United States
Department of
Agriculture

Forest Service

Pacific Northwest
Forest and Range
Experiment Station

General Technical
Report
PNW-176

December 1984

Logging Costs for Management Planning for Young-Growth Coast Douglas-Fir

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Abstract

Fight, Roger D.; LeDoux, Chris B.; Ortman, Tom L. Logging costs for management planning for young-growth coast Douglas-fir. Gen. Tech. Rep. PNW-176. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1984.** 10 **p.**

Logging cost equations are provided that can be used for analyses of silvicultural regimes. These equations include costs for all phases of logging from felling to loading onto a truck. They are presented by various components so that the user can substitute other values if some components do not seem applicable. Where appropriate these costs vary by size of trees harvested and volume removed at a logging entry. It is especially important that these cost relationships be reflected in logging costs used in evaluations of silvicultural regimes because the evaluations will otherwise be biased to favor regimes that produce too much small wood and use thinnings that are too frequent, too light, and too expensive.

Keywords: Costs (logging), logging economics, timber harvest planning, management planning (forest), young-growth stands, Douglas-fir (coast).

Contents

Introduction

Silvicultural regimes and cultural practices can significantly affect the size of trees harvested and the volume removed at each harvest; these are important determinants of the costs of logging. The logging costs used in analyses of silvicultural regimes and cultural practices should therefore reattstically reflect the effect of size and volume harvested. To do otherwise is to systematically bias the results to favor regimes that produce too much small wood and use thinnings that are too frequent and too light. This could result in unnecessarily high logging costs.

This paper presents an approach that can be used to develop logging costs that are appropriate for analyses of silvicultural regimes for coast Douglas-fir ***(Pseudotsuga menziesii*** (Mirb.) Franco var. ***menziesii).*** The various components of delay-free logging cost are represented by simple equations. Delays appropriate for each component are also represented by simple equations. A table of stump-to-truck logging costs of the sort required by DFSIM WITH ECONOMICS (Fight and others 1984), DP-DFSIM,[1] and FORPLAN[2] can be most easily produced from these equations with an electronic spreadsheet.' The spreadsheet provides maximum flexibility in developing tables for any range of diameters and volumes harvested and in making modifications to many of the cost components. All volumes are expressed in thousand cubic feet (MCF) for trees 5 inches in diameter at breast height (DBH) and larger to a 4-inch top. Because there are so many variations of board foot volumes we do not attempt to. convert any data to a board foot basis. See Dykstra (1978) for a discussion of conversion ratios for stands in the Douglas-fir region. A table of conversion ratios by DBH could be put into an electronic spreadsheet and used to convert any of the cost tables to a board foot basis. All costs are in dollars per thousand cubic feet unless specified otherwise and are in 1983 dollars. All references to diameter are to arithmetic mean diameter and care should be taken not to confuse it with quadratic mean diameter that is reported in some silvicultural reports. **A** more detailed description of the conditions and assumptions under which these equations were developed is presented elsewhere.[3]

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[1] Unpublished manuscript, 1984, "DP-DFSIM—Overview & User's Guide," by K. Norman Johnson and Kathy E. Sleavin, Colorado State University, Department of Forest and Wood Sciences, Fort Collins, Colorado.

[2] Unpublished manuscript, 1980, "Forest Planning Model (FORPLAN) User's Guide and Operations Manual," by K. Norman Johnson, Daniel B. Jones, and Brian M. Kent, U.S. Department of Agriculture, Forest Service, Systems Application Unit for Land Management Planning, Fort Collins, Colorado.

[3] Unpublished manuscript, 1984, "Stump-to-Truck Timber Production Cost Equations for Young-Growth Coast Douglas-Fir," by Chris B. LeDoux, Roger D. Fight, and Tom L. Ortman, U.S. Department of Agriculture, Northeastern Forest Experiment Station, Forestry Sciences Laboratory, 180 Canfield St., Morgantown, West Virginia 26505.

Yarding Costs

The yarding cost equations are based on data developed from the THIN cable yarding simulation model (LeDoux and Butler 1981). It is not practical for the analyst who has little background in logging engineering to use this or other yarding cost simulators directly. The input requirements for these models are detailed and are site and equipment specific. This detail may be important for users who want to estimate the logging costs for a particular harvest operation. The silvicultural analyst, however, is generally concerned with logging costs for representative stands that will be harvested 30 years or more in the future. The silvicultural analyst should therefore be concerned with costs for equipment that are representative of the kinds of equipment likely to be in common use in the future. The yarding equations presented were developed by taking the costs estimated by the THIN model for combinations of diameter, volume harvested, and average slope yarding distance and regressing the results on those variables. The result is an equation that estimates yarding costs for the specified diameter, volume harvested, and average slope yarding distance. The yarding costs are based on studies using two specific yarders, a Koller K300 yarding uphill with the carriage returned by gravity and a Washington 078 yarding uphill rigged with a running skyline.[4] The cutoff diameter where the smaller yarder (represented by the Koller) is assumed to be replaced with a larger yarder (represented by the Washington) is to some degree arbitrary. In this report costs for the small yarder are used for harvests with an average DBH of up to 16 inches. Costs for the large yarder are used for harvests with an average DBH exceeding 18 inches. For harvests with an average DBH from 16 to 18 inches, the logging cost is interpolated from the small yarder cost for 16 inches and the large yarder cost for 18 inches. Although these costs do not relate to any specific machine, there is a range of machines currently in existence and additional ones potentially available in the future that span the gap between the two for which data are presented. Because there is not a well-defined point where a larger yarder must be used, and because there are other yarders intermediate in size between the ones used here, it is more reasonable to smooth the transition between small and large yarders than to have a discrete jump in the cost at a specific DBH.

Delay-Free Costs of Yarding With a Small Yarder

The equation for delay-free costs of yarding with a small yarder is:

$$\text{COST} = 491.4 - 40.48(\text{DBH}) + 0.8886(\text{DBH})^2 + 0.1205(\text{SYD}) + 16.1/\text{VOAC};$$

where: DBH = the arithmetic mean diameter breast height of trees harvested,
VOAC = the volume harvested per acre in thousand cubic feet, and
SYD = the average yarding distance measured along the slope.

To use this equation to estimate a logging cost for a particular situation, the appropriate values for DBH, VOAC, and SYD are inserted into the equation. The valid range for application of this equation is diameters from 6 to 16 inches, volumes from 0.4 to 15 MCF/acre, and slope yarding distances up to 1,200 feet.

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[4] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

Table 1[5] gives estimated delay-free costs of yarding with a small yarder for combinations of diameter and volume harvested per acre with an average slope yarding distance of 500 feet. Note that this and other tables may include estimates of costs for implausible combinations of DBH and volume per acre. We have not deleted those from the tables because programs like DP-DFSIM often explore parts of the response surface that are "implausible." Costs for all combinations of DBH and volume harvested that these programs test must be included for the programs to operate successfully. If the estimated costs appear implausible, the user should first verify that the cost is for a combination of DBH and volume per acre that is realistic.

[5] Tables presented here are taken directly from an electronic spreadsheet program.

Table 1—Delay-free yarding cost for small yarders

DBH	THOUSAND CUBIC FEET PER RCRE					
	0.50	1.00	1.58	2.86	5.00	18.88
INCHES	- - - - - DOLLRRS PER THOUSAND CUBIC FEET - - - - -					
6	373	357	351	343	344	342
8	317	588	295	292	288	286
16	268	252	246	243	239	237
12	226	210	204	202	137	135
14	131	175	178	167	162	168
16	163	147	142	133	134	133

Delay-Free Costs of Yarding With a Large Yarder

The equation for delay-free costs of yarding with a large yarder is:

$$COST = 737.4 - 61.09(DBH) + 1.2926(DBH)^2 + 0.1497(SYD) + 52.7/VOAC.$$

The valid range for application of this equation is diameters from 18 to 24 inches, volumes from 0.4 to 15 MCF/acre, and slope yarding distances up to 1,200 feet. Table 2 gives estimated delay-free costs of yarding with a large yarder for combinations of diameter and volume'harvested per acre with an average slope yarding distance of 500 feet.

Table 2—Delay-free yarding cost for large yarders

DBH	THOUSRND CUBIC FEET PER RCRE					
	0.58	1.88	1.58	2.88	5.88	18.80
INCHES	- - - - - DOLLRRS PER THOUSFIND CUBIC FEET - - - - -					
18	237	164	167	158	142	137
28	213	168	1'43	134	118	113
55	133	147	129	120	184	33
24	196	143	126	117	181	36

Yarding Delays

The estimated delay for clearcut harvest is 9 percent. For partial cuts delay is estimated with the equation:

$$\text{Percent delay} = 22.9 - 2.61\ (VOAC).$$

The valid range for application of this equation is from 0.4 to 5.4 MCF/acre. Beyond 5.4 MCF/acre the estimated delay should be 9 percent, the same as for clearcut harvest. Table 3 gives estimated delays for yarding for partial cutting for a range of volumes harvested per acre.

Table 3—Yarding delay

MCF/ACRE	8.58	1.00	1.58	2.00	5.00	18.88
PERCENT	22	20	13	18	18	9

Yarding Costs With Delay

Delay percentage is the percentage of time that equipment is idle. The percentage of total time that is productive time is therefore 100 minus the delay percentage. The delay-free costs that are calculated on total time must therefore be converted to productive time. This is found by dividing the delay-free cost by the proportion of time that is productive (the productive time percentage expressed as a proportion). For example, if the delay is 10 percent, the proportion of nonproductive time is 0.1 and the proportion of productive time is 0.9. The cost with delay is estimated by dividing the delay-free cost by the proportion of productive time. Table 4 gives estimated yarding costs with delay for combinations of diameter and volume harvested per acre for partial cutting with a slope yarding distance of 500 feet.

Table 4—Yarding cost with delay

DBH	THOUSAND CUBIC FEET PER ACRE					
	8.58	1.88	1.58	2.08	5.00	10.00
INCHES	- - - - - DOLLFSRS PER THOUSRND CUBIC FEET - - - - -					
6	475	447	433	423	381	376
8	404	377	364	355	313	314
10	341	3i6	384	296	265	260
12	288	263	252	245	218	214
14	244	213	283	283	1841	176
16	208	185	175	169	149	146
18	302	231	286	192	157	1541
20	272	201	176	163	131	124
22	254	184	153	146	116	109
24	250	180	155	142	112	1415

Felling, Limbing, and Bucking Costs

Delay-free costs of felling, limbing, and bucking are estimated with the equation:

$$\text{Cost} = -17.4 + 876/\text{DBH}.$$

The valid range for application of this equation is diameters from 6 to 24 inches. Table 5 gives estimated delay-free costs of felling, limbing, and bucking for a range of diameters.

Table 5—Delay-free felling, limbing, and bucking cost

DHH (IN)	6	8	10	12	14	16	18	E0	22	24
$/MCF	1E3	92	78	56	45	37	31	26	22	19

The estimated delay for felling, limbing, and bucking in a clearcut harvest is 4 percent. The delay for partial cutting is estimated by the equation:

$$\text{Percent delay} = 18.3 - 3.33(\text{VOAC}).$$

The valid range for application of this equation is from 0.4 to 4.3 MCF/acre. Beyond 4.3 MCF/acre the estimated delay should be 4 percent, the same as for clearcut harvest. Table 6 gives estimated delays for felling, limbing, and bucking in partial cutting for a range of diameters.

Table 6—Felling, limbing, and bucking delay

MCF/ACRE	8.58	1.00	1.58	2.00	5.041	141841
PERCENT	17	15	13	12	4	4

Costs for felling, limbing, and bucking with delay are calculated as described earlier by dividing the delay-free costs by the proportion of productive time. Table 7 gives estimated felling, limbing, and bucking costs with delay for partial cutting for a range of diameters and volumes harvested per acre.

Table 7—Felling, limbing, and bucking cost with delay

DBH	THOUSRND CUBIC FEET PER RCRE					
	0.58	1.00	1.541	2.00	5.841	141.80
INCHES	- - - - - DOLLRRS PER THOUSRND CUBIC FEET - - - - -					
6	154	151	148	146	134	134
8	110	1418	106	184	36	36
10	84	83	81	73	73	73
12	67	65	64	63	58	50
14	54	53	52	51	47	47
16	45	44	43	42	33	33
18	38	37	36	35	33	33
20	32	31	341	38	28	28
22	27	26	26	25	23	23
24	23	e2	22	22	241	20

Branding Costs

To facilitate accountability for harvested logs, some managers require that logs be branded with an identification mark on one or both ends. This cost per MCF will depend on the number of logs per MCF to be branded and the cost per log for branding. Thus, the following equation applies:

$$COST = (LOGS)(BRANDCOST);$$

where: LOGS = the number of logs per thousand cubic feet harvested and
BRANDCOST = the cost per log for branding.

Substituting in the equation for number of logs per thousand cubic feet and a cost for double-end branding per log of $0.15 the equation becomes:

$$COST = (-47.9 + 1678/DBH)(0.15).$$

Note that the first set of parentheses contains the terms that estimate the number of logs. The estimates for the number of logs are based on a bucking rule that specifies 40 feet as the preferred log length. The cost per log in this equation includes delay so no adjustment for delay is applied. Table 8 gives costs with delay per thousand cubic feet for branding for a range of diameters.

Table 8—Branding cost with delay by diameter

DBH (IN)	6	8	10	12	14	16	18	20	22	24
$/MCF	35	E4	18	14	11	9	7	[illegible]	4	3

Loading Costs

Delay-free costs of loading are estimated with the equation:

$$Cost = -9.8 + 545/DBH.$$

The valid range for application of this equation is diameters from 6 to 24 inches. Table 9 gives estimated delay-free costs of loading for a range of diameters.

Table 9—Delay-free loading cost by diameter

DBH (IN)	6	8	10	12	14	16	18	20	22	24
$/MCF	81	58	45	36	29	24	20	17	15	13

The delay for loading is estimated by the equation:

$$\text{Percent delay} = -4.0 + 104/\text{DBH}.$$

The valid range for application of this equation is diameters from 6 to 13 inches. Beyond 13 inches the estimated delay should be 4 percent. Table 10 gives estimated delays for loading for a range of diameters.

Table 10—Loading delay by diameter

DBH (IN)	6	8	10	12	14	16	18	20	22	24
PERCENT	13	9	6	5	4	4	4	4	4	4

Costs for loading with delay are calculated by dividing the delay-free costs by the proportion of productive time. Table 11 gives estimated loading costs with delay for a range of diameters.

Table 11—Loading cost with delay by diameter

DBH (IN)	6	8	10	12	14	16	18	20	22	24
$/MCF	94	64	48	37	30	25	21	18	16	13

Stump-To-Truck Logging Costs

The costs that have been discussed so far can all be reasonably expressed as a cost per MCF and will vary with volume per acre harvested or diameter or both. These costs can all be summed to produce a table of stump-to-truck costs that can be used directly in many analyses requiring costs per unit volume. Various electronic spreadsheets can be used to produce these component tables and to combine them to produce a total table. Table 12 gives combined costs (for those discussed so far) for the small yarder doing a partial cut with a 500-foot slope yarding distance. With a little ingenuity the spreadsheet can be set up so that a

Table 12—Stump-to-truck cost with delay

DBH	THOUSRND CUBIC FEET PER RCRE					
	8.58	1.08	1.58	2.00	5.88	18.80
INCHES	- - - - - DOLLRRS PER THOUSRND CUBIC FEET - - - - -					
6	723	663	630	606	546	535
8	688	543	518	437	445	435
10	513	462	433	413	368	353
12	448	392	364	345	307	238
14	331	357	389	231	257	243
16	347	293	266	249	218	210
18	433	332	283	264	220	208
20	337	236	254	230	183	177
22	375	274	233	209	170	158
24	366	266	225	201	162	151

set of tables for the small yarder can be recalculated for the large yarder by changing very few entries in the spreadsheet. It also could be set up to use the small yarder equations for diameters up to 16 inches (or some other value) and use the large yarder equations for diameters over 18 inches. If such a table were put into the DFSIM WITH ECONOMICS program (Fight and others 1984), the program would automatically interpolate for values needed between 16 and 18 inches to produce the desirable transition between machines that was mentioned earlier (see "Yarding Costs"). Only basic file manipulation capabilities are required to develop a program that can take the file prepared by the spreadsheet and put it in the form required by DFSIM or other programs. Some spreadsheets have graphics capabilities that could be useful in reviewing and modifying various cost components. The eye can quickly pick up anomalies from a graph that might easily be overlooked for a very long time in a table of values.

In addition to the costs discussed above that have been expressed as costs per thousand cubic feet harvested, there are some costs that are better expressed as costs per acre harvested. Each harvest operation involves moving in and rigging up equipment and then taking down and moving out that equipment. Each harvest operation also typically involves several changes of equipment and cables from one yarding corridor to the next within the same harvest unit. These costs are not affected by the volume harvested, but rather, depend only on the number of times they occur. The most direct way of accounting for these costs is to convert them to a cost per acre, which can then be incorporated in the investment analysis program. If they were converted to a cost per MCF they would be valid only for the average volume harvested. A silvicultural regime that includes thinnings will invariably involve a wide range of volumes especially between the thinning and clearcut harvest volumes. Cost tables that included these costs expressed as costs per MCF would therefore invariably include systematic distortions of the costs between thinnings and clearcut harvests and also between thinnings of different magnitudes.

Costs of Moving Equipment

Costs of moving in, moving out, rigging up, and taking down, including delays, are estimated with the equation:

$$\text{Cost} = 1240 + 12.55(\text{round-trip mileage}).$$

This value is estimated for the average round-trip mileage for the location in question. It is then divided by the average acreage of the harvest units. This gives a cost per acre harvested that can be used directly in the financial analysis.

Costs of Changing Yarding Corridors

Delay-free road changing costs are estimated with the equation:

$$\text{Cost} = 43 + 0.0001271(\text{SPAN})^2;$$

where: SPAN = horizontal length of the span in feet.

The span is the distance from the landing to the tailhold for the cable. Span may exceed the corridor length by a substantial distance because it is often necessary to go beyond the end of the cutting unit to find a tailhold point that provides the desired lift. The valid range for application of this equation is from 300 to 3,000 feet. Table 13 gives estimated delay-free road changing costs for a range of span lengths.

Table 13—Delay-free road changing cost by length of span

SPAN (FT)	588	1000	1500	2000	2500	3800
DOLLQRS	75	170	329	551	837	1187

.The delay for road changing is estimated by the equation:

$$\text{Percent delay} = 4.9 + 0.0052(\text{SPAN}).$$

The valid range for application of this equation is from 300 to 1,950 feet. Beyond 1,950 feet the estimated delay is 15 percent. Table 14 gives estimated delays for road changing for a range of span lengths.

Table 14—Road changing delay by length of span

SPAN (FT)	588	1888	1508	2808	2500	3000
PERCENT	8	10	13	15	15	15

Costs for road changing with delay are calculated by dividing the delay-free costs by the proportion of productive time. Table 15 gives estimated road changing costs with delay for a range of span lengths. This cost is multiplied by the number of road changes and divided by the average number of acres harvested in a unit to get the cost per acre for road changes. Road changes include a pivot to a new tailhold from the same landing as well as a parallel shift of the yarding corridor.

Table 15—Road changing cost with delay by length of span

SPQN (FT)	588	1800	1588	2088	2588	3000
DOLLQRS	81	189	377	649	985	1396

Concluding Comments

The cost equations described here provide a relatively complete package of costs that is needed to analyze management of young-growth Douglas-fir in mountainous terrain of western Oregon and western Washington. These costs do not include a separate allowance for profit and risk, but they do include a 15 percent rate of return on invested capital, a value commonly used by businesses for evaluating capital investments. For silvicultural planning purposes, we think it reasonable to use these estimated costs without additional allowances for profit and risk. It may be desirable to adjust these results, which are in 1983 dollars, to update them to current dollars for analyses done in future years. Because logging costs are a broad mixture of labor, capital, fuel, and other costs, this updating should be done with a broad price index. The price deflator for the gross national product is probably a good one to use (Council of Economic Advisers 1983): Certainly the consumer price index would not be appropriate. Because the costs represent a broad mix of cost components it is probably not reasonable to try to adjust these costs for anticipated real price changes without going back and doing the simulations again and developing new equations. Care should be taken not to apply these equations outside the range of values specified for each independent variable. To do so may result in unrealistic cost estimates.

Metric Equivalents

1 inch (in) = 2.54 centimeters
1 foot (ft) = 30.48 centimeters
1 mile = 1.609 kilometers
1 acre = 0.404 hectare
1,000 cubic feet (MCF) = 28.3 cubic meters

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