of product to mill (in hours)	0.1154	0.0018
Estimated timber sale average skid distance (in 100 feet)	-0.1947	0.7888
Region 3 (Southwestern)		
Sale Characteristic (Variable)	Parameter estimates	p-value
Intercept	0.5808	0.3529
Log-transformed sawtimber TEA advertised rate	0.7204	<0.0001
Number of bids per timber sale	0.6555	<0.0001
Sawtimber volume (in 100 CCF)	0.0130	0.0069
Round-trip transportation of product to mill (in hours)	-0.0040	0.9604
Estimated timber sale average skid distance (in 100 feet)	-0.2112	0.0037
Difference: Region 3 - Region 2		
Sale Characteristic (Variable)	Parameter estimates	p-value
Number of bids per timber sale	0.4934	0.0033
Sawtimber volume (in 100 CCF)	0.0186	0.0005
Round-trip transportation of product to mill (in hours)	-0.1194	0.1786
Estimated timber sale average skid distance (in 100 feet)	-0.1947	0.0399

^aThe coefficient estimates from the log-transformed high bid amount model were exponentiated and adjusted by subtracting 1 to calculate the percentage change in the high bid amount, e.g., $e^{0.1154} - 1 = 0.122$ (12.2%).

In Region 2, sawtimber volume (in 100 CCF) and round-trip minutes (RTM) significantly influenced contractors' high bid submissions for USFS TEA timber sale offerings. The average skid distance estimates ($p = 0.7888$) and total number of bids submitted per sale ($p = 0.1581$) did not significantly influence high bid amounts in Region 2. For every additional 100 CCF of sawtimber volume estimated for timber sales across Region 2, the high bid amount is expected to decrease by 0.56% (i.e., $e^{-0.0056} - 1 = -0.0056$) if other timber sale characteristics and the number of bids remain the same. As a key factor in TEA haul cost calculations, RTM determine the estimated time for

sawtimber to be delivered from the cutting site to the nearest appraised sawmill or processing facility. With each additional hour of round-trip travel time, the high bid amount is expected to increase by 12.2% (i.e., $e^{0.1154} - 1 = 0.122$).

For Region 3, which includes NFs in Arizona and New Mexico, sawtimber volume estimates significantly influenced high bid amounts. An additional 100 CCF of sawtimber volume in the appraisal estimate is predicted to increase the high bid amount by 1.31% (i.e., $e^{0.013} - 1 = 0.0131$). Unlike Region 2, average skid distance ($p = 0.0037$) and total number of bids submitted per sale ($p < 0.0001$) significantly impacted high bids in Region 3. For each additional bid submitted, the high bid amount is predicted to increase by 92.6%. As an indicator of stump-to-truck operational processing costs, an increase of 100 feet in estimated skid distance is anticipated to lower the high bid amount by 19.1%. However, the RTM estimate for haul cost did not significantly influence bidding behavior in Region 3.

The model was also valuable in examining differences in how key variables influenced high bid amounts between the two regions. In the TEA method, the high bid amount refers to the winning bid for each product in a timber sale. Statistically significant differences between the regions were found in how three variables influenced high bid amounts: the number of bids, sawtimber volume, and average skid distance. In Region 3, each additional bid per sale is associated with a 63.8% higher high bid amount compared to Region 2 ($p = 0.0033$). For every 100 CCF increase in sawtimber volume per sale, the high bid amount in Region 3 is expected to increase by 1.9% more than in Region 2 ($p = 0.0005$). Additionally, a 100-foot increase in the average skid distance is expected to reduce the high bid amount in Region 3 by 17.7% less than in Region 2 ($p = 0.0399$).

4. Discussion

4.1. Stump-to-truck operational costs

From 2020-2024, the calculation of a skid-yard (stump-to-truck processing) cost represented the largest portion of TEA sale cost center estimates for both regions. The stump-to-truck operational cost associated with harvesting timber, specifically the felling, skidding, and processing sequence, are influenced by machine productivity rates and site characteristics. In a given treatment, the skid-yard (i.e., stump-to-truck) costs related to estimating operational productivity are heavily influenced by system balance (Vitorelo et al. 2011). The combination of harvesting machines used for felling, skidding, and processing stump-to-truck operational costs are referred to as a system (Chang et al. 2023). Treatment production costs are often impacted by operational delays of other factors contributing to system imbalance, which can significantly affect overall productivity (Rummer 2008). The current TEA method for calculating timber sale skid-yard costs is not designed to incorporate fluctuations in productivity or system balance into operational cost estimates.

An important element of TEA skid-yard cost calculations for both regions involves estimating volume per acre (vol/acre) and tree size, based on total tree volume (CF/tree) in Region 3 and average sawtimber DBH in Region 2. Similar mechanical treatment economic feasibility studies have identified increases in harvest productivity directly related to larger tree sizes (Adebayo et al. 2007; Pan et al. 2008; Louis et al. 2021), or harvest cost increases associated with a decrease in average DBH (Han et al. 2004; Pan et al. 2008). Current TEA calculations align with these findings, as decreases in tree volume and DBH correlate with higher estimated skid-yard costs. In Region 3, the NFs with the lowest average CF/tree sawtimber estimates (Apache-Sitgreaves and

Coconino) correspond to the highest skid-yard cost estimates among the five NFs represented. By including tree size (CF/tree and DBH) and vol/acre estimates on 2400-17 appraisal forms, logging contractors are better equipped to estimate productivity and overall stump-to-truck costs more accurately.

Although skid distance is an important site-specific factor that can create system imbalances and increase production costs (Rummer 2008), it is not factored into the Region 2 logging cost adjustment (LCA). An increase in average skid distance has been shown to directly raise estimated skid-yard costs (Soman et al. 2019). In a study of mixed-conifer stands by Adebayo et al. (2007), skidding of sawlogs from cut stumps to landings for processing accounted for 36% to 54% of the total harvesting cost in cut-to-length (CTL) and whole-tree (WT) harvest operations. Along with tree-length (TL) operations, WT harvesting methods are commonly used in the western US for fuel reduction treatments (Han and Han 2020). Another study on harvesting operational costs in southwest Idaho (Han et al. 2004) identified skidding as the most expensive system component, with the exception of a mechanical CTL system. Despite its proximity to more processing facilities and mills, which reduce haul costs, the Apache-Sitgreaves NF in Arizona had the highest estimated skid-yard cost and skid distances for all three sale products (sawtimber, non-sawtimber, biomass). Higher average skidding distances reduce harvesting production rates, so careful consideration of skid trail placement is essential during the operational planning phase (Pan et al. 2008). Skidding distance has a notable impact on stump-to-truck harvesting cost and could be incorporated into the Region 2 LCA equation to predict overall harvest operational costs more accurately.

Another key operational variable to consider adding in the TEA calculation for skid-yard costs is ground slope (as a percentage). While increasing logging operations on steep slopes may help expand treatment acreage in the western US, it can present additional cost challenges, particularly due to the need for tethered mechanical equipment (Woolsey et al. 2024). Current TEA calculations for Regions 2 and 3 do not account for cable yarding or helicopter removal estimates, as logging operations typically do not occur on slopes exceeding 35%. Since ground slope impacts logging machine productivity and overall cost (Louis et al. 2022; Chang et al. 2023), it could be incorporated into TEA skid-yard cost calculations or listed on appraisal sheets to give potential bidders a clearer understanding of projected stump-to-truck harvest costs.

To improve the consistency and accuracy of the TEA skid-yard cost calculation, combining regional operational cost variables into a single updated equation for both regions could be an option. Additional factors, such as ground slope percentage or fuel cost adjustments, might also be incorporated into the calculation to better inform the total operational stump-to-truck cost of mechanical thinning treatments across both regions. Another option is the inclusion of an external stump-to-truck cost estimation tool, which could utilize available prescription or cruise report data to incorporate a broader range of operational factors and site conditions into TEA skid-yard cost estimations. The ThinCost_1.0 model (Chang et al. 2023) was developed by incorporating a wide range of new variables and updated productivity equations based on field-derived empirical study data. It estimates stump-to-truck production costs using user inputs for machine productivity, cost rates, thinning prescription data (tree volumes and average DBH), stand-specific variables (e.g., ground slope and species composition), and operational

variables (skid distance), across five input tabs. While further research might be necessary to validate and assess its accuracy using available USFS TEA timber sale data, site prescriptions, and cruise reports, the ThinCost_1.0 model represents an opportunity to provide standardization and consistency in the development of skid-yard costs across the two regions.

4.2. Transportation costs and wood products

In the analysis of TEA data from Regions 2 and 3, haul estimates for transporting sawlogs and other timber products accounted for the second largest portion of total stump-to-truck harvesting and delivery costs, at 28.9% in Region 2 and 38% in Region 3. Round-trip minutes (RTM) is used to calculate transportation costs by multiplying the travel time from the cutting site to the nearest processing facility (i.e., the most advantageous appraisal point) by a haul rate factor that accounts for \$/CCF/mile. This estimate incorporates factors such as different road types, alignment classes, delays, and average speed (mph). Using RTM, rather than total haul miles, provides a more practical and accurate estimate of transportation costs, as road conditions (e.g., gravel/dirt vs. paved roads) affect travel speeds. Thus, RTM is a better measure of cost, reflecting overall time traveled rather than just distance.

As evidenced by average haul costs for sawtimber products on the Coconino NF (\$88.56/CCF), Kaibab NF (\$87.13/CCF), and Gila NF (\$84.62/CCF) in Region 3, limited market availability for forest products resulting from mechanical thinning operations contributes to significantly higher estimated transportation costs. By comparison, the three NFs in Region 2 with the highest haul costs (Pike-San Isabel, San Juan-Rio Grande, and White River) averaged \$63.35/CCF. As small-diameter timber is removed from

various different projects in the Southwest for restoration and wildfire fuel reduction purposes, the lack of markets and infrastructure for processing and manufacturing this timber often leads to increased hauling costs, hindering efforts to scale up treatments across the landscape (Woolsey et al. 2024; Townsend et al. 2019; Hjerpe et al. 2009). Based on TEA data from 28 timber sales in Region 3, the average DBH for sawtimber (product 01) was 15.9 inches, while non-sawtimber (product 08) averaged 11.0 inches, underscoring the prevalence of small-diameter timber, which is less marketable, in recent sales across Arizona and New Mexico. A similar trend is observed in Region 2, where the average DBH for sawtimber from 63 sales was 11.7 inches. For instance, the San Juan-Rio Grande NF (\$65.17/CCF) in Southwestern CO and Pike-San Isabel NF (\$63.05/CCF), southwest of Denver, CO, exhibited the highest haul costs, total miles, and round-trip minute estimates for transporting sawtimber sale products to nearby processing facilities.

The current TEA method requires determining the most advantageous appraisal point for each sale haul cost calculation, meeting these criteria: (1) constitute a location within the sale's working circle where raw materials or products (e.g., sawlogs) can be sold, (2) be a facility capable of processing the end product, including having the capacity to manage the estimated sale volume, and (3) total transportation costs must be less than if appraised to other facilities. Reduced capacity and sawmill closures across the western US have limited the ability to select appraisal points closer to timber sales, thus increasing haul cost estimates (Spelter 2002). For example, in Region 3, TEA sales from the Coconino and Kaibab NFs in Northern Arizona often require sawtimber to be appraised at facilities in the White Mountain region of eastern Arizona, typically over 100

miles from sale locations. A similar trend is observed in Region 2, where sawtimber from several sales on the San Juan-Rio Grande NF have been appraised to Montrose, CO, also at a distance exceeding 100 miles. Recent research on mill capacity and closures in Arizona, New Mexico, and Colorado is limited. Conducting a regular census of lumber processing facilities, detailing their capacity and product outputs (e.g., firewood, pallets, poles), would help ensure that appraisal locations remain up-to-date as timber markets evolve and mills close or adjust production. While this approach may not resolve the broader issue of limited processing facilities, it could help maintain the accuracy of TEA haul cost estimates.

4.3. Factors influencing purchasers' bidding behavior

Examining regional trends in TEA bidding behavior and competition can reveal key timber sale characteristics most likely to influence bid rates and attract greater interest in future timber sales. For each potential offering, factors such as physical site conditions, treatment objectives, sale characteristics, contractor efficiency, and harvesting method will influence the amount a bidder is willing to pay for stumpage (Kilgore and Blinn 2005). While limited to timber sale characteristics data recorded and tracked by the USFS TEA method, the analysis of bid behavior was constrained by the exclusion of factors explored in similar studies, such as the seasonality of offerings and harvest restrictions (Dahal and Mehmood 2005; Brown et al. 2012), as well as a lack of available data on contractor productivity and costs.

In both regions, the amount of sawtimber volume (in CCF) available in a given sale was a significant factor influencing high bid amounts, reinforcing findings from similar studies that total appraised volume is a key determinant of bid behavior and an

important element of sale design (Kilgore and Blinn 2005; Brown et al. 2012; Dahal and Mehmood 2005). In Region 3, sawtimber volume positively influenced high bid amounts, with each additional hundred cubic feet increasing the bid price per CCF by 1.9% more than in Region 2. Higher sawtimber volumes may be more attractive to buyers in Region 3, who are looking to maximize the amount of harvested sawlogs transported to processing facilities in Phoenix, AZ, for conversion into wood pallets (Bolton, T., Campbell Global, Flagstaff, USA, personal communication). In contrast, timber markets and processing facilities in Region 2 are more flexible, utilizing a wider variety of timber sizes and species to produce a diverse range of products such as posts, poles, biochar, and other lumber items (Reader, T., Colorado State Forest Service, Durango, USA, personal communication).

Operational sale characteristics that could impact stump-to-truck harvest productivity and cost were a relevant factor in bid behavior only in Region 3, where increases in skid distance estimates were associated with a decrease in high bid amounts by approximately 19.1%. In Region 2, however, skid distance did not significantly influence high bid prices (p-value = 0.789). Timber sale guidelines that estimate skid distances or the location of landings may be difficult to ground-truth prior to preparing and submitting a bid for an upcoming sale. Although lower extraction distances have been shown to increase skidder productivity (Chang et al. 2023), contractors may not place significant emphasis on TEA skid distance estimates prior to purchasing a sale. It may be more feasible to create a logging plan layout with skid trail and landing locations strategically designed to maximize productivity and reduce costs once a sale has been purchased and ground-truthed. In a survey of timber sale bidders in Minnesota, Kilgore

and Blinn (2005) found that guidelines specifying merchantable residual trees required to be left on-site had a greater influence on bid behavior than guidelines concerning skid trail and landing placement or slash disposal. Additionally, few timber harvesters took the opportunity to physically visit a potential sale site before preparing their bids (Kilgore and Blinn 2005).

4.4. Market competition and number of bids

Competition for USFS TEA timber sales can be assessed regionally by evaluating the number of bids received for the stumpage offered for each individual sale (Leefers and Potter-Witter 2006). The number of bids received per sale in Region 2 was significantly lower than Region 3, where approximately 65% of the timber sales analyzed received only one bid. With a lower number of total sale offerings during the analysis period, Region 3 experienced higher levels of competition, as indicated by overall bid totals per sale. Similar to previous studies showing that an increased number of bids raised stumpage prices, signifying heightened competition (Brown et al. 2012; Dahal and Mehmood 2005; Leefers and Potter-Witter 2006), the number of bids received for a sale had a significant positive influence on high bid amounts in Region 3. Sales that receive no bids may occur, while practices such as intentional underpricing and preclusive bidding may also exist and can be difficult to detect. However, increasing the number of bidders and competition for sales could lead to higher bid amounts. This, in turn, may help establish consistent TEA base period prices that better reflect market values.

Building and designing upcoming timber sales to make them more appealing to contractors can increase competition by raising the total number of bids received, generating higher bid amounts, and decreasing the likelihood of receiving no bids.

Providing detailed and accurate sale characteristics, including species composition, timber volume and quality, and harvesting guidelines or restrictions (Kilgore and Blinn 2005), or offering sales with increased volume per acre (Brown et al. 2012), can effectively increase high bid amounts, help bidders accurately predict operational costs, and potentially draw more competition. Additionally, strategically locating and timing sale offerings to align with mill productive capabilities and timber demand could help contractors better plan for potential revenue and profit margins based on mill capacity. Adding incentives for sales with lower quality timber, such as USFS investment in road improvements to better facilitate winter logging, allowing additional wood decks during winter months to meet mill contract requirements during the slow season, or considering a diesel/fuel cost adjustment to accommodate rapidly changing fuel prices, might support logging contractors in maintaining long-term operational stability and financial security.

4.5 Regional differences

When appropriate, adjusting TEA cost center calculations to ensure consistency across USFS regions is beneficial when timber species, site conditions, and lumber industry infrastructure exhibit sufficient similarities. Sale feature differences (e.g., salvage sales in Region 2) can still be addressed in the TEA method through quality adjustments, while incorporating skid distance into skid-yard cost calculations might enhance consistency across regions. Haynes et al. (2016) proposed reorganizing TEA regional appraisal zones to better align with local lumber markets. Similarities in markets delineated by haul miles and RTM between NFs in SW Colorado (R2) and Arizona (R3) present an opportunity to create new zones that address discrepancies in haul cost estimates, ensuring more consistent expected advertised rates for bidders across both

regions. Updated appraisal zones could also potentially address regional variations in contractor availability, mill capacity, and sale offerings that impact competition and the number of bids submitted per sale offering.

5. Conclusion

To meet the WCS goal of rapidly increasing the pace and scale of fuels and forest health treatments in the coming years, it is essential to understand the nuances and barriers to implementing mechanical thinning restoration treatments in priority landscapes. Evaluating the economic feasibility of these treatments, particularly harvest productivity costs and transportation expenses, is key to scaling up efforts to expedite treatment acreage across western landscapes. Accurately assessing these operational aspects is crucial for balancing treatment objectives with the need to ensure financial returns, thereby maintaining the economic viability of the process for all parties involved. The USFS Transaction Evidence Appraisal (TEA) method is designed to provide a consistent and accurate determination of fair market value for stumpage by assessing operational costs, regional competition, and market adjustment factors. Recent TEA sales in Regions 2 and 3 have allocated a significant portion of sale cost adjustments to stump-to-truck processing and hauling estimates. While further research is needed, integrating emerging harvest productivity cost modeling tools that encompass additional sale characteristics could provide more accurate and consistent skid-yard cost estimates across both regions.

Despite challenges such as limited market availability and high transportation costs in the southwest US, updated data on processing facilities and production capacity, along with potential fuel cost adjustments, could help streamline haul cost estimates and alleviate some of the economic pressures logging contractors face. By increasing

sawtimber volumes to incentivize upcoming sale offerings and strategically releasing sales based on location and market demand, it may be possible to attract additional bidders, boosting competition and stumpage bid amounts to stabilize base period prices and maintain consistent sale advertised rates.

These strategies could help balance economic feasibility with restoration objectives, ensuring both profitability and treatment efficiency. A detailed understanding of the current TEA method, coupled with potential improvements and bidding behavior considerations, assures accurate economic analysis of fuel restoration treatments in the western US. To achieve broader landscape-scale objectives in addressing the wildfire crisis, aligning operational cost estimation methods, market incentives, and restoration goals could enhance implementation of treatments to restore and maintain healthy, productive forest ecosystems.

Funding

Funding for this study was partially provided by the U.S. Department of Agriculture Forest Service (Joint Venture Agreement No: 24-JV-11111107-013).

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Appendix

Breakdown of TEA calculation for the **Live Stump** timber sale from the **Rio Grande NF** in **USFS Region 2** from **2023**. 2400-17 Report of Timber Sale example included.

Background Information:

USFS Region: 2 (Rocky Mountain)
National Forest: Rio Grande NF (09)
Ranger District: Divide (04)
Fiscal Year: 2023
Sale Name: Live Stump

Step #1: Evaluate Products, Species, Condition (Appraisal Group) & Volume in the sale.

Product(s): Sawtimber (01) only

Species (Species Code):

Douglas Fir (204)	Engelmann Spruce (093)	True Fir (025)
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Condition: Live

Volume (in CCF):

Species:	Douglas Fir	Engelmann Spruce	True Fir
Volume:	2257	27	345

Total Volume: 2629 CCF

Step #2: Determine product Base Period Price (BPP) from TEA bulletin. (in \$/CCF)

Base Period Price (BPP):

Species:	Douglas Fir	Engelmann Spruce	True Fir
BPP:	\$1.25	\$14.21	\$3.00

Step #3: Calculate the Market Adjustment (based on the WWPA index). (in \$/CCF)

Calculation (*Region 2): Market adj. = (WWPA/Avg. WWPA x BPP) – BPP

Market Adjustment:

Species:	Douglas Fir	Engelmann Spruce	True Fir
Adjustment:	\$4.23	\$-5.23	\$0.00

Step #4: Calculate the Adjusted BPP (BPP + Market Adjustment). (in \$/CCF)

Adjusted BPP:

Species:	Douglas Fir	Engelmann Spruce	True Fir
Adjusted BPP:	(\$1.25 + \$4.23) = \$5.48	(\$14.21 – \$5.23) = \$8.98	(\$3.00 + \$0.00) = \$3.00

Step #5: Calculate all of the sale cost center adjustments against their base costs from the TEA bulletin. Sale cost centers = Skid-Yard, Haul, Road Maintenance, Slash Management, and Temporary Road. (in \$/CCF).

Note:

If Sale Cost > Base Cost = Negative Adj. (-)

If Sale Cost < Base Cost = Positive Adj. (+)

Skid-Yard Cost: (Base Cost – Sale Cost)

Species:	Douglas Fir	Engelmann Spruce	True Fir
Base Cost:	\$72.76	\$72.76	\$72.76
Sale Cost:	\$74.09	\$74.09	\$74.09
Adjustment:	\$-1.33	\$-1.33	\$-1.33

Haul Cost: (Base Cost – Sale Cost)

Species:	Douglas Fir	Engelmann Spruce	True Fir
Base Cost:	\$43.40	\$51.98	\$49.04
Sale Cost:	\$37.79	\$37.79	\$37.79
Adjustment:	\$5.61	\$14.19	\$11.25

Road Maintenance: (Base Cost – Sale Cost)

Species:	Douglas Fir	Engelmann Spruce	True Fir
Base Cost:	\$3.09	\$6.20	\$6.20
Sale Cost:	\$1.86	\$1.86	\$1.86
Adjustment:	\$1.23	\$4.34	\$4.34

Slash Management: (Base Cost – Sale Cost) *There was \$0 slash management cost for this sale

Species:	Douglas Fir	Engelmann Spruce	True Fir
Base Cost:	\$1.74	\$1.60	\$1.93
Sale Cost:	\$0.00	\$0.00	\$0.00
Adjustment:	\$1.74	\$1.60	\$1.93

Temporary Road: (Base Cost – Sale Cost)

Species:	Douglas Fir	Engelmann Spruce	True Fir
Base Cost:	\$2.24	\$5.01	\$5.38
Sale Cost:	\$1.66	\$1.66	\$1.66
Adjustment:	\$0.58	\$3.35	\$3.72

Step #6: Calculate any sale Quality or Unusual adjustments (if applicable). For the Live Stump timber sale, there was an unusual fuel cost adjustment of \$0.96/CCF but no quality adjustment.

Unusual Adjustment: (Fuel Cost):

Species:	Douglas Fir	Engelmann Spruce	True Fir
Adjustment:	\$-0.96	\$-0.96	\$-0.96

Step #7: Total up all of the sale cost center and quality/unusual adjustments. (in \$/CCF)

Species:	Douglas Fir	Engelmann Spruce	True Fir
Skid-Yard Adj.	\$-1.33	\$-1.33	\$-1.33
Haul Adj.	\$5.61	\$14.19	\$11.25
Road Maint Adj.	\$1.23	\$4.34	\$4.34
Slash Adj.	\$1.74	\$1.60	\$1.93
Temp Road Adj.	\$0.58	\$3.35	\$3.72
Unusual Adj.	\$-0.96	\$-0.96	\$-0.96
Total Adjustment:	\$6.87	\$21.19	\$18.95

Step #8: Determine the Predicted Bid Rate (PBR). $PBR = (Adjusted\ BPP + Total\ Adjustment)$. (in \$/CCF)

Species:	Douglas Fir	Engelmann Spruce	True Fir
Adjusted BPP:	\$5.48	\$8.98	\$3.00
Total Adjustment:	\$6.87	\$21.19	\$18.95
PBR:	\$12.35	\$30.17	\$21.95

Step #9: Apply the Competition (or rollback) Factor based on competitive (10%) vs. non-competitive (5%) area as determined and listed in the TEA bulletin. For this example, the competition factor for the Rio Grande NF was set at 10% (competitive). (in \$/CCF)

Species:	Douglas Fir	Engelmann Spruce	True Fir
Competition Amount:	\$0.55	\$0.90	\$0.30

Step #10: Calculate the Indicated Advertised Rate. (in \$/CCF) The Indicated Advertised Rate is the Predicted Bid Rate (PBR) – Competition Amount. (in \$/CCF) *include any Specified Road costs or Timber Property Value costs if applicable. In this example, there were not.

Species:	Douglas Fir	Engelmann Spruce	True Fir
Indicated Adv. Rate:	$(\$12.35 - \$0.55) =$ \$11.80	$(\$30.17 - \$0.90) =$ \$29.27	$(\$21.95 - \$0.30) =$ \$21.65

Step #11: Decide if an Adjustment to Base Rate is needed. For this example, the base rate for each species was \$2.84/CCF. The Indicated Advertised Rate for each species was above the \$2.84/CCF base rate so no adjustment was needed.

Step #12: Set the final Advertised Rate and calculate the total value for each species/product (Value = Advertised Rate x Volume). For this example, with no Adjustment to Base Rate needed, the final Advertised Rate will be the same as the Indicated Advertised Rate from Step # 10. (in \$/CCF)

Species (Product)	Douglas Fir	Engelmann Spruce	True Fir
Advertised Rate:	\$11.80	\$29.27	\$21.65

Total Value:	(\$11.80 x 2257) = \$26,632.60	(\$29.27 x 27) = \$790.29	(\$21.65 x 345) = \$7,469.25
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Total Sale Value (TSV) = \$34,892.14

2400-17 Report of Timber Sale form example for Live Stump timber sale:

*Example is from an Excel Spreadsheet created from a 2400-17 form and is not the official USFS 2400-17.

Region:	02 - Rocky Mountain	Year:	2023
Forest:	09 - San Juan/Rio Grande	Stars/Sale ID:	005
Sale Name:	Live Stump	Haul Miles:	72
(Product #) Appraised To:	(01) Blanca, CO	RTM	334
Ground Base Vol (Total):	2629	Roads in Place?	?
Ground Base Skid Cost:	\$74.09		
CCF/Acre (Ground/Base):	14.8		
CF/Tree (Ground/Base):	14		
Skid Distance (Ground/Base):	675		

	1st	2nd	3rd		<u>Total or Avg. *</u>
1.) Product/Unit of Measure	01-03	01-03	01-03		
2.) Species Group	DF	ES	TF		
3.) Species Code	204 (Douglas Fir)	093 (Engelmann Spruce)	025 (True Fir)		
4.) % By Species	85.85%	1.03%	13.12%	A	100.00%
5.) Volume (CCF)	2257	27	345	T	2629
6.) DBH (Inches)	13.30	13.30	13.30	A	13.3
7.) Base Period Price (BPP)	1.25	14.21	3.00	A	1.61
8.) Market Adjustment	4.23	-5.23	0.00	A	3.58
9.) Adj BPP (7+8)	5.48	8.98	3.00	A	5.19
10.) Base Skid-Yard Cost	72.76	72.76	72.76	A	72.76
11.) Sale Skid-Yard Cost	74.09	74.09	74.09	A	74.09
12.) Skid/Yard Cost Adj (10-11)	-1.33	-1.33	-1.33	A	-1.33
13.) Base Haul Cost	43.40	51.98	49.04	A	44.23
14.) Sale Haul Cost	37.79	37.79	37.79	A	37.79
15.) Haul Cost Adj (13-14)	5.61	14.19	11.25	A	6.44
16.) Base Road Maint Cost	3.09	6.20	6.20	A	3.53
17.) Sale Road Maint Cost	1.86	1.86	1.86	A	1.86
18.) Road Maint Cost Adj (16-17)	1.23	4.34	4.34	A	1.67
19.) Base Slash Cost	1.74	1.60	1.93	A	1.76
20.) Sale Slash Cost	0.00	0.00	0.00	A	0.00
21.) Sale Slash Adj (19-20)	1.74	1.60	1.93	A	1.76
22.) Base Temporary Road Cost	2.24	5.01	5.38	A	2.68
23.) Sale Temporary Road Cost	1.66	1.66	1.66	A	1.66
24.) Temp Road Cost Adj (22-23)	0.58	3.35	3.72	A	1.02
25.) Quality Adjustment	0	0	0	A	0.00
26.) Unusual Adjustment	-0.96	-0.96	-0.96	A	-0.96
27.) Total Adjustment	6.87	21.19	18.95	A	8.60

(Sum: 12, 15, 18, 21, 24, 25, 26)

28.) Predicted Bid (9+27)	12.35	30.17	21.95	A	13.79
29.) Competition Amount	0.55	0.90	0.30	A	0.52
30.) Ind Adv Rates (28-29)	11.80	29.27	21.65	A	13.27
31.) Base Rates	2.84	2.84	2.84	A	2.84
32.) Adjustment to Base Rates	0	0	0	A	0.00
33.) Advertised Rates (30+32)	11.80	29.27	21.65	A	13.27
34.) Sale Specified Road Cost	0	0	0	A	0.00
35.) Base Indices (Month - Year)	211.76	167.18	189.47		
36.) Timber Property Value	0	0	0	A	0.00
Total Sale Value (TSV):	\$34,892.14				
Bulletin Label: (Month) Rev. #	BU230423 (04) Rev. 0				

MBF = Thousands of Board Feet

CCF = Hundreds of Cubic Feet

*Volume-Weighted Avg.