FOREST HARVEST SETTING DESIGN EVALUATION INCORPORATING LOGGERS' PREFERENCE.

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Abstract

Forest Harvest Setting Design Evaluation Incorporating Loggers' Preference.

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This study brings industrial design together with established market research principles via loggers perceived importance of harvest cost variables. The results are applied to the efficient design of contemporary forest harvest operations. The research establishes the feedback link between appraisal and planning, providing guiding details for timber harvest setting design. Closing the loop from appraisal and design of harvest settings provides information for more efficient logging and increased stumpage values.

A representative, well designed, broad scale survey of timber production specialists, loggers, yielded a new application of market research. Analysis establishes correlation among the factors that affect harvest costs as perceived by loggers. The factors are used in conjoint analysis and estimate the utility of a variety of setting design parameters.

The interactions of planning variables that affect harvest cost are poorly understood. Information in the short term will be valuable to decision makers evaluating harvest setting design with or without structural retention, STR, prescriptions. Meanwhile, forest planners need to know the consequences of design decisions especially those involving retention.

Contemporary high timber values brought about by constraints on supply, partly through regulations, mask inefficient harvest methods, since, despite "high" logging cost, timber sellers still make considerable profit. Old growth timber offered this luxury but the second growth timber supply is distributed across smaller timber, lower quality logs with higher harvest costs, and a diminishing timberland base. Litigation of timber sales has slowed the timber production capability of the Pacific Northwest region; appellant claims are often an automatic reaction to the public listing of timber sales. If foresters take no action to establish efficient alternative silvicultural systems, this relationship is likely to remain the status quo in the Pacific Northwest.

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Acknowledgments

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Introduction

Dyson (1990) says strategic decisions have enduring effects, are broad in scope, and are difficult to reverse. Planning timber harvest has elements of all of these. Decisions made about placement of harvest units are certainly irrevocable once harvested; affect a broad scope of values at the watershed level; and endure through rotations as logging modifies the vegetation and basin structure. Planning evaluates options before action and proposes decisions that limit both cost and concern for future impacts (Depta 1984). Landscape planning makes decisions about the setting level location and layout of harvest units. A planner, for example, prescribes a yarder (e.g., 90 foot tower with a 2000 foot span) for a setting based on the typical conditions (slope length, steepness, streams, shape of slope).

Setting design is the fundamental basis for the means of timber harvest. The timber, terrain, access, and equipment and crew demands are all considered when designing the efficient extraction of logs. Logging production is dependent on the setting design and site characteristics (e.g. yarding distance, piece size, equipment complement,) but the implicit interaction between the variables is hard to measure (Weigand and Burdett 1992, Sauder and Wellburn 1987).

Time and motion measurements of logging systems, production studies, combine with common sense adjustments as the references that guide forest engineers, who create the economically efficient, environmentally benign harvest plans. Production studies measure site-specific conditions with unique combinations of equipment and various levels of crew proficiency. But there is no measure of common sense perceptions of the foresters. These factors place reasonable doubt on the broad scale use of time and motion results. Yet, for lack of anything better, forest engineers make use of production equations and rely on wisdom and common sense to guide setting design. These conventional approaches to contemporary advancements in forest management leave much to be desired.

The example I can cite from personal experience is my early attempts at experimental design of a harvest study that incorporated green tree retention in the western Cascades and Olympic Mountains. Aside from the issues of replication and location of suitable sites; the problem of experimental control of the harvesting system became the most prominent. The sites were all very different topographically and decisions about which of many equipment complements to use, cast doubt on the practical applications over the broad range of conditions in the Pacific Northwest.

Structure and tree retention, STR, harvest operations are in practice now on an "experimental" basis as well as the many operational demonstrations in the region. Demonstration of Ecosystem Management Operations (DEMO) Study, administered by the USFS (R-6 and PNW), designed in 1991 at the University of Washington is an experimental study of green tree and structural retention. DEMO is an empirical approach with the lengthy timeframe for results, great expense, and a narrow frame of inference. A definitive study focusing on economics, engineering, and silvicultural systems will take years to complete.

Harvest cost is used as a measure of logging feasibility. Optimizing forest management regimes requires understanding of the trade-offs between harvest cost variables. The trade-offs loggers make to log a timber sale are based on their perception of production; and can be considered judgments. The critical variables identified by loggers can improve the design of efficient settings. Harvest planners would like to know how timber sales could be designed to meet both economic and ecologic objectives.

Logging costs and mill value of logs combined is the stumpage price, the amount (e.g., dollars per thousand board feet, $/Mbf) a purchaser pays for timber. Historically, logging costs comprised a much higher percentage of stumpage because log values were low. When logging cost and mill prices are similar, small changes in either may produce a deficit timber sale, where costs exceed revenues. While logging costs have not changed substantially, contemporary mill prices have climbed recently for a number of reasons including greater demand for logs and declining federal log supply. Often market value greatly exceeds the costs of operations. And since cost is a small proportion of the value, there has been little incentive for efficient design of low-cost harvest settings.

In one sense forestry has returned to the "old growth" syndrome, where high log prices mask many of the costs. Old growth timber stands, because of their high value, could hide some system inefficiency--the high value can absorb some of the costs of poor designs. An example in recent sales, Douglas-fir old-growth sold for $2,700 per Mbf (Arbor-Pacific October 1993) while logging costs rarely exceed $270 per Mbf; a range of an order of magnitude. As prices decline, forest management becomes less profitable because of the proportionally higher harvest costs. One risk associated with high contemporary log value is that foresters may take the attitude that careful, cost effective layout is not important.

Irregardless of fluctuating or high price of timber, the forest engineer should develop efficient harvest designs. As constraints on harvest increase, efficiency becomes more important, one of the transformations in American business (Hawken and McDonough 1993). Second growth timber will not be as economically forgiving with design mistakes. Logging costs are greater with low value thinning stock or second growth timber yet the behavior of loggers and timber purchasers show something very different. Bid prices for stumpage are high suggesting, at least, a willingness to harvest these sales. Therefore, perceptions of logging contractors indicate that they appraise the situation differently.

Problem statement

Logging operations often are under severe environmental constraints but the problem is one of identifying and controlling those variables that contribute to harvest costs. Design trades off the attributes of timber sales and results in an engineered harvest setting. Presently, there is no clear process that helps the forest engineer design improved harvest units or settings. Loggers know their costs. Perceptions of loggers about the cost of new approaches to forest management are causing them to change their behavior (Weigand and Burdett 1992). The loggers are aware of the increased cost of harvesting as they often shoulder the financial burden. But until recently no one has actually asked loggers what factors contribute to the costs (Keegan et al. 1995, Ray et al. 1994) or how setting design might improve, given the numerous design decisions.

This study ascertains the logger's perceptions about the cost of timber harvest. Loggers are the consumers, in a sense, of settings, and they place high utility on maximum daily production. Perceptions can improve product designers' ability to satisfy customers (Churchill 1991, Green and Wind 1975), for example, thereby increasing the utility of timber harvest settings. If planners understand logger's perception of the cost controlling parameters, they can propose rational trade-offs, which result in timber harvest designs with high utility to loggers.

Hypothesis

The hypothesis is that market research techniques can assess the setting attributes important to loggers and with knowledge of timber sale attributes and their interactions, setting designers can plan more efficient harvest settings. Current methods (e.g., Time and Motion study) are not adequate given the wide range of variability in the Pacific Northwest forest types. Harvest prescriptions have increased retention of live and dead trees on present-day settings. Designs should be based on site (e.g., topography, soils, hydrology), silvicultural prescription (e.g., clearcut, shelterwood, structural retention), equipment (e.g., tower, skidder, harvester) , and personnel conditions and perceptions, irregardless of the market influences.

In this approach, the loggers perception will be the principal line of evidence. Market research has developed techniques for similar problems of sensing perception. By extension, these psychometric methods are applied to the forest engineering environment. A market survey of loggers measures those production variables that are of great importance--highest utility--to loggers.

There are two central hypotheses in my study. First, I hypothesize that market research methodology can measure the traditional parameters of setting design and identify the relationship between the variables. The application of a series of multivariate analytical techniques provides a perceptual map of the utility values of setting attributes perceived by loggers.

Secondly, the perceptions of loggers are useful for determining trade-offs between setting design variables. The methodology will demonstrate the consequences of specific design decisions including the pattern of structural retention.

I conclude that market research, properly modified to the forest engineering sector results in feedback to planners (silviculturists and forest engineers) involved in setting design. The attribute utilities of loggers, preferences, help designers create more efficient harvest planning.

Current dilemma of forest planners

There is some doubt whether the design engineers are using the correct setting parameters to optimize objectives and value. Beyond some of the basic features that loggers prefer (e.g., uphill over downhill cable yarding), planners do not know what the loggers think about the attributes of setting design. Loggers know how their operating constraints affect production. The setting designers often hear about loggers' concern only when the sale layout is ready to be cut and yarded.

Likewise, our means of value appraisal includes very little information about setting layout and design. For example, if the trade-offs between the amount of sidehill yarding and yarding distance were known, setting designs could describe boundaries that offered the highest utility to loggers. This utility gains higher acceptability (e.g., bidding success, lower contract logging prices) and more efficient production.

While there is economical rationale for judging the pertinence of timber sale layout, setting design procedures (e.g., identifying unit boundaries, assigning equipment types, providing road access) presume certain priorities (e.g., economic efficiency, payload, deflection, yarding distance). There is no clear understanding of the interaction between setting design variables or how a contract logger perceives the interrelated variables. Loggers decide the best way to work a particular piece of ground; how they arrive at decisions is unknown.

Time and motion equations estimate logging production once the equipment and boundaries are set. By backing up in the design process and evaluating decisions about setting size, internal configuration, and layout, options appear less distinct. Consideration of the loggers' ideas about this level of design will yield higher acceptability of timber sales.

A decision system is needed to maintain high levels of operational efficiency. Innovative combinations of harvest tools and ecological knowledge may produce higher value from timberland operations by simply planning more efficiently.

Harvest planners are still learning about the economics and operational feasibility of timber sales that include elevated levels of structural retention (STR). With this silivicultural system, forest structure is retained as "aggregated" or "dispersed" trees over a setting (Fig. 1) so that many ecological processes can be regenerated. Prescribing logging systems with STR involves two principal costs: Foregone or deferred timber revenue and decrease in unit revenues because of increased unit harvesting costs ($/Mbf). The latter of these is the concern in this study; specifically, identifying the interactions among important factors of setting design.

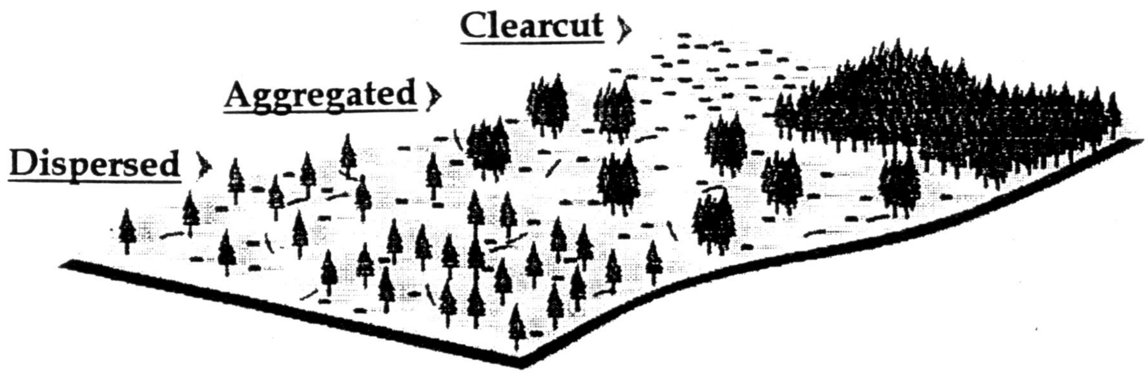


Figure 1 Patterns and levels of structural retention proposed in the Pacific Northwest. Structural diversity created is hypothesized to be a surrogate for biological diversity and emulates natural forest disturbance patterns with the intent of regenerating forest ecosystem functions (Berg and Schiess 1994).

Background

Managed forest landscapes are shifting from stand level, isolated setting design to basin level, integrated harvest plans. Basin level plans blend design engineering, silviculture, and landscape ecology based on the proximity of stands to one another, their position in the catchment (Cullen and Schiess 1992, Swanson et al. 1988). Planning harvest and transportation systems over large blocks of land has made technological improvements in recent years (Sessions and Sessions 1992, Schiess et al. 1988) recognizing the ecological (Franklin 1992, 1993; Naiman et al. 1992) and silvicultural conditions (Oliver et al. 1992, Boyce 1985, Hoffman 1941). Efficient watershed management allocates human efforts and energy while maintaining environmental values (Oliver et al. 1992, Swanson and Berg 1991, Swanson et al. 1990, Nelson 1971, Smith and Haley 1971) including a broad range forest and social values (Naiman and Décamps 1991, Hemstrom 1990, Cissel 1990, Alig 1989, Weisbrod 1964

Landscape models, such as FORPLAN (Iverson and Alston 1986), ALA (area level analysis, Jones et al. 1986), and LMS (landscape management system; McCarter et al. 1995) offer frameworks to build from but the primary focus is timber production. Within the landscape, stand level planning deals with sub-watersheds (3000-6000 acres) over decades. PLANS (Twito et al. 1987) and SNAP (Sessions and Sessions 1992) use detailed setting level data and logging network analysis over discrete time periods. Road and timber sale sequencing is based on maximizing present net value (PNV) for future timber sale. If settings are not designed to optimal efficiency levels then the accumulated PNV values from the settings will misrepresent the value of landscape level plans.

Silvicultural and forest engineering systems influence the efficient harvest and transportation of timber (Fridley and Schiess 1990, Smith 1986, Hawley 1946, Matthews 1942). Benefits of efficiency become clear when viewed cumulatively in a linked system that includes forest management, engineering, and ecology (Mitsch and Jorgensen 1989, Ripley and Yandle 1969, Ruth and Silen 1950). Silvicultural engineering defines resources (e.g., timber type, road network, habitat areas), management goals (e.g., timber yield, habitat maintenance, water quality and yield) and the complex linkages between these elements (Oliver et al.1992, Schiess et al.1988, Depta 1984, FAO 1983).

Settings, (the harvest unit including the boundary, equipment, and layout), can be measured by a range of variables. Variables are defined as the measures used to design settings, appraise costs, and bid on the value of timber sales. Planners are guessing about the relationship of cost variables. The value of any sale may be improved by minimizing costs. If the utility to loggers is optimal for those variables that can be affected by the setting design then the daily production will be high. Production studies are often collapsed to report shift level figures (e.g., daily production, log trucks loaded per day). It is at this shift level that this study proposes to have the greatest impact.

Precise measures of elements of the logging cycle are less important than the overall improvements in setting design. It is the relative changes in production (e.g., higher or lower utility) associated with alternate designs that are important to loggers, not the absolute measures (e.g., $100/Mbf vs. $110/Mbf).

The relationship between the logger and forest engineer

The relationships between the landowner, forest engineer, timber buyer, and logger are complex (Fig. 2). Typically, the landowner has the forest engineer design the transportation system and the harvest settings (location and configuration). The landowner then offers timber for sale by the setting or a group of settings. A purchaser buys the timber and then usually contracts to logger for the harvesting. Rarely does the logger offer input to the setting designer about how the particular harvest unit is put on the ground. Most times there are adjustments, usually on a small scale, made to the original setting design by the logger *in situ* in the hopes of gaining greater production--the loggers measure of utility.

Timber sales are usually bought by paying a retainer (e.g., 10% of sale value), the remainder is due upon completion of the harvest and cleanup operations. Loggers are not typically successful bidders because of the two reasons. First, the great up-front expense needed for securing the sale and their high capital investments in equipment. Also, an established relationship between a timber buyer and a logger, both bidding on timber sales, would put the logger in the position of being bidding competition, perhaps jeopardizing the relationship.

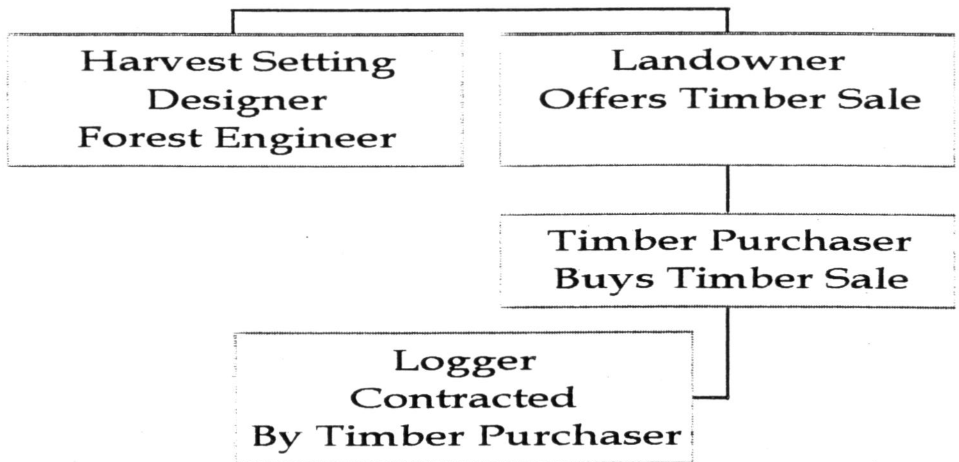


Figure 2. Relationship diagram of the entities involved in transferring logs from the harvest settings to mills.

Landowners predict the outcome by offering timber for sale at an appraised price. Current methods of appraisal do not suitably account for the added costs of STR. Realistic estimates of timber value include the influences of harvest costs that result from regulations, layout, and operator experience. As a rule, a timber purchaser depends on the logging contractor's bid to be representative of the market. The logger's price to harvest a particular setting, cost, is a function of the quality of the timber, and difficulty of "landing" the timber. Logging cost is not affected by the market price for logs; as one of the loggers remarked:

> ***"It costs the same to move a ton of lead as it does to move a ton of gold!"***

Currently, we understand very little about the way that a logging contractor arrives at his bid. If one could understand the thought process of logging contractors (if their perceptions about the timber sale were known), then appraisals might better satisfy both biological and economic goals.

If the purchaser knows that their logger has a reputation for high productivity then they can afford to bid more for the stumpage. Much of the synthesis is done by the contracting logger, who is responsible for maintaining high production rates often with less than optimal designs.

Bidders overlook seemingly important cost variables because they need to acquire sales (Rucker 1984, Koppl 1991). Loggers often shoulder the burden of additional costs. This implies that the logger knows ways of improving efficiency when it is to his advantage. Layout and design should be based on minimizing cost variables. One recent study in the Southeastern United States (Ray et al. 1994) found that loggers believe they can create "aesthetically pleasing" harvest units but the costs, while all agree would be slightly more than clearcutting, are unknown.

One must acknowledge the utility of time and motion study but there has been limited success with establishing general relationships between site, setting configuration, equipment, timber, labor, and regulation. Time and motion studies are based on uniform conditions and have been successful only in predicting cost for specific combinations of site and equipment configurations--logging cost variables. The landscapes in the Pacific Northwest are anything but uniform. Loggers have had to live with those decisions. For example, two timber sales may be identical (e.g., same A verage Y arding D istance, Slope, Timber), as viewed from conventional regression equations. Results from the equations are identical but one sale has a fair amount of sidehill yarding, which looks quite different from a logger's perspective.

Costs of alternative harvesting patterns across the landscape are unknown. Structural retention varies the level, pattern, and type of live and dead trees left in reserve on the harvest unit for habitat functions. The practice of STR is being implemented but there is no good measure to determine impact on forest planning, production, or means to improve design. Appraising costs from STR is left to loggers, who learn by trial and error. These "***seat-of-the-pants***" appraisals are rooted in perception of harvest costs and, as such, have not been measured and only partially described (Keegan et al. 1995, Birch and Johnson 1992, Weigand and Burdett 1992).

A means of sensing the perceived costs of logging should help explain the difficult trade-offs involved in the layout of timber sales. Complex silvicultural prescriptions add other complexities to setting design before even simple interactions are understood. Design level changes in decision making ensure higher efficiency at the landing based on the integration of many fields of knowledge (Dimancescu 1992, Dyson 1990).

As forest engineers implement new practices, including STR, they estimate harvest costs. Harvest conditions are extremely varied and changing social and regulatory demands make such calculations suspect. Feasibility of harvest operations, without prior information, will be difficult to predict. Planning based on costs the loggers perceive would help design more efficient harvest settings in the absence of empirical information. There are some well-known relationships about log size, yarding direction, and yarding distance but the decisions about what trade-off loggers would make has not been studied.

Although the logs are the commodity that one most associates with timber sales, rarely do loggers buy the logs; timber purchasers contract loggers to do the work. The market, in this case, is the harvest setting purchasers--loggers. Ultimately, contract price is affected by the loggers perception of the shift level of production (e.g., truckloads of logs per day; total daily operating cost ,$/Mbf). This is the measure of utility for most loggers. It is critical to understand how the loggers form opinions and arrive at judgments of cost. Rarely have harvest plans explicitly addressed loggers' concerns or preferences.

As a rule, experienced loggers integrate a lot of practical experience to arrive at cost estimates. A logger has some mental algorithms that map steps of assessing cost. These perceptual maps have been validated based on experience: The unsuccessful logger has gone out of business because of faulty estimation. As planners, forest engineers do not have a repeatable evaluation method for "rating" timber sale layout.

Objective

The objective of this study is twofold: first, evaluate the usefulness of perceptual mapping techniques through market research technology and , second, to use this technique to develop utility values for setting design attributes. In my study, a conceptual construct centers around the type of question to be used in a survey about the loggers' perceptions of logging costs. Market research techniques allow insight into the variables that are of great importance to loggers.

Additionally, the object was to understand the contract logger approach to appraising harvest costs. Loggers' perception reflects experience and offers the setting designer an evaluation tool. If the designer has the integration process loggers use, he can use it to evaluate the relative utility of settings. It is not the absolute difference between settings that is important but, rather, the relative scale between setting designs.

Two specific objectives were formulated. First, a new way of describing the complex interactions of the setting design variables is needed to advance our knowledge of how the human factors of setting design might be described. This was the object of using perceptual mapping techniques from the fields of business and marketing. Second, loggers are identified as the crucial link in the design process and provide synthesis of local knowledge based on many years of practical experience. Loggers integrate a number of factors to get an assessment of their costs.

It is the attributes of an object (e.g., timber sale setting) that we measure not the objects themselves. The relative values of setting attributes are best considered jointly rather than one at a time. This is the case when a logger arrives at a landing and begins to assess the approach to be used harvesting the setting. Conjoint analysis measures the trade-offs between pre-determined combinations of attributes and preferences of subjects, loggers, are inferred.

Further, the methods identify variables and quantify their contribution to the operational costs as attribute utility. These utilities can be used to assess the trade-offs loggers make, information valuable for harvest design and basin planning. A more detailed description of these attributes is gained from the utility of specific levels of each attribute, called the part-worth utility. The objectives are to employ part-worth utility to make better decisions about setting design based on loggers' preferences.

As sweeping changes in our forest management practices outpace our ability to assess the consequences of implementation, forest engineers need to have some guides for the practical design of harvest settings. It is critical for a designer to have an assessment tool that evaluates the utility of setting layout. STR implemented now operates on a ***trial and error*** basis until baseline information begins to supply justification in forest planning.

Literature Review

Conventional Production Measurement--Time and Motion Study

Forest production is the relationship of the volume of goods and services (e.g. logs, chips, or even habitat) produced to the physical inputs used in the logging system (Pearce 1961, Riggs et al. 1979, Stenzel et al. 1985). Logging costs are measured and partially controlled (e.g. Tennas et al. 1955, Hermann 1960, Binkley 1965, Binkley and Lysons 1968, Schillings 1969, Mann 1979, Mann and Mifflin 1979, FAO 1981, 1983). Logging cost estimates rely on production equations from detailed time and motion study (Matthews 1942, Lussier 1961, Pearce 1961). These detailed studies are often aggregated to produce shift level or daily production figures. At the shift level a number of factors are integrated over the day affecting daily production. In the absence of valid TM information, the planner makes decisions about the logging system and the bottom line is daily production. Few TM methods measure the aspects of daily operation like amount of sidehill yarding, road changes for cable ways, or terrain (Ledoux et al 1986).

Time and motion study (TM) improves planning and control of operations; compares work methods, tools, equipment performance, and cost (Matthews 1942, Conway 1978, Stenzel et al. 1985, Bjőrheden 1991). TM estimates total input of resources per unit time for distinct elements of production cycles (Bjőrheden 1991). Equations predict the cost of logging for a narrow range of conditions, site, equipment configurations (e.g. Peters 1973, Sauder and Nagy 1977, LeDoux et al. 1986, Saunder and Wellborn 1987, Howard and Coultish 1993). Most equations assume that the boundaries and equipment are specified and sites are clearcut. Trying to extrapolate from these equations to partial harvest alternatives (e.g., thinning, STR) is difficult.

Confusion about equations has been the result of the great variety of measures used in the studies. For example, Aubuchon (1982) reports similar systems and conditions produce very different values. These methods evolved in industrial engineering to determine the input of time in the production process; factories were the testing ground, offering a controlled environment. Brandstrom (1933) first applied these industrial techniques to early tractor and cable harvesting in the Pacific Northwest forests. Unlike factories, extracting logs, (supply of materials), is highly variable (Staaf and Wiksten 1984, Stenzel et al. 1985, Silversides and Sundberg 1988).

Forests are biological systems and are often more complex and varied than controlled production systems (Odum 1989). Site conditions, equipment complement, and stand character reduce broad based reliability of regression based estimates of production (Howard and Coultish 1993, Giles and Sessions 1987, Berg 1966).

Computer simulations are effective for the study of production trade-offs made between setting design variables (Silversides and Sundberg 1988, Schilling 1969) but the range of conditions make such approaches time consuming and expensive. Value engineering attempts to attain optimal values for a product, often referred to as common sense operations (Riggs et al. 1979). These approaches rarely measure the human element (skill, mental disposition, perception, safety), or contractual obligation of the loggers (timing of harvest, supply demands, condition of equipment).

Timber Appraisal

There are three distinct methods of appraising timber and forestland; residual value of inventory, present worth (PNW) or income projections, and transaction evidence (Duerr et al. 1978, Davis and Johnson 1987). The appraiser's job is to estimate the value as it is (Duerr et al. 1978). Appraisals approximate cost as one of the elements of timber value (commodity price less costs, *stumpage*). Appraisers cannot fully account for costs if they do not understand the sources of harvest costs.

Residual Value Appraisal

Residual value inventory appraisal (RV) is based on the current value of the logs; either on the stump, delivered to the landing, or delivered to the mill. The value represents the wood price less extraction cost, hence the residual value. Costs of extraction, manufacturing, profit are itemized and subtracted from the mill value. Region 6 of the USFS (Washington and Oregon) currently uses a modified RV appraisal adapted from models previously developed in Region 2, 3, and 4. The model incorporates a 4 or 8 month rolling average of recent timber sales supplemented with forest wide reference tables. A "Stump-to-Truck" value replaces many pages of harvest cost computations (LeDoux et al. 1986). But the result offers little guidance to the designer about the acceptability of the setting.

Transaction Evidence Appraisal (TEA)

TEA is the prediction of sale value (estimated high bid) based on the recent sales of like property (e.g. timber, real estate). True market conditions should prevail if the model was based on numerous recent transactions over a reasonable time period (Niccolucci and Schuster 1995). The wide range between actual and predicted bids reflects some loss of value, or bid premium (Schuster and Niccolucci 1989). The reasons for experimenting with TEA were substantial overbids to appraised price of timber and escalating appraisal preparation. An administrative study in 1980 tested the TEA approach to predicting bid price (Merzenich et al 1982). Appraisals use regional or forest-wide cost information that is too general for setting design purposes and yet is the basis for cost estimation. The problem is that TEA provides no feedback to the designer.

Current appraisal methods lack detail about the setting configuration such as arrangement of the boundary, the internal arrangement, and STR. Effects on costs are unknown, most are driven by the lumber value. In the Pacific Northwest, only one design variable, average yarding distance (AYD) is consistently a significant part of any TEA model (Jim Alegria BLM-Portland, Personal Communication). If costs were known they could be used in the design of sales and improve the accuracy of appraisals, both will improve value.

Design of harvest settings

The market is presumably not controllable but harvest cost can be controlled by design. There are several ways to improve productivity; increase the flow of materials to the workers, increase the quality of the labor, and improve efficiency of use of material and labor (Riggs et al. 1979). The latter is partially accomplished through better planning (Bushman and Olsen 1988). If the variables that make work more efficient are identified then design can make use of them to improve production (Dieter 1991, Fight et al. 1984). Design of efficient harvest settings for extracting logs from the forest requires monitoring and quality control feedback information to improve performance or quality (Walters 1986, Deming 1986, Ishikawa 1982). One goal of forest design establishes the feedback link from appraisal to planning (and back again), by providing guiding details from loggers for setting design. A means to sense the logger's perception of costs would help appraise costs. This is because the logger's bid is a synthesis of cost to deliver the logs.

Measuring Loggers Perception

Structured interviews of loggers extract the perceptual cues or utility that they use when contracting to log timber sales. The problem is how to interpret the responses to questions about costs. A market survey of loggers would reveal the perceived relationship between logging cost variables. Developing these methods requires careful scrutiny and reliable measures of perception and preference.

Market research has developed quantitative techniques for measuring perceptions, as a means of improving the market value of products. These methods measure similarity or dissimilarity of objects or values (e.g., Green and Wind 1975). The methods gauge hypothetical constructs of perception that are not directly measurable. Guidelines for designing valid measures of perception are based in psychological measurement theory, psychometrics, and are critical to valid inference (Peter 1981, Peter and Churchill 1986). A point in time estimate of perception (e.g., 1994 logger's perception) is called a cross-sectional study. Tracking perceptions and behavior over time is a longitudinal study (e.g., trends in logger's perception from 1974 to 1994). Longitudinal studies project forward and forecast trends in perception or behavior in the near future using elements of psychohistory (Nunnally 1978, Asimov 1993, 1955).

Market Research in Forestry

Examples of market research applied to production industry (e.g., forestry) are rare (i.e., Gelb 1988, Keegan et al. 1995, 1993) but have successfully improved the bidding success. Gelb describes the improved bidding success for a off-shore drilling company, Western Oceanic, by providing a "numerical rating of priorities placed by [their] clients." These techniques apply in any industrial market. Yet forestry surveys to date have typically been of generally of low sophistication (e.g., Loggers view of safety (Evans 1981); TFW Roads, (Cogan 1991); Perceptions of wildlife trees (McComb and Hope 1994). Results have been primarily descriptive statistics and frequencies of responses to questionnaire items.

Evans (1981) reported the descriptive results from a simple, well designed questionnaire. She asked loggers about their perception of chainsaw safety and use of safety devices. The captive sample was from one large timber company's loggers but demonstrated the effectiveness of polling loggers about their perceptions. The results were very specific but only presented simple descriptive statistics that do not allow for insight about the causes or relationships between questionnaire items.

Coogan Associates (1991) produced a survey of land managers about the effectiveness of road building and sediment control. The process of developing the questionnaire was almost more useful than the results. The questionnaire identified 14 pages of items of concern while results reported only the percentages of responses to the items for a small sample size (46). A more prominent result is the 14 pages of critical issues that warrant more detailed study.

Perceptions about wildlife trees (McComb and Hope 1994) indicate differences in sectors of forestry specifically biologists and logging contractors. Their questionnaire was more complex but analysis was based on simple testing of differences between two samples. Results reported percent of responses by category and excluded "no opinion" responses, which placed greater emphasis on items of concern. While the study used sophisticated methods the deeper relationships between important wildlife tree factors were absent.

Keegan et al. (1993) identified the cost of a number of very specific, commonly practiced STR prescriptions. Keegan et al. (1995) reported actual dollar figures for harvest costs (tractor and cable systems) for the timber types and STR practices in western Montana. But these studies focused on the mean responses and have not explored the relationship between variables, precisely the information that is needed by setting designers. Simple descriptive analysis does not capture the depth of information that could result from multivariate statistics.

Ray and others (1994) reported the perceptions loggers have about creating aesthetically pleasing harvest units. Their contingent value methods used a survey protocol and in-depth personal interviews to assess actual cost increases. The analysis was of the mean responses and while the methods were extremely time consuming the conclusions are somewhat vague. They report that the loggers agree costs increase with STR applications for aesthetics while offering little description of the source of cost.

Perceptions about the aesthetics of timber harvest have been effective for establishing the boundaries of public acceptability. Larkoski and others (1994) used a sophisticated focus group approach to assess the public perceptions of timber harvest appearance, specifically clearcutting.

The results are being applied to timberland practices to, in a sense, validate the study. They have also put the driving principles into a landscape aesthetics course that is administered to the harvest planners. While this method is extremely helpful for identifying some general adjustments in harvest design, it does little to establish the source of additional costs of these operations

Simple frequency analyses of the responses to a questionnaire offer only superficial information with no indication of the importance of the variable means relative to other variables. Multivariate statistics result more in-depth view of the relationship between variables. It is the correlation of a number of variables that yields the rich description of a population's preference, a map of their perceptions. Factor and conjoint analysis are examples of functional techniques that can be applied to the forest engineering environment.

Design of a Survey Questionnaire

First, inquiry is constructed based on logical questions.

Design of a device to measure the construct is a process; defining the frame of reference and the dimensions of the topic. The construct of a study is the fundamental underpinning of research (Peter 1981) and becomes operational when the concept, e.g., harvest settings, is defined by measurable indicators (Cook and Campbell 1979).

Properly designed surveys yield useful, reliable information. Survey responses are reliable if they consistently agree with similar questions perhaps asked in different ways (Peter 1979). Reliability is affected by the basic construct of questions; unclear questions yield wide variances around the response variables. It is important to frame the questions that are being asked in a clear, concise manner to avoid pitfalls of invalid constructs, narrow ranges of scales, and irreproducible results (Cook and Campbell 1979). Reliable research may not be valid if the questions are not sensibly posed or any of the other design elements of the study are faulty (Reibstein et al. 1988).

Elements of a valid survey are not only the empirical results but, almost as importantly, the construct of the measures and scales used to answer questions

(Peter and Churchill 1986). Fundamental to valid constructs in a market survey are the measurements and scales for comparing responses. Scales used to sense variables are properly designed if they are similar in the range, direction, and intent (van der Ven 1980). Clearly organized constructs have directional scales (one-way) and comparable ranges. Design of a operational construct begins at this level (Spector 1992).

Multivariate Analysis of Perceptual Data

Statistical analysis has advanced since the onset of high speed computers. The use of multiple-variable techniques in market research has increased tremendously in the recent decades (Churchill 1992, Jackson 1983). Principal Components (of variance) Analysis (PCA) originated in the 1930's by Harold Hotteling to summarize data in some lower number than the original number of variables. Factor analysis, possibly with PCA but involving rotation to improve interpretation, tries to assess the underlying conceptual basis for the variance; it attempts explain the factors based on the relative loading of variables used.

Multivariate analyses may be interpreted individually or used as input for further analysis. For example, using principal component analysis identifies groupings of variables based on their correlation. Factor results select a minimal set of variables that explain the variabiltiy within the data. Factor analysis can then generate a set of attributes from factors for further study (e.g., conjoint analysis, Johnson 1991). The interaction or correlation between variables describes the structure of the variance and explains the behavior of variables or relationship of factors (Hair et al. 1992, Churchill 1991). Interdependent multivariate methods imply no variable is more important than the others and explore data looking for relationships between variables as indicated by highest correlation coefficients (Huber and Holbrook 1979, Hauser and Koppleman 1979).

Results from factor analysis can generate a perceptual map of the relationship between the variables, summarize the factors influencing the data, and display the inter-relationships within the data. Perceptual maps of respondents offer insight about composite dimensions of important attributes (e.g. long yarding distance, poor deflection). A perceptual map of the logging cost variables may offer a strategic look at the design of harvest settings (e.g., Johnson 1971). Exploring the dimensions of loggers' perceptions will help designers to understand cost variables.

Perceptions are distinguished from preferences in psychology and marketing. Perceptions are cognitive beliefs about things (e.g., big, small). Preferences are affective evaluations about these things (e.g., big is good). While perceptual mapping involves locating the relative positions of things in a cognitive space, conjoint analyis involves deducing peoples part worth utilities for attributes of objects from indications of their preferences for or evaluation of trade-offs among combinations of attribute levels.

Conjoint Analysis

Most decisions involve trade-offs, gaining more of one feature or attribute while sacrificing other features. Conjoint analysis describes the choices made by respondents in complex, multi-attribute decisions. Conjoint analysis determines attributes that respondents most prefer by estimating how much each of the attributes is valued based on the respondents choice. Rather than asking the respondents to report the importance of attributes, conjoint analysis infers the value, utility, from the choices made between combinations of attributes. Conjoint analysis is the value of things *considered jointly* rather than one at a time.

An additive composition rule, as used in this study, defines the utility of any combination of attributes by the sum of the part-worth utilities of the attribute levels of the combination. Conjoint analysis identifies optimal levels and the importance of each attribute level in the design of a product (e.g., cars, timber harvest settings).

Aggregating Individual Utility Values

We can estimate utility values for individual respondents and thereby predict that respondents acceptance or preference of a product with specified levels of attributes. But it is the pooled results that offer the most use in developing product designs with broad acceptability. Once aggregated the part worth utilities can be used to evaluate preference of product designs with specified attribute levels.

Aggregation of the individual values can be done a number of ways. The pooled utility estimate can be the simple average, the approach taken in this study, or more sophisticated segmentation methods (e.g., Moore 1980) by logical groups (e.g., in ground based logging systems by conventional tractor or skidder loggers vs. the more contemporary mechanized harvester/forwarder systems). The goal is to group respondents utility values so the predictive capability most closely matches that of the individual utility values. Sample size may limit the amount of classification of respondents.

Reliance on the simple mean for the pooled utility estimate may lead to the "majority fallacy" (after Moore 1980) where the item chosen by the average respondent is not the item chosen most often. For example, half of the population prefer large cars. The other half prefer small cars but the "average" respondent prefers medium size cars, a choice rarely made.

Conjoint analysis is becoming more common in the market environment. The output from conjoint analysis (i.e., Attribute part-worth utility and importance) are derived from intensive interviews. Because the interviews are comprehensive, fewer samples are taken (Johnson 1991, Green and wind 1975, Green and Rao 1971). Dependence methods as used in marketing imply that there is some possibly causal relationship between the attributes of an object or product and some dependent variables, e.g. attitude or behavior (Green and Kreiger 1994).

Measuring judgments has some intricacies that keep the analysis from becoming biased (Green and Rao 1971). There are well-developed methods for teasing these judgmental data from a questionnaire or intense interview (Green et al. 1990, Jackson 1983). Attribute representation must be complete, realistic, and meaningful. The reliability and accuracy of conjoint analysis measurement requires clear labeling and complete description of the attributes (MacLachlan et al. 1988).

The product profiles used in trade-off analysis are most often verbal descriptions of the factors of interest. Presentation of the tradeoffs can be pairwise trade-off grids comparing two attributes at a time (after Green and Wind 1975). A full profile trade-off offers a more realistic comparison because the products to be compared (e.g., timber sales) are completely described. There are no examples, that I know, of conjoint analysis of forest engineering data. Full conjoint analysis becomes complicated in the case of a large numbers of variables, because of the large number of comparisons necessary and the difficulty of keeping all attributes in the respondents minds simultaneously.

Several methods are available to use when measuring the trade-offs and careful evaluation of the method chosen is essential (Green and Kreiger 1994, Johnson 1991, Acito and Jain 1980). If well constructed, production companies can count on great returns from investment in such expensive studies (Gelb 1988).

Conjoint analyses detail the utility associated with the variables; the utility of the most important variables allows setting designers a basis for deciding location and configuration of harvest settings.

Some variables may be chosen as surrogates because they make more intuitive sense such as log size for both size of timber (1) and volume per acre (2). It is important to test the true independence of these variables by either inspection of the correlation matrix or factor loading table.

The respondent selects the most preferred combination until the trade-off matrix is complete--a full ranking of pairs of attributes--which is the basis for part worths utility value estimation. Separate part worth models allow each level of an attribute to have part worth and can be useful when summing to compare the whole worth of specific harvest designs with different levels of attributes.

As used in product design, a manufacturer or designer has a number of attributes that can vary. Prototypes can be designed using these attributes and the utility values can be estimated using the part-worth values. Market preference or likelyhood of purchase can be estimated for a number of pre-designed configurations. Similarly, various products (e.g., settings) can be decomposed to their attributes to give a common basis for comparison. Comparison is used to evaluate the preferences of an infinite number of designs to how people will react.

Summary

Logging costs are only partially recognized in conventional appraisal methods and offer very little feedback to the planner about setting design. Likewise, traditional engineering approaches to quantifying the influence of site conditions and equipment limitations do not recognize many of the other variables that affect a logger's daily production.

If loggers thoughts or preferences were known, then the complex placement of harvest settings could be evaluated. Designs that consider logger's perceptions may improve operation efficiency by offering the highest utility to the logger.

Methods

Traditional market research methods are tested in the forest engineering environment. Environment in this particular context means the social and economic conditions surrounding contemporary timber harvest methods. A market analysis approach explores the importance of traditional cost parameters of setting design and identifies new parameters than have traditionally been assumed. In this approach, the logger's perception was the principal line of evidence to accomplish the following.

1.) Distinguish a list of logging cost variables using focus group research.

2.) Explain the relationship of cost variables using factor analysis.

3.) Analyze trade-offs by loggers between cost attributes of timber sales using conjoint analysis.

Research design

The methods identify important harvest cost factors that affect contract logging companies and explore the relationship between these factors. In the case of logger's perception, it is important to first identify all of the timber harvest variables; through a series of interviews and questionnaires the critical factors of setting design are then analyzed. This procedure allows rapid assessment of the perception loggers have about aspects of setting design.

An exploratory study was developed because so little is known about the interactions between setting design variables from the logger's perspective.

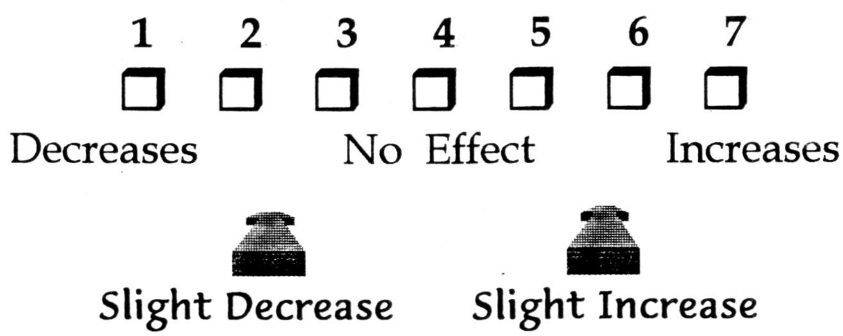
Focus groups helped describe the variables used in a questionnaire that gathered the logger's perceptions. Survey techniques establish the harvest variables important to loggers using factor analysis. Conjoint analysis uses the most important independent factors, or attributes, and assigns part worth utility values to the levels of setting attributes. Conjoint analysis details trade-offs that are important to loggers and yields utility values associated with the key attributes (Churchill 1991, Sawtooth Software 1987). Conjoint analysis derives attribute utility values associated with STR prescriptions as well as the more conventional clearcutting.

The sampling design for the survey was to identify the population of loggers in western Washington and then mail a questionnaire to each person. The population was not large enough to achieve reasonable returns using random or stratified randome sampling. A random sample of the respondents was used to identify the conjoint analysis subjects.

Response to the questionnaires was the primary data and used as input to the conjoint study. There are no other sources for data to be used in the analysis. Existing data for this type of study either does not exist or if it does it is considered proprietary and is unavailable and, either way, must be collected. Subjects for the questionnaires were loggers and a subset of these individuals were selected for the more detailed conjoint study. Federal law requires that anonymity of subjects be guaranteed (Human Research Act). This study qualifies for exemption from University review (Appendix A).

Introduction to the approach

This methodology used is described in Figure 3. A pilot study assessed how effective questionnaires were in distinguishing the importance of logging variables. Several scaling procedures were tested and the 7-point, demonstrated below, was selected because it allows for the expression of intensity.



Logging engineers from the largest industrial and agency landowners of western Washington were contacted for the initial list of cost and design variables (108 variables total). The list was pared down by process of combining confounded or duplicate variables to form an initial questionnaire of 20 variables.

Focus groups were assembled from the largest landowners in western Washington and included a group of forest engineers and a group of forest managers and silviculturists. Additional groups included the academic advisors of this study and personal interviews of key individuals who were unavailable for the focus groups. The focus group results were consensus on the 14 variables used in the study and a pre-tested questionnaire (Appendix B).

The revised questionnaire was mailed to four groups: logging contractors listed in the 1994 phone directory; landowner's preferred contractors lists; the thinning survey mailing list (Ken Dodd, University of Washington); and the logging contractors on the Washington Contract Loggers Association mailing list Following the initial mailing in June 1994 was one follow-up mailing in August 1994.

The responses were immediately codified (Appendix C) and entered into SPSS (SPSS, Inc. 1994 Ver. 6.1). Factor analysis (Norusis 1990) identified four factors of most importance in explaining the variance. Loggers perceptions about harvest costs were mapped to a four dimensional space using factor analysis of questionnaire data. The interpretation is that the variables comprise more complex factors--the axes. Factors are based on the questionnaire response of loggers about setting layout variables. Perceptual mapping includes a range of methods to identify unrecognized dimensions, in this case, the perceived costs of timber harvest (Churchill 1990, Hair et al. 1992). The factors were described as measurable setting attributes and levels of each attribute were assigned.

The selected attributes were passed to the conjoint study where adaptive conjoint interviews were developed (Sawtooth Software 1987). The interviews were installed on a laptop computer and administered to a sub-sample of the loggers (Appendix F). Adaptive conjoint analysis (ACA) derived the part-worth utility values for each level of the attributes.

Methodology Process Chart
Flow of Information

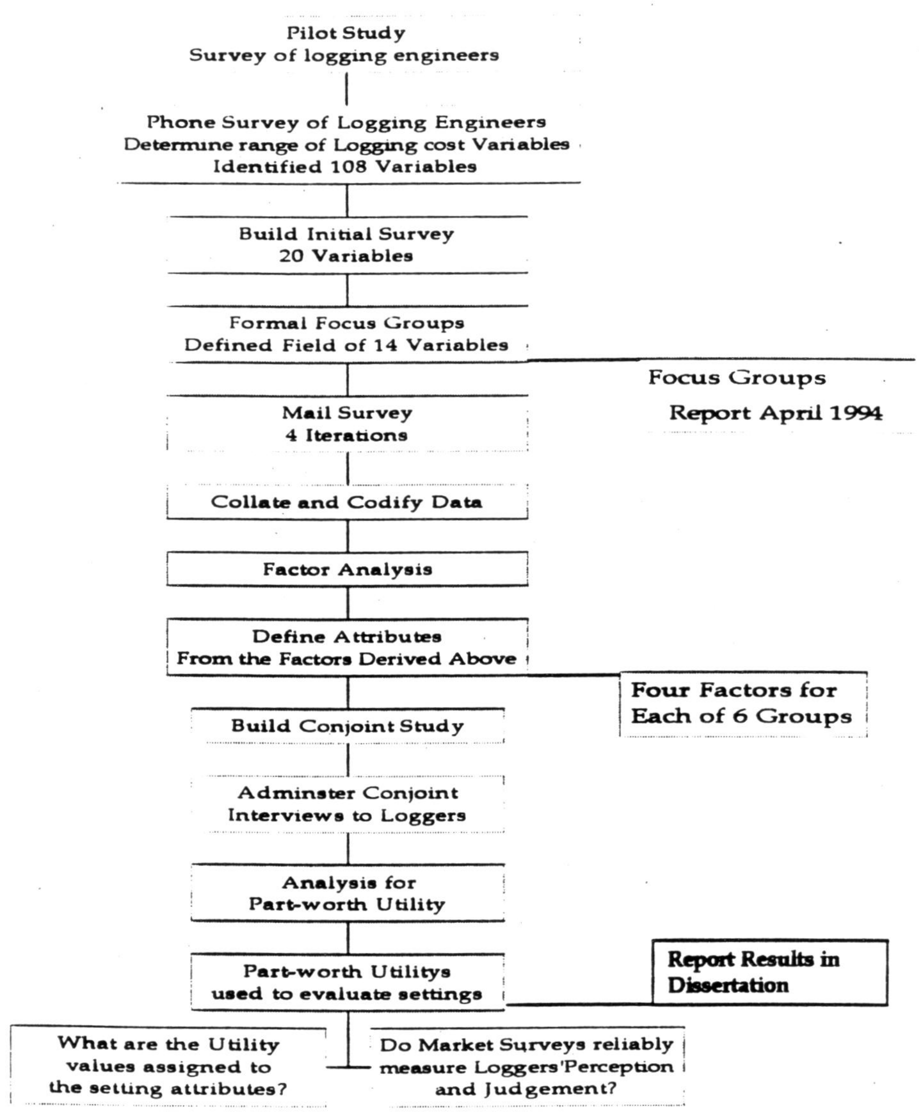


Figure 3. Flow chart of methodology. This is the pathway of information from the data collection to the production of part-worth utilities.

Detailed description of methods

Variables in this study are harvest costs, delineated by formal focus group of forest land owners, engineers, and loggers. Developing the questionnaire requires construction of reliable measurement scales (Spector 1993, Dilman 1978).

A questionnaire approach sampled loggers to determine the costs the loggers perceive. This is a cross-sectional survey for exploratory study at one point in time but provides a baseline for longitudinal studies about the shifting perceptions of loggers over time.

Cable and ground-based logging systems are delineated. Structural retention (STR) level, pattern, type is after Berg and Schiess (1994) where they prescribe three distinct silvicultural regimes:

Clearcut -- 0 % retention of stand volume.

Aggregated -- 12 % of the stand volume on the site is retained (*i.e.*, dominant and codominant trees left standing) in 1-3 acre clumps in an operationally efficient arrangement.

Dispersed -- 12 % of the stand volume on the site is retained in a dispersed pattern (*i.e.*, dominant and codominant trees left standing); approximately 6-10 trees per acre spaced evenly over the entire site @ approximately 65-80 foot spacing.

Focus Group Research

A focus groups are assembled and led by a moderator to talk about a topic, or focus, of interest to the sponsor. Eight to 12 people is a reasonable size; smaller groups are too easily dominated by a few individuals and larger groups lose some of the participation of individuals (Greenbaum 1988). A series of open focus groups held at the University of Washington College of Forest Resources during March 1994 evaluated response variables for incorporation into the survey questionnaire. Focus group membership for this study was professionals from the larger timber holding companies and public agencies (DNR and USFS) responsible for design and planning for timber sales, principally harvest engineers and foresters.

Group participants were selected by telephone from a list of individuals active in the field of silviculture and engineering in the western Cascade and Olympic Mountain regions of western Washington State. They were screened based on their professional activities and chosen to have broad representation across organizational affiliation (agency and industry) and extensive experience with forest operations (silviculture and engineering).

Additional focus groups were held for marketing experts and a subset of loggers. A total of 23 people participated in the discussions (Appendix E). A series of detailed, structured interviews were conducted to capture the thoughts of individuals who were unable to participate in one of the formal focus groups.

Participants were charged with discussing timber harvest variables and pre-testing a questionnaire. The focus groups efforts included a critique of the questionnaire. The value of focus group research depends on the preparation done by the moderator in advance of the sessions. The preparation tasks included familiarization of the subject, selection of the group members, and development of an outline to direct discussion. The moderator's outline was developed and used to guide discussion to keep the topics successively narrowing toward the primary objective--the questionnaire.

The group's members were first introduced to each other and the procedures explained. A series of general questions began discussion to get people talking. There were several topics discussed in the context of the broader study. These topics formed the basis for initial open dialog about the variables associated with logging cost and effects of structural retention harvest cost. These topics were embodied in the questionnaire already in development. Harvest costs were discussed as a means of focusing on the elements of the questionnaire. Finally, the in-depth investigation began with the groups responding to the questionnaire, which took 20 minutes of time from the group discussion but was productive. The discussion finally focused on the content and style of the questionnaire. Modifications, based on the recommendations of the focus groups and advisors, were to include 14 variables and improve the measurement scales to include a measure of "direction and magnitude".

Survey questionnaire design

Questionnaires must be carefully designed, with analysis pre-conceived. When there is a clean design, the task of cogent synthesis is still monumental. Results from the focus groups provided a framework to build a valid and reliable questionnaire.

Data structure is based on the questionnaire (Appendix B). The data are blocked on the two harvest systems, cable and tractor, then each silvicultural regime is analyzed independently within a block. This survey identifies those cost variables that have the greatest variability and influence on harvesting costs between traditional (clearcutting) and new approaches to forestry (STR).

Questionnaire development primarily focused on the type of task and the complexity of the responses. Because the questionnaire was a complicated device there were several checks on the logger's response built into the questionnaire. A series of variables regarding payload, yarding direction, haul cost were embedded in the questionnaire for a reliability check. Payload variables (size of timber, logs per turn, and total volume) were to distinguish which of three terms about timber held the most importance to loggers. The yarding direction series included uphill and downhill (variables #9 and #10), which are inversely related between harvest system (cable and ground based); cable systems vary inversely to ground based. Haul cost should have no effect on logging costs and should be isolated as an unimportant variable.

This study used a questionnaire with scales designed to evaluate the perceived importance of the harvest layout parameters. The questionnaire relates loggers' perception of a number of variables to harvest cost by silvicultural system (Table 1). Loggers answered a question about how increases in specific cost variables affect unit logging cost. Loggers indicated how each of the cost variables affected the total logging cost (decrease, increase, none) using different harvest methods (tractor or cable), under the three silvicultural regimes (clearcut, aggregated retention, and dispersed retention).

Table 1 Entities studied were harvest costs associated with two harvest systems; cable and ground-based, and with three silvicultural systems; clearcutting, aggregated, and dispersed structural retention.

Silvicultural Systems within Logging Systems

Cable Logging:	Ground-based Logging:
Clearcut	Clearcut
Dispersed STR	Dispersed STR
Aggregated STR	Aggregated STR

Harvest Cost Variables

1 Size of Timber (Average scaling diameter)
2 Payload (Pieces per turn)
3 Total Harvest Volume (Mbf total)
4 Topography (from even to dissected)
5 Slope (Percent)
6 Yarding Distance (500-1000 ft.)
7 Yarding Distance (>1000 ft.)
8 Stand Density (Trees per Acre)
9 Uphill Yarding*
10 Downhill Yarding*
11 Equipment (Types and Amount)
12 Labor (Demand)
13 Skill (Experience and Education)
14 Haul Distance (From Landing to Mill) **

* Yarding direction is inversely related between Cable and Ground systems
**Hauling should have no effect on logging cost

Questionnaire Method

Each variable was rated by the influence of cost variables. The questionnaire elicited subject's perceptions of the important costs affecting logging cost. The respondent was instructed to answer the following question for each of the 14 variables:

1.) How does an increase in (***variable***) affect the unit logging cost ($/Mbf)?

[Responses were given on the 7-point scale shown earlier.]

Questionnaire design was based on the 10 most important variables identified by the focus groups with a dummy variable for a reliability check (haul cost) and three piece size variables (size of logs, pieces per turn, and total sale volume). The responses were along a seven point scale (1 - 7); 1 decreases costs, 4 has no effect, and 7 increases costs. These scales are easily understood by the respondent (Churchill 1991, Spector 1992), offer an expression of intensity, and yield discrete data (Churchill 1991). The major benefit of the scale is that it forces the subject to make allocations based on perception (Spector 1992). This rating tells how much "weight" the subject assigned to each of the variables in estimating the cost of logging. This response is in the language of the logger, who estimates logging cost of standing timber. Respondents gave perceptions about costs of different silvicultural systems.

Sample Frame

Target population of a survey must be well defined and appropriately sampled if the study is to be valid. Target population is western Washington State loggers, who are responsible for bidding or assist in estimating the harvesting costs associated with proposed timber sales. These people make decisions about how the land is to be logged and know much more than they may be "consciously" aware. The target for the survey was drawn from Washington Contract loggers Association (WCLA) and small independent loggers (gypos). Cooperation of the DNR, timberland owners, Washington Forest Protection Association, the various timber action groups, and the WCLA were useful in defining the population. The target audience for this project is the landowners and harvest engineers who make decisions about the design of timber sale units.

Sampling members of the logging community requires several strategies for identification. There may be differences in the character of the respondents. (adopters vs resistors, logging firms vs log buyers, contractors vs owners). Sample selection made reasonable attempt was made to identify all of the loggers in western Washington. First, I generated a list of the population from WCLA members, DNR contractor lists, 1994 telephone directory, companies preferred contractors lists. The telephone list was verified by phone before surveys were mailed (60 of 324 listing still valid). The survey was mailed to all subjects (June 1994) with one additional mailing (August 1994) to the remainder of non-respondents. Individuals who were not represented on any of the other lists were identified and surveyed on location in the small timber towns (e.g. Carson, Morton, Randal, Darrington, Forks, Elma, Cougar, Deming, Quilcene and Port Angeles) usually at the local chainsaw shop or heavy equipment garages.

Since there are relatively few loggers in western Washington, there was a possibility for a complete census of the individual loggers. While I tried to contact all the loggers, I suspect that some were not reached, therefore, the inference (Cook and Campbell 1979). Population size for the initial questionnaire was 450 subjects; 90 subjects (20%) was the target number of acceptable responses. Given the nature of survey devices such as questionnaires, there were some unacceptable questionnaires, rejected because of unreliable responses. The differences between the mean values of responses of the first and second mailing were used to estimate the effect of non-response bias.

Stratification criteria were not strictly applicable because of the sacrifices made in sample size. Olympic peninsula, North Cascades, and Southern Cascades were proposed as the geographic strata but the archetypal "loggers" was not clearly discernible in pre-sample strata. Instead, loggers were grouped as to functional role, cable or ground based systems.

Data Collection

Survey administration was through mail with a return mail envelope. This assured that the respondents simultaneously executed the questionnaire. Structured questionnaire applications often require some explanation to assure a high degree of acceptable responses. A cover letter and a one page description were included with the three page questionnaire, in which I instructed the subjects about the survey procedure.

Quality assurance included the prompt checking and entry of the response data. The "pulse" or quick collection of the data required a close watch because there was only a limited opportunity to capture the responses. Data code and dictionary were developed in advance of the questionnaire administration and followed the recommendations of the focus group and advisory committee.

Questionnaire analysis began by codifying the data. Coding translates the responses (scale metrics) into numerical entities. Data editing followed the entry to assure the proper transfer from the questionnaire to ASCII flat files as defined by the data dictionary (Appendix C).

The conjoint analysis was a completely separate stage with a different method of administration and sample. The conjoint analysis was administered on a more personal level. First the sample was drawn from the pool of valid respondents. There were 20 respondents identified for both the cable and the ground based data. In-person interviews (Appendix E) were conducted that lasted a minimum of one hour and as long as two hours. Much of the time was spent in explaination, using pictures and verbal descriptions. The comments that were made incidental to the specific conjoint were recorded and reported as anaecdotal information.

Analysis and Interpretation

The questionnaire responses were analyzed with multivariate techniques (Hair et al. 1992, Norusis 1990) to isolate variables or combination of variables (Factors) that are of importance in harvest design. Multivariate techniques, factor and conjoint analysis, in sequence, evaluated the environment of harvesting timber with contemporary market survey methods. Tabulation and analysis was with SPSS (SPSS Inc. 1993) and specialized applications developed by Sawtooth Software (1987). The initial questionnaire results are from factor analysis, which objectively selected attributes for inclusion in the final conjoint analysis.

SPSS-FACTOR (Norusis 1990) explains the dimensions by which the loggers perceptions about the logging and silvicultural systems vary. Factor analysis results in surrogate variables, or attributes, of harvest settings that, collectively, account for variation in the data based on correlation matrices. Factor analysis reduces the field of variables to an orthogonal (uncorrelated) set of lower dimensionality. First the entire block of data (either cable or ground-based) was analyzed to see the general pattern of correlation between variables across silvicultural system; clearcut and STR, aggregated and dispersed. Then each of the silvicultural systems were analyzed independently.

Reliability checks built into this study ascertain if the variance is associated with the methods as opposed to measurement of the responses. Haul distance is used as a response variable that should have no influence on logging costs to determine if factor analysis distinguishes a factor "Haul Distance". Secondly, the respondents were asked to evaluate the influence of yarding direction on logging cost (increase, decrease, none). For the respondents that answered questions #9 and #10 (Uphill yarding and Downhill yarding), the influences should be opposite between the ground-based and cable harvest systems.

Missing cases were handled by replacement with mean values after demonstrating the improvements gained in the solutions. Likewise, Varimax rotation was used because of improvements noted in the overall solutions while minimizing the effect on the sampling adequacy.

Selection of variables was done by successive iterations of the factor routine holding the solution to 4 factors. The fourth factor was considered for removal if it explained little of the variance. This procedure was iterated until four distinct factors were isolated. The isolated factors were either combinations of variables or individual variables. These final solutions yielded the four factors that, by definition, were independaent and explained most of the variance in the data. Factor analysis produces a rich description of the elements in a "market space", here the logging environment. The procedure for variable reduction was similar for all groupings (Appendix F and Table 4).

The final factors passed to the conjoint study, attribute selection, were based on one of three conditions. First, if the factor was composed of a single variable then the variable became the conjoint attribute. Second, if the factor was composed of more than one variable then one of two choices were made to name the attribute. The first choice was to define a new name for the attribute if the combination of the variables comprising the factor were not too abstract. If the relationship between the variables within a factor was indecipherable, then the variable with the highest factor loading was chosen as a surrogate variable and passed to the conjoint study as an attribute.

For example, if two variables comprise factor one, uphill yarding (.93) and long yarding distance (.90), and two other variables comprise factor two, moderate yarding distance (.85) and topography (.83); then a decision must be made about naming the factor. In this case, factor one would be called yarding direction (with levels uphill, sidehill, and downhill) and factor two would be named yarding distance (with 3 levels). The variable with the highest loading (number in parentheses) is assigned as the surrogate for that factor--or attribute.

Conjoint Analysis

Individual part worth utility is calculated using ordinary least squares (Sawtooth Software 1987; pg. B-1). A clear, simple description of this method is found in Hair et al. (1992; pg. 408). This type of regression uses preference ratings for the trade-off combinations as the dependent variable and a dummy variable for the independaent variable, representing presence or absence of particular attribute levels. Individual utility values are aggregated to a pooled utility using the simple mean of the individual values. The ***POINTS.EXE*** program distributed by Sawtooth Software (1987) generates a file of the individual respondent's utilities, after rescaling them. These values are then submitted to SPSS (1993) for a detailed look at the variance of each utility and the distribution of individual respondent's part-worth values. This is used to assess the proper aggregation method (e.g., mean, median, mode, segmentation) for pooled utility estimates.

The overall utility uses the respondents average utility with the additive composition rule, where the overall preference for a combination of attributes, is represented as:

$$\textbf{Preference}_{\textbf{Setting}} = \textbf{PW}_1 + \textbf{PW}_2 + \textbf{PW}_3 + \textbf{PW}_4$$

where the $\text{Preference}_{\text{Setting}}$ is composed of the estimated part worths for the attributes (PW_1, PW_2, PW_3, PW_4) and assumes no interaction between terms (after Hair et al. 1992).

Conjoint analysis estimates the utility the respondents attach to the attributes in the study. Conjoint study can also estimate the part-worth of described attribute levels. Only the most significant and truly independent variables were used in the conjoint analysis (Riebstein et al. 1988). The decision to use surrogate variables depends on the application (Hair et al. 1992). The levels of each attribute are selected based on realistic, actionable, and communicable criteria (MacLachlan et al. 1988). The levels chosen must make sense from an operations standpoint and be easily understood by the respondents, loggers. It is assumed that the essential set of attributes are complete, include the potential range of an attribute, and based on the factors described. The attributes and levels used in this study are listed in Table 3.

Adaptive Conjoint Analysis

Adaptive Conjoint Analysis (ACA; Sawtooth Software 1987) takes advantage of the rapid querying capability of computers and streamlines the interview based on the subject's response (Green and Krieger 1994, Johnson 1991, Louviere 1988).

ACA builds the orthogonal array of trade-offs required to have a complete analysis. Computer interview technology assists in the collection, summary, and analysis of conjoint data. As the respondent replies, improbable comparisons are eliminated. This saves time and does not tax the respondent's will.

ACA streamlines the interview process so that much more information can be gained about trade-offs in a shorter period of time. It is still a compromise between presenting the complete, realistic description of harvest settings and the complexity of the task being asked of the respondent. To make this task less daunting a series of drawings to accompany the computer interview were made that clarified the concepts being conveyed. ACA is very powerful in collecting data while minimizing the work of the respondent.

The subjects for the detailed conjoint interviews were randomly selected from the pool of respondents who completed valid questionnaires. ACA first asks the respondent to eliminate any level of any attribute that they consider unacceptable, reducing the set of trade-offs. The next step establishes the subject's preference for the levels within each attribute. Attribute importance is established next by asking respondents how important is the difference between the high and low levels of the attributes. The relative importance of the attributes is confirmed by offering paired comparisons followed by product designs, verbal descriptions of harvest settings based on the attributes in the study. Visual depictions or descriptions of concepts are used to establish a frame of reference for the respondent (e.g., Appendix E).

An additive composition rule was used in this conjoint analysis. The attribute part worths are summed to determine the whole worth of a product's complete combination of attributes (Churchill 1991, Hair et al. 1992). Here the product is the timber sale. Conjoint part worth models allow computation of a utility for each level of an attribute. The overall utility of a specific timber sale would be the sum of the part worths for that particular sale.

This study used the composite utility values for the loggers from the simple mean of each individuals utility. Utility values were translated to an evaluation method.

Table 2 Attributes and levels used in conjoint analysis (ACA).

Attribute	Level
Yarding Direction	
	Uphill
	Sidehill
	Downhill
Yarding Distance	
	<500 Ft.
	500′-1000′
	>1000 Ft.
Yarding Distance and Direction	
	<500′, Uphill
	<500′, Downhill
	500′-1000′, Uphill
	500′-1000′, Downhill
	>1000′, Uphill
	>1000′, Downhill
Terrain (Topography)	
	Even Up-Down Slope
	Broken Up-Down Slope
	Even Cross Slope
	Broken Cross Slope
Piece Size (Scaling Diameter)	
	<12″
	12″-24″
	>24″
Stand Density (Trees per Acre; Spacing)	
	134 TPA; 18′X18′
	302 TPA; 12′X12′
	680 TPA; 8′X8′
Stand Structure (Stocking; Stand Diameter)	
	200 TPA; 6″-12″ DBH
	200 TPA; 12″-36″ DBH
	400 TPA; 6″-12″ DBH
	400 TPA; 12″-36″ DBH
Skill (Experience)	
	No Experience
	4 yr. Forest Eng. Degree
	5 yr. Experience
	10 yr. Experience

Results

The objective of this study was to understand the contract logger approach to timber sales. A survey of loggers reveals the relationship between cost variables associated with logging. The methods successfully described the relationship between factors perceived by loggers contracting to log a timber harvest setting. Additionally, the relationship between these factors changed dependent on the silvicultural prescription; specifically for structural retention (STR) compared to clearcutting. The trade-offs made by almost 120 loggers identified the part-worth utility for the levels assigned to setting design attributes.

Factor Analysis

The factor analysis (FA) successfully accomplished three objectives: identify the unimportant variables (e.g., Haul Cost); discern terms preferred by loggers regarding timber (for example, piece size, payload, or total volume), and reduce the field of variables to four well defined, independent factors.

The placement of a dummy variable, *Haul Cost,* verified the method of sensing logger's perception through the questionnaire. FA identified this variable as contributing very little to the explanation of the variance. This test demonstrated that the procedure was feasible and offered some confidence in assigning importance to the remainder of the variables. In all cases, across cable and ground systems, *Haul Cost* contributed very little to the factor solution. A mean value of 4.00 would have no effect from the questionnaire. The mean values are shown in Table 3.

Table 3 Mean values for dummy variable, Haul Cost.

Variable	Mean	Std Dev.	Label
Cable Systems			
CC14CBL	4.46	1.40	Haul Distance-Clearcut
A14C	4.69	1.37	Haul Distance-Aggregated
D14C	4.86	1.46	Haul Distance-Dispersed
Ground Based Systems			
CC14TR	4.40	1.37	Haul Distance-Clearcut
A14T	4.64	1.25	Haul Distance-Aggregated
D14T	4.71	1.36	Haul Distance-dispersed

Haul Cost, consistently, was the variable linked with other variables that least explained the variability in the data; indicated by low communality values. Factor analysis successfully identifies variables least associated with other variables.

The factor procedure successfully extracted 4 factors for each of the two data subsets (cable and ground-based logging) that were most important in explaining the variability in the data. Eight separate factor analyses were completed: overall, and for each silvicultural regime (CC, AGGR, DISP) sets within each of the cable and ground data sets.

Table 4 has three parts: (a) the variables used in the solution, (b) the importance of the factors, and (c) the rotated factor matrix. The list of the variables (Table 4a) are the result of successive iterations of factor analysis using the questionnaire responses. Each iteration identified a few variables that had the least importance in explaining the variance within the data. The important factors are then translated to a single descriptive attribute, listed at the end of the methods section (Table 2). Communality is the amount of variance a variable shares with all factors derived (Table 4b); high communality indicates that a large amount of the variance in a variable has been accounted for by the factor analysis (Hair et al. 1992).

The importance of a factor is described in several ways. First, Table 4b shows the factors and the associated eigenvalues (defined as the sum of the individual eigenvector values for each variable) with the percent of variation that each factor explains. Secondly, the rotated factor matrix (Table 4c) details the variables that make up the factor. Only the variables that are part of the final solution are displayed. The associated eigenvectors for the variables indicate the strength of their contribution to the factor.

Table 4 Final Statistics for Overall Factor Analysis (Typical; See Appendix F for the detailed statistics).

A. Variables selected for Cable Overall (Clearcut, Aggregated, and Dispersed):

Variable	Label	Communality *
Long Yarding (aggr)	A7C	.95366 *
Stand Density (aggr)	A8C	.92596 *
Uphill Yarding (aggr)	A9C	.94528 *
Downhill Yard. (aggr)	A10C	.97540 *
Long Yarding (disp)	D7C	.96705 *
Stand Density (disp)	D8C	.89164 *
Uphill yarding (disp)	D9C	.96030 *
Downhill Yard. (disp)	D10C	.96887 *.

Note: The table shows the amount of variability in the selected variables explained by the factors.

B. Importance of factors selected from variables:

Factor	Eigenvalue	Percent of Var.	Cumulative % of Var.
1	4.10604	51.3	51.3
2	2.43063	30.4	81.7
3	.60321	7.5	89.2
4	.44827	5.6	94.9

Note: The table shows the contribution of each factor to the overall Factor Analysis.

C. Rotated Factor Matrix:

	Factor 1	Factor 2	Factor 3	Factor 4	
D10C	**.89777**	.01640	.38042	.13373	Dnhill Yrd
A10C	**.89697**	.04255	.39740	.10536	
D9C	.01523	**.93534**	.06309	.28500	Uphill Yrd
A9C	.03091	**.92049**	-.00652	.31140	
D7C	.41517	.05546	**.87645**	.15311	Lg Yrd Dist
A7C	.44355	.02607	**.85504**	.15860	
A8C	.15415	.29742	.11649	**.89452**	Stand Density
D8C	.09128	.42415	.19182	**.81646**	(TPA)

Note: Eigenvalues, factor loading are shown. Variables that are loaded high on the same factor are used either as surrogate variables (choose one) or combine to describe a new attribute.

Trade-offs were made such when dropping variables that have the least importance as measured by the perceptions of loggers. I have let the data lead to the list of variables that would comprise the attributes. The questionnaire successfully extracted the most important design variables as perceived by loggers (i.e., the set fo variables that are uncorrelated and explain most of the variation in the set of all variables). This is the first step in the analysis and provides a rational basis for decisions about attributes for both conjoint analysis and setting configuration.

Attribute selection

Factors carried over to the conjoint analysis are attributes. Selection was either one surrogate to represent the factor or an expanded name for the attribute based on the variables that comprise tha factor. Surrogate variables are chosen based both on the factor loading and presence of similar measures in the other factors. The final list of attributes was different for each of the eight conjoint studies and were based on the specific factor solution.

For each attribute, levels were assigned. Attributes had at least three levels and the more complex attributes had up to six levels. This point in the study requires a fair bit of subjectivity in describing the actionable levels. The test of appropriateness for the levels was the acceptance of them by the loggers involved in the conjoint study. Indications were that the levels were sensible for the attributes used in each conjoint interview. Table 2 from the methods section lists the levels assigned to the attributes for the conjoint study.

Conjoint Analysis
Personal interviews with loggers yielded the average utility values (part-worths) for every level. The ACA program generated the utility values shown in Table 5. The table columns are the conjoint studies; overall for both cable and ground-based logging systems and individual results for each of the three silvicultural systems (clearcut, aggregated, and dispersed). Rows are broken down by attribute and the levels. Not all attributes were included in each conjoint study, because of the results from the factor analysis. Entries in the table are the utility values for the each level of the attribute--also called the part-worth utility. This is the finest resolution that was calculated but interpolation, where sensible, within the range of the attribute is acceptable. Interpolation between levels is valid but extrapolation beyond the range of the level is suspect.

The utility value of a setting is the sum of the individual part-worth utility from Table 5. As a measure of the overall utility of one setting over another, the sum of utilities can be compared. Important comparisons can be made across the table between the different harvest systems and silvicultural regimes. Within an attribute the relative importance of the levels can be assessed. For example, in the Pacific Northwest steep terrain and cable yarding are both abundant.

Yarding distance and direction; the greatest utility is for short, uphill (u= 44). But there is little advantage over moderate distance (500-1000 feet) uphill (u=43). The decision could be made to layout the longer distance with no substantial loss in the utility of the setting while gaining a great advantage in size of setting from a landowners viewpoint.

Interpolate utility values between values to gain a more precise utility for things like yarding distance. Do not extrapolate beyond or below the utility values.

Aggregation by mean respondent values was justified after inspection of both the variance and distribution. There were high variances associated with a few of the part-worth values. But this is partly attributed to an artifact of the ACA computation, which substitutes a large negative number (-9.999) for attribute levels that the respondent selects to be eliminated from the possible trade-off combinations. The distibutions also reflect this artifact, some of which are highly skewed or bimodal. A decision to use the mean aagregation is based on the predominance of symetrically distributed part-worth values.

Segmentation was simply not possible with the limited sample size but there was a high degree of consistency among the population.

Table 5 Utility values associated with critical harvest setting design variables.

Average of individual utility values of harvest setting attribute levels listed by conjoint analysis.

	Harvest System							
	Cable	Ground	Cable			Ground		
	ACA-C	ACA-T	ACA-1	ACA-2	ACA-3	ACA-4	ACA-5	ACA-6
			Silvicultural Regime					
			CC	Aggr	Disp	CC	Aggr	Disp
Attribute								
Level								
Yarding Direction								
Uphill			57	68	83	12		27
Sidehill			22	12	11	14		6
Downhill			6	17	23	56		66
Yarding Distance								
<500 Ft.				52	45		64	66
500'-1000'				30	29		27	22
>1000 Ft.				1	1		1	0
Yarding Distance and Direction								
<500', Uphill	44	22						
<500', DnHill	19	49						
500'-1000', Uphill	43	4						
500'-1000', DnHill	2	32						
>1000', Uphill	25	0						
>1000', Dnhill	0	9						
Terrain (Topography)								
Even Up-Down Slope	41	50	47			47	60	66
Broken Up-Down Slope	20	20	19			25	24	27
Even Cross Slope	26	32	26			27	30	31
Broken Cross Slope	4	3	7			2	1	2
Piece Size (Scaling Diameter)								
<12"	7	1			6		0	
12"-24"	36	39			46		50	
>24"	28	29			42		35	
Stand Density (Trees per Acre; Spacing)								26
134 TPA; 18'X18'								34
302 TPA; 12'X12'								26
680 TPA; 8'X8'								
Stand Structure (Stocking; Stand Diameter)								
200 TPA; 6"-12" DBH			2	2	5	0		
200 TPA; 12"-36" DBH			34	34	33	38		
400 TPA; 6"-12" DBH			21	24	23	20		
400 TPA; 12"-36" DBH			51	50	52	51		
Skill (Experience)								
No Experience	7		7	11		0	0	
4 yr. Forest Engr. Degree	16		11	12		19	18	
5 yr. Experience	43		43	44		38	42	
10 yr. Experience	39		45	43		50	49	

Note: Utility values are additive. The values for a specific setting are summed to yield overall utility of the setting. Comparisons of settings is based on the total utility. The combination of attributes that contribute to total utility values may vary between settings.

Utility Associated with Setting Design Attributes.
Yarding distance and direction are critical either individually or combined. ACA successfully distinguished the obvious inverse relationship between these variables. On cable settings, loggers prefer the uphill direction always over downhill. The opposite was true of ground-based logging.

The difference between the silvicultural approaches (CC, AGGR, & DISP) was interesting. For cable systems in both CC and AGGR, loggers prefer sidehill over downhill yarding. However, prescribing DISP, the utility indicates loggers favor downhill yarding even though it was likely to be more expensive and dangerous. By speaking with the loggers about this pattern of utility values, they felt it was more difficult to protect the remaining trees from damage during yarding. This was because of gravity pulling the logs down into the retention.

Yarding direction was one of the strong attributes that affected both cable and ground operations. Downhill logging was verified as. generally, the least preferable situation. This study indicates the utility shifts to favor downhill yarding only when the silvicultural regime calls for dispersed retention.

Terrain is a variable that planners have very little ability to control in setting design. The designers can sometimes choose the amount of adverse conditions (e.g., broken cross slopes) to include in the sale boundary. Avoid broken cross slopes when placing setting boundaries while striving to include even slopes. Related to this variable is the shape of the slope, such as concavity or convexity. This was not part of the study but loggers were more than eager to point out that convex, bowl-shaped slopes offer better deflection and thereby improve the yarding chance.

There was less of a difference between the moderate terrain conditions, broken down slope (benches and terraces) and even cross slopes implying that these conditions are not as critical to improving operational efficiency.

The ***topography/terrain*** variable is important to achieve positive deflection, defined as the measurement of sag in a span of cable. The terrain cannot be altered but loggers agree that setting designs could be arranged to minimize the amount of broken slopes. Broken cross slope does have appeal to some tower loggers who prefer to fall timber uphill along the ridges. The terrain and slope both interact in terms of how much the crew has to move around, which can influence the production because the crew becomes exhausted. The shape of the terrain (e.g., concave, convex, or flat) is related to deflection and was poorly described by the topography variable

Size could have more levels because the greater than 24 inch class includes the very large logs, maybe include a 24-36 inch, then 36 inch and greater. In the composite of stand structure there were only two size class levels defined A medium size class may have been quite functional looking at the importance of this variable. The part-worth utilities do, however, lend themselves to interpolation. In the contemporary market place, 12 inch logs are not considered small anymore because the chip-and-saw market will take much smaller stems.

Piece size and densities (piece count) are the components that loggers pay attention to because of the effect the attributes have on production. Increasing piece size had an increasing preference in cable systems generally while ground-based systems generally had higher production and more consistent turn sizes with moderate size wood. Loggers prefer moderate size because of two things. First, ground-based machinery has effective limits on the size of log skidded. Second, there is a shift in the technology occurring in both harvest and processing of logs. Mechanized processor/forwarder systems have a difficult time processing large dimension timber. Harvesting of one or more sizes of timber in advance uses the most efficient system for the various size categories, typically greater than 24 inches' diameter and less than 24 inches' diameter.

Mills are downsizing the size of the processing machinery because of limited supply of large logs. The harvesting technology is, likewise, shifting to highly

Mills are downsizing the size of the processing machinery because of limited supply of large logs. The harvesting technology is, likewise, shifting to highly efficient mechanized harvesting and forwarding (skidding) machines that have an upper limit to the size that they can handle. Mechanized harvesters efficiently log material up to 24 inches in diameter on the scaling (small) end. Twenty-four inch logs are near the upper end of the size that can economically harvest.

Stand structure (piece size and stocking) was a better composite measure than either piece size or stocking variables alone. The hook time is increased widely spaced stands because of the greater distance between stems and slows production. Equally important was that in dense stands, machinery is difficult to maneuver.

Skill - The general trend was that increasing field experience results in lower logging costs with the one exception of tower logging. Loggers preferred training a cable logger, their feeling was that by ten years the person has the skill they are going to use and may have picked up some undesirable habits. Loggers, generally, preferred a person with some college level training in forest engineering over no experience. Loggers never came close to equating five years in the woods with a four year forest engineering degree. This is not a surprise since the University is not training loggers, but rather engineers.

Interesting results are that increased experience is not necessarily a good thing; a logger with 10 years experience but who is 40 years old will not be useful to a crew that needs chokermen or hooktenders, both very strenuous jobs. A person with five-years experience was seen as being trainable and more flexible. The type of experience was important; ten years experience in ground based logging would do little to prepare a worker for tower logging. The region (timber type) where the logger was experienced becomes important because of local variations in the logs and operations.

Awareness of logging methods can assist in the rational design of harvest settings but logging itself is a trade learned by years of on the ground practice. One logger told me about his first awareness of the tenure of old time loggers.

> *'When I first went to work in the woods as a choker setter the rigging slingers were all in their thirties and the hook tenders were all gray-haired. I knew I was going to be setting chokers for along time.'*

Skill was confusing but also questionable as a design variable. The utility maybe misleading because the type of experience, age of the person, and job assignment all affect skill. There are many well established logging firms that would prefer their employees gain experience elsewhere. This is because of the desire to maintain production at high levels and a reluctance to invest in the training of people undecided about career directions. Similarly, an employee with a four year degree might not be satisfied merely logging and may leave for a management job. Loggers asked what is the skill of the forester handling the sale; cable logging needs an experienced forester to successfully lay out settings.

Equipment was eliminated from the analysis because of confusion about what is an increase in equipment. This confusion is from a poor construct, hence, poor quality information. The types of equipment used changes depending on the predominant timber type and methods. Mechanized harvesters and processors are increasing in numbers while the large steel towers (90-100 feet tall) are sitting in machine shop yards rusting. The down-sized equipment affects logger's preference for log size; mechanized harvesters are inefficient with large timber. Shovel logging has a different set of problems than other ground based systems. Dispersed retention limits these operations. The yarding distance for shovels is not practical over about 300 feet.

Intermediate supports for cable systems have gone out of fashion and many of the rigging skills have disappeared. Now that interest in use of intermediate supports is coming back in vogue there is little of the original knowledge that remains. The industry changes and the replacement of equipment often exceeds the depreciation of old machines. There may still be a need for the large towers if landowners move toward either reducing mid-slope roads or silviculture that yields large dimension timber.

Interview with the Logger--Anecdotal information

Personal interviews with the loggers during the conjoint study yielded many insights that were beyond the scope of the study. As an element of the results, some of the more salient points are presented here. Use of anecdotal information is not widely accepted because of the lack of accountability. Misuse of this type of information has been when one perspective is highlighted to support or refute empirical results. This study presents the comments and thoughts of loggers who have contributed as an attempt at complete reporting. The anecdotes offer more insight about the complexity of the logging industry by pointing out where the survey approach lacks resolution of the logger's perception.

The survey did not provide for the yarding and topographic conditions that may force a logger to shift between tower and ground based logging systems. The setting may be designed for ground based systems but the nature of the terrain (e.g., wetlands, broken micro-topography) may dictate a small tower system would achieve higher production and do a better job. Other topographic obstacles contribute to feasibility such as talus and swamps. Forested wetlands are recognized by law but are difficult to protect. Streams constrain all operations often requiring special engineering and design of logging systems.

Stumps often anchor logging towers during yarding but relic stumps from the primary forest can overwhelm any advantages. Both tower and ground systems can be adversely affected by this legacy. One logger told of a sale that they pre-logged the springboard-stumps (8-10 feet tall) just to improve yarding.

The problem of logging small timber has become one of material handling. The landings are already crowded because of the need to minimize the area taken out of forest production. Loggers now sort logs into as many as 20 grades, adding even more complexity to the logging operation. Log length was not included in the survey but was an important component of price. Timberland owners are frequently asking for set lengths. For example, poles and pilings are long logs and are more difficult to extract.

The loggers do not mind STR but pointed out that improper placement of wildlife reserve patches can seriously impede production. They felt that if they could select the leave trees, given specifications for retention, the production could be optimized. The setting designers have the opportunity to keep difficult yarding conditions as reserve areas on the boundary of timber sales. However, ecologically this approach may not maintain the site quality (e.g., structural diversity, dispersal and refuge habitat islands) or protect native forest conditions across the landscape.

There was near unanimous disapproval of dispersed STR. The loggers felt that even with dominant, well-formed trees, root damage can destabilize dispersed retention. There were concerns about the safety of leaving dispersed trees and snags.

Perhaps there are a number of attributes that are differentially important to the various strata of loggers. The levels and definition of attributes may also be improved because there are many variations of logging systems.

Jurisdiction of the timber sale is also important. Private land has much more flexibility to modify the setting configuration while public lands are more rigid in the administration of the sale. A small landowner has limitations because of ownership boundaries. Public agencies (WA-DNR and USDA Forest Service) do an acceptable job of design but changes, if needed, are sometime difficult to render. The jurisdiction also limits the market of the logs with public timber restricted to domestic markets. Loggers do see improved contract prices for logging settings with export timber; private landowners can afford to pay loggers more for logging when the log prices are high. Conversly, on public sales where competition among loggers is fierce, efficient design becomes even more important in attracting high bids--good setting design will reduce costs and allow higher stumpage bids.

Without a doubt the loggers mentioned the market--log price--as being influential. They were reminded that the market was not a focus of the study. Rather than focus on the pure price variables, the study focused on the components that contribute to logging contract price. The amount of work available in an area affects contract prices; related to the amount of timber sales being offered.

Terminology between loggers is inconsistent (e.g., Slovinski = Grabinski= Gravinski = Polock; all define the block on a bite cable rigging design). Definition using terms is less useful than descriptions. There will probably never be a standardized jargon. This indicates that to communicate to a broad spectrum of loggers there will need to be ample explanation.

Another point with loggers was "Compared to what?" The presence of a baseline condition or pre-designed settings would have anchored their perceptual frame of reference. A base case would have given the loggers some standards for scaling, while limiting analytical interpretation. A study that offered specific settings and asked what price would the logger offer (after Keegan et al. 1995) would be interesting but not extremely useful because of the broad range of timber sale configurations. As previously mentioned, log price is driven by markets and current market conditions would overshadow most logging costs; even poor design does not chase away bidders.

Roads were mentioned by loggers as another expense. The variable haul cost was not important but construction of internal roads for access to timber is considered by some as a part of the logging and can be expensive. Road layout is critical to loggers and they would prefer to push the roads themselves given guidelines for erosion and stream protection.

Season also affects the amount and type of logging in the Northwest. In an informal poll developed on the fly, loggers most preferred logging in the fall after the fire season and before the winter rain and snow hit. Summer logging was next because of the long days, followed by winter logging. Spring season logging was least preferred because of the trees susceptibility to damage during the sap flowing season. One logger informed me that in the spring,

"If you look at the tree wrong the bark falls off."

Weather is related to season and affects logging operation most markedly on ground based systems but hauling of logs is limited during prolonged wet weather to protect roads from excessive damage.

The density of loggers in an area will also drive the price down. In recent years timber prices have remained high and many new, less experienced loggers have entered the market. This has led large timber companies to back off the long-term commitments they have traditionally held with a set of loggers. The landowners are favoring a competitive bid process to get the cheapest logging. This practice drives contract prices down even further, forcing responsible loggers out of business, or pushing loggers to move to less populated regions (e.g., Montana, Idaho, Oregon, or eastern Washington).

The importance section of the conjoint interview asked the logger to place importance on the difference between the most preferred and one of the least preferred levels of an attribute. There were four items in the scale (1-4) and yet many loggers would have liked to have an item between 2 and 3 (e.g., 2.5).

Classes *of Loggers*

There are various strata of loggers that are perhaps more significant than the mere geographical distribution. The size of the firm ranges from the one-man skidder show to the fully capitalized firm with hundreds of employees. Below are composite profiles of contemporary logging firms.

Small size operations

Dick is a typical 'Gypo' logger who lives on a shoe string. He cares for his grandkids when the work is slow. He may get a few jobs a year and spends the rest of his time working on his ragged fleet of machines. His skidders and towers are pieced together, customized for jobs he has done. He is an honest man that does not grasp the complexities of managing for structural diversity. He tries to do a good job and often leaves high levels of trees behind but the type of material will do little to accelerate habitat development or create high quality logs. He has learned how to operate within high levels of retention because of his past experience in thinning-both cable and ground skidding.

Medium size operations

Dean works with members of his family and close friends. His wife keeps track of the books so that the men can just log. The family has been in business for several generations and each generation has had to adapt to the logging environment of the day. There are few payments due because the equipment, still quite functional, is paid in full. The owners are involved in the logging and the bidding of future contracts. The business may have the equipment to operate several sales simultaneously but rarely does because of the lack of control by the owners. If equipment sits idle it is of little concern since the machinery is viewed as tools and offers the business the flexibility to bid on a variety of logging jobs.

The exception to the medium size profile is the newly emerging mechanized operation that uses one or several processor and forwarder systems. The sheer expense of these machines forces them to remain productive as many hours per day as is physically possible. Because of the great expense and high rates of production, these firms may have small payrolls of highly skilled operators.

These firms are innovators and capitalizing on the great extent of small dimension timber from thinning prescriptions.

Large size operations

Gordy runs a large logging corporation with many employees. The skill employed include road builder, mechanics, foresters, and all the jobs in the actual logging. The payroll is very large as are the fixed costs such as medical insurance, liability insurance, and interest on loans. He may face $12,000.00 per day with all costs combined. The crews are told to maximize production but to work safely. The equipment from as many as five fulltime logging jobs, or sides, is rarely idle and moves from one side directly to the next landing unless it is in need of extensive repair. The mechanics and fuel trucks supply the needs of the equipment on the landing. Having numerous of contracts ahead is imperative to keep up the payments on this scale of operation.

Discussion

Forest Engineering and Design Implications

The most important element of this study allows provision of design information from loggers to planners. Utility measures can be transformed into design criteria. The degree to which design decisions can be made by forest engineers based on the utility information presented here is demonstrated in the following example.

Setting Evaluation

A quantitative measure of setting preference is the comparative utility between settings. There may be a number of feasible solutions to the setting layout but they may differ in acceptability. With utility values for specific design parameters, the relative merit of one design over another can be evaluated. Figure 7 is a snapshot of the Siouxon Creek planning area F report (University of Washington 1992) and shows three individual settings; A, B, and C.

The utility values are proportioned corresponding to the attribute levels within the setting boundary. The amount of sidehill yarding was estimated by assigning either uphill or downhill yarding attribute levels to the yarding corridors based on the dominance of either condition over the majority of the corridor. The lengths of the corridors were measured and the proportion of yarding direction assigned to the setting. The corridors are spaced 200 feet apart, which is a lateral yarding distance of 100 feet at the far end of each corridor. Currently, there is no established method of calculating the precise amount of yarding conditions because of topographic variations across the landscape. In this example the length and direction of the yarding corridors are used to estimate amount of yarding by the conditions in this study; uphill, sidehill, and downhill. Other approaches would be to compute the proportional area or timber volume in the yarding corridors.

Setting A has very little sidehill yarding (4%), no downhill yarding, and 96% uphill yarding for a combined yarding direction utility value of 56. Setting B has no downhill, and estimated 30% sidehill, and is mostly uphill yarding (70%) with a utility of 47. Setting C has the lowest utility for yarding direction, with 28 because of both a high proportion of downhill (30%) and sidehill (40%) yarding.

Adding the other attributes (Table 6) for the settings (A,B, and C), a quantitative measure (total utility) evaluates the differences between settings based on preference; higher preference will attract more bidders. A setting with high utility may achieve the high value through a number of combinations of attributes. Likewise, the utility value changes, and hence sale acceptability, as STR is prescribed (Table 6).

Preferences for the settings indicate that setting A is the preferred design for clearcutting and C is the least preferred. This is because of the high utility placed on uphill yarding (or disincentive for downhill yarding). Also the terrain is more even in both settings A and B. Aggregated STR uses a different set of utility values and yarding distance is of much greater importance. For this reason, setting C, with many short turns, is preferred above all, in spite of the higher proportion of downhill and sidehill yarding. Setting B has both long yarding distances and 30% sidehill yarding, making it the least preferred design with aggregated STR.

Dispersed retention also has a low utility for any yarding direction other than uphill, even with a fair amount of sidehill yarding (30%), setting C is equally acceptable as setting A. This is because of the high utility placed on short yarding distance. B is never of optimal preference because of the long distances and presence of sidehill yarding, the design for C does not differ from setting A based on the loggers utility of dispersed retention. This evaluation method allows the designer to see what design changes need to be made in the setting layout. While far from foolproof, the development of a quantitative rating system is useful to planners. The consequences of decisions at the most primary level of harvest planning can now be judged based on the perception of the loggers.

It is interestin to note that for either of the retention options setting C has near equal utility. This suggests that setting configuations with landings centrally located, yarding directions well distributed, and relatively short yarding distances are near optimal for STR. The added times to re-string the yarding roads are reduced and the difficult yarding directions are minimized.

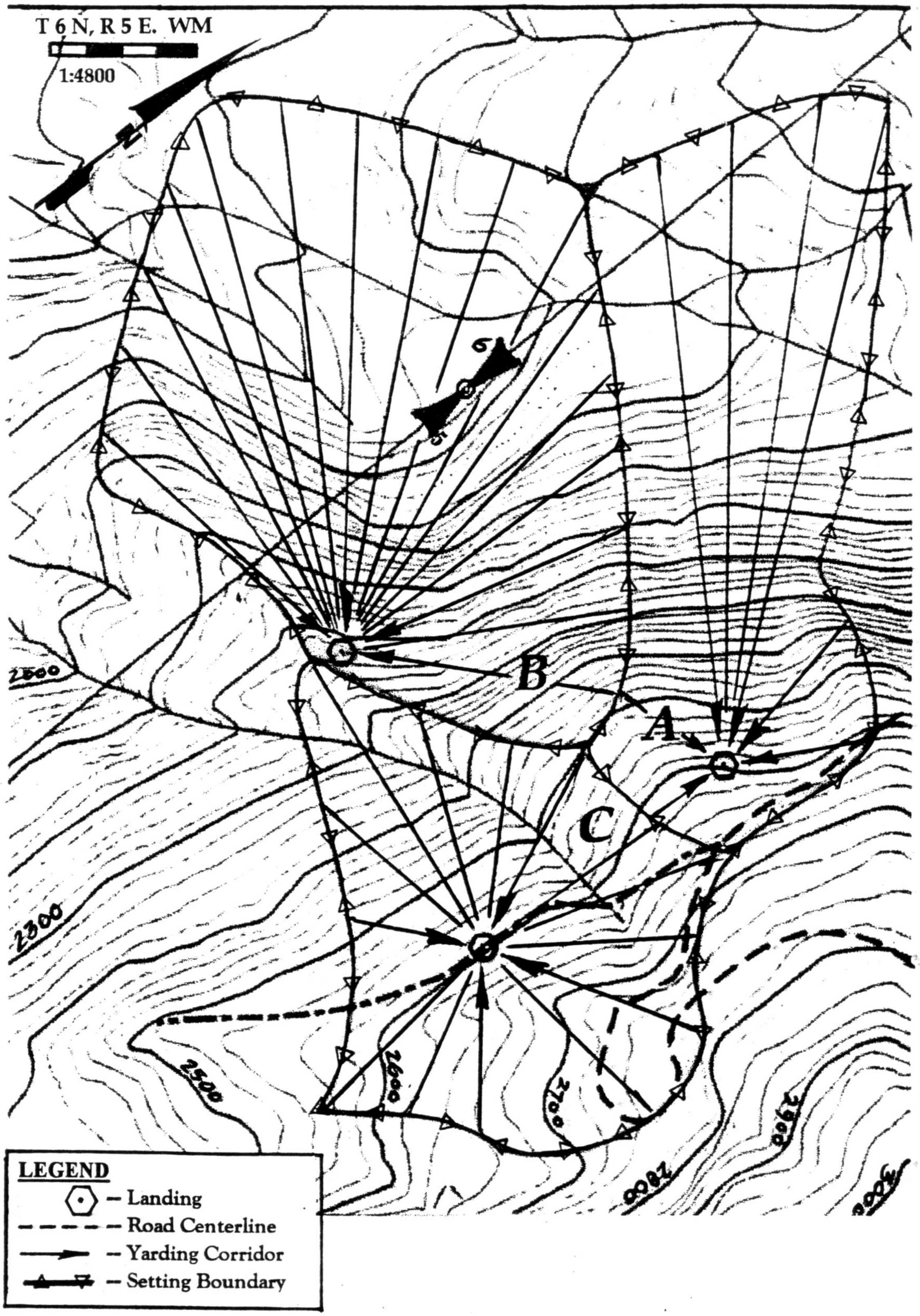


Figure 4 Settings A, B, & C display the attributes that can be evaluated by utility values. Settings are from University of Washington (1992).

Table 6 Utility values for settings A, B, & C using the utility evaluation. Cable setting comparisons are based on attribute utility values (Table 5).

Silvicultural System / Attribute / Level	*Setting* A			B			C		
Clearcutting									
Yarding Direction									
Uphill	0.96 * 57	54.7		0.7 * 57	39.9		0.3 * 57	17.1	
SideHill	0.04 * 22	0.88		0.3 * 22	6.6		0.4 * 22	8.8	
Downhill							0.3 * 6	1.8	
		55.6			46.5			27.7	
Topography (slope)									
Even, Down/Up	0.96 * 41	39.4		0.7 * 41	28.7		0.6 * 41	24.6	
Even, Cross/Side	0.04 * 26	1.04		0.3 * 26	7.8				
Broken, Cross/Side							0.4 * 4	1.6	
		40.4			36.5			26.2	
Yarding Direction & Distance									
<500'; downhill	0.1 * 19	1.9					0.9 * 44	39.6	
500-1000', downhill				0.3 * 2	0.6		0.1 * 2	0.2	
1000'<; uphill	0.9 * 25	22.5		0.7 * 25	17.5				
		24.4			18.1			39.8	
			120			**101**			**93.7**
Aggregated STR									
Yarding Direction									
Uphill	0.96 * 68	65.3		0.7 * 68	47.6		0.3 * 68	20.4	
SideHill	0.04 * 12	0.48		0.3 * 12	3.6		0.4 * 12	4.8	
Downhill							0.3 * 17	5.1	
		65.8			51.2			30.3	
Yarding Distance									
Less than 500'	0.1 * 52	5.2					0.9 * 52	46.8	
500'-1000'				0.3 * 30	9		0.1 * 30	3	
More than 1000'	0.9 * 1	0.9		0.7 * 1	0.7				
		6.1			9.7			49.8	
			72			**61**			**80.1**
Dispersed STR									
Yarding Direction									
Uphill	0.96 * 83	79.7		0.7 * 83	58.1		0.3 * 83	24.9	
SideHill	0.04 * 11	0.44		0.3 * 11	3.3		0.4 * 11	4.4	
Downhill							0.3 * 23	6.9	
		80.1			61.4			36.2	
Yarding Distance									
Less than 500'	0.1 * 45	4.5					0.9 * 45	40.5	
500'-1000'				0.3 * 29	8.7		0.1 * 29	2.9	
More than 1000'	0.9 * 1	0.9		0.7 * 1	0.7				
		5.4			9.4			43.4	
			86			**71**			**79.6**

The conjoint attribute "Yarding Distance and Direction" (YD&D) for the overall (cable Vs. ground-based) lacked the fine resolution of either attribute considered alone, as in the analysis done for each of the STR regimes. Unfortunately, YD&D lacked sidehill levels. The attribute, YD&D, is incompletely described, from a conjoint standpoint. In the example described in Figure 7, for the purpose of apportionment of the part-worth utility, sidehill is equated with the more adverse downhill yarding level. This limitation is demonstrated in setting B, of which all of the sidehill yarding (30%) is 500-1000 feet; assigned the adverse condition, downhill yarding (utility value = 2).

PLANS (Twito et al. 1987) provides technical feasibility (Payload per area by skyline profile) and offers engineers immediate feedback. But there has never been a means to judge the preference of setting designs. Utility can be added for attributes, such as yarding direction, and offers an assessment for the designer. The USFS could expand PLANS beyond payload analysis to setting evaluation, including provisions for STR.

Some attributes had no representation in the example, not from neglect. I assumed the timber type to be uniform in the area, valid to the extent that the stands are adjacent and I lack sufficient inventory data (e.g., volume per acre, density) to justify otherwise. Clearly, the comparative values of the stands would change in light of "timber appraisal" information regarding piece size and stand structure.

Timber size may influence the feasibility of downhill logging; better timber conditions would make the overall sale more desirable. The relationships between attributes, however, such as piece size and yarding direction, make the "Picture" of preference much less clear. Perhaps this indicates that an interactive effects conjoint composition rule (after Hair et al. Pg 390, Kreiger and Green 1994) would be useful in describing such complex relationships.

Increasing piece size may improve desirability of a sale only up to a point. One disadvantage of downhill logging is that logs sustain higher levels of damage during yarding, reducing value to some extent. Damage becomes less tolerable as the defects begin reducing the grade of premium logs. Value of a timber sale is sensitive to the reduction of premium logs to lower grades. Therefore, at high log values, as well as very low log values, the utility of downhill yarding may decrease.

The four important variables selected for each conjoint analysis were not always the same in the different regimes, as a result of the Factor analysis (Table 5). Terrain was not an important conjoint variable in the STR regimes; resulting in the greater importance being given the other attributes.

As one who designs for optimal conditions, the forest engineer is less concerned with market fluctuations. Until now, most appraisal methods emphasized volume and quality of logs from a setting. Utility values of settings can now be used as a gauge of the acceptability by loggers; high values will attract bidders (and hence more competitive bids for stumpage).

Survey methods in forest engineering

The methodology, using a survey questionnaire, in this study gave fast results compared to the long time frames and great expense of TM. Focus of the research was at the design level to reduce costs at the most basic level rather that trying to re-fit landings with the equipment of purchasers--usually low bidder. With the set of utilities from this study, setting design can focus on the variables of importance. The utility values incorporate the local knowledge from the school of hard knocks. Loggers have a great wealth of knowledge that design engineers can now use to evaluate the location and configuration of harvest settings.

This survey effectively closes the loop in the study design process by including loggers and relaying design information to forest engineers (Fig. 5). The results identify optimal levels of important attributes.

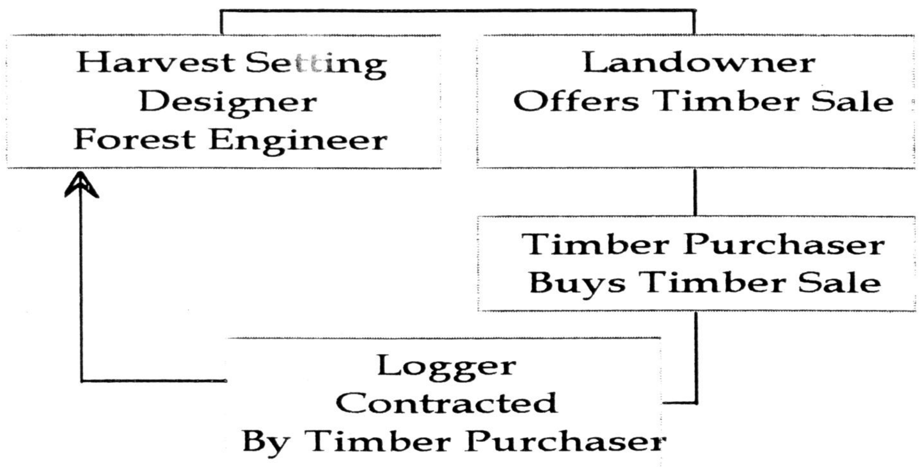


Figure 5. The closed loop in design of timber harvest settings by the use of loggers perception to compare acceptabilty of setting design.

The timber industry is undergoing a number of shifts simultaneously, with emphasis on biological impacts on harvest, advances in technology, and attrition of a knowledgeable, experienced labor pool. Young resource managers can benefit from the results presented here by correctly making decisions about the complex trade-offs that the logger would make. The utility values offer a guide and instruct new setting designers about appropriate boundary and layout concerns.

Comparisons to time and motion data are inevitable but results are useful for backing up in the design process to the point before the equipment and boundaries have been set. This is a point before the common regression equations have any value. The decisions made based on the utility to loggers will improve setting design.

Equipment affects the design of conventional settings because the limitations of machinery in use are well known. But the degree to which the setting is confounded by site conditions is not well understood. As equipment types and uses change the distinction between equipment-driven design vs. site-driven decisions will become less clear. The use of utility values as presented here will help make the difficult decision more clear.

Loggers' Preference

Preferences of loggers are used as market insight for product development. In the case of setting designs, high utility is synonymous with high production. Loggers will be capable of higher production (lower logging costs) and purchasers will be able to bid more successfully.

Utility Description

Relationships between variables is the first step toward efficient setting designs. The exploratory research done here not only identifies critical variables that loggers perceive but also more adequately describes the trade-off between them with a quantiative measure of utility. This allows the designer to make setting decisions before the boundary or equipment is specified. Efficiencies in the operations will cascade through the timber harvest system.

Logger sector analysis

Loggers Information System is only conceptualized here as an application of preference data. By knowing the relative preferences and equipment complement of logging contractors, the correct match of loggers to sites with specified conditions, of high utility, would be possible. This is informally practiced on private timberlands by the "preferred contractors" lists. The present informal system puts a logging contractor on a timber sale that is most likely to achieve the best results for the landowner and provide the logger with a desirable work environment.

LIS is part of a long range plan of the landscape management system (McCarter et al. 1995) where an expert system organization would be able to project forest stand dynamics and forest management economics. The utility values can be used as a quantitative LMS scalar in the economic assessment of individual settings, accumulated and presented at the landscape level

Uses of loggers inventory system

Having the loggers listed by type of equipment and preference allows a better match of the contractor and the setting. Settings could, in a sense, be custom designed for a class or species of logger. Forestry has moved to a silviculture that demands exacting performance in terms of residual tree requirements (e.g., species, distribution, damage). It would be sensible, both from an economic and sivicultural perspective, to begin prescribing, as opposed to recommending, the type of logging system for a setting. A logger information system (LIS) may be a useful development. Many industrial timberland owners have a crude variant of this concept by maintaining a quiver of preferred contractors and assigning them appropriately.

Sector description for work methods planning

As technology development outpaces the forest engineers' ability to empirically test equipment performance and logging production variables, market survey methods provide a rapid assessment vehicle. The combined local knowledge of loggers who are operating with advanced systems (e.g., helicopters, mechanized processors and forwarders) holds the to how these systems perform. The planner can get direct design information from the specific sectors of loggers. Helicopter loggers, for example, could provide detailed planning information used to evaluate improvements of the work patterns and layout of aerial setting designs.

Many of the work pattern and operational procedures of mechanized harvesting systems have been developed by trial in Scandinavia (Silverside and Sundberg 1988). This knowledge must be researched in the forest conditions of the Pacific Northwest. By selecting the most experienced operators and estimating the utility of known variables and exploring additional variables specific to the Northwest, forest engineers can advance in their ability to design operationally efficient mechanized settings.

Both of the examples cited above involve expensive machinery and high operating costs. There stands to be great improvements with relatively little expense and effort using the methods described here. The utility values can be used to describe where experiments might be useful. Trials might be developed that verify or expand on the relationships described here, such as rules for deciding about when uphill yarding becomes sidehill.

From the private landowners or their agent's perspective, This study provides a decision tool for a more complete description of the consequences of choosing particular management alternatives. Setting designs that include STR result in higher logging costs and, therefore, lower bids for stumpage. An example is when a landowner decides to use dispersed STR. Yarding will then be best accomplished by either uphill or downhill, limiting the amount of sidehill yarding. This could mean a number of long , parallel settings as opposed to a single setting, sweeping radially across the timber sale.

Preference data from surveys provides fast feedback to rapidly changing conditions. But these results cannot be projected too far into the future because both perceptions and conditions are changing. The methodology described here assumes that the loggers correctly perceive the attributes. Where the loggers carry myths, perceptions and preferences can be used to debunk falsely held perceptions that have resulted from improper use of tools or logging methods.

Conclusions

Market research methodology, properly modified to the forest engineering sector, can be used to measure the traditional parameters of setting design and identify the relationships between variables. A survey of western Washington loggers can provide useful feedback to planners (silviculturists and forest engineers).

The application of a series of multivariate analytical techniques allows assessment of loggers' utilities associated with hypothetical setting design parameters. Factor analysis based on the responses of the subject pares the possible variable combinations for use in a conjoint study. ACA software efficiently presents loggers with attribute-level combinations and asks for their camparitive evaluations. Utility values of setting attributes are thus derived from loggers' evaluations of attribute combination trade-offs.

Preferences of loggers are useful for determining trade-offs between setting design variables. The methodology demonstrates the consequences of specific design decisions including the pattern of structural retention. The quantitative utility values of setting design parameters help evaluate efficient harvest planning. Utility values allow forest engineers to compare harvest designs that differ by the levels of design attributes.

Landowners need information to evaluate forest harvest settings that are both biologically defensible and economically feasible. As landowners and their agents (foresters and engineers) understand the logger's preferences and perceptions, they can begin to prescribe operations that minimize costs. If utility is the satisfaction obtained from goods, then setting designs with high utility are assumed to be preferred-- loggers' preference is improved daily production. With improved daily production, unit harvest costs decline, measured by dollars per unit volume (e.g., \$/Mbf, \$/cunit, or \$/ton). Harvest costs influence bid price (a buyer's appraisal) for standing timber. As harvest costs are minimized by rational design decisions, bids increase for stumpage.

This is especially true for public landowners where the settings cannot legally be designed for specific logging contractors. The public foresters must design for the broad approval of loggers. Designs planned using the knowledge of the complex relationships among design attributes result in higher stumpage values as competition among bidders for well designed settings increases.

Private landowners have the flexibiltiy to modify settings at the design stage to accomodate contractors with very specific requirements.

This study offers new information about the perceived effect that new approaches to forestry have on harvest cost. Structural retention costs are both foregone timber receipts and decreased unit revenues for timber sold. The former of these two issues is an inventory issue and easily accounted for by monitoring, the second is the influence these silvicultural regimes have on logging. With increased social awareness of forest operations and subsequent regulations that define stand structure targets, the means to evaluate the consequences of boundary location, internal configuration, and design of timber harvest parcels are going to be of great interest.

Conjoint analysis is complex when dealing with the number of variables in this study. This is the first example of conjoint analysis of forest engineering data. This research application is unique with respect to the forestry environment. As a tool for characterizing logger's preference, this analysis helps plan timber harvests based on the important variables. This process improves our appraisals of the harvest cost effect on stumpage price. Concepts of multivariate analysis are abstract and are difficult to grasp and convey. Summary of analysis into an understandable story requires speculation and creativity.

This exploratory project contributes to a better understanding of the relationship of logging cost variables. The trade-off between the factors are quantified to assist planners who decide the location and configuration of harvest settings. A windfall opportunity was the study of interactions of cost variables associated with new approaches to forestry, specifically structural retention. Market surveys can capture these preferences. However, loggers will soon learn to manipulate a standardized format. Continual improvement and design of survey devices will be necessary to collect useful preference data for longitudinal study of loggers' psychohistory.

Guidelines

Harvest costs are an important element in feasibility and implementation of intensive silvicultural systems. Recommendations for design of efficient timber harvest settings are from the survey of loggers' perceptions.

Generally, ground based preferences are less crucial than cable logging. Errors in ground based setting design are more forgiving primarily because of cost associated with the setup time for tower logging. However, ground based operations are more sensitive for attributes of distance and piece size because the increasing effect of turn cycle time and equipment limitations, respectively.

Yarding direction - There is a distinct advantage to uphill yarding in cable clearcutting. Downhill yarding is only preferred when corridors are in dispersed retention, a situation that may become common with contemporary interest in thinning forest stands.

Yarding distance - External distances beyond 1000 feet should be minimized and completely avoided when ground skidding in dispersed retention or thinning. External distances of 500 feet or less are preferred. The exceptions are obvious when the attribute yarding direction is considered simultaneously where 500 to 1000 feet is preferred almost as much as the shorter externals. This is most apparent in cable harvest systems where the short and moderate yarding distances are of almost equal preference.

Terrain - The lay of the land is not something that cannot be controlled but limiting setting size in difficult terrain is possible. The design implications are that boundary placement should consider the amount of broken terrain and limit the size of settings where conditions are of low preference (e.g., steep incised streams, broken cross slopes, terraced slopes).

Piece size - Foresters should be made aware, again, of the high importance log size has to loggers. Growing and tending timber stands to produce high quality logs will generally yield lower production costs while improving the value of timberland operations.

Stand Structure - Dense, small dimension forest stands have low acceptability by loggers because of difficulty maneuvering and the added labor demands. There are hundreds of thousands of acres of this timber type that needs treatment. Limiting the size of settings in these conditions will increase acceptability perhaps enticing higher stumpage bids. The optimal trade-offs for other variables are influenced by stand structure. As stand structure becomes adverse the other design variables become even more crucial.

Skill - of the logger, is again, not a design variable as much as it indicates both the value loggers place on practical training and the increasing level of competence required to accomplish some of the more complex forest operations. The preference is clearly for about 5 years experience. As technology changes there is a demand to improve the working knowledge of loggers.

In general, ground based attributes are generally less crucial, errors in setting layout are more forgiving. However, based on the findings cable yarding is not as sensitive to distance as the ground based operations, tractor systems are affected by long turn lengths.

Future Research Needs

The items mentioned here are beyond the scope of this research effort but are recognized as important, viable information.

Validation of the utility values presented here is of great importance. The loggers should be asked if they are in agreement, for example, by offering settings designs with a variety of preference rankings (product proto-typing). This can test the loggers' technical basis as well. Validation through comparisons with known results from time and motion study will test whether the assertions presented here are borne out. The spirit of adaptive management is to react to new information to improve our collective ability, for example, to make better decisions about setting design.

A scale of evaluating the bidding success could be developed. There may be threshold values of utility that bring considerably higher stumpage premiums. Likewise, this system could be used to avoid sales with very low numbers of acceptable bids, thus saving time by avoiding pulling the sale and re-design. As an example, a standardized overall utility of 100 might bring high stumpage bids where settings with values below 50 may be expected to have low bid success. This method is divorced from the fluctuating log market; changes in log value do not influence the utility based on design attributes. A retrospective study of past sales rated by utility value could be correlated with the known number of bidders or bidding premiums (after Niccolucci and Schuster 1994).

Perhaps the most promising of the prospects is incorporating the utility value into existing planning tools, such as PLANS (Twito et al. 1987). This would expand the evaluation of settings beyond the purely technical into the perceived operational chances for success. By example, PLANS uses the contour map (DTM) for skyline analysis. If PLANS could calculate the angle of interception between the contour and yarding corridor, then the amount of yarding direction per corridor for each setting can be estimated. With this value (amount of yarding direction) the utility of the setting can be estimated and compared to alternatives or other settings.

Limitations of this research

Sample size limitations of this study preclude effective classification of loggers. This reason alone influenced the use of the simple mean as the aggregation method of respondent utility values.

There were poorly constructed survey items that were dropped from the final analysis (e.g., equipment , labor). The remaining items represent the planning environment for harvest settings. As the items are presently represented in the survey questionnaire, they are valid. However, the overall model may be less than completely represented until all of the items, even those presently overlooked, can be included.

Generalizability of these results is limited by the small sample size. While there is a degree of consistency among the population, the broad application of these specific utility values must be with caution.

These methods are still experimental. Advancements made in this study are the extention of market pschometrics to forest engineering. As the first application, there are likely unforseen drawbacks that may be rectified in future research and validation.

Some of the utility values derived from individual repondents have skewed or bimodal distributions. For example, in the overall conjoint analyses (cable and ground based) only a few attribute levels are of sufficiently low variance and symmetry to justify broad application to the industry from the present study. Before such application the sample size should be increased to improve the precision of the utility estimates.

Adaptive management mandates that we begin and then move forward. I am not intimidated by the challenges to this research yet to come, merely hopeful for further advancement.

There are 3 main contributions from this research. First, the methodology borrows from market research techniques to bring psychometric data into the forest management and engineering field. This study is the first product of the newly established program of Silvicultural Engineering at the College of Forest Resources.

Secondly, the industrial design philosophy embedded in the evaluation technique presented incorporates human factors into forest design and engineering. This tool offers planners another quantified decision tool for establishment of efficient, safe, and sound timber harvest. As we develop these methods further there will be improvements made to both these results and the questionnarie devices used to collect data.

Finally, it is a new approach to the application of psychological data where the product being evaluated, setting design, is constrained by physical, biological, and silvicultural design variables.

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Appendix A Human Subjects Act Requirements--Form HS EX-1

Form HS EX-1 (rev 8/91) UNIVERSITY OF WASHINGTON * PLEASE TYPE *

Grant and Contract Services, Human Subjects Division

CERTIFICATION OF EXEMPTION

University procedures provide for departmental review of research involving human subjects exempt under federal, state, and university regulations. The exempt categories and exceptions are described on the back of this form. Exempt research may be approved by the department chair, director, or dean provided it is in accord with the general principles stated in the UW Handbook, Vol. IV, Part II, Ch. 2, Sect. 1 (see back of form). This form, properly endorsed, certifies that the research described here qualifies for exemption, and should be forwarded to Grant and Contract Services, Human Subjects Division, JM-22.

PRINCIPAL INVESTIGATOR Dean Rae Berg ACADEMIC TITLE Research Assistant

DEPARTMENT/DIVISION For. Mgmt. & Eng. Mail Stop AR-10 Telephone 543-7657

PROJECT TITLE Loggers Perception

STARTING DATE Jan. 1994 ANTICIPATED TERMINATION DATE Jun. 1995

FACULTY SPONSOR (IF PRINCIPAL INVESTIGATOR IS A STUDENT) ____

GRANT TITLE (IF DIFFERENT FROM PROJECT TITLE) ____

PRINCIPAL INVESTIGATOR ON GRANT (IF DIFFERENT FROM PI LISTED ABOVE) Peter Schiess

FUNDING AGENCY AND APPLICATION DUE DATE (IF APPLICABLE) USDA PNW Forest Service

I. Check category(ies) under which this research qualifies for exemption (see back of sheet for description of exempt categories): ___1 X 2 ___3 ___4 ___5 ___6

II. ABSTRACT: State briefly a) the purpose(s) of the research, b) what subjects will do (if applicable), c) the nature of the data to be obtained, and d) how anonymity or confidentiality will be maintained. Add sheets if necessary.

a) Describe loggers perception about contemporary timber harvest costs.

b) Subjects answer mail questionnaire.

c) Rank order and Likert scales on questionnaire is the data source.

d) Confidentiality is maintained by anonymous reply to questionnaire.

III. HUMAN SUBJECTS:	Yes	No
Are any subjects under 18 years of age?		X
Are any subjects confined in a correctional or detention facility?		X
Is pregnancy a prerequisite for serving as a subject?		X
Are fetuses in utero subjects in this research?		X
Are all subjects presumed to be legally competent?	X	
Are personal records (medical, academic, etc.) used without written consent?		X
Are data from subjects (responses, information, specimens) directly or indirectly identifiable?		X
Are data damaging to subjects' financial standing, employability or reputation?		X
Is material obtained at autopsy used in the research?		X
Are facilities, staff, or patients from CHMC involved?		X

IV. PRINCIPAL INVESTIGATOR: I certify that the information provided above is correct and that, to the best of my ability to judge, this research qualifies for exemption and will be conducted in accord with the general principles stated in the UW handbook, Vol. IV, Part II, Ch. 2, Sect. 1.

PRINCIPAL INVESTIGATOR'S SIGNATURE [signature] DATE ____

V. CHAIR, DIRECTOR, OR DEAN: I certify that this research is exempt from federal regulations and that it is in accord with the general principles stated in the UW handbook, Vol. IV, Part II, Ch. 2, Sect. 1.

SIGNATURE [signature] TITLE ____ DATE ____

* VALID FOR FIVE YEARS AS LONG AS APPROVED PROCEDURES ARE FOLLOWED *

Appendix B Survey Questionnaire

Perception of Harvest Costs Questionnaire

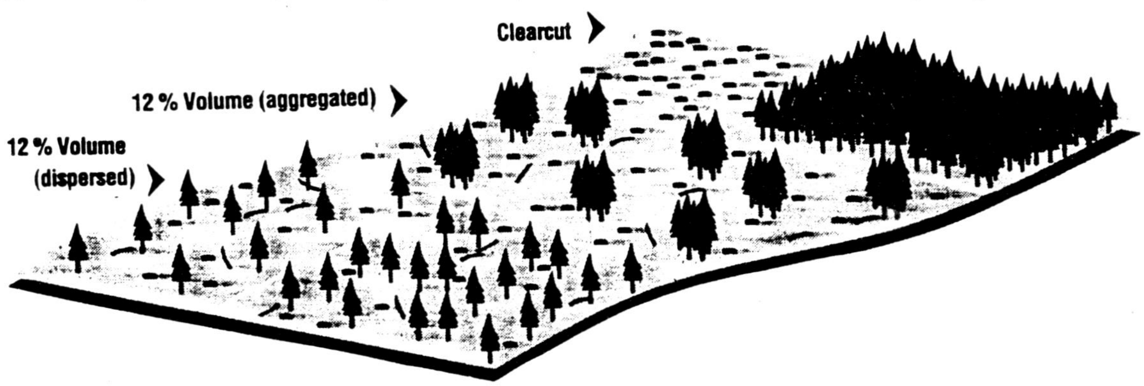
Background - There are many variables that may affect harvest costs; this survey identifies those that are most useful for planning and layout of harvest settings.
I would like to know your perception of the important logging costs. Your response will help design engineers layout efficient harvest settings--the first time around.

This study describes three silvicultural systems being used widely in the Pacific Northwest. Harvest costs may vary between patterns of retention; dispersed or aggregated.

1. **Clearcut** - 0 % retention of stand volume.

2. **Aggregated** - 12 % of the stand volume on the setting is retained (*i.e.*, dominant and codominant trees left standing) in 1-3 acre clumps in and operationally efficient arrangement.

3. **Dispersed** - 12 % of the stand volume on the setting is to be retained as dispersed trees - approximately 6-10 trees per acre spaced evenly over the entire site @ 65-80 foot spacing.



Instructions-Answer the following question for each of the variables (listed on the next pages):

How does an increase in *the Variable* affect unit logging cost? (for example $/MBF)

Indicate how important each of the cost variables is in determining the total logging cost for a given site using different harvest methods (tractor or cable), under the three silvicultural regimes.

1	2	3	4	5	6	7
❐	❐	❐	❐	❐	❐	❐
Decreases			No Effect			Increases

Slight Decrease

Slight Increase

Part I

	Ground Based Harvest System							Cable Harvest Systems						
	☐ Decreases	☐	☐	☐ No Effect	☐	☐	☐ Increases	☐ Decreases	☐	☐	☐ No Effect	☐	☐	☐ Increases
1. Size of Timber (average tree diameter)														
Clearcut	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Aggregated	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dispersed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Payload (logs per turn)														
Clearcut	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Aggregated	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dispersed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3. Total Harvest Volume (Mbf total)														
Clearcut	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Aggregated	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dispersed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4. Topography (even, dissected)														
Clearcut	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Aggregated	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dispersed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5. Slope (percent)														
Clearcut	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Aggregated	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dispersed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6. Moderate External Yarding Distance (About 600-1000 feet)														
Clearcut	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Aggregated	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dispersed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7. Long External Yarding Distance (More than 1000 feet)														
Clearcut	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Aggregated	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dispersed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8. Stand Density (Trees per acre)														
Clearcut	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Aggregated	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dispersed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Part I

	Ground Based Harvest System							Cable Harvest Systems						
	☐ Decreases	☐	☐	☐ No Effect	☐	☐	☐ Increases	☐ Decreases	☐	☐	☐ No Effect	☐	☐	☐ Increases

9. Uphill yarding

Clearcut	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Aggregated	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dispersed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

10. Downhill yarding

Clearcut	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Aggregated	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dispersed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

11. Equipment (Type)

Clearcut	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Aggregated	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dispersed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

12. Labor (demands)

Clearcut	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Aggregated	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dispersed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

13. Employees' logging skill-level (Experience and Education)

Clearcut	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Aggregated	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dispersed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

14. Haul Distance (Stump to Mill)

Clearcut	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Aggregated	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dispersed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Rank the top five ***most*** important variables.
1
2
3
4
5

Rank the top five ***least*** important variables.
1
2
3
4
5

Part II Background Information:

(1) Age ____ (2) Male ❐ Female ❐

(3) School Completed:
Some High School ❐ High School ❐ Some College ❐ College ❐

(4) Job Title________________________________
Contractor ❐
Corporation ❐
Small Company ❐
Other ❐
Specify ______________________________

(5) How many years have you worked with this employer? ____years.

(6) How many years have you worked in logging total? ____years.

(7) Do you own ❐ or lease ❐ your equipment?

(8) Please list any other forest experience.

____

____

(9) Do you have other experience in preparing cost estimates/bids? Yes ❐ No ❐
If so, please indicate below:

____

____

(10) Besides experience and judgement, what tools do you use to make decisions about setting layout? (for example, hand-held calculator, Logger-PC, PLANS)

____

Part III

(11) Would changing the level of structural retention (for example, 12% to 24% of stand volume) change your rating of any of the variables listed above? Yes ❐ No ❐

(12) Rank which silvicultural system by cost (Most expensive = 1, Least expensive = 3)

Clearcut__________ Aggregated_____________ Dispersed________

Include specific comments : ____

____

Appendix C Data Dictionary

Section 1 Demographics

1	Respondent	Number			
2	Age	Years			
3	Gender	0=Female	1=Male		
4	Education	1=Some HS	2=HS complete	3=Some college	4=College complete
5	Business	1=Contractor	2=Corporation	3=Small Co.	4=Other
6	Tenure	Years at last job			
7	Experience	Years in logging			
8	Own Equipment	0=No	1=yes		
9	Bidding experience	0=No	1=Yes		
10	Uses omputers	0=No	1=Yes		
11	Does the level of retention affect Bid price	0=No	1=yes		
12	Rank the cost of the retention systems	1=most costly	2=less costly	3=least costly	
13	Comments				

Section 2 Cost Scales

2.1 Cable Harvest (C) for each of three structural retention systems; 0%retention (Clearcut, CC), 12% aggregated retention (A), and 12% dispersed retention (D).

1 Size of Timber
2 Payload
3 Total Harvest Volume
4 Topography
5 Slope
6 Moderate Yarding Distance 600-1000 ft. external
7 Long Yarding Dsitance greater then 1000 ft. external
8 Stand Density
9 Uphill yarding
10 Downhill Yarding
11 Equipment Type
12 Labor Demands
13 Employee Skill Level
14 Haul Distance

2.2 Ground Based Harvest (T) for each of the three retention systems described above, the list of variables is the same.

Appendix D Focus Group Report

Attitudes about the Costs of New Approaches to Forest Harvest

Report of the Focus Groups at the University of Washington

College of Forest Resources March 18-23, 1994

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Executive Summary

This research was to explore the variables associated with appraising the cost to log and how cost may change with structural retention at harvest. The vehicle to assess this is a questionnaire aimed at the professional logger. If loggers perceptions were known, decisions about the placement and design of harvest might approach more efficient levels.

It is not that the logger is making land management decisions but rather that the decisions made are based, in part, on what is going through a loggers mind when presented with trade-offs between variables. Land managers can then address issues that improve efficiency of operations.

A series of three focus groups were conducted at the College of Forest Resources involving land managers and logging engineers representing the major land management organizations in western Washington.

Recommendations: Modify questionnaire to reflect results of pre-testing, and Implement the questionnaire as per plan.

The modifications complete as of May 1, 1994. Administration of the questionnaire begins as soon as the subject population is sufficiently large to be sampled. The logger population still requires some development before sampling for respondents can proceed.

Action based on the focus group:

- Changes made to the base question. A simple rewording improves the clarity and understanding of the relationship between the base question to each variable.
- Variable scales modified to detect the direction of influences with increases in the variable.
- Variable list modified; Two variables removed and other new variables added, such as stand age, density, and brush conditions.

Conclusion Focus group research provides a wealth of information for both:

(1) describing the contemporary relationship between landowners and loggers and
(2) providing a critical review and pre-testing of a questionnaire.

Appendix E Interview screens from the conjoint study.

Frame # 1 Hello!

I'd like to ask some questions about Cable Logging systems.
You can answer all my questions by typing numbers from
the top row of the keyboard.
Please press any key now.

Frame # 2

There are a few things before start. Should you have trouble,
Dean is there nearby to help you.
If you want to go back and review a question or change an answer
just press the X key, and enter the question number
I'm going to ask you to evaluate different kinds of
cable logging settings. Some of these setting designs
are currently offered, and others may be designed
in the future.
Press any key to continue.

Frame # 3

First, I will show you all of the features we will
consider. Your first job is to ELIMINATE any that
would be so UNACCEPTABLE that you would NEVER CONSIDER
logging a harvest setting with that feature..

Anything you eliminate will be gone forever; so don't
cut your options down too far by eliminating too many features.

Press any key to continue.

Frame # 4

Now I would like to know your preferences for the features
I have just described.

For each of these features separately, I will ask you to
choose the option that you would like most,
then the one you like next most, etc.,
until you have ranked every option

Press any key to continue.

Frame # 5

My next question will be different. I will NOT be
asking about what you prefer.
Instead, I would like to know about what you are
MOST LIKELY TO CHOOSE next time you buy this type
of product.
Press any key to continue.

Frame # 6

So far you've told me about your preferences. Now I'd
like to find out how IMPORTANT each feature is to you.

I will ask you to rate how important it would be for
you to get the option you'd most like to have in each
feature.
Press any key to continue.

Frame # 7

Based on what you've told me, I'm going to make up some
cable settings that differ in these features.

In each question I present two settings, described by
by combinations of features. One is shown at the top of the screen
and the other is shown at the bottom.

I ask which setting design do you prefer, and how
how strong is your preference?
Press any key to continue.

Example of Product Preference screen.

```
Strong  |Convenient|  Two Cable Harvest Setting descriptions will appear.
Prefer  |          |
  1     |          |    First, decide whether you would prefer the
        |   but    |
  2     |          |    the setting design on the top half of the screen
        |          |
  3     | High Cost|         or the one on the bottom half.
        |          |
  4     |          |
        |          |    Then decide how strong your preference,
--5-----|--- OR ---|         use the scale at the far left.
        |          |
  6     |          |      If you prefer the example on the top,
       Inconvenient     type a number from the top half of the scale.
  7     |          |
        |          |    If you prefer the setting described on the bottom,
  8     |   but    |    type a number from the bottom half of the scale
        |          |
  9     |          |
        | Low Cost |          If you prefer neither type 5
Strong  |          |
Prefer  |          |
Bottom  |          |           Press any key to continue.
```

Frame # 8

This is the last section. Based on everything you've
told me, I'm making up three cable harvest settings.

You should like the first design the least,
the second one more,
the third one the best.

I'll ask how likely you would bid to log this setting
if it were available right now.

Press any key to continue.

Frame # 9

Thanks very much for your help!
Please tell Dean that you have finished

Appendix F Detailed Final Statistics

Overall Ground-based (Clearcut, Aggregated, and Dispersed):

Variable	Communality	*	Factor	Eigenvalue	Pct of Var	Cum Pct
CC1TR	.73200	*	1	3.74788	37.5	37.5
CC13TR	.75179	*	2	2.87852	28.8	66.3
A1T	.86020	*	3	1.35792	13.6	79.8
A4T	.93799	*	4	.68334	6.8	86.7
A7T	.91293	*				
A13T	.92104	*				
D4T	.92584	*				
D7T	.92738	*				
D9T	.83135	*				
D13T	.86713	*				

Rotated Factor Matrix:

	Factor 1	Factor 2	Factor 3	Factor 4	
D7T	**.94598**	-.04699	.15973	-.06913	Lg Yrd Dist
A7T	**.92645**	-.01500	.18647	-.14012	"
D9T	**.90069**	-.07410	.11552	-.03575	Uphill Yrd.
A13T	.00033	**.90623**	.12648	.28946	Skill
D13T	.09513	**.85543**	.12637	.33218	"
CC13TR	-.26320	**.78861**	-.21009	.12837	"
A4T	.11176	.01904	**.96168**	-.01748	Topog
D4T	.27132	.02072	**.92289**	-.00808	"
A1T	.02577	.34727	-.01073	**.85955**	Size
CC1TR	-.31884	.30253	-.03375	**.73326**	"

Final Factor Analysis Statistics for Cable Harvest System.

Cable Clearcut (C-CC):

Variable	Communality	*	Factor	Eigenvalue	Pct of Var	Cum Pct
CC1CBL	.84861	*	1	2.91943	41.7	41.7
CC4CBL	.84689	*	2	1.86076	26.6	68.3
CC6CBL	.87905	*	3	.93800	13.4	81.7
CC7CBL	.84678	*	4	.44160	6.3	88.0
CC8CBL	.89970	*				
CC13CBL	.97297	*				
CC10CBL	.86579	*				

Rotated Factor Matrix:

	Factor 1	Factor 2	Factor 3	Factor 4	
CC6CBL	**.88616**	.13230	.27493	.02606	M.Yrd.Dist.
CC4CBL	**.87212**	.14009	.01775	.25759	Topog
CC10CBL	-.00534	**.92352**	-.11343	-.00252	Dnhill Yard.
CC7CBL	.28904	**.86575**	.11360	-.02835	Lg Yrd Dist.
CC8CBL	.04036	.14067	**.91102**	.21984	TPA
CC1CBL	.38143	-.28562	**.74945**	.24470	Size
CC13CBL	.23981	-.03553	.41581	**.86099**	Skill

Cable Aggregated (C-AGGR):

Variable	Communality	*	Factor	Eigenvalue	Pct of Var	Cum Pct
A1C	.90383	*	1	2.66055	44.3	44.3
A7C	.90105	*	2	1.81950	30.3	74.7
A8C	.90618	*	3	.62077	10.3	85.0
A9C	.97833	*	4	.41074	6.8	91.9
A10C	.86955	*				
A13C	.95263	*				

Rotated Factor Matrix:

	Factor 1	Factor 2	Factor 3	Factor 4	
A7C	**.94312**	.07683	.07517	-.00509	Lg Yard Dist.
A10C	**.92447**	.04548	-.07595	.08409	Dnhill Yard.
A8C	.30106	**.81333**	.03692	.39074	TPA
A1C	-.16455	**.73435**	.56742	.12455	Size
A13C	.04102	.14435	**.93185**	.24852	Skill
A9C	.04236	.32961	.32077	**.87464**	Uphill Yard.

Cable Dispersed (C-DISP):

Variable	Communality	*	Factor	Eigenvalue	Pct of Var	Cum Pct
D1C	.99753	*	1	2.97379	49.6	49.6
D6C	.96752	*	2	1.59343	26.6	76.1
D7C	.88686	*	3	.48907	8.2	84.3
D10C	.91911	*	4	.45219	7.5	91.8
D8C	.86950	*				
D9C	.86797	*				

Rotated Factor Matrix:

	Factor 1	Factor 2	Factor 3	Factor 4	
D10C	**.95067**	.08160	.09220	.01343	Dnhill Yard.
D7C	**.80882**	.11608	.46455	-.05827	Lg Yrd Dist.
D9C	-.05226	**.86075**	.25795	.24044	Uphill Yard.
D8C	.28792	**.84838**	.09805	.23925	TPA
D6C	.32069	.27387	**.87578**	.15057	Md Yrd Dist.
D1C	-.03155	.36031	.11537	**.92379**	Size

Final Factor Analysis Statistics for Ground-Based Harvest Systems

Ground-based Clearcut (T-CC):

Variable	Communality	*	Factor	Eigenvalue	Pct of Var	Cum Pct
CC4TR	.91335	*	1	2.66194	38.0	38.0
CC6TR	.83701	*	2	2.02636	28.9	67.0
CC7TR	.82046	*	3	.85238	12.2	79.2
CC8TR	.90091	*	4	.48124	6.9	86.0
CC9TR	.87006	*				
CC13TR	.90689	*				
CC1TR	.77324	*				

Rotated Factor Matrix

	Factor 1	Factor 2	Factor 3	Factor 4	
CC9TR	**.90588**	.10788	.03350	-.19151	Uphill Yard.
CC7TR	**.84423**	.13924	-.24269	.17160	Lg.Yrd Dist.
CC4TR	.04489	**.94663**	.11332	-.04875	Topog.
CC6TR	.26636	**.78131**	.20925	.33441	Md.Yrd.Dist.
CC8TR	-.01314	.16795	**.91240**	.20017	TPA
CC1TR	-.31591	.17425	**.69299**	.40353	Size
CC13TR	-.01717	.10729	.38993	**.86200**	Skill

Ground-based Aggregated (T-AGGR):

Variable	Communality	*	Factor	Eigenvalue	Pct of Var	Cum Pct
A13T	.79441	*	1	2.37353	39.6	39.6
A6T	.91067	*	2	1.56184	26.0	65.6
A7T	.99650	*	3	.76896	12.8	78.4
A4T	.85741	*	4	.57973	9.7	88.1
A1T	.83412	*				

Rotated Factor Matrix:

	Factor 1	Factor 2	Factor 3	Factor 4	
A1T	**.90667**	.07155	.03414	-.07600	Size
A13T	**.77246**	.07238	.43823	-.02048	Skill
A6T	.26418	**.89059**	.02345	.21718	Md Yrd Dist.
A4T	-.21092	**.70612**	.55182	.09912	Topog
A11T	.32715	.12923	**.87514**	.03679	Equipment
A7T	-.07906	.20226	.04333	**.97338**	Lg Yrd.Dist.

Ground-based Dispersed (T-DISP)

Variable	Communality	*	Factor	Eigenvalue	Pct of Var	Cum Pct
D4T	.87561	*	1	3.04949	50.8	50.8
D6T	.88280	*	2	1.36672	22.8	73.6
D7T	.90453	*	3	.70199	11.7	85.3
D8T	.94607	*	4	.38834	6.5	91.8
D9T	.91533	*				
D10T	.98221					

Rotated Factor Matrix:

	Factor 1	Factor 2	Factor 3	Factor 4	
D9T	**.93121**	.19659	-.05649	.07954	Uphill Yard.
D7T	**.90643**	.23168	.06828	.15680	Lg.Yrd Dist.
D6T	.35202	**.85053**	.18793	-.01242	Md Yrd.Dist.
D4T	.14321	**.83024**	.07082	.40098	Topog
D10T	-.01984	.15674	**.93834**	.27708	Downhill Yard.
D8T	.19187	.21504	.36593	**.85388**	TPA