A COMPUTER SIMULATION MODEL FOR ASSESSING WOOD PROCUREMENT

PRACTICES IN THE SOUTHEASTERN UNITED STATES

by

WILLIAM HARRISON HOWELL

(Under the Direction of Michael L. Clutter)

ABSTRACT

A mill specific decision-making tool that assesses wood procurement practices in the southeastern United States was developed. This spreadsheet based Monte Carlo simulation model captured the dynamic nature of the wood procurement system as well as provided realistic results for four different procurement strategies. Managers can use this user-friendly model to address issues that affect the efficiency of an individual mill's procurement effort, such as during periods of reduced capacity.

INDEX WORDS: Wood Procurement, Risk, Monte Carlo Simulation, Models.

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DEDICATION

This thesis is dedicated to my loving wife for her support and inspiration through all of the rough times; to my parents for their encouragement; to my family for their support.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. INTRODUCTION

Throughout the southeastern United States there exist a wide variety of wood-based industries, each with their own strategy on how to best manage their raw materials needs. Regardless of the strategy used, "the primary role of the system is to provide the firm's various wood-using facilities with the raw materials they need at the lowest possible cost, given a certain level of risk" (Harris 1987).

Raw materials costs represent forty to sixty percent of the variable costs for most finished wood products (Harris 1987). Wood procurement managers are faced daily with decisions that impact both the cost and certainty of the raw materials supply at their facilities. These managers "weigh" these cost and risk issues when formulating such raw materials sourcing strategies. However, in many cases there does not exist tools to help quantify the impact of such choices on cost and risk.

Risk in a raw materials procurement context is the uncertainty associated with future raw materials deliveries and costs. There exists, in general, a high degree of positive correlation between the certainty of raw materials deliveries and their associated costs over the long run. Procurement managers attempt to choose a set of raw materials sourcing strategies that most closely fit the cost and risk objectives at the manufacturing facility.

In general, procurement organizations attempt to formulate strategies that maintain some reasonably steady state inventory level based upon time of the year, projected mill usage, etc. In many cases, significant additional costs are added when these inventory levels are either significantly above or below these target inventory levels. For instance, when a given manufacturing facility is close to running out of raw materials the procurement organization is usually offering substantial incentives to those supplying raw materials. Similarly, if the mill inventory is at physical capacity then the procurement organization has to discontinue deliveries no matter what the cost may be for those raw materials.

Procurement organizations use some form of quantitative measure to determine the risk associated with their facility's procurement strategy. Within a given procurement system the measure of risk may vary, based on the procurement manager, mill type and location, time of year, etc. Therefore, an infinite number of quantitative measures of risk exist.

One commonly used quantitative measure of risk associated with manufacturing facilities is the probability of reducing mill inventories to zero – running the mill out of raw material. Traditionally this phenomenon has been viewed as a significant negative occurrence. More recently, due to high costs and low profitability many procurement organizations have identified this as a valid strategy in order to maintain raw materials costs at a level that insures profitability. Obviously, tradeoffs exist between mill downtime, shutdown costs, and procuring expensive raw materials in times of severe raw materials inventory shortages. Hence, the quantification of raw materials inventory levels and costs within an analysis tool for procurement planning may be useful to aid in assessing risk as well as cost.

PROBLEM & JUSTIFICATION

Shapiro (2001) points out that models for optimizing inventory management decisions have been applied for over 60 years in other industries, such as photography (Kodak) and electronics (Hewlett Packard). By using inventory management models, these companies have been better able to keep items stocked, decrease delivery time, and reduce the cost of goods to both the company and consumers. According to LeBel and Carruth (1997), "Spreadsheet-based stochastic models are useful in assisting procurement organizations to develop the proper balance between logging capacity and inventory levels." However, few models are able to determine the following:

1) The best strategy to manage the logging production capacity and raw material inventories at the mill;
2) The amount of logging production capacity needed to minimize the cost to a given mill, at a given level of risk; and
3) The size of raw material inventory to minimize cost for a given level of risk.

CRITERIA

Several criteria were used for assessing the simulation model, including:

1) Does the model represent the dynamic nature of a wood procurement system?
2) Does it produce realistic results?
3) Does it provide a useful decision making tool?

These questions and others will be discussed later in the thesis.

CHAPTER 2. LITERATURE REVIEW

RAW MATERIAL SUPPLIERS

The costs and risks associated within a given wood procurement system depend on the types of suppliers used. Within the southeastern United States mills receive raw material from four broad types of raw materials suppliers: logging contractors, wood dealers, other facilities, and gatewood.

Logging Contractors

A logging contractor can be defined as an entity that operates equipment to harvest and deliver wood to another entity (mills, wood dealers). Logging contractors can have delivery contracts with mills and wood dealers. Most logging contractors deliver to more than one mill and harvest more than one product. Some logging contractors purchase their own raw material, while others harvest raw material purchased or owned by mills.

A preferred supplier is a logging contractor that has a contract with the mill and a long-term relationship. Normally, preferred suppliers are guaranteed a certain amount of production and are the last to have their production lowered by the procurement organization in times of reduced production. Non-preferred suppliers are logging contractors that have no long-term contract with a mill. Non-preferred suppliers are the first to have production lowered by the procurement organization in times of reduced production. Preferred suppliers are normally logging contractors that consistently have high production rates, where non-preferred suppliers normally have lower production rates. Greene and others (2002) found that over 50% of the logging contractors in the South were preferred suppliers to at least one mill.

Logging contractors in the southeastern United States use many different logging systems, including in-woods chipping, tree-length, and cut-to-length. The costs and production rates associated with each system depends on many factors, including the type of equipment used, labor availability, and availability and utilization of equipment.

Wood Dealers

In the early and mid-1900's the forest products industry was expanding, and from this expansion the wood dealer system was born. Flick (1985) defined a wood dealer as, "an independent businessman who contracts to deliver a specified amount of raw material to a mill." Wood dealers can be thought of as middlemen. They contract with the mill and in turn contract with logging contractors to harvest and deliver wood to the mill. This system allows for mills to contract with only one person and be able to obtain raw material from many small private landowners. Wood dealers purchase tracts of timber themselves and then hire logging contractors to harvest the purchased wood, along with hiring logging contractors to harvest timber purchased or owned by the mill.

Wood dealers allow for companies to have a dependable wood supply, while at the same time consolidating the many small fragmented markets. This system allows for flexibility in a company's wood procurement system, by allowing the dealer to decide which logging contractors to use, and having the wood dealer oversee the logging contractors. Wood dealers may manage the stumpage inventory rather than mills.

These systems also have some disadvantages. By using wood dealers mills lose the direct control over logging contractors (contractor issue). Most of the agreements with wood dealers are short-term, thus not guaranteeing a long-term fiber supply.

Other Facilities

Other facilities supply large quantities of raw material to mills. In the United States, this is most commonly seen in paper mills (Johnson and Steppleton 2002). The common facilities that supply paper mills with chips are chip mills, plywood mills, lumber mills, and other solid wood product facilities. Chip mills produce chips as their primary product, whereas other mills produce chips as residues during operations. Chips can be purchased from any of these mills, with chips purchased from another mill within the same company being called "captive" (Shaw 1991).

Receiving raw materials from other facilities has advantages. First, other facilities operate on a consistent basis, and for this reason can supply a mill with raw material in adverse weather conditions. Second, raw material received, in most cases, is already processed. When chipping machines breakdown at the paper mills, this supply of raw material is invaluable. Third, other facilities typically supply a higher quality product due to quality control measures. Finally, this form of raw material allows for easy transportation by rail. Many of the facilities supplying chips are located near railways. The disadvantages are that this form of raw material may only be available in areas where other facilities are located, and a more expensive form of fiber.

Gatewood

Gatewood is any raw material delivered to the mill that is not under a pre-negotiated contract. The gatewood market is a "spot market." Gatewood can be thought of as the mill advertising a certain price per ton, and if raw material is brought to the mill, then it will be bought at the advertised price. Gatewood is typically only supplied by logging contractors and wood dealers.

Gatewood can be a large proportion of the raw material received at any given mill. However, gatewood is the most variable source of raw material to the mill from a supply perspective. When weather conditions worsen, gatewood supply lessens drastically. This form of raw material supply is normally the least expensive in typical market conditions.

INTEGRATION

While these distinct categories of suppliers and sources of raw material are convenient for illustration, more often than not, these distinctions are blurred in reality. For example, a wood dealer may also be a logging contractor who supplies gatewood to a mill. There is no strict classification, because they continually change, and any strict adherence to these classifications may result in unnecessary confusion. These classifications have been made to establish guidelines for the structure of the generalized wood procurement model. Every procurement system is different, and will have different definitions for their suppliers.

MILL INVENTORY

Mill inventory is the amount of raw material that is maintained by the mill on the mill site. The amount of mill inventory is typically a joint decision between procurement and mill managers. Managing mill inventory is important to avoid mill closures, because the costs of shutting down a pulp and paper mill are substantial. In addition, mills take several hours or days to shutdown and restart, costing millions of dollars. However, the procurement manager must strike a balance between minimizing inventory costs while maintaining enough raw material to keep the mill running.

STAGES FOR DEVELOPING SIMULATION MODELS

Simulation models need to be developed correctly. Most simulation models follow a common format involving three phases: 1) initialization, 2) modeling, and 3) implementation (Webster 1982, Shannon 1975).

Initialization Phase

The initialization phase; in many cases, is the first step in starting any simulation project. This phase includes problem definition, definition of objectives and criteria, and system definition. First, the designer should identify the problem that the model addresses. In itself, problem definition can be the largest obstacle in designing a simulation model. In many cases, the focus of the problem often grows in size and evolves away from the initially defined problem as time progresses (Webster 1984). The designer should maintain a tight focus on the problem being addressed by the simulation model.

Second, the designer should formulate a series of objectives for the simulation model to meet, along with the criteria for meeting those objectives. The final step in the initialization phase is system definition. System definition according to Shannon (1975) is "determining the boundaries, restrictions, and measure of effectiveness to be used in defining the system to be studied."

Modeling Phase

The modeling phase includes model formulation, data preparation, selection of a programming language, coding of the model, and model validation. First, the real system being modeled should be described in a flow chart (format the model). From this diagram, the programming language and data needed for the model can be identified and prepared for use within the model. It is essential with the design of any simulation model that the designer think ahead about what data are going to be required for the model, making sure that the data are not too expensive to collect or unavailable to end users. The designer should also decide what computer program(s) are going to be used to develop the simulation model, for the data may impact what computer program(s) can be used. Additionally, the model should be programmed using the selected computer programming language. Finally, the model should be validated to ensure accurate and attainable results.

Implementation Phase

The final stage is the implementation phase, which includes strategic planning, tactical planning, experimentation, analysis of results, decisions obtained from the model, and follow up studies. According to Webster (1984), "no simulation project should be started unless this phase is built into the time frame of the simulation development." The first stage is deciding on the experiment that will yield the desired information from the model. The following step is deciding on how each simulation should be conducted to meet the experiment designed previously. Following the experimental design, the simulation model should be used for experimentation, with the results analyzed and findings reported. Finally, the user should allow for follow up studies. Make sure that the model can be updated for further use, and decide on what other studies can be conducted.

SIMULATION

Simulation is the process of designing a model that reproduces real systems for the purpose of conducting experiments, understanding functionality of systems, and evaluating different management strategies (Shapiro 2001, Shannon 1975, Krajewski 1990). Thus, simulation includes the construction of the model, along with analytical use of the model. Shannon (1975) stated that simulation is "a methodology of problem solving." Since, the rapid growth of personal computers simulation models are more commonly used by managers faced with operational decisions.

There are two broad categories of simulation models – deterministic and stochastic (Shapiro 2001). Both categories of models are commonly used by businesses today. However, these two categories of models differ with respect to the action of the inputs of the model.

Shapiro (2001) best described deterministic simulation models as “models that describe a system's dynamic behavior assuming no random effects.” Deterministic simulation models do not allow for the incorporation of uncertainty. Stochastic simulation models are often times referred to as Monte Carlo simulation models. These models differ from deterministic models in that they allow for uncertainty to be incorporated into the model through the introduction of random variables. Stochastic models are used to replicate business systems in response to random variations within key parameters affecting them (Shapiro 2001). These types of simulation models are most commonly used for training personnel, predicting outcomes, and making decisions.

Simulation differs from optimization. Krajewski (1990) defined optimization as "the procedures to determine the best results." Therefore, simulation differs from optimization in that unless the best sets of inputs are used, a sub-optimal result will be defined by simulation.

PRIOR MODELS & STUDIES

Most wood procurement systems try to secure the desired amount of raw material at the lowest cost given a certain level of risk. This is accomplished by carrying the smallest possible inventory without running out of wood while reducing the amount of time logging contractors are working at reduced capacity (LeBel and Carruth 1997). Although there are many variations of wood procurement systems, few attempts have been made to simulate the dynamic nature of wood procurement systems. Brinker and Jackson (1987) best stated the reason for this lack of research,

> "Although wood procurement encompasses a large proportion of industrial forestry activity, very little research has been done in this area. It is an area where confidentiality is widely practiced, thus making research data difficult to obtain"

For this reason, much of the research has been in the form of surveys. Most surveys have attempted to identify procurement activities taking place, regional differences, or suggestions as to how wood procurement systems can be improved. Baumgartner (1976) pointed out problems in the procurement systems of Illinois pulp and paper mills and suggested that the current system could be improved. The article stated, "With increasing timber demand and prices, wood procurement systems must be reevaluated." Killian (1983) in describing the wood procurement system for the southern United States paper industry stated that, "An efficient, cost effective wood procurement system is a must for any forest products company." He also pointed out problems within wood procurement systems in the southern United States, and made suggestions on how those problems could be resolved. Maass (1991) discussed changes within the system that should be taken into consideration, such as increasing transportation costs, logging contractor availability, reduction in timber availability within the public sector, regulation, and increased competition. Gellerstedt and Dahlin (1999) discussed the current logging systems in Sweden and how they related to the rest of the world. In this article they concluded that logging systems have moved towards “hotter” systems that maintain buffers in logging capacity rather than woodyard inventory. Cox (2001) discussed inventory in a just in time system and how inventory levels and supplier sizes could be reduced significantly, assuming, long term agreements are maintained with suppliers.

Based on these and earlier articles, some attempts have been made to simulate wood procurement systems. The earliest studies looked at procurement systems as a transportation problem. The first two attempts to design computer simulation models of wood procurement systems were Hewson (1960) and Hamilton (1964). Both of these models dealt exclusively with pulp and paper mills and were based on the assumption that the demand for pulpwood was based on the production of the paper machines.

Hewson’s model looked at events affecting the pulpwood inventory at the mill, wood usage by the mill, wood orders, and wood receipts. The model was used to evaluate different procurement procedures, inventory policies, and mill production levels relative to the risk of running out of wood. Hewson concluded, "Simulation models are powerful tools that can be used to analyze the dynamic nature of a pulpwood procurement systems, only if proper care is used in developing the model to ensure that the model accurately reflects the actual conditions encountered."

Hamilton's model used sectors that were divided as follows: mill, dealer, and producer. Hamilton found that irregular changes in paper production by the mill and seasonal fluctuations in inventory levels were the cause for erratic wood flows. Hamilton also concluded that the real benefit of simulation models was to vary only a few factors at a time while leaving all of the others fixed.

Following Hewson's and Hamilton's models, Galbraith and Meng (1981) analyzed and reported on a stochastic computer simulation model developed for a New Brunswick, Canada pulp mill. The model incorporated such data as interest rate on inventory investments, unit cost of running out of inventory, unit variable costs of handling inventory, cost of over inventory, and the probability distributions of roundwood demand and deliveries. The model was used to predict optimum wood inventory levels for New Brunswick pulp mills. Winer (1982) later noted the following about the model designed by Galbraith and Meng (1981), "The practical value of this simulation approach has already been demonstrated at the Mead mill at Kingsport, TN, where the model has proved effective in helping to keep inventories within an optimum range."

Following these two articles, attempts were made to model wood procurement systems using different techniques. Mercado and others (1990) used linear programming to optimize log procurement in southern pine dimension lumber manufacturing. This model was useful, but only considered the optimization of the wood procurement system for dimension lumber mills, rather than the system as a whole. Shaw (1991) developed a computer simulation model of the wood procurement system of a single paper mill for both industrial and educational purposes. However, it was only used for educational purposes, due to the program not being "user friendly." Brinker and Jackson (1991) reported on the use of a geographic information system (GIS) to assist in simulating and predicting regional procurement practices. Their model was effective for small areas where detailed information could be gathered on standing wood inventory levels, number and types of mills, and the infrastructure of the area.

LeBel and Carruth (1997) discussed current concerns in wood procurement, and presented a "probabilistic spreadsheet model to simulate the variability present in procuring wood fiber for a paper mill." This particular model used mill parameters, logging contractor data, weather downtimes, and system efficiency information as its inputs. They concluded, "Spreadsheet-based stochastic models are useful in assisting procurement organizations to develop proper balance between logging capacity and inventory levels." Their model was useful for assessing procurement systems at paper mills. Barret and others (2001) designed the Log Truck System Simulation (LTSS), which is a computer model for predicting the turn-around time for log trucks at the mill and the effects that turn-around time has on harvesting. Their model was useful in accessing the cost of wood deliveries when logging contractors were working under- and over-capacity.

Greene and others (2002) reported the causes of unused logging contractor production capacity, along with mill inventory, purchases, and usage trends. The project was the largest and only of its kind, consisting of 83 participating logging contractors and 152 participating mills, located from eastern Texas to Maine. Data for the project were collected over a two-year period. Participating logging contractors and mills submitted weekly reports enumerating such data as number of loads harvested per day, amount of wood used per day, and reasons for less usage or harvest. From these weekly responses and a follow-up survey, they found that only 65% of the logging force capacity was utilized, increasing costs by an average $1.66 per ton or $430 million dollars annually. The most common reason for the lost production were "market factors." They concluded that "mill wood usage and purchase patterns impact logging contractor production levels and per ton costs."

Even with all of these models, surveys, and research, there has been no computer simulation models developed from the entire systems' standpoint (both contract suppliers and the mill), or for an entire region in the United States. There are few models with which an individual mill, whether it is a paper mill, lumber mill, or plywood mill, can enter data and simulate their specific wood procurement system.

CHAPTER 3. METHODS

The objective was to develop a computer-based spreadsheet simulation model to assess wood procurement systems in the southeastern United States (Virginia to eastern Texas). Through use of Monte Carlo simulation techniques, the model provided mill specific results to identify optimal levels of logging production capacity, mill inventory, and procurement strategy. The model focused on the risk-reward tradeoffs regarding inventory levels, procurement strategies, and number and type of suppliers. Identified by the model were possible changes that reduced cut and haul cost for a given level of risk associated with the wood procurement systems.

MODEL INITILIZATION

Decisions

To investigate the effects of wood procurement decisions, the model had to accurately reflect the decisions procurement managers routinely face. These decisions could be broken into many different time frames – hourly, daily, weekly, monthly, quarterly, and yearly. However, for this model decisions were based on two broad time categories – weekly and the length of the simulation.

Weekly Decisions

For this model, weekly decisions were inputs that a procurement manager would know or accurately estimate during the course of a given week. These inputs included:

1) Mill usage, and
2) Desired inventory level.

Simulation Decisions

For the model, some inputs were fixed for the simulation. These included:

1) Location of the mill
2) Raw material product
3) Type of mill
4) Number of weeks to simulate
5) Supply force (size and types of suppliers)
6) Beginning inventory
7) Pricing for wood dealers, other facilities and gatewood

In reality many of these decisions had already been made, such as the location of the mill, the type of mill, and the wood product used by the mill. However, for this model all of these decisions were important to the simulation process.

Tools

The first step was deciding on the appropriate modeling technique. Monte Carlo simulation techniques were chosen because procurement systems contain many stochastic variables. This simulation technique provided for the flexibility needed within the model while quantifying the interactions among the variables.

Identifying the appropriate computer software and programming languages were the next sep in translating these ideas into an operable computer simulation model. After reviewing several software packages and programming languages, Microsoft Excel®, BestFit®, and @RISK® were chosen as the software packages and Visual Basic for Applications (VBA) as the programming language. These programs are by far the most common technical architecture used for Monte Carlo simulation today, thus many users are familiar with the tools developed.

PROCUREMENT STRATEGIES

There exist an infinite number of procurement strategies for mills in the southeastern United States. However, for the simulation model the number of procurement strategies had to be limited. The following four procurement strategies were used:

1) Fixed Cost Strategy. Production is based on supplier fixed costs and mill usage.
2) Split Evenly Strategy. Production is based on mill usage and split evenly between suppliers.
3) Average Weekly Production Strategy. Production is based on suppliers average weekly production and mill usage.
4) Full Capacity Strategy. Suppliers work at their full production without regard for mill usage.

Fixed Cost Strategy

The fixed cost strategy was assumed to generate the lowest cost per ton for strategies that allocate production based on mill usage. It was hypothesized that if contract suppliers with the highest fixed cost were allocated the most production, then their fixed cost would be distributed over more tons and cut and haul costs reduced. For example, if the total fixed cost of the system were $10,000 and one supplier had fixed cost of $1,000, then that supplier would receive one tenth of the total production for that week. However, this strategy assumed that those suppliers with high fixed costs also had high production rates. The fixed cost strategy is not a commonly practiced procurement strategy, but was chosen for the model as a hypothetical strategy.

Split Evenly Strategy

The split evenly strategy was hypothesized to generate the highest cost per ton. Allocating production based on this strategy ignores costs and production rates. For example, if the system consisted of ten suppliers then every supplier would receive one tenth of the total production for the week. This strategy is practiced by some mills, and for that reason, was included in the model.

Average Weekly Production Strategy

The average weekly production strategy was hypothesized to generate average cost per ton values equivalent to the fixed costs strategy. It was hypothesized that fixed costs were proportional to production. Using this strategy, suppliers with the highest production rates in a given week were allocated the most production. For example, if the total production of the system was 10,000 tons and one supplier had an average production rate of 1,000 tons, then that supplier would receive one tenth of the total production for that week. This strategy allows fixed costs to be distributed over many tons. However, this strategy assumed that those suppliers with high production rates also had low variable costs. This is the most commonly practiced procurement strategy by mills in the southeastern United States, and therefore, was included in the model.

Full Capacity Strategy

The full capacity strategy does not allocate production based on mill usage, and was hypothesized to generate the lowest cost per ton. This strategy does not allow contract suppliers to work at reduced or over capacity levels caused by fluctuations in mill usage. Therefore, fixed costs for suppliers were distributed over the greatest possible tons without suppliers occurring additional expenses. However, this strategy assumed that mills accepted everything that contract suppliers produced within a week regardless of mill usage. This procurement strategy is not commonly practiced in the southeastern United States.

ASSUMPTIONS

All models are abstract representations of real world systems requiring some form of simplifying assumptions. The assumptions for this model are outlined below.

Time Horizon

1) The model assumes a weekly time step.
2) The model assumes 52 weeks in the year, and every 13 weeks constitutes a quarter.
3) The simulation length cannot be longer than 26 weeks.

Location

1) Mills are located in Arkansas, Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Texas or Virginia.
2) Every state is split into two regions, based on the Timber Mart-South Regions (Figure 1).

Mill

1) Up to 90 percent of weekly mill usage can be derived from gatewood.
2) The procurement system being modeled serves a single mill.
3) Mill usage is stochastic.

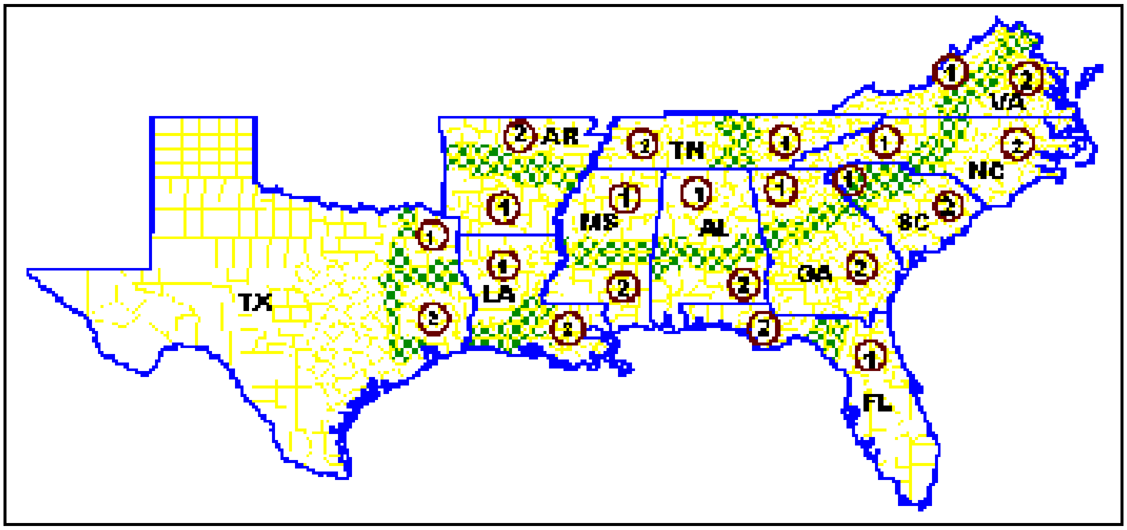

Figure 1. Map of Timber Mart-South Regions.

4) The word “inventory” represents all of the specified type of raw material available for use at the mill.

5) Ending inventory for the previous week is the beginning inventory for the following week.

6) The mill is a pulp and paper mill, lumber mill, or plywood mill that utilizes only one product (Table 1).

7) Mills that reported in the Greene and others (2002) study are representative of all mills in the southeastern United States. Therefore, weekly raw material usage distributions derived from these data are representative of mills in the southeastern United States (Appendix A).

8) Mills accept the amount of raw material that maintains inventory levels within the acceptable range.

Table 1. List of products allowed in each state.

State	Pine Roundwood	Hardwood Roundwood	Pine Chips	Hardwood Chips	Pine Sawtimber	Pine Chip'n'Saw	Pine Plylogs	Hardwood Plylogs
AL	X	X			X	X	X	X
AR	X	X	X	X	X	X	X	X
FL	X	X				X	X	
GA	X	X	X	X	X	X	X	X
LA	X	X	X	X	X			
MS	X	X	X		X	X	X	X
NC	X	X	X	X	X	X	X	X
SC	X	X	X	X	X	X	X	
TX	X	X	X	X	X		X	
VA	X	X	X	X	X		X	X

Note: An X signifies that the model allows for that product to be simulated for that state. Those products without an X for a particular state signify that the model does not allow the simulation of that particular product for that state. States with no X for a specific product does not mean that the product is not used by mills found within that state, only that we do not have data for that product in that state.

9) Mills attempt to operate 52 weeks per year. However, mills do close for planned and mandatory shutdowns, therefore, users can adjust mill usage for this purpose.

10) Mills accept the percentage of weekly usage comprised from gatewood every week, with the remaining production allocated to contract suppliers.

11) Pulp and paper mills have wood dealers, tree length logging crews, in-woods chipping crews, and other facilities.

12) Lumber and plywood mills have wood dealers and tree length logging crews.

13) Stumpage is secured and readily available for harvest.

<u>Supply Force</u>

1) Four procurement strategies are used: 1) fixed costs; 2) split evenly; 3) average weekly production; and 4) full capacity.

2) Contract suppliers are defined as wood dealers, other facilities, tree-length logging crews, or in-woods chipping crews.

3) A wood dealer is an individual that has a contract with the specific mill to deliver a specified amount of raw material within a given week.

4) Other facilities are other manufacturing facilities that provide raw material to the specified mill.

5) Tree-length logging crews are entities that harvest and deliver wood to the mill in tree-length form. These entities have direct contracts with the specified mill.

6) In-woods chipping crews are entities that harvest and deliver wood to the mill as chips. These entities have direct contracts with the specified mill.

7) For a given week, if a supplier cannot produce the amount allocated to them then the amount that they cannot produce is allocated to the remaining suppliers based on the procurement strategy used.

8) Wood dealers experience the same variability in production as tree-length logging crews.

9) Production by other facilities experience the same variability as pine sawtimber usage for a lumber mill.

10) Logging crews located in Alabama, Florida, Georgia, and South Carolina that reported in the Greene and others (2002) study are representative of all logging crews in the southeastern United States. Logging crews reporting in these four states were chosen as a representative subset because they supplied the vast majority of the weekly reports. Also, logging crews within other states had unusual production rates due to vandalism, long haul distances, and unusual harvesting methods. Therefore, distributions for weekly production derived from these data are representative of logging crews (Appendix B).

11) The model permits up to 9 wood dealers, 9 other facilities, 26 tree-length logging crews, and 26 in-woods chipping crews.

12) Contract suppliers have production rates greater than or equal to zero.

13) Gatewood deliveries experience the same variability in production as tree-length logging crews.

14) Within the fixed cost system, wood dealers and other facilities maintain full capacity production levels, with all remaining production being allocated among the logging crews within the system. This is because wood dealers and

other facilities are assumed to only have variable costs, and therefore, production cannot be allocated to these suppliers based on fixed costs.

15) The system cannot produce more than 150 percent of its average production.

16) Average weekly production assumes a 40-hour work week.

17) If the amount of production allocated to a logging crew exceeds 125 percent of their logging production capacity, then variable costs for all tons produced in excess of 125 percent will increase by 25 percent per incremental hour.

18) All logging crews only deliver to the specified mill.

19) All logging crews only harvest the specified product.

Costs

Raw material costs can be defined in a number of different ways such as costs per hour, cost per machine, and cost per crew. The method used for this model divided raw material costs into two components – stumpage and cut and haul costs. Stumpage costs are associated with controlling the raw material. Cut and haul costs are associated with harvesting and delivering the raw material to the mill. Regardless of the type of supplier used, stumpage costs are present. Therefore, stumpage costs are considered to be sunk costs and not included within the model. The following assumptions regarding costs were made:

1) All costs migrate to the mill.

2) Logging crews located in Alabama, Florida, Georgia, and South Carolina that reported in the Greene and others (2002) study are representative of all logging crews in the southeastern United States. Logging crews reporting in these four states were chosen as a representative subset because they supplied

the vast majority of the weekly reports. Also, logging crews within other states had unusually high costs due to vandalism, long haul distances, and unusual harvesting methods. Therefore, distributions of fixed costs per week and variable costs per ton derived from these data are representative of logging crews (Appendix C).

3) Gatewood, wood dealers, and other facilities report delivered cost and use tier pricing. Tier pricing consists of pricing based on the percentage of total logging production capacity utilized by the mill. Up to five tiers are allowed, with each tier being a different level of the logging production capacity being utilized. For example, a two tier pricing system maybe as follows. If the logging production capacity being utilized by the mill is between 0-100 percent then the delivered price per ton is $20, and if the logging production capacity being utilized by the mill is over 100 percent then the delivered price per ton is $25.

4) The delivered prices for wood dealers and other facilities remain constant throughout the simulation time period. Therefore, the tier pricing for wood dealers and other facilities cannot be changed from week to week.

5) The delivered prices for gatewood can be changed by quarter, but must remain constant within any given quarter.

6) For tier pricing, as the utilization of the logging production capacity increases so do delivered prices.

7) All costs reported in the simulation are cut and haul costs.

8) Delivered prices are greater than stumpage values for all contract suppliers.

9) Cut and haul costs for wood dealers, other facilities, and gatewood are delivered costs minus stumpage values.

10) Default stumpage values used by the model are based on 2002 Timber Mart-South Quarterly Reports (Appendix D).

11) Total cost to the mill is the sum of all the individual suppliers' costs plus the costs of gatewood deliveries.

Weather

1) Rainfall affects all deliveries. Probabilities of rainfall occurrence and distributions for the amount of rainfall per week were derived from National Climatic Data Center data for 1897-2000 (Appendix E).

2) Rainfall experienced in a given week only affects production for that week.

3) Rainfall during the winter season (weeks 1-13 and 47-52) has a different effect on production than rainfall during the rest of the year (weeks 14-46). The equation used to adjust production is as follows:

$$Y = 100e^{(-0.1603xz - 0.18755x)}$$

Where,

Y = percentage of average weekly production allowed after rainfall effects,

e = the base of the natural logarithm,

x = amount of rainfall (inches) within a given week, and

z = dummy variable (z = 1 if winter, z = 0 otherwise).

Simulation

1) The number of iterations per simulation must be between 1 and 10,000.

2) Unless specified, the simulation model generates a new random number seed for each simulation.

MODEL VARIABLES

Both the system and the variables of interest of the model were clearly identified prior to the development of the model. The two broadly defined types of variables were performance and internal variables. According to Shaw (1991), “ Performance variables are those that the user is directly interested in, whereas internal variables are those that impact the performance variables.”

Performance Variables

This model contained several variables of potential interest to procurement managers, including:

1) Inventory variables
   a. Beginning inventory
   b. Usage
   c. Total receipts
   d. Total costs
   e. Ending inventory
2) Rainfall
   a. Weekly amount
   b. Effect on production for each supplier

3) Suppliers

   a. Type of supplier

   b. Weekly production

   c. Estimated costs (fixed and variable)

   d. Cost per ton

   e. Percentage of capacity worked

4) Whole system

   a. Weeks when mill is running at a reduced capacity level

   b. Estimated costs per ton

   c. Average hours worked

   d. Capacity level of the system

Therefore, the values of these variables for each week were stored on separate worksheets, with each worksheet depicting a different procurement strategy.

Internal Variables

Internal variables determine the value of each performance variable. Internal variables can describe probability distributions, represent decisions being made, and characterize additional features about the system.

Probability Distributions

The goal of this model was to incorporate the inherent risk and uncertainty within a wood procurement system. Many of the performance variables were determined by probability distributions. Most of the internal variables were parameters that defined the scope of each distribution. These distributions were determined through the use of computer software (BESTFIT®) using prior research data, and included:

1) Probability of rainfall,

2) Probability distributions for the amount of rainfall,

3) Probability distributions for suppliers' variable cost per ton,

4) Probability distributions for suppliers' fixed cost per week,

5) Probability distributions for suppliers' production, and

6) Probability distributions for raw material usage by mills.

Decision Variables

This model used other internal variables that are often referred to as "decision variables." These included:

1) Target inventory for a given week, and

2) Total tons allowed for delivery by the mill.

Other Internal Variables

Other internal variables also played a part in this model. These were deterministic, or fixed in value, and included:

1) Percentage of weekly usage derived from gatewood, and

2) The beginning inventory level for the simulation.

MODEL DEVELOPMENT

First, the problem was broken into small subparts, and a simple model was constructed from the subparts. The model consisted of several suppliers delivering wood to a mill. The simple model contained three sections, 1) Mill, 2) Production force, and 3) Summary. Each individual section was then programmed and linked together to form the model. Additional constraints and variables were programmed into the simple model using a series of logic statements.

VBA allowed for the programming of individual tasks into subprocedures. These subprocedures could then be linked together to form the model. Over 200 subprocedures were developed for tasks such as the allocation of production, determination of mill receipts, effects rainfall had on production, logging production capacity utilized, and many other functions within the model. The entire computer program can be seen in the attached compact disk (CD) located in the back of the thesis.

MODEL EXECUTION

Overview

The simulation model consists of the "PROCUREMENTMODEL" workbook that contains the "Start" worksheet (Figure 2). The "Start" worksheet contains the title and authorship information about the model, and a button entitled "Press Here to Start." The "Press Here to Start" button starts the simulation model. When the model is started, it presents the user with a series of input forms to fill out. Upon completion of all of the input forms, the user is then presented with a form entitled "Simulation." This form contains the “Run Simulation" button that is used to start the simulation process. When the simulation process is initiated, the simulation model creates four different procurement systems, runs the simulation, generates a "SummaryReport" worksheet, and then terminates by displaying to the user the results of the model.

Input Phase

Before the model can simulate the system, the user must first enter values for a series of parameters that describe the system under normal operating conditions. Through the use of programming constraints, the model prevents the system from beginning under operating conditions that are not normal.

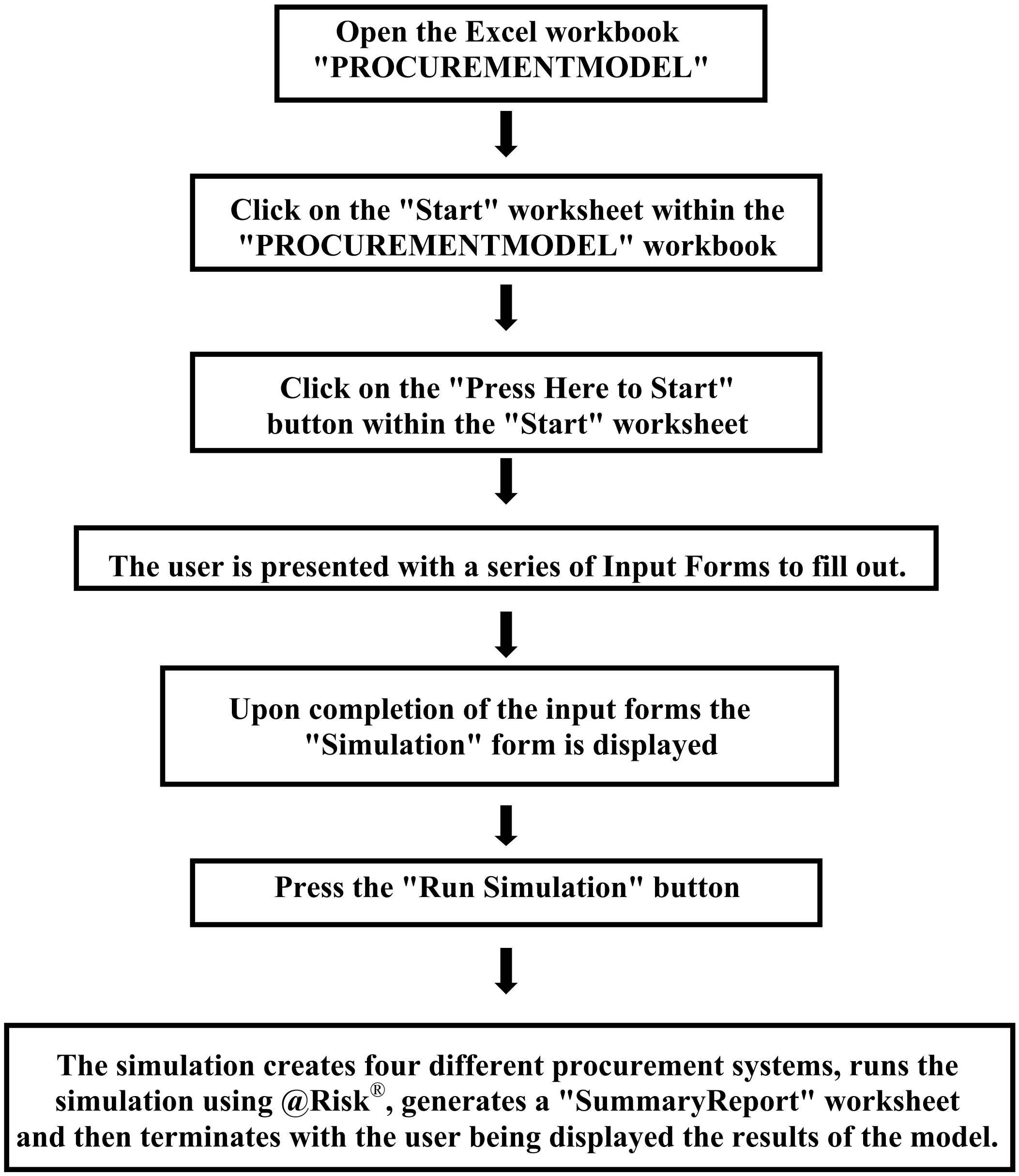

Figure 2. Structure of the generalized wood procurement model.

Users supply the inputs into the model by completing a series of forms that are displayed. The inputs required from the user include:

1) Location of the mill
    a. State
    b. Region
2) Type of mill
3) Type of raw material used by the mill
4) Beginning and ending week for the simulation
5) Number and types of different suppliers
6) Stumpage prices for each quarter
7) Fixed costs per week, variable costs per ton and average weekly production for tree-length and in-woods chipping crews.
8) Estimates for weekly deliveries from wood dealers and other facilities.
9) Tier pricing for wood dealers and other facilities, assuming prices entered are delivered costs (stumpage plus cut and haul costs).
10) Estimated percentage of weekly receipts derived from gatewood
11) Tier pricing for gatewood by quarter, assuming prices entered are delivered costs (stumpage plus cut and haul costs).
12) Estimated weekly mill usage and target inventory
13) Beginning inventory
14) Number of iterations for the simulation to run.
15) Option to enter a random number seed to duplicate previous simulations.

After completing each form, the inputs are recorded within the worksheets entitled "Input" and "Tables" (Appendix D).

Simulation Phase

Upon completion of the input forms, the simulation of the system takes place. The simulation model uses the inputs provided by the user to create four wood procurement systems. Within each procurement system, the model creates several logic statements.

One logic statement is used to determine the potential deliveries to the mill (Figure 3). Within this statement the mill uses the inputs for beginning inventory, anticipated mill usage, and target inventory level. From these inputs the model determines how much raw material is needed for each week. This is accomplished by subtracting the amount of raw material the mill already has from the amount of raw material needed for the week. Therefore, the equation adds mill usage and target inventory together (amount needed), and then subtracts beginning inventory (amount the mill has).

Another logic statement was used to allocate production to each supplier (Figure 4). This logic statement is the most complex within the model, and consists of several subprograms. First, production is allocated to each supplier based on the specified strategy. The allocated production is then transformed into a percentage of logging production capacity utilized for each supplier. This is accomplished by dividing the production allocated by the average weekly production for each supplier. From this stage five different possibilities arise.

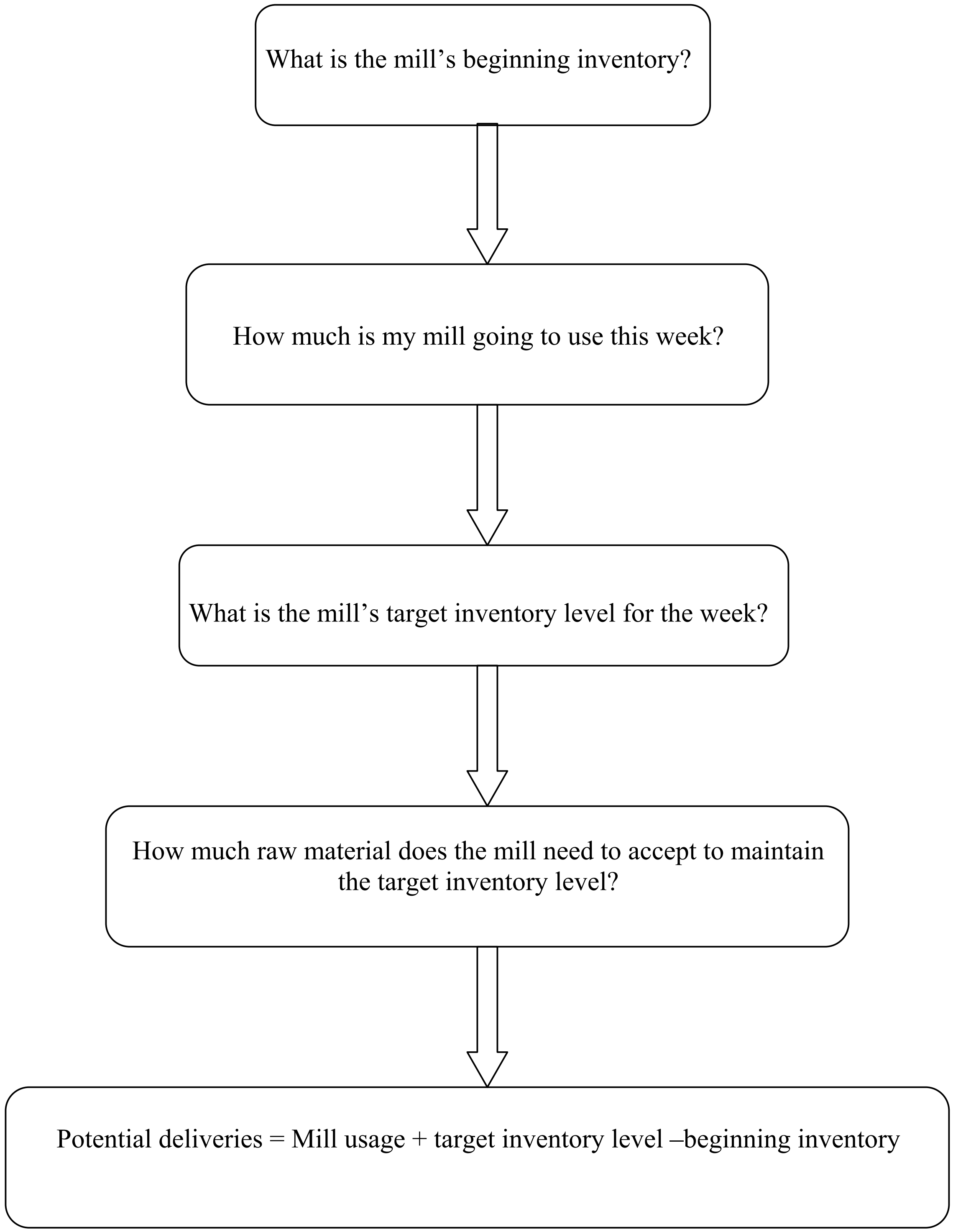

Figure 3. Flow chart for determining potential deliveries to the mill.

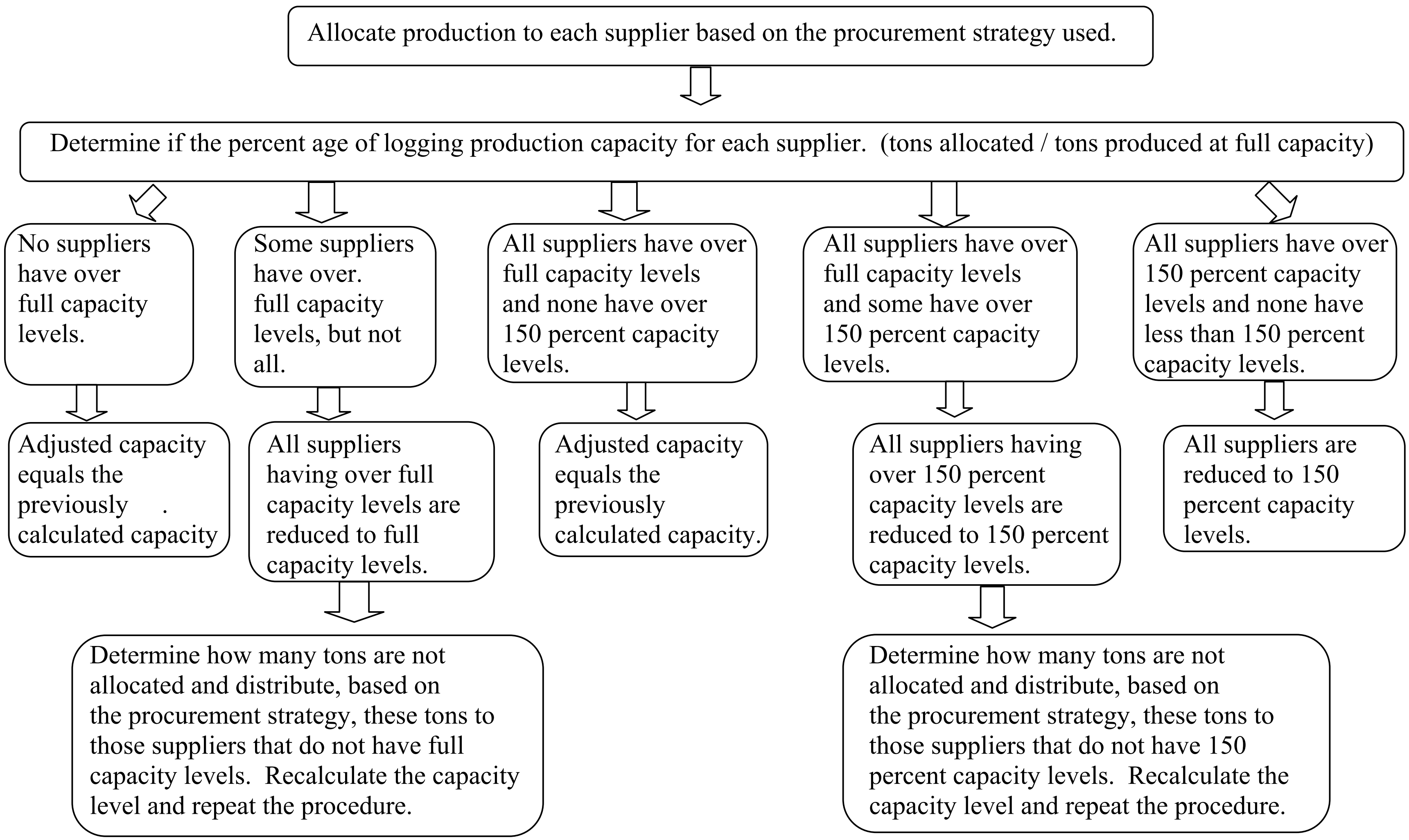

Figure 4. Flow chart for determining the allocation of production to each supplier.

The first possibility is all suppliers have less than full capacity levels. If this is the case then adjusted logging production capacity equals the previously calculated logging production capacity.

The second possibility is some suppliers are over full capacity levels and others are not. Logging production capacity has to be adjusted in order to meet the constraint that no one supplier can work over full capacity before all suppliers are working at full capacity levels. Therefore, those suppliers that have more production allocated to them then they can produce at full capacity levels are reduced to full capacity levels. The production subtracted from those suppliers that are now producing at full capacity levels is then divided, based on the procurement strategy used, among the remaining suppliers not working at full capacity levels. Upon completion, adjusted capacity levels are calculated by taking the newly allocated production and dividing by average weekly production at full capacity levels for each supplier.

The third possibility is all suppliers have logging production capacity levels over full capacity levels and no suppliers have more than 150 percent logging production capacity levels. If this is the case then the adjusted logging production capacity is equal to the previously calculated logging production capacity.

The fourth possibility is all suppliers have over full capacity levels of logging production capacity and some have over 150 percent logging production capacity levels. Logging production capacity has to be adjusted in order to meet the constraint that no one supplier can work over 150 percent logging production capacity. Therefore, those suppliers that have more production allocated to them then they can produce are reduced to 150 percent logging production capacity levels. The production subtracted from those suppliers that are now producing at 150 percent logging production capacity levels is then divided, based on the procurement strategy used, among those remaining suppliers not working at 150 percent logging production capacity levels. Upon completion, adjusted capacity levels are calculated by taking the newly allocated production and dividing by average weekly production at full capacity levels for each supplier. The final possibility is all suppliers have greater than 150 percent logging production capacity levels. In this situation production is limited so that all suppliers are only allocated production to where 150 percent logging production capacity levels are reached. For, suppliers cannot physically produce more than 150 percent of their logging production capacity within a given week. Once capacity is adjusted, the model repeats this procedure until all suppliers meet one of the criteria where the previously calculated logging production capacity equals the adjusted logging production capacity.

The simulation creates several more logic statements within each system. The model takes between five minutes and six hours, depending on the size of the supply force, the time period of the simulation, and the speed of the computer. Upon completion, the model terminates, and the model results are shown to the user.

Results

The results of the simulation are contained within the following worksheets:

1) Input – Contains the inputs of the model.

2) Tables – Contains some inputs into the model and the effects rainfall has on the amount of gatewood supplied.

3) Production_Force – Contains data about each supplier in the model for each week, assuming a 40-hour work week. The data contained in this

sheet are assumed to represent the suppliers working at full capacity. The sheet includes items such as supplier type, variable cost per ton, fixed costs per week, percentage of production missed due to rainfall, and tons produced per week after weather affects.

4) Split_Evenly – Contains a wood procurement system using the split evenly strategy. The worksheet is broken into three sections, 1) mill, 2) production force, and 3) summary section.

   a. Mill. The mill section includes mill usage, total costs, total receipts, and whether or not the suppliers were working under full capacity.

   b. Production Force. The production force section includes the amount of production (tons) allocated to each supplier, fixed costs per week, variable costs per ton, and total costs.

   c. Summary. The summary section contains a brief summary of the system and includes: the logging production capacity utilized by the system, average number of hours worked, average cost per ton, and whether or not the suppliers were working under full capacity.

5) Split_Fixed_Costs – Contains a wood procurement system using the fixed cost strategy. This worksheet also contains the three sections that were mentioned in the "Split_Evenly" worksheet.

6) Split_Ave_Wk_Production – Contains a wood procurement system using the average weekly production strategy. This worksheet also contains the three sections that were mentioned in the "Split_Evenly" worksheet.

7) Full_Capacity – Contains a wood procurement system using the full capacity strategy. This worksheet also contains the three sections that were mentioned in the "Split_Evenly" worksheet.

8) Summary – Contains a summary of the four different procurement strategies. This worksheet contains: the average, standard deviation, 5 percent level, and 95 percent level for the ending inventory and total costs of each system, the average cost per ton, gatewood receipts, receipts from contract suppliers, logging production capacity utilized, along with the number of times each strategy ran out of raw material in a given week.

9) SummaryReport – Contains a summary of the output of the simulation. This is an @RISK® generated report that specifies such things as the type of sampling used, the random number seed, number of iterations, and statistics on all designated input and output cells.

MODEL VALIDATION

One thousand simulations were conducted to validate the model. Validating the model consisted of ensuring that the underlying assumptions and the model's results were consistent with the observed data. The model contained many probability distributions and underlying assumptions, most of which were based on empirical data. To validate the derived probability distributions, the data collected for these assumptions were analyzed and distributions were fit to the data (BestFit®). The distributions chosen were those that best reflected the empirical data. The other underlying assumptions were based on data or the opinions of experts in the area.

STATISTICAL TESTING

Upon completing the simulation model, 45 pre-determined systems were modeled and the results tested for statistical significance. A one-way analysis of variance (ANOVA) model was used. The results tested for statistical significance included:

1) Within a single simulation
    i. Average costs between systems.
    ii. Total costs between systems
    iii. Ending inventory between systems
2) Between simulations for each system
    i. Average costs per ton
    ii. Ending Inventory
    iii. Total costs
    iv. Number of times with zero inventory

CHAPTER 4. RESULTS

MODEL VALIDATION

The model results were validated by comparing the results of individual simulations with Timber Mart-South quarterly reports. One thousand simulations were conducted, each with different user specified inputs, to see if the results of the simulation represented a wood procurement system. If the results did not agree with the expected results, then corrections were made to the model.

For example, an initial simulation resulted in inaccurate ending inventory levels (Table 2). In the example, the targeted ending inventory level was triple of that specified. It was determined that that production was allocated to each supplier incorrectly.

Table 2. Simulation results when production was allocated incorrectly.

Strategy	Specified Inventory Level (tons)	Resulting Inventory Levels (tons)
Split Evenly	10,000	33,257
Fixed Costs	10,000	33,257
Average Weekly Production	10,000	33,257
Full Capacity	10,000	33,257

Another example was when the model generated inaccurate values for the average cost per ton (Table 3). In this example, the average cost per ton was $22.45 for the split evenly strategy, $8.00 above those reported by Timber Mart-South. Upon detecting this error, it was determined that the variable costs per week for each supplier were incorrectly calculated.

Table 3. Simulation results when variable costs were incorrect.

Strategy	Average Cost per Ton ($/ton)	Logging Production Capacity Utilized (%)
Split Evenly	$22.43	100.43
Fixed Costs	$22.53	100.43
Average Weekly Production	$22.27	100.43
Full Capacity	$16.50	100.00
Timber Mart-South	$15.21	N/A

Another correction to the model was made when the results of every simulation reported the same values for the three strategies of allocating production based on mill usage (Table 4). To correct for this error, costs for individual suppliers were added, instead of using average values for each type of supplier.

Table 4. Simulation results when average costs were used for each type of supplier.

Strategy	Average Cost per Ton ($/ton)	Capacity (%)	Number of Suppliers
Split Evenly	$15.14	100.43	6
Fixed Costs	$15.14	100.43	6
Average Weekly Production	$15.14	100.43	6
Full Capacity	$13.87	100.00	6

Upon validation of the model, every simulation produced by the model accurately portrayed wood procurement systems, while accounting for the risk of the system (Table 5).

Table 5. Results for a simulation of a lumber mill located Alabama Region 1 using pine sawtimber during Quarter 2 where all suppliers worked at full capacity levels.

Strategy	Cost per Ton		
	Low	High	Average
Split Evenly	$ 13.73	$ 15.02	$ 14.52
Fixed Costs	$ 13.70	$ 14.96	$ 14.46
Average Weekly Production	$ 13.54	$ 14.93	$ 14.36
Full Capacity	$ 13.67	$ 14.45	$ 14.04
Timber Mart-South	$ 14.15	$ 16.27	$ 15.21

MODEL PERFORMANCE

Execution Speed

The model of computer used greatly affected the execution speed. For example, on a Dell Dimension XP5 with a Pentium II processor, 256 MB of RAM and an Intel MMX™ Technology processor, the model took five minutes to simulate a week. However, on a Dell Dimension 4550 with a Pentium IV Processor, 512 MB of RAM and a 3.06 GHz processor, the model took less than one minute for the same amount of simulated time. Regardless of the model of computer, the input phase took five minutes for an experienced user or ten to fifteen minutes for a first-time user to enter data.

The size of the procurement system being modeled also affected the execution speed. For example, a system with 40 contract suppliers took longer to simulate than one with 30 contract suppliers. The execution speed depended on the length of the simulation. For the quicker of the two computers described above, the model took three minutes to simulate four weeks and nine minutes to simulate twelve weeks.

User Friendliness

This model has several features that should make the model user friendly. First, this model was designed in Microsoft Excel® and uses @Risk®, because they are widely used programs. For those individuals not familiar with Microsoft Excel® or @Risk®, many instruction books are available.

Every form contains a note box that provides brief instructions and examples on how to complete the form. Forms also contain a series of buttons that allow users to navigate between forms. Forms are clearly labeled, and only ask users for information that is required. Finally, this model runs all add-in programs (@Risk®) automatically.

Output

When the model terminates the "SummaryReport" worksheet is opened and the remaining output of the model is contained within eight worksheets. Every worksheet is clearly labeled. First time users, may have some trouble going from one worksheet to another, but should be able to use the "Help" menu found within Microsoft Excel® to determine how to move from worksheet to worksheet. The contents of every worksheet are labeled, and the user's manual contains detailed sections that explain how to interpret the results (Appendix D).

EXAMPLE

Inputs

To fully understand the potential of the model, it is best to discuss the results of some predetermined scenarios. The inputs used impact the results of the model therefore the results presented in this section used the inputs below (Table 6). Please note that if different inputs were used, results may vary.

Results

Forty-five different simulations were conducted, with 16 simulations where the number of suppliers used changed, and 29 simulations where the target and beginning inventory levels changed. From these simulations, the average cost per ton significantly (alpha = 0.05) differed between all four procurement strategies (Table 7). The split evenly strategy had the highest average cost per ton while the full capacity strategy had the lowest cost per ton. A large difference in average cost per ton existed between the three procurement strategies where production was allocated and the full capacity system. This implies that the mill paid between \$0.67 and \$0.81 to allocate production.

Table 6. Inputs used for the example simulations.

Input	Value
Location	Georgia Region 2
Mill Type	Pulp/paper mill
Product	Pine Roundwood
Weeks	14-26 (Quarter 2)
Suppliers	Tree length logging Crews
Percentage Gatewood	25%
Stumpage Value	$6.91 / ton
Gatewood Price	$22.04 / ton
Mill Usage per Week	10,000 tons
Target Inventory per Week	5,000 tons
Number of iterations	10,000
Random Number Seed	121501

Table 7. Comparison of the average cost per ton for the four different procurement strategies at full capacity levels.

Strategy	Average Cost per Ton	Standard Deviation
Split Evenly	$ 14.65	$ 1.67
Fixed Costs	$ 14.58	$ 1.63
Average Weekly Production	$ 14.51	$ 1.66
Full Capacity	$ 13.84	$ 0.57

Note: All strategies were significantly different at a 95% confidence level.

Determined from the model were the shapes of the distributions of average cost per ton for each of the different strategies. The distributions associated with the frequency of average cost per ton differed significantly between the three strategies and full capacity (Figure 5). However, the shapes of the distributions for the three strategies where production was allocated were the same, just the modes and means differed.

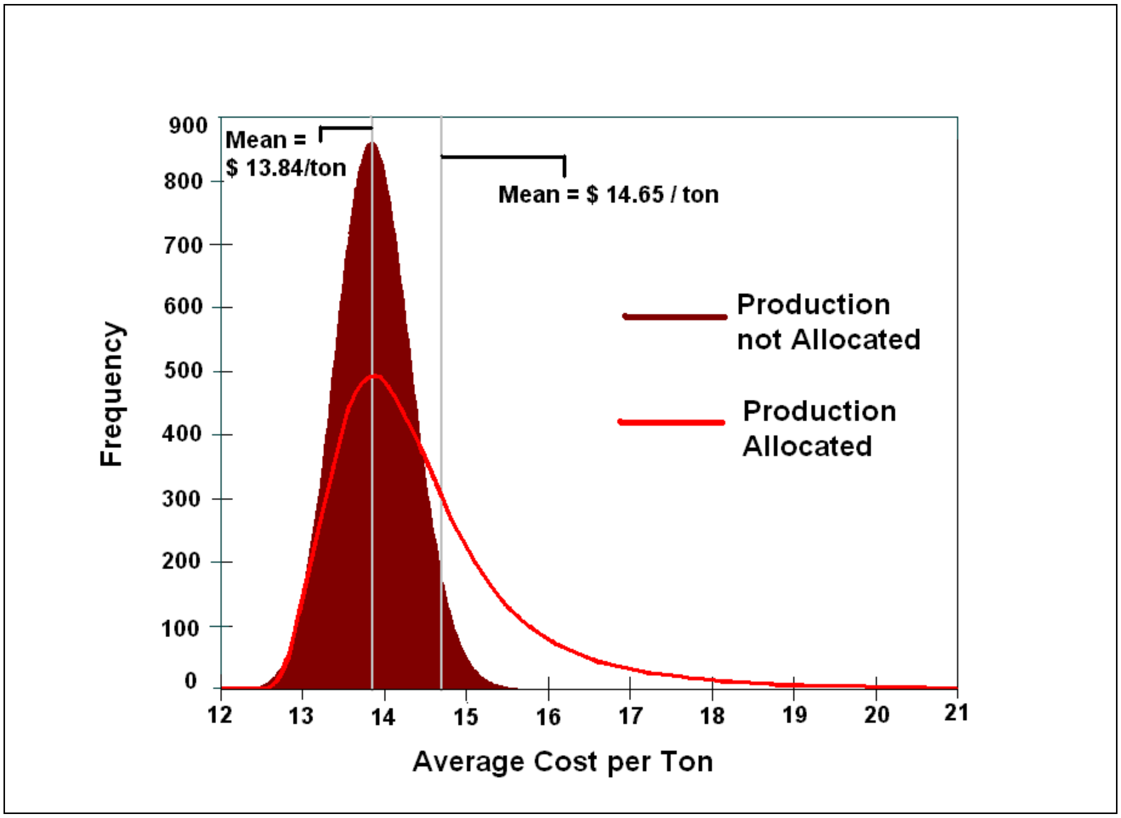

Figure 5. Frequency distributions for average cost per ton for the full capacity and split evenly procurement strategies at full capacity levels.

When production was not allocated to each supplier, average cost per ton followed an almost normal distribution (Figure 5). However, when production was allocated, this distribution was skewed to the left. The mode for the split evenly and full capacity strategies were the same, but the average cost per ton differed.

From the model the factors that affected the average costs per ton were determined, along with their relative impact (Figure 6). Mill usage had the largest impact on average cost per ton when allocating production. In fact for every one standard deviation increase in mill usage, average cost per ton decreased by 0.64 standard deviations. Gatewood production had the second largest impact, followed by variable and fixed cost for each supplier.

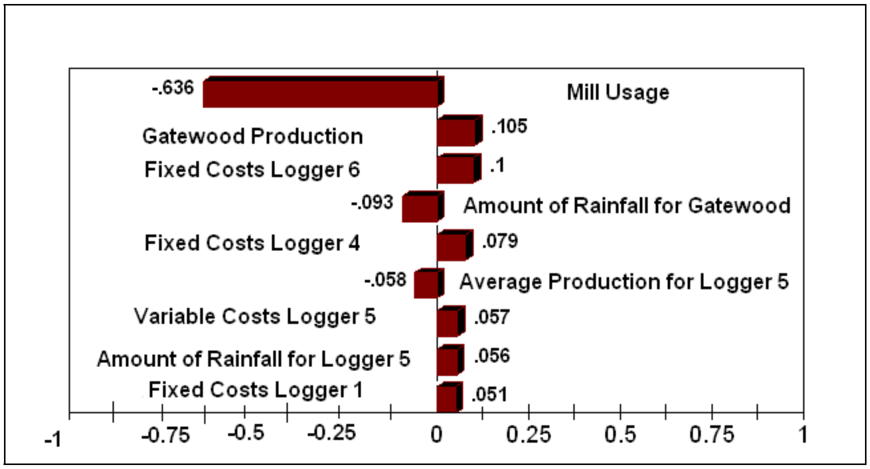

Figure 6. Sensitivity analysis for the average cost per ton using the split evenly procurement strategy.

The size of supply force greatly affected the cost of the system (Table 8). In the example, if a mill maintained one half a week's inventory it could reduce the size of its supply force until approximately 80 percent of the logging production capacity was being utilized and still maintain zero risk of running out of wood. By reducing the size of the supply force at this mill from 20 suppliers to seven, costs were reduced by $9.13 per ton and the risk of running out of wood did not change. However, when the system was utilized greater than full capacity, the average cost per ton and risk of running out of wood increased.

Inventory levels affected the costs and risk of the system. The smaller the inventory level for a given week, the greater the chance of running out of raw material in that week and following weeks (Table 9). In the example, the optimal size of inventory was one half weeks worth of inventory.

Table 8. Comparison of the average cost per ton, percent utilization of logging production capacity, and probability of zero inventory for the split evenly procurement strategy when the number of suppliers varied.

Number of Suppliers	Average Cost per Ton	Average Percent Utilization	Probability of Zero Inventory
20	$23.86	32	0
19	$23.57	34	0
18	$23.00	36	0
17	$22.15	38	0
16	$21.43	40	0
15	$20.78	41	0
14	$20.25	45	0
13	$19.48	49	0
12	$18.14	53	0
11	$17.52	58	0
10	$16.91	61	0
9	$15.71	70	0
8	$15.25	78	0
7	$14.73	82	0
6	$14.65	100	0
5	$14.92	120	0.0017

Table 9. Comparison of the probability of zero inventory when varying the beginning inventory levels for the split evenly procurement strategy when there were seven tree-length logging crews.

Equivalent Days of Inventory	Beginning Inventory Level (tons)	Probability of Zero Inventory
2.00	20,000	0
1.90	19,000	0
1.80	18,000	0
1.70	17,000	0
1.60	16,000	0
1.50	15,000	0
1.40	14,000	0
1.30	13,000	0
1.20	12,000	0
1.10	11,000	0
1.00	10,000	0
0.90	9,000	0
0.80	8,000	0
0.75	7,500	0
0.70	7,000	0
0.65	6,500	0
0.60	6,000	0
0.55	5,500	0
0.50	5,000	0
0.45	4,500	0
0.40	4,000	0
0.35	3,500	0
0.30	3,000	0.000008
0.25	2,500	0.000015
0.20	2,000	0.000069
0.15	1,500	0.000100
0.10	1,000	0.000177
0.05	500	0.000277
0	0	0.001685

CHAPTER 5. DISCUSSION

MODEL EVALUATION

The model was evaluated using the following criteria:

1) Does the model represent the dynamic nature of a wood procurement system?
2) Does it produce realistic results?
3) Does it provide a useful decision making tool?

The following sections address the model's advantages and limitations for meeting these criteria.

Advantages

Dynamic Nature

The model was successful at reproducing the dynamic nature of wood procurement systems. Wood procurement systems have many stochastic factors that provided for the dynamic nature of the system. Monte Carlo simulation techniques were used that allowed for the flexibility in the system while quantifying the effects of the stochastic variables such as mill usage and contract supplier production. These variables provided for the dynamic nature of the system. The dynamic nature of the system especially holds true when other factors that are even more unpredictable, such as rainfall, were incorporated into the model.

Realism

The realistic results produced by the model can be attributed to the many concepts that were incorporated into the model (Table 5). For example, the model's users are allowed to input their specific mill data (Appendix D). Users can vary target inventory levels to simulate building and reducing inventory at their mill. The model allows users to vary mill usage per week to simulate scheduled or mandatory downtime. Users can also vary the prices paid to wood dealers, other facilities and gatewood, along with the size and type of production force. Finally, the model allows for adjustments to be made to the procurement system when inventory levels move outside of an acceptable range.

Decision Making

Many models are designed for training. Training models typically involve generalized situations and are used to train groups of people on how to handle these generalized situations. However, with procurement systems, decisions are typically mill specific. For this reason this model provides mill specific results. The model provides a tool that procurement managers can use to help make decisions for their specific mill.

By using this model, individuals should gain some insight into how their decisions affect their procurement system. For example, procurement managers could use this model to investigate the tradeoffs between cut and haul costs, running out of raw material, and the size of their supply force. Procurement managers could also look at the cost impact of their decisions, and how production should be allocated to different suppliers. Other issues that could be examined are the tradeoffs between inventory levels, cut and haul costs, and the logging production capacity for the mill. Finally, this model could also be used to determine the inventory levels for a given level of risk.

Potential

Currently, the results of this model only considered cut and haul costs. However, the model can be manipulated to include stumpage costs. This can be accomplished by entering all raw material costs (stumpage plus cut and haul) for contract suppliers.

Caution should be taken that all contract suppliers define their raw material cost in a similar manner.

In addition, the simulation time period is limited to 26 weeks due to software restrictions. Often, managers need to see seasonal effects within their procurement system. Users can easily address this issue in the following manner. To simulate one year, the first 26 weeks would have to be simulated. The ending inventory for week 26 should be used as the beginning inventory for week 27, and then simulate the following 26 weeks.

The model has established a framework in which additional procurement strategies can be modeled. The only additional piece of programming that would have to be added is the manner in which production is allocated to each supplier. All of the remaining code and structure of the model will remain the same. Therefore, this model can easily accommodate several other procurement strategies.

Limitations

Dynamic Nature

The model does not take into account the correlation or interdependencies between certain events. For example, a large amount of rainfall in one week could affect production for more than one week to follow. This is a subtle, but important, limitation. Further research is needed to collect more data to determine the interdependencies between variables within the model, and incorporate these interdependencies.

Though this is a limitation of the model, the model has been designed to accommodate for the correlation between events. By using @Risk® the model has built in programming that allows for the incorporation of correlation coefficients between events. However, the correlation matrix is limited by the width of a Microsoft Excel® worksheet, which is why the model has been designed to only allow for the simulation of 26 weeks or the width of a Microsoft Excel® worksheet.

Realism

Simulations are only as good as the data used and the underlying assumptions of the model. For example, in real life logging crews deliver to more than one mill, and in the model it is assumed that logging crews only delivered to the mill in question. This model does not take into account that logging crews harvest more than one product. All of the costs and decisions associated with securing stumpage and the transportation of raw material are not considered. However, the foundation for creating a model that can support these and other aspects of the system has been created. Future research should take into account aspects of the procurement systems not modeled by this model, specifically costs and decisions of securing stumpage.

The model also produces results that over and under estimate costs for certain products in some states and regions when using the default values. For example, average cost per ton for pine sawtimber in Arkansas Region 2 was consistently greater than those reported by Timber Mart-South. This limitation of the model is due to reduced amount of data for specific areas. In the Greene and others (2002) study few logging crews from Arkansas and none from Mississippi were surveyed. Future research should be conducted to collect logging cost data from more logging crews across the southeastern United States.

The model may not have accurately represented the impact that rainfall has on production. Production was impacted based on a predictor equation derived from expert opinions. To achieve a more accurate estimate of how rainfall should affect production, additional data should be collected. This data can come from lab studies on the soil moisture content and how it impacts harvesting equipment, or possibly from surveys distributed to logging contractors and mill managers to rate the weather in the area and the amount of production received.

Functionality

Determining reliable estimates for the input values is time consuming and heavily dependent on data availability. Several user forms have to be completed, and this in itself may provide cumbersome for some users. When additional activities, such as securing stumpage and haul distances, are added to the model the execution time will increase.

EXAMPLE

There were significant differences between each of the four procurement strategies simulated by the model. The split evenly strategy yielded the highest costs per ton compared to the other strategies, because no method was used to try and reduce costs for suppliers within the system. Therefore, a supplier with high costs and low production rates was allocated the same amount of production as a supplier with high production rates and low costs.

The fixed cost strategy had the second highest average cost per ton. One possible reason was that suppliers with high fixed costs did not necessarily have high production rates. Therefore, suppliers with high fixed costs could not always disperse these costs. In general, producers with high costs and low production rates should have higher average cost per ton compared to suppliers that have the same costs and higher production rates.

The average weekly production strategy had the lowest average cost per ton for strategies where production was allocated based on mill usage. This strategy was originally hypothesized to have the lowest average cost per ton for strategies where production was allocated. One possible reason for this was that costs were dispersed over more tons. This strategy allocates a higher percentage of production to those suppliers that can produce the most. If a supplier had high costs and high production rates, they were allowed to disperse their costs over a greater number of tons. If a supplier had low costs and high production rates, they were rewarded for their business strategy. However, those suppliers with low production rates, and typically higher costs, were not allocated as much production, and therefore suffer when production was restricted.

The full capacity strategy had the lowest average cost per ton. This strategy was hypothesized to have the lowest average cost per ton because suppliers could not work over or under full capacity levels. By allowing producers to work at their full potential, not based on mill usage, production levels were more constant for each supplier. Therefore, on average this strategy will yield lower average cost per ton.

Prior to the configuration of the model, it was hypothesized that mills paid a premium to allocate production. The model was able to show and quantify the premium paid for allocating production. One major cause for the premium paid was because production was based on mill usage (Figure 6). Mill usage is variable, for one cannot predict when machines exhibited mechanical difficulties or when markets changed. Therefore, suppliers were working both under and over full capacity.

The results in the example indicated that there were weeks when contract suppliers had high costs because production was limited due to mill usage and weather (Figure 5). The sensitivity analysis illustrates that the biggest reduction in cost could be achieved by reducing the fluctuations that occurred in mill usage. One possible solution is to maintain constant production levels for suppliers. This can be accomplished by using either a preferred supplier system or allowing inventory at the mill to fluctuate more. Further studies should be conducted to determine how wood procurement systems can be changed to more closely represent the full capacity strategy.

The size of the supply force affected the utilization of the logging production capacity for each supplier. The smaller the supply force, the greater the utilization of the logging production capacity, indicating fixed costs were allocated across more tons. In general, systems that utilized more of their logging production capacity had lower costs per ton. However, if the size of the supply force becomes too small, costs increased along with the risk of running out of wood.

In the example, by only utilizing 80 percent of the logging production capacity the mill was allowed some flexibility. First, the mill maintained some form of surge capacity, in the form of logging production capacity, to correct for low inventory levels. Second, the mill maintained low costs levels without any risk of running out of raw material. Lower costs were achieved by allowing suppliers to work greater than 80 percent of their logging production capacity, but the risk of running out of raw material increased. Third, if one supplier could not supply the mill with their allocated amount, then the remaining suppliers had the ability to supply the amount that the others could not.

However, it should be pointed out that the results were based on the assumptions that every supplier only harvested one product and delivered to the specified mill. Furthermore, the model only observed cut and haul costs, and there are other costs and considerations that were not incorporated into the model that may need to be taken into consideration (i.e. haul distances, stumpage costs, profit, return on investment, and public perception).

Inventory levels affected the costs and risk of the system. When target inventory levels were high, carrying costs were typically higher, but the risk of running out of raw material was less. When target inventory levels were low, carrying costs were typically lower, but the risk of running out of raw material and paying more per ton were greater. In the example, the best inventory level was one half of week (Table 9).

CHAPTER 6. CONCLUSIONS

There had been little research on modeling wood procurement systems. Currently, few models are available on a region wide basis to generate mill specific results for various procurement strategies under uncertain conditions. The intended utility of the model was to be able to determine:

1) The best strategy to manage the logging production capacity and raw material inventories at the mill;
2) The amount of logging production capacity needed to minimize the cost to a given mill, at a given level of risk; and
3) The size of raw material inventory to minimize cost for a given level of risk.

The model is capable of evaluating current wood procurement practices, and providing useful information to wood procurement managers, researchers, and educators. Procurement managers can use the model to identify the lowest cost and risk system, and the most beneficial systems to both contract suppliers and mill procurement personnel.

The model has two significant limitations. First, the model does not allow for the interdependencies between events. This could results in the model creating more randomness in a simulation than would actually be encountered in a real wood procurement system. The second limitation is the execution speed of the model. On older computers to simulate many weeks, the model may take several hours to complete.

Notwithstanding its limitations, this model offers several advantages. One of the model's advantages is its ability to replicate the dynamic nature of procurement systems.

This model allows for the simultaneous variation of many of the stochastic variables contained within a wood procurement system, and then quantifies the effects of these variables. Another advantage of the model is its success in producing realistic results that are mill specific and for several different procurement strategies. Many of the models in the past produced realistic results, but were designed to replicate only one type of mill and procurement strategy. The final advantage of the model is that it can replicate the dynamic nature of a wood procurement system. With these advantages the model has significant potential for use as a decision making tool. This model could be an invaluable tool for procurement managers, who make important, and often, irreversible decisions under uncertain conditions.

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APPENDIX A. LIST OF DISTRIBUTIONS OF MILL USAGE BY WOOD TYPE AND PRODUCT.

LIST OF TABLES

TABLE A1. QUARTERLY DISTRIBUTIONS FOR WEEKLY USAGE OF PINE PULPWOOD BY PULP AND PAPER MILLS, ASSUMING MEAN EQUAL TO ONE.

Quarter	Distribution		
	Type	**Alpha**	**Beta**
1	Weibull	2.7227	1.0857
2	Weibull	3.9460	1.0853
3	Weibull	3.3207	1.0947
4	Weibull	3.0594	1.1194

Probability density function for a two-parameter Weibull distribution.

$$f(x) = \alpha\beta^{-\alpha}x^{\alpha-1}\exp\left(-\left(\frac{x}{\beta}\right)^{\alpha}\right)$$

Where,

x = weekly mill usage by pulp and paper mills for pine pulpwood
α = shape parameter
β = scale parameter
exp = the base of the natural logarithm.

TABLE A2. QUARTERLY DISTRIBUTIONS FOR WEEKLY USAGE OF PINE PULPWOOD CHIPS BY PULP AND PAPER MILLS, ASSUMING MEAN EQUAL TO ONE.

Quarter	Distribution		
	Type	**Alpha**	**Beta**
1	Weibull	3.6776	1.1038
2	Weibull	3.6388	1.1123
3	Weibull	3.5485	1.1178
4	Weibull	3.5456	1.0684

TABLE A3. QUARTERLY DISTRIBUTIONS FOR WEEKLY USAGE OF HARDWOOD PULPWOOD BY PULP AND PAPER MILLS, ASSUMING MEAN EQUAL TO ONE.

Quarter	Distribution		
	Type	Alpha	Beta
1	Weibull	2.2593	1.1402
2	Weibull	3.7631	1.0517
3	Weibull	3.7440	1.0755
4	Weibull	2.6304	1.1724

TABLE A4. QUARTERLY DISTRIBUTIONS FOR WEEKLY USAGE OF HARDWOOD PULPWOOD CHIPS BY PULP AND PAPER MILLS, ASSUMING MEAN EQUAL TO ONE.

Quarter	Distribution		
	Type	Alpha	Beta
1	Weibull	2.6484	1.1290
2	Weibull	2.7646	1.1305
3	Weibull	2.3731	1.0975
4	Weibull	2.7865	1.1028

TABLE A5. QUARTERLY DISTRIBUTIONS FOR WEEKLY USAGE OF PINE SAWTIMBER BY LUMBER MILLS, ASSUMING MEAN EQUAL TO ONE.

Quarter	Distribution		
	Type	Alpha	Beta
1	Weibull	5.2416	1.0711
2	Weibull	5.0601	1.0922
3	Weibull	5.3792	1.1032
4	Weibull	4.1099	1.0548

TABLE A6. QUARTERLY DISTRIBUTIONS FOR WEEKLY USAGE OF PINE CHIP'N'SAW BY LUMBER MILLS, ASSUMING MEAN EQUAL TO ONE.

Quarter	Distribution		
	Type	Alpha	Beta
1	Weibull	6.1919	1.1351
2	Weibull	5.9974	1.0991
3	Weibull	4.2752	1.0686
4	Weibull	3.8637	1.0427

TABLE A7. QUARTERLY DISTRIBUTIONS FOR WEEKLY USAGE OF PINE PLYLOGS BY PLYWOOD MILLS, ASSUMING MEAN EQUAL TO ONE.

Quarter	Distribution		
	Type	Alpha	Beta
1	Weibull	4.8223	1.0890
2	Weibull	6.9813	1.1124
3	Weibull	5.9531	1.0580
4	Weibull	4.2131	1.0537

TABLE A8. QUARTERLY DISTRIBUTIONS FOR WEEKLY USAGE OF HARDWOOD PLYLOGS BY PLYWOOD MILLS, ASSUMING MEAN EQUAL TO ONE.

Quarter	Distribution		
	Type	Alpha	Beta
1	Weibull	1.3029	1.0560
2	Weibull	1.6535	0.87591
3	Weibull	1.7631	1.2423
4	Weibull	2.0432	1.2069

APPENDIX B. LIST OF DISTRIBUTIONS OF SUPPLIERS PRODUCTION BY SUPPLIER TYPE

LIST OF TABLES

TABLE B1. QUARTERLY DISTRIBUTIONS FOR WEEKLY PRODUCTION BY WOOD DEALERS, ASSUMING MEAN EQUAL TO ONE.

Quarter	**Distribution**			
	Type	**Gamma**	**Alpha**	**Beta**
1	Weibull		12.977	1.0019
2	Weibull		14.997	1.0721
3	Weibull		16.043	1.0371
4	Log Logistic	0.0000	20.678	0.97044

* Assume distributions for production by wood dealers are the same as tree length logging crews

Probability density function for a Log Logistic distribution.

$$f(x) = \frac{\alpha\left(\frac{x-\gamma}{\beta}\right)^{\alpha-1}}{\beta\left[1+\left(\frac{x-\gamma}{\beta}\right)^{\alpha}\right]^{2}}$$

Where,

x = weekly production in tons
α = shape parameter
γ = location parameter
β = scale parameter

TABLE B2. QUARTERLY DISTRIBUTIONS FOR WEEKLY PRODUCTION BY TREE LENGTH LOGGING CREWS, ASSUMING MEAN EQUAL TO ONE.

Quarter	**Distribution**			
	Type	**Gamma**	**Alpha**	**Beta**
1	Weibull		12.977	1.0019
2	Weibull		14.997	1.0721
3	Weibull		16.043	1.0371
4	Log Logistic	0.0000	20.678	0.97044

TABLE B3. DISTRIBUTION FOR WEEKLY PRODUCTION BY IN-WOODS CHIPPING CREWS, ASSUMING MEAN EQUAL TO ONE.

Distribution		
Type	**Alpha**	**Beta**
Weibull	7.6188	1.0585

TABLE B4. QUARTERLY DISTRIBUTIONS FOR WEEKLY PRODUCTION BY OTHER FACILITIES, ASSUMING MEAN EQUAL TO ONE.

Quarter	Distribution		
	Type	**Alpha**	**Beta**
1	Weibull	5.2416	1.0711
2	Weibull	5.0601	1.0922
3	Weibull	5.3792	1.1032
4	Weibull	4.1099	1.0548

* Assume the distributions for production by other facilities are the same as pine sawtimber mill usage distributions.

APPENDIX C. LIST OF DISTRIBUTIONS OF VARIABLE AND FIXED COSTS BY SUPPLIER TYPE

LIST OF TABLES

TABLE C1. QUARTERLY DISTRIBUTIONS FOR VARIABLE COSTS PER TON FOR TREE LENGTH LOGGING CREWS, ASSUMING MEAN EQUAL TO ONE.

Quarter	Distribution		
	Type	**Alpha**	**Beta**
1	Weibull	9.7311	1.0661
2	Weibull	9.4023	1.0606
3	Gamma	184.34	0.0054958
4	Weibull	9.4425	1.0725

Probability density function for a Gamma distribution

$$f(x) = \frac{\beta^{-\alpha} x^{\alpha-1} \exp\left(-\frac{x}{\beta}\right)}{\Gamma(\alpha)}$$

Where,

α = shape parameter
β = scale parameter
x = values for variable cost per ton
$\Gamma(\alpha)$ = results from gamma function which is displayed below.
exp = the base of the natural logarithm

$$\Gamma(\alpha) = \int_0^\infty t^{\alpha-1} e^{-t}\, dt$$

Where,

t = time
e = the base of the natural logarithm
α = shape parameter

TABLE C2. DISTRIBUTION FOR VARIABLE COSTS PER TON FOR IN-WOODS CHIPPING CREWS, ASSUMING MEAN EQUAL TO ONE.

Distribution		
Type	**Alpha**	**Beta**
Weibull	6.4684	1.0717

TABLE C3. QUARTERLY DISTRIBUTIONS FOR FIXED COSTS PER WEEK FOR TREE LENGTH LOGGING CREWS, ASSUMING MEAN EQUAL TO ONE.

Quarter	**Distribution**		
	Type	**Alpha**	**Beta**
1	Weibull	7.8907	1.0384
2	Weibull	8.6441	1.0563
3	Weibull	11.715	1.0325
4	Weibull	10.220	1.0822

TABLE C4. DISTRIBUTION FOR FIXED COSTS PER WEEK FOR IN-WOODS CHIPPING CREWS, ASSUMING MEAN EQUAL TO ONE.

Distribution		
Type	**Alpha**	**Beta**
Weibull	8.7498	1.0572

APPENDIX D. USER'S MANUAL FOR THE GENERALIZED WOOD PROCUREMENT MODEL

TABLE OF CONTENTS

Page

GENERALIZED WOOD PROCUREMENT MODEL FOR THE SOUTHEASTERN UNITED STATES

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TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION

This user's manual was designed to provide a description of the contents and operating instructions for the Generalized Wood Procurement Model (GWPM) designed by William Howell and Michael Clutter. The user guide is divided into five chapters: 1) introduction; 2) getting started; 3) user inputs; 4) simulation; and 5) interpreting results.

The GWPM was designed to reproduce wood procurement systems throughout the southeastern United States and to evaluate the risk and cost of different procurement strategies. This model provides a useful decision making tool to assess procurement strategies within a given mill. Users are asked to fill out a series of forms to describe their system. From this description, four different procurement strategies will be simulated for their procurement system:

1) <u>Fixed Cost Strategy.</u> Production is based on supplier fixed costs and mill usage.
2) <u>Split Evenly Strategy.</u> Production is based on mill usage and split evenly between suppliers.
3) <u>Average Weekly Production Strategy.</u> Production is based on suppliers average weekly production and mill usage.
4) <u>Full Capacity Strategy</u>. Suppliers work at their full production without regard for mill usage.

GWPM is user-defined. You will be able to determine the location and type of mill, the type of wood product used by the mill, the number and type of contract suppliers, mill usage and target inventory. The model is divided into two distinct phases: 1) input and 2) simulation. The input phase involves providing the model with a description of your procurement system. The simulation phase involves using the inputs to simulate different procurement strategies for your mill. Upon completion of the simulation phase you will receive detailed information on four procurement strategies including items such as average cost per ton, number of times each system ran out of wood, total costs and ending inventory levels.

CHAPTER 2. GETTING STARTED

Prior to starting the GWPM please make sure that your computer system meets the following requirements:

-Microsoft Office 1998® or higher

-Microsoft Excel 1998® or higher

-@Risk 4.0® or higher

-Pentium PC or faster with a hard disk

If your computer system meets these requirements, then to start the GWPM follow the directions below.

1) Insert the GWPM CD-ROM into your CD-ROM drive
2) Open Microsoft Excel®
3) Select the *File* menu from the toolbar
4) Select *Open*
5) Select the CD-ROM drive from the *Look-in* drop box
6) Open the workbook entitled "PROCUREMENTMODEL."
7) Click *Enable Macros*

Upon enabling the macros, the file should automatically start @Risk®. The workbook "PROCUREMENTMODEL" includes only one worksheet called "Start" (Figure D1). The "Start" worksheet contains the title and authorship information of the model, and a button entitled "Press Here to Start." Press the "Press Here to Start" button to start the simulation and proceed to Chapter 3 of the user's manual.

Note: If you have already run a simulation, @Risk® will display three question boxes to you. To answer these question boxes and proceed with the model follow the instructions below.

1) The first message box displayed will read, "Create a new simulation file based on the @Risk® settings stored in PROCUREMENTMODEL.xls?" This message box will also contain a "Yes" and "No" button, select "Yes."
2) Another message box will appear that states, "Do you want to save the current simulation file before creating the new one?" with three option buttons: 1) "Yes;" 2) "No;" and 3) "Cancel". If you do not wish to save the previous

simulation select “No”. If you wish to save the previous simulation select “Yes” and you will be displayed a window asking you where to save the file. **DO NOT SELECT CANCEL.** If you select “Cancel” you cannot proceed with the simulation model.

3) The final message box is identical to the first @Risk® message box. This message box states, “Create a new simulation file based on the @Risk® settings stored in PROCUREMENTMODEL.xls?” This message box contains a “Yes” and “No” button, select “Yes” and the model will begin.

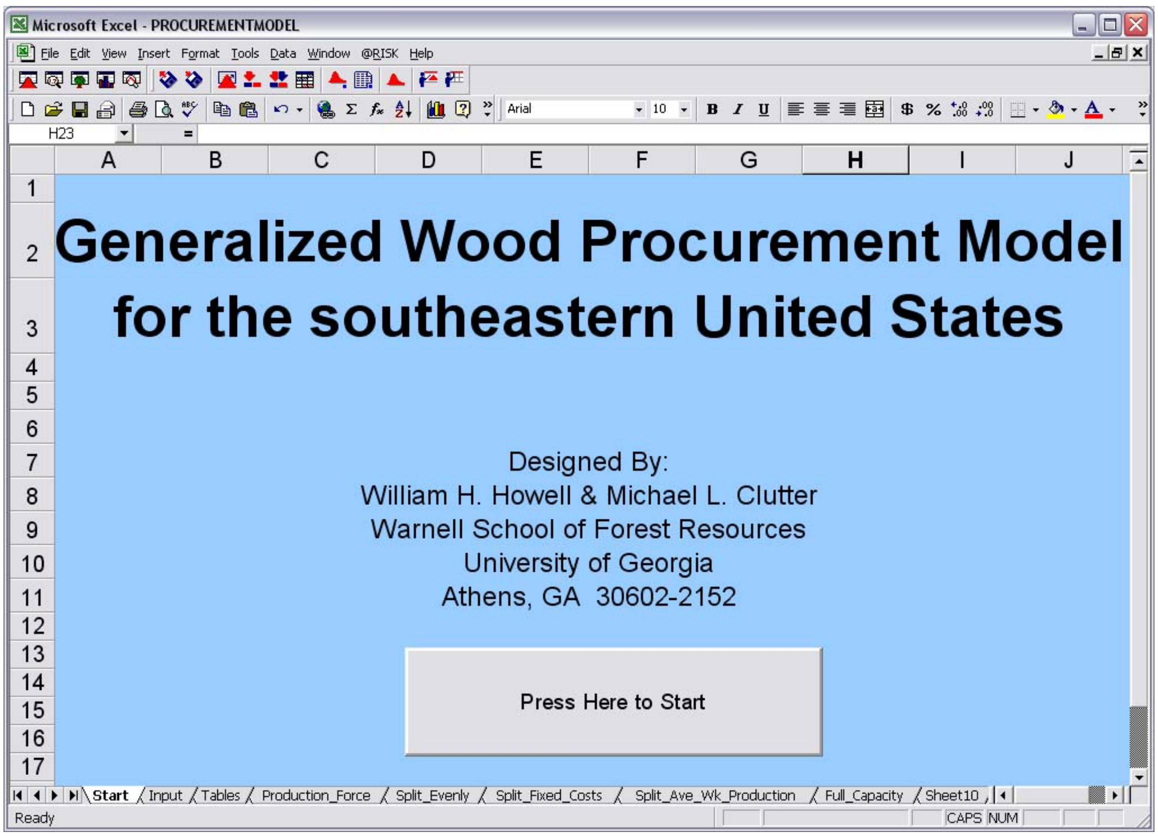


Figure D1. Contents of the “Start” worksheet.

CHAPTER 3. USER INPUTS

The GWPM requires you to enter information about several aspects of your procurement system. You will be asked to fill out a series of forms that describe your procurement system. This chapter discusses in detail every user form contained within the GWPM.

GENERAL INFORMATION

Contained within every form are two pieces of information, 1) a note box and 2) menu of buttons. The note box is located either at the bottom or upper right corner of every form. Every form automatically displays the note box. Note boxes contain brief instructions and examples of how a form should be completed.

The menu of buttons will vary depending on the form displayed but may include: 1) Back; 2) Clear; 3) Exit; or 4) OK. The "Back" button displays the previously viewed form. The "Clear" button clears the current form. The "Exit" button exits the entire simulation. The "OK" button records the inputs and displays the next user form.

FORMS

Mill Type

The "Mill Type" form is the first form displayed. Four pieces of information must be entered: 1) state; 2) region; 3) facility type and 4) product (Figure D2).

State.

In the lower left corner of the form, there is an information box entitled "Location Information." Located within this box is a drop down menu that allows you to select the state in which your mill is located. You must first select the state in which your mill is located before you are given the option to do anything else within this form. Upon specifying a state, the option to specify the type of mill will be displayed (Figure D3).

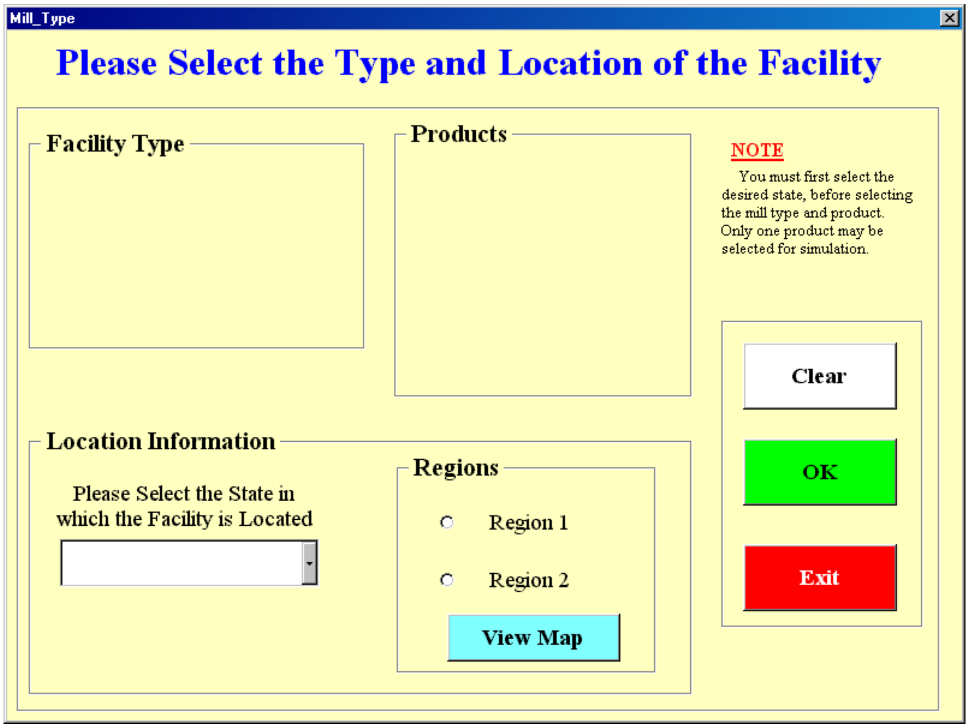


Figure D2. “Mill Type” user form.

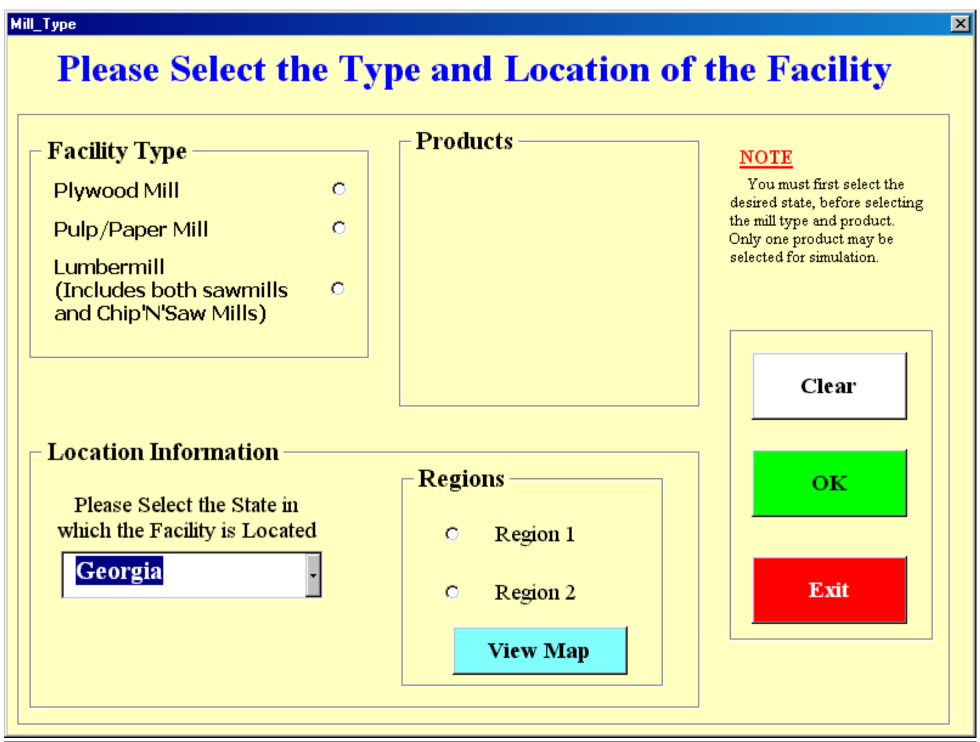


Figure D3. “Mill Type” form as seen after a state has been selected.

Region.

Located next to the specified state in which your mill is located are two option buttons that allow you to select the region where your mill is located. Every state is divided into two regions.

Option: View Map. If you are unsure of which region your mill is located, press the "View Map" button. This will display a map of the southeastern United States, with each state being split into two regions (Figure D4). Once you have located the region in which your mill is located, press the back button and you will return to the "Mill Type" form.

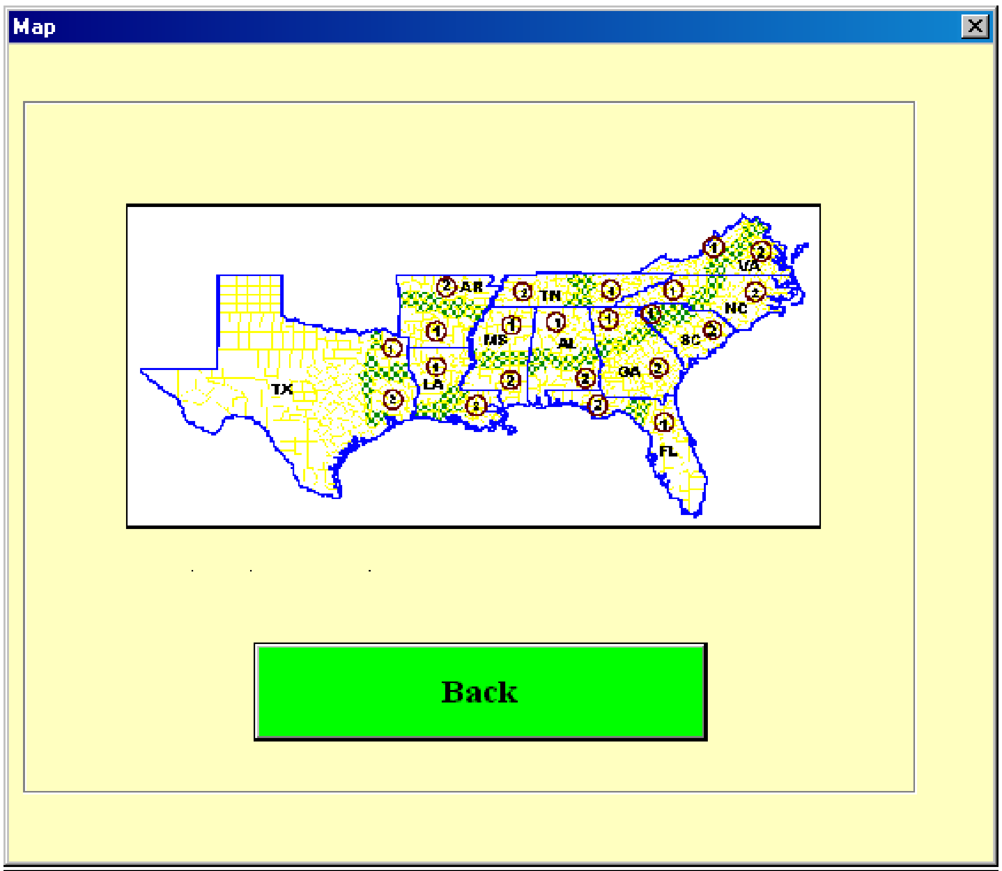


Figure D4. Map that is displayed when the "View Map" button contained within the "Mill Type" form is pressed.

Facility Type.

Located in the upper right hand corner of the "Mill Type" form is the option to select the type of facility. Depending on the state selected, the available types of facilities are pulp and paper, plywood and lumber mills. You must specify the type of facility that you wish to simulate before the list of products is displayed (Figure D5).

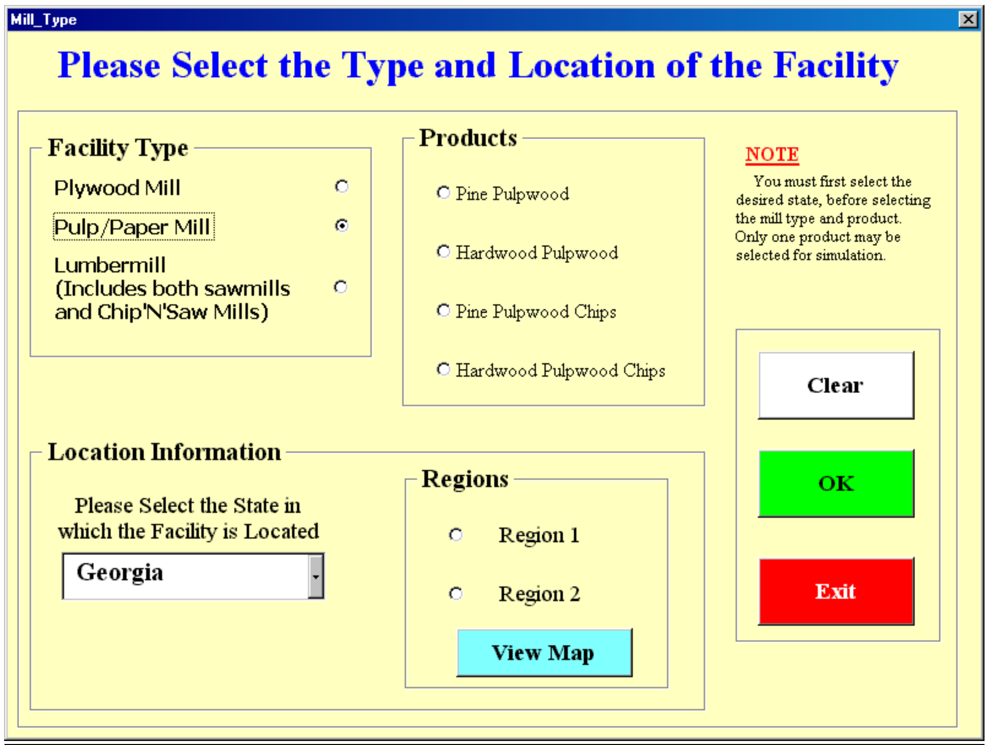


Figure D5. “Mill Type” form as seen after a state and facility type has been selected.

Product

Located in the middle of the form is a list of available products for the specified facility type and state. The products available for simulation will depend on the state and facility type selected. If everything is completed accurately, press “OK” and proceed to the next form.

Note: All facility and product types are not available for simulation in every state. In some states, there were insufficient data to provide an accurate portrayal of wood procurement systems for certain facility and product types.

Beginning and Ending Week

The "Beginning and Ending Week" form is the second form displayed (Figure D6). This form allows you to specify the weeks that you wish to simulate. The simulation assumes that there are 52 weeks in the year, and that week one begins the first of January with every seven days thereafter being another week. When specifying the weeks to simulate, the beginning week must be greater than the ending week. Also, you are only allowed to simulate up to 26 weeks. Upon entering the beginning and ending week, press "OK' and the "Contract Suppliers Information" form will be displayed.

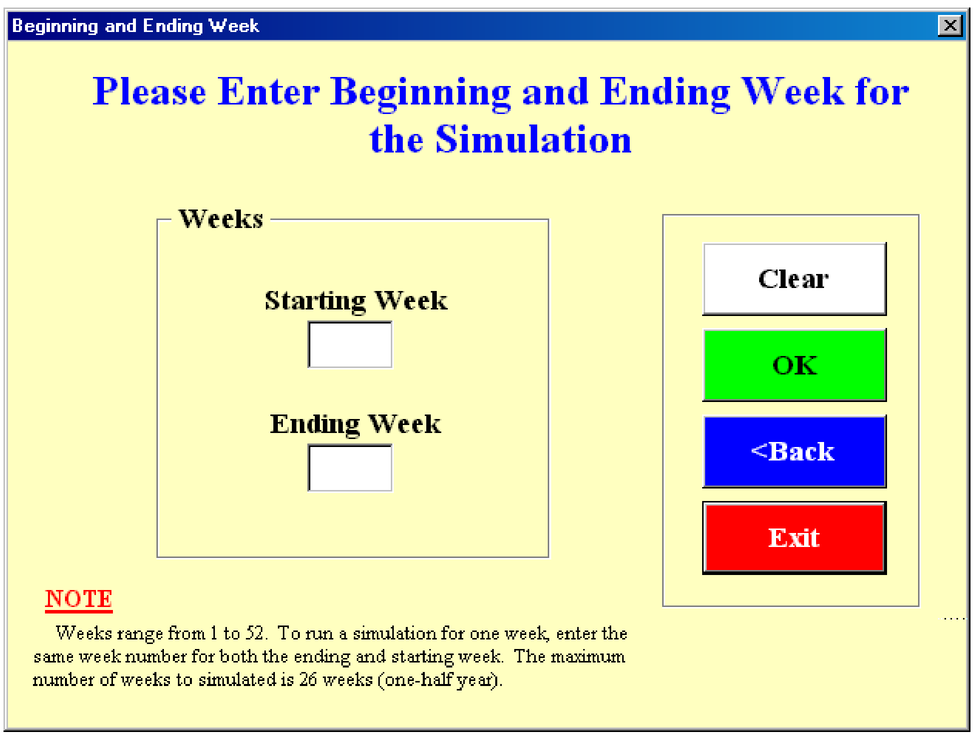


Figure D6. "Beginning and Ending Week" form.

Contract Suppliers Information

The "Contract Suppliers Information" form is the third form displayed (Figure D7). This form allows you to specify the number and type of contract suppliers used by your mill. You are allowed to have up to 9 wood dealers, 9 other facilities, 26 tree-length logging crews, and if your mill is a pulp and paper mill, up to 26 in-woods chipping crews. You are limited on the size of your contract supply force, for the number of weeks to simulate multiplied by the number of contract suppliers cannot exceed 256. This restriction is due to the width of a Microsoft Excel® worksheet. If you have exceeded this limit an error message will be displayed to you. Select "OK," and either go back and reduce the number of weeks to simulate by using the "Back" button to return to the "Beginning and Ending Week" form, or reduce the number of contract suppliers used by your mill. Upon the completion of the "Contract Suppliers Information" form press the "OK" button and the "Stumpage Values" form will be displayed.

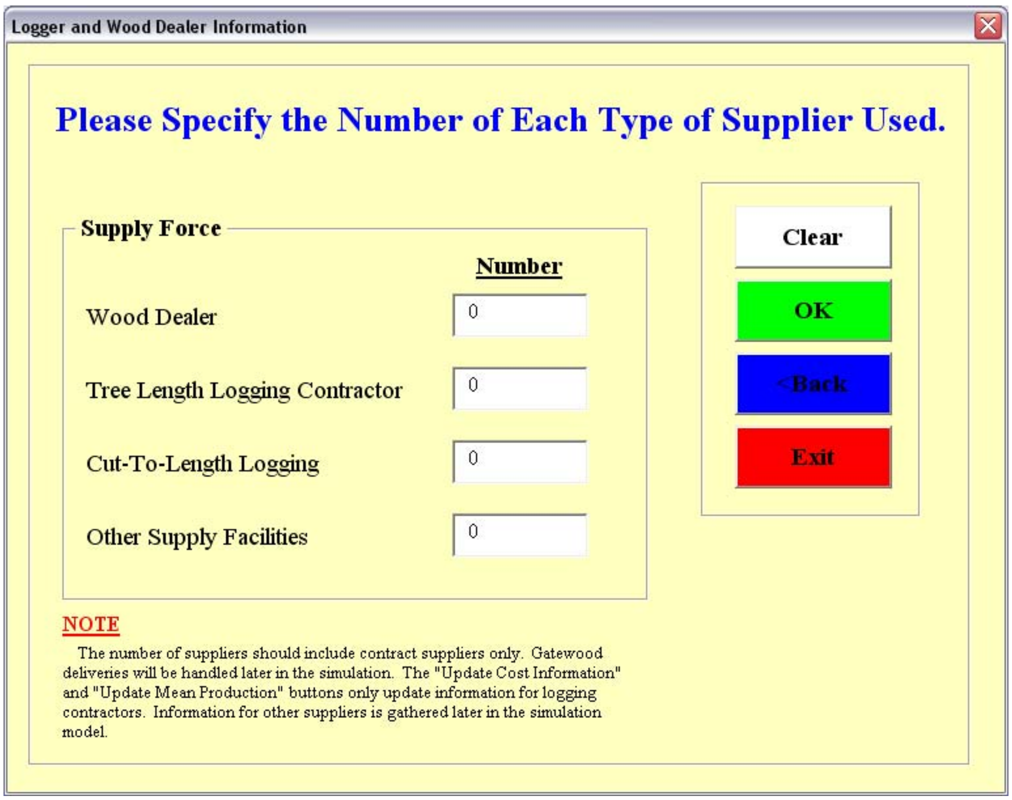


Figure D7. "Contract Suppliers Information" form.

Stumpage Values

The "Stumpage Values" form allows you to specify the stumpage values used to calculate the cut and haul costs for each supplier. The form lists the quarter, specified product and the default stumpage values. All default stumpage values were based on the 2002 Quarterly Timber Mart-South Reports (Figure D8). To change these values click on the text box in question, delete the old number, and enter the new value. Stumpage values must be greater than or equal to zero. After the stumpage values have been entered, press the "OK" button, and the "Percentage of Gatewood" form will be displayed.

Note: If you wish to analyze the system from a total cost aspect, and not based on cut and haul costs, please enter zero for all stumpage values. However, upon doing so, you must include the cost of stumpage into all of the remaining costs entered.

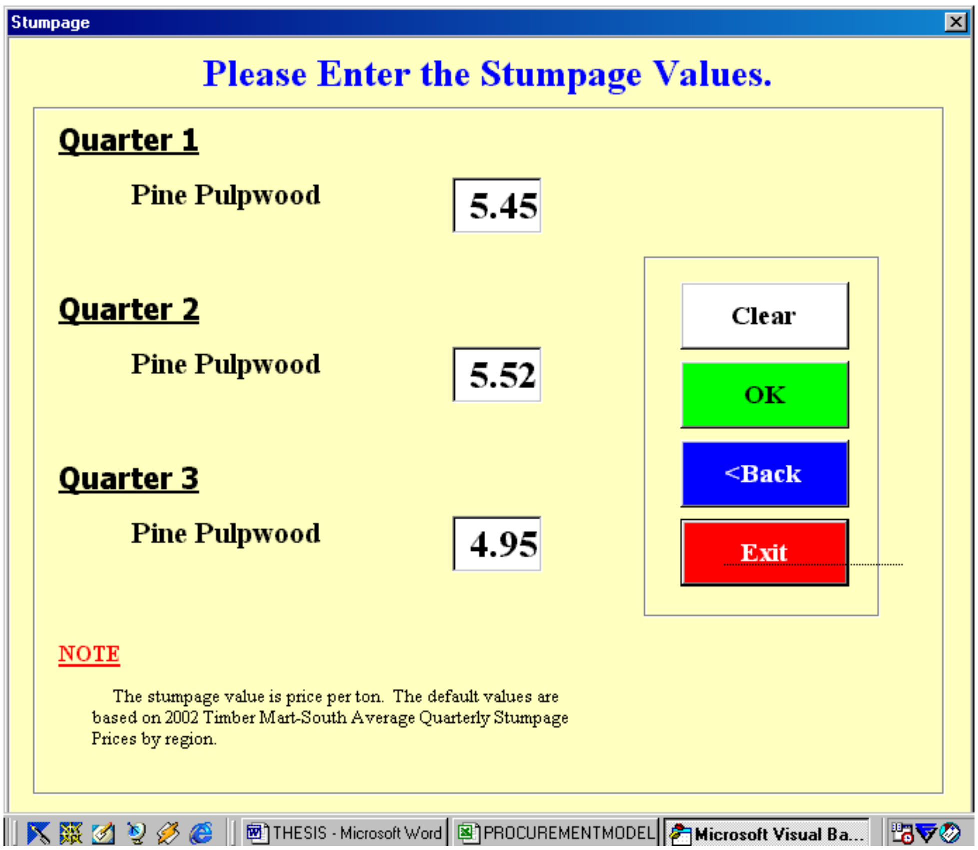


Figure D8. The "Stumpage Values" form.

Percentage of Gatewood

The "Percentage of Gatewood" form allows you to enter the estimated percentage of weekly receipts derived from gatewood (Figure D9). In the text box enter a number between 0 and 90. Do not enter the value as a decimal, but as a percentage. Please note that this percentage will be used throughout the simulation, meaning you cannot vary the estimated amount of gatewood received by your mill from week to week. Upon completion press the "OK" button. The next form displayed will depend on the weeks you specified to simulate. If you are simulating any weeks between 1-13 the "Tier Pricing for Gatewood Quarter 1" form will appear. If you are simulating any weeks between 14-26 the "Tier Pricing for Gatewood Quarter 2" form will appear. If you are simulating any weeks between 26-39 the "Tier Pricing for Gatewood Quarter 3" form will appear. Otherwise the "Tier Pricing for Gatewood Quarter 4" form will appear.

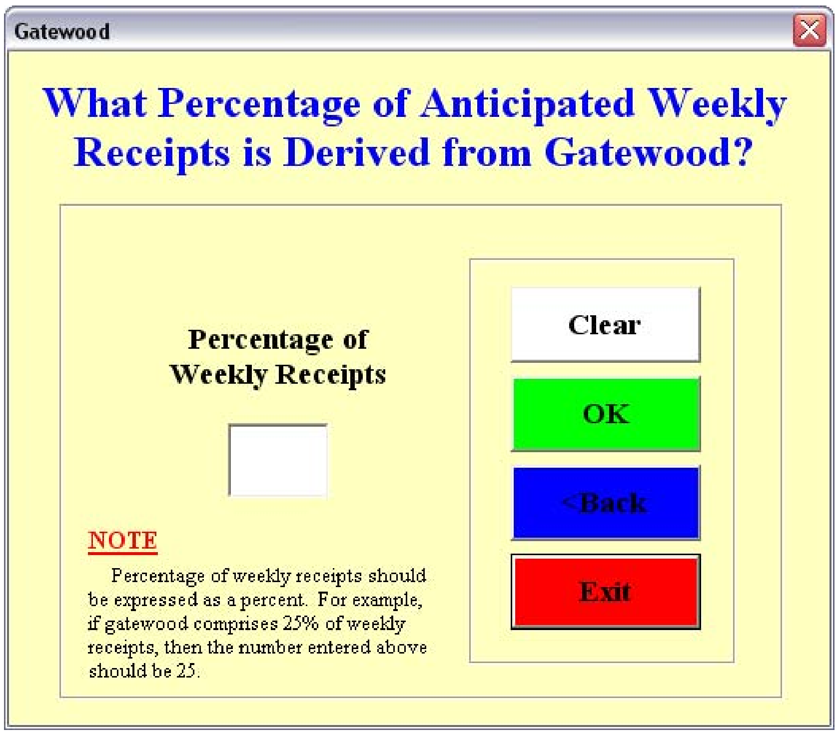


Figure D9. “Percentage of Gatewood” form.

Tier Pricing for Gatewood Forms

The “Tier Pricing for Gatewood Quarter (1-4)” forms allow you to specify the price per ton paid for gatewood deliveries by quarter using tier pricing (Figure D10). Tier pricing consists of pricing based on the percentage of the logging production capacity being utilized by the mill. Up to five tiers are allowed, with each tier being a different level of logging production capacity utilization. For example, a two tier pricing system maybe as follows. If the logging production capacity being utilized by the mill is between 0-100 percent then the price per ton is $25 and if the logging production capacity being utilized by the mill is over 100 percent then the price per ton is $30. By using tier pricing, you are able to vary the price, based on the demand for raw material in your system.

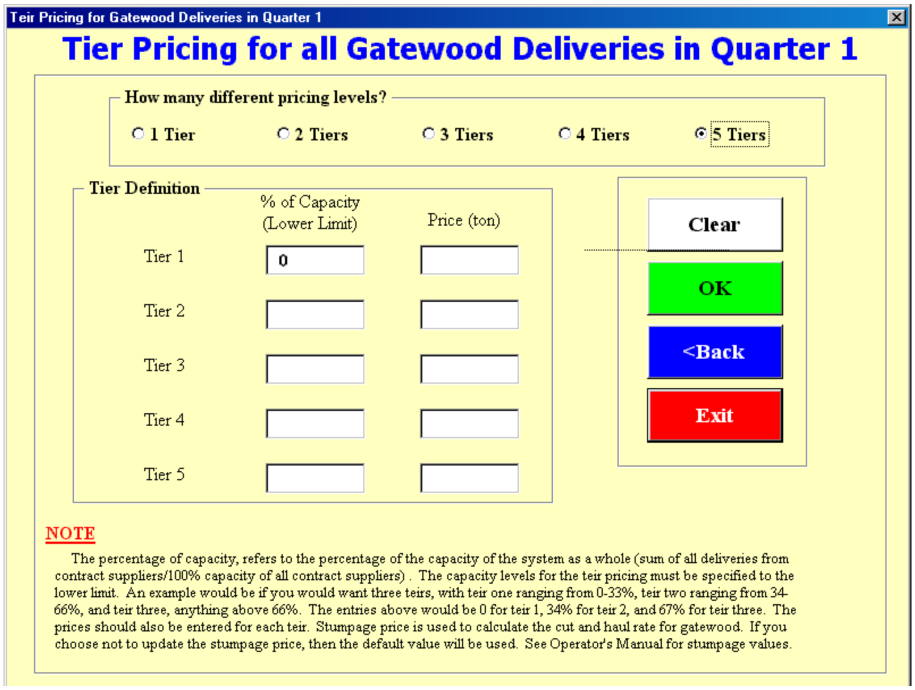


Figure D10. “Tier Pricing for Gatewood Quarter1” form.

To complete the “Tier Pricing for Gatewood Quarter (1-4)” forms, you must complete two steps. First, on the top of the form is the option of specifying the number of tiers you wish to have present in your pricing strategy (Figure D9). You must first specify how many tiers you wish to have present in your pricing strategy.

Second, after selecting the number of tiers a series of text boxes should appear, one column will be specified as the “% of Capacity (Lower Limit)” and the other as the “Price per Ton.” The column of text boxes titled "% of Capacity (Lower Limit)" will have a 0 displayed in the first box. You must have zero as the percentage of capacity for the first tier. The information you supply in this form is used to create a “Vlookup Table” in Microsoft Excel®, and for that reason you must specify the lower limit of the logging production capacity being utilized by the system. For example, you have a five tier pricing structure for the wood dealers in your system. The entries for the logging production capacity utilized by the system could be 0, 26, 51, 76 and 101. This implies that from 0-25, 26-50, 51-75, 76-100, and greater than 100 percent of the logging production capacity being utilized that gatewood suppliers are being paid a different price per ton. The logging production capacity for each tier must be in ascending order. For example, tier two cannot be 75 percent and tier three be 50 percent, and so forth.

The column of boxes entitled "Price per Ton" requires you to enter the delivered price per ton (cut and haul plus stumpage costs) for each tier. You must enter a price for every tier specified. The price per ton for each tier must be greater than the stumpage values entered and in ascending order. For example, tier two cannot be $25 and tier three be $15, and so forth.

Upon completion of this form, press "OK." If you have specified any tree-length logging crews you will be displayed the “Tree-length Logging Crews Production” form (p.90). If you have specified no tree-length logging crews, but have specified in-woods chipping crews then the “In-Woods Chipping Crews Production” form will be displayed (p.93). If you have specified no tree-length logging and in-woods chipping crews, and at least one wood dealer, then the next form displayed will be the “Amount Supplied by Wood Dealers” form (p.96). Otherwise, the “Amount Supplied by Other Facilities” form will be displayed (p.98).

Tree-length Logging Crews Production

The “Tree-length Logging Crews Production” form allows you to enter the average amount produced (tons) per week for each individual tree-length logging crew (Figure D11). On this form, there will be one text box for each crew. In Figure D10, the number of tree-length logging crews specified on the “Contract Suppliers Information” form was 20. Therefore, 20 text boxes labeled “Crew 1” through “Crew 20” were displayed containing default values. Please note that you must enter a positive numeric value for each text box displayed. Upon completion of this form press the “OK” button and the “Tree-length Logging Crews Fixed Costs” form will be displayed.

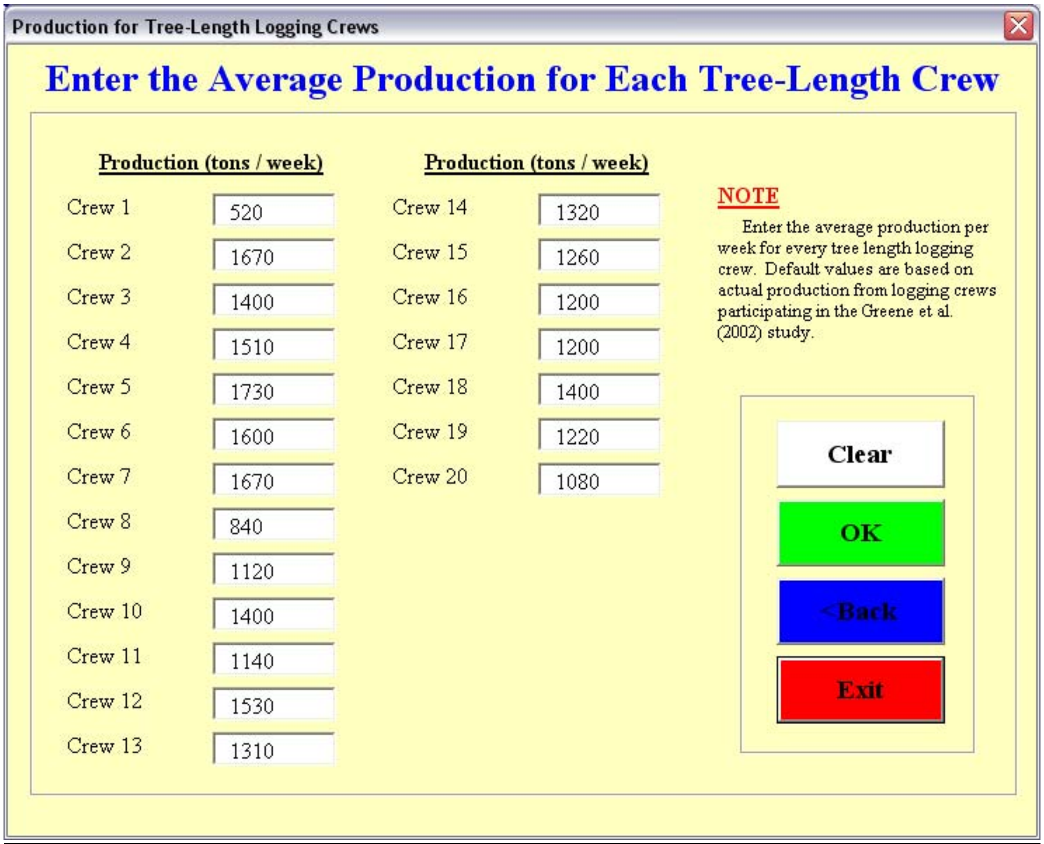


Figure D11. "Tree-length Logging Crews Production" form.

Tree-length Logging Crews Fixed Costs

The "Tree-length Logging Crews Fixed Costs" form allows you to enter the average fixed costs for each individual tree-length logging crew (Figure D12). On this form, there will be one text box for each crew. In Figure D12, the number of tree-length logging crews specified on the "Contract Suppliers Information" form was 20. Therefore, 20 text boxes labeled "Crew 1" through "Crew 20" were displayed containing default values. Please note that you must enter a positive numeric value for each text box displayed. Upon completion of this form press the "OK" button and the "Tree-length Logging Crews Variable Costs" form will be displayed.

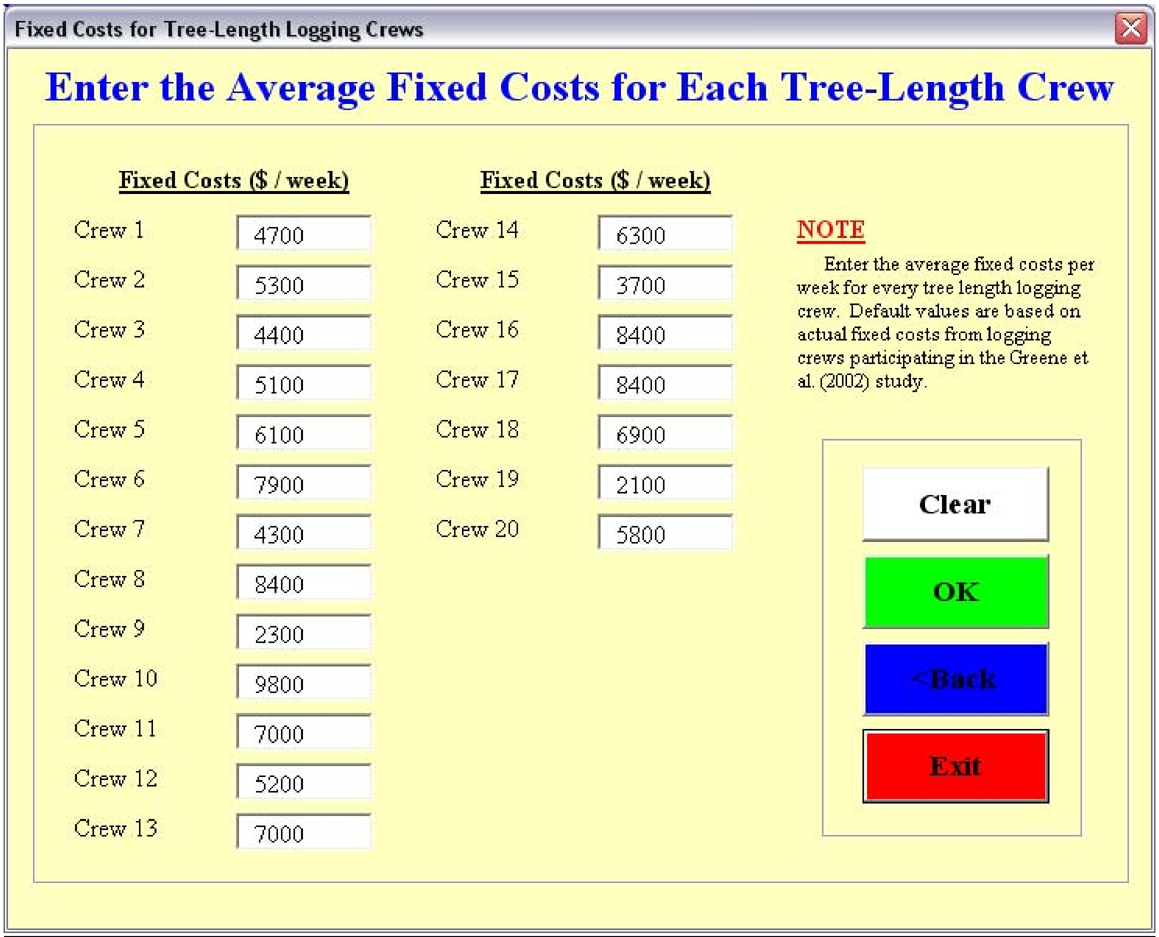


Figure D12. “Tree-length Logging Crews Fixed Costs” form.

Tree-length Logging Crews Variable Costs

The “Tree-length Logging Crews Variable Costs” form allows you to enter the average variable costs per ton for each individual tree-length logging crew (Figure D13). On this form, there will be one text box displayed for each crew. In Figure D13, the number of tree-length logging crews specified on the “Contract Suppliers Information” form was 20. Therefore, 20 text boxes labeled “Crew 1” through “Crew 20” were displayed containing default values. Please note that you must enter a positive numeric value for each text box displayed.

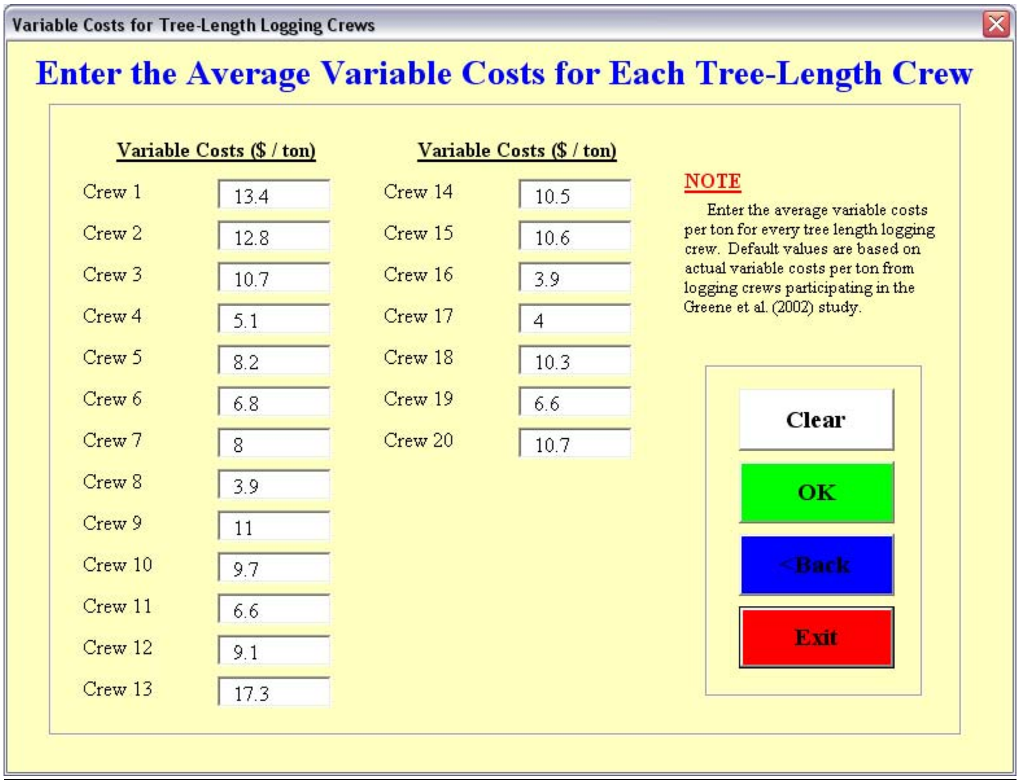


Figure D13. “Tree-length Logging Crews Variable Costs” form.

Upon completion of this form press the “OK” button. If you have specified only tree length logging crews on the “Contract Suppliers Information” form then the “Mill Usage” form will be displayed (p.99). If you have specified any in-woods chipping crews then the “In-woods Chipping Crews Production” form will be displayed (p.93). If you specified no in-woods chipping crews and at least one wood dealer then the “Amount Supplied by Wood Dealers” form will be displayed (p.96). Otherwise the “Amount Supplied by Other Facilities” form will be displayed (p.98).

In-Woods Chipping Crews Production

The “In-Woods Chipping Crews Production” form is almost identical to the "Tree-length Logging Crews Production" form, only the labels differ (Figure D14). For details on completing this form see "Tree-length Logging Crews Production" form (p.90). Upon completion of this form press the “OK” button and the “In-Woods Chipping Crews Fixed Costs” form will be displayed.

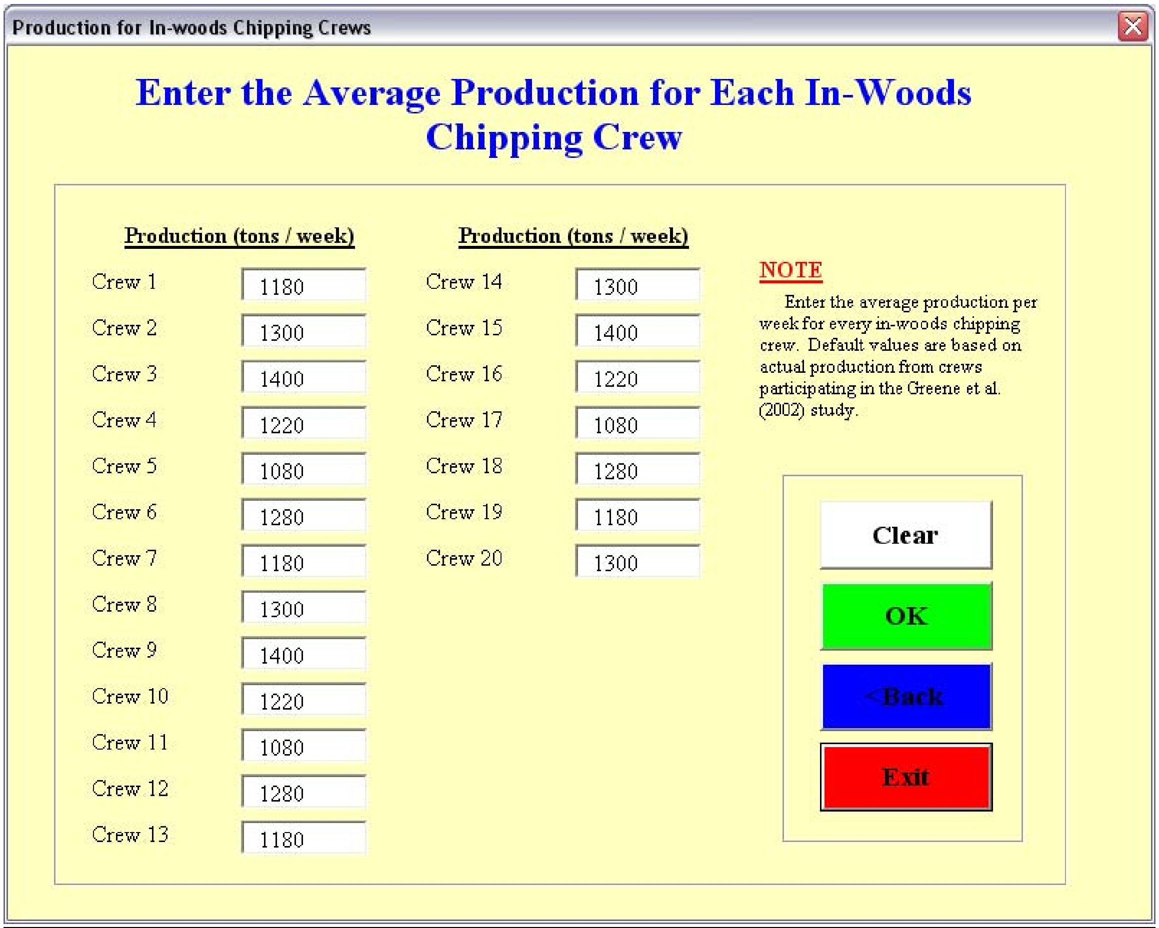


Figure D14. “In-Woods Chipping Crews Production” form.

In-Woods Chipping Crews Fixed Costs

The “In-Woods Chipping Crews Fixed Costs” form is almost identical to the "Tree-length Logging Crews Fixed Costs" form, only the labels differ (Figure D15). For details on completing this form see "Tree-length Logging Crews Fixed Costs" form (p.91). Upon completion of this form press the “OK” button and the “In-Woods Chipping Crews Variable Costs” form will be displayed.

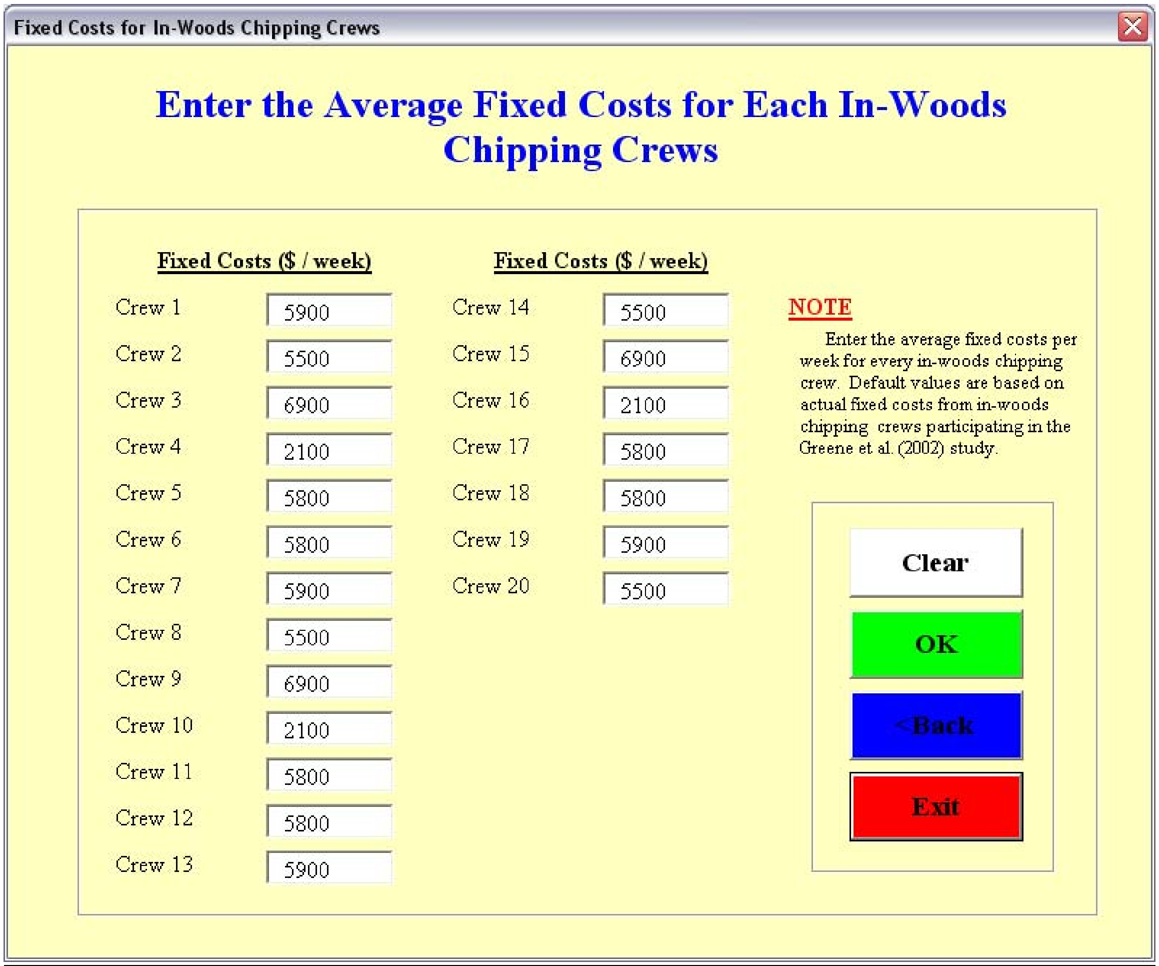


Figure D15. “In-Woods Chipping Crews Fixed Costs” form.

In-Woods Chipping Crews Variable Costs

The “In-Woods Chipping Crews Variable Costs” form is almost identical to the "Tree-length Logging Crews Variable Costs" form, the only difference are the labels (Figure D16). For details on completing this form see "Tree-length Logging Crews Variable Costs" form (p.92). Upon completion of this form press the “OK” button. If you have specified only tree length logging crews and/or in-woods chipping crews on the “Contract Suppliers Information” form then the “Mill Usage” form will be displayed (p.99). If you specified any wood dealers then the “Amount Supplied by Wood Dealers” form will be displayed (p.96). Otherwise the “Amount Supplied by Other Facilities” form will be displayed (p.98).

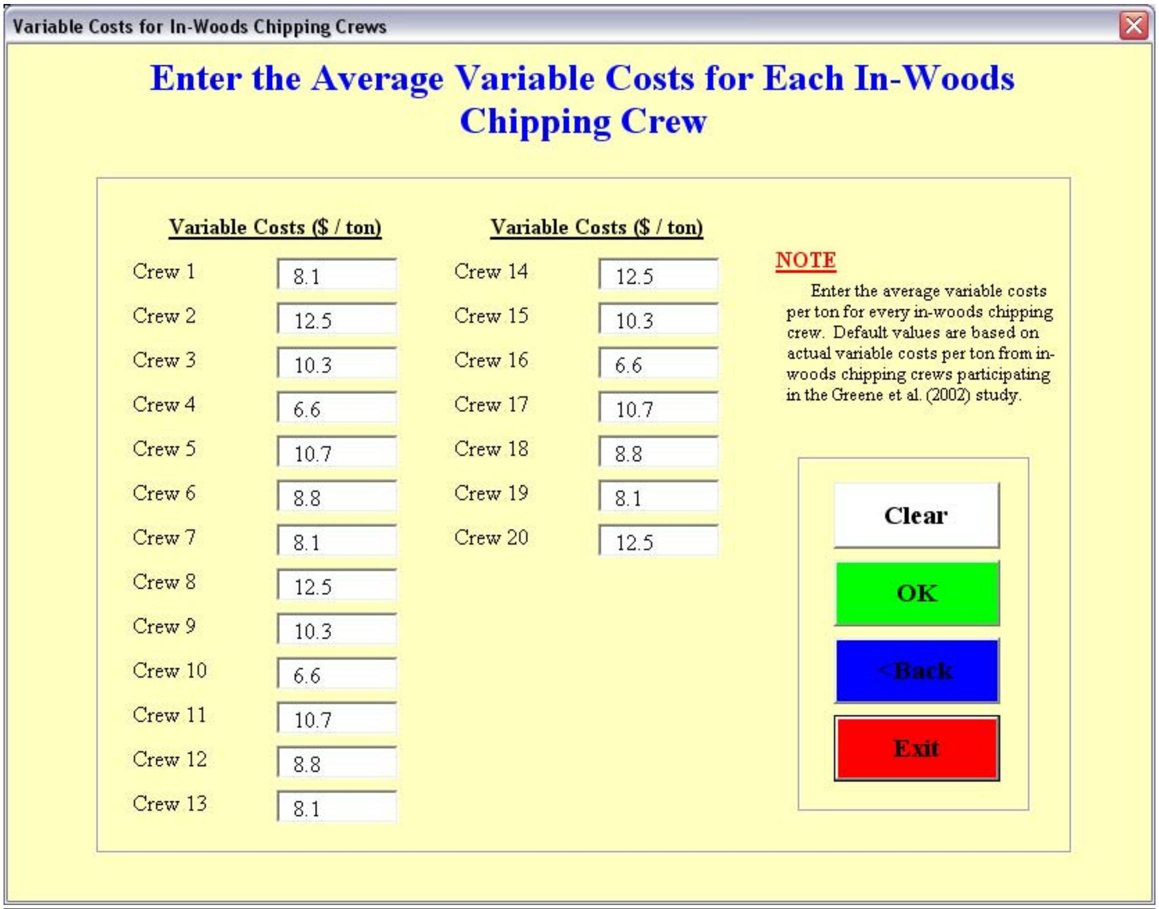


Figure D16. “In-Woods Chipping Contractors Variable Costs” form.

Amount Supplied by Wood Dealers

The “Amount Supplied by Wood Dealers” form allows you to enter the average amount supplied (tons) per week by each wood dealer (Figure D17). On this form, there will be one text box displayed for each wood dealer. In Figure D17, the number of wood dealers specified on the “Contract Suppliers Information” form was nine. Therefore, nine text boxes, labeled “Wood Dealer 1” through “Wood Dealer 9” were displayed.

Please note that the amount entered for each wood dealer will be used throughout the simulation, meaning you cannot vary the amount supplied by each wood dealer for each week. Upon completion of this form press the "OK" button and the "Tier Pricing for Wood Dealer 1" form will be displayed.

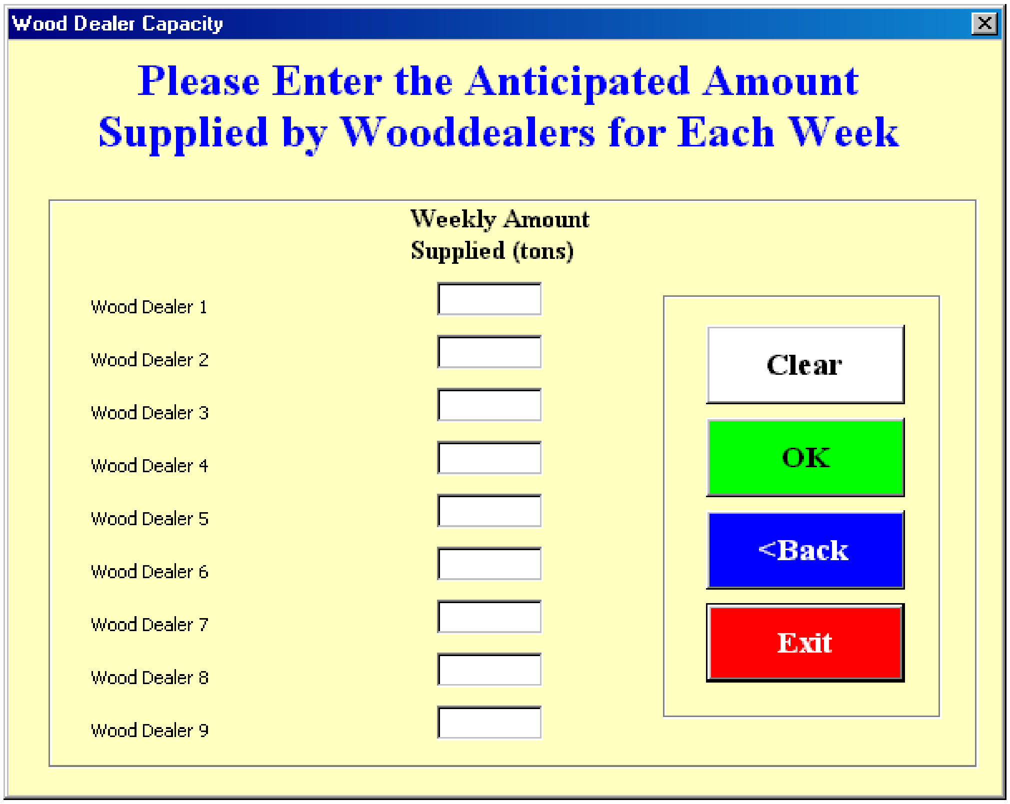


Figure D17. “Amount Supplied by Wood Dealers” form.

Tier Pricing for Wood Dealer Forms

The “Tier Pricing for Wood Dealer (1-9)” forms are almost identical to the "Tier Pricing for Gatewood Quarter (1-4)" forms, only the labels differ (Figure D18). For details on completing this form see "Tier Pricing for Gatewood Quarter (1-4)" forms (p.88). Upon completion of the form press the "OK" button. If you have more than one wood dealer you will be presented with an identical form for each wood dealer. If you have no more wood dealers and no other facilities then the "Mill Usage” form will be displayed (p.99). Otherwise, the next form displayed will be the "Amount Supplied by Other Facilities" form (p.96).

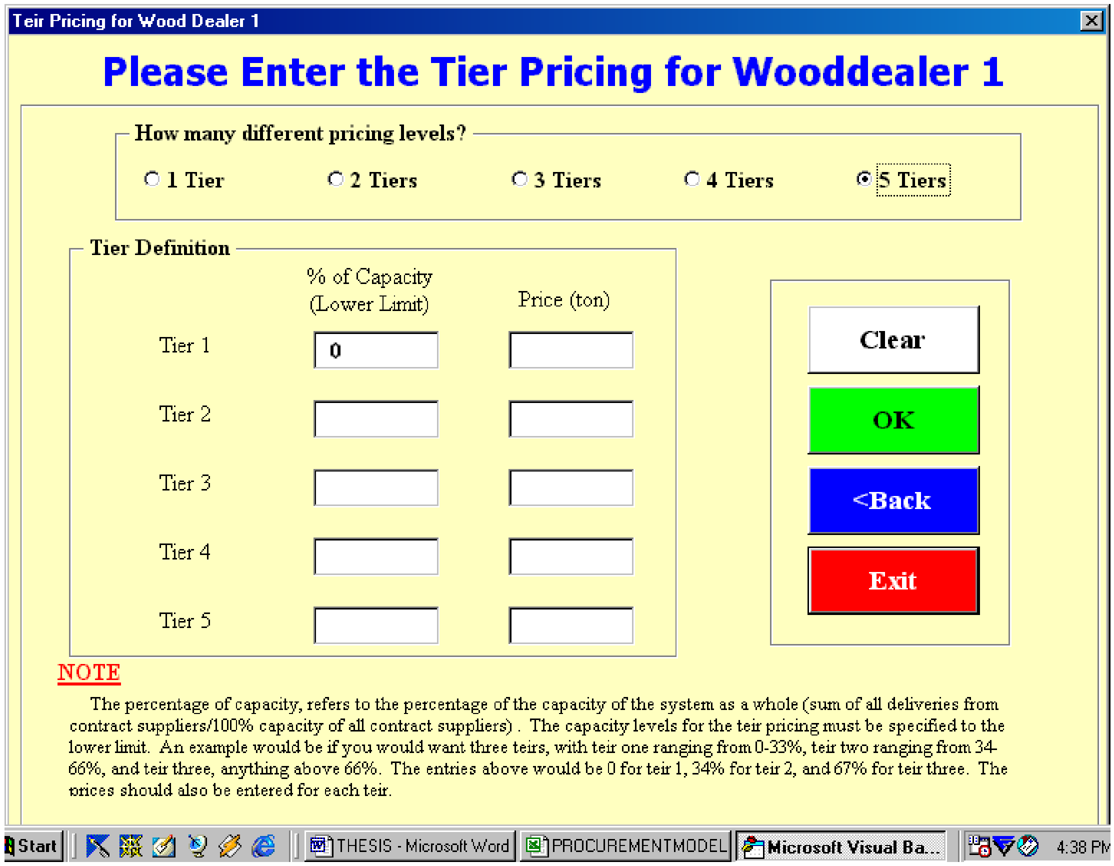


Figure D18. “Tier Pricing for Wood Dealer1” form.

Amount Supplied by Other Facilities

The “Amount Supplied by Other Facilities” form is almost identical to the "Amount Supplied by Wood Dealers" form, only the labels differ (Figure D19). On the form, there will be one text box displayed for each facility used. In Figure D19, the number of facilities specified on the “Contract Suppliers Information” form was nine. Therefore, nine text boxes labeled “Facility 1” through “Facility 9” were displayed. For details on completing this form see "Amount Supplied by Wood Dealers" form (p.96). Upon completion press the "OK" button and the "Tier Pricing for Facility 1" form will be displayed.

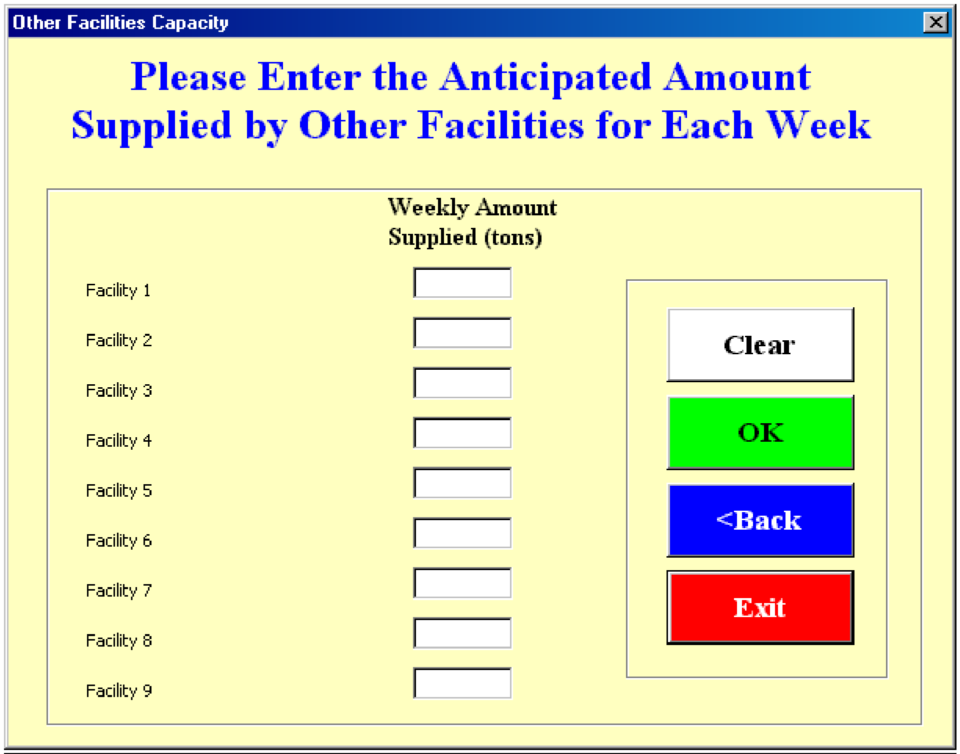


Figure D19. “Amount Supplied by Other Facilities” form.

Tier Pricing for Facility Forms

The “Tier Pricing for Facility (1-9)” forms are almost identical to the "Tier Pricing for Gatewood Quarter (1-4)" forms, only the labels differ (Figure D20). For details on completing this form see "Tier Pricing for Gatewood Quarter (1-4)" forms (p.88). Upon completion press the "OK" button, if you specified more than one facility on the “Contract Suppliers Information” form, then an identical form will be displayed for each facility. Otherwise, the "Mill Usage” form will be displayed.

Mill Usage

The "Mill Usage" form allows you to enter a positive numeric value greater than or equal to zero for the mill usage (tons) within every given week of the simulation (Figure D21). Displayed on the form is a text box for every week of the simulation. This allows you to alter mill usage to take into account mandatory shutdowns and holidays. In Figure D21 the number of weeks entered in the "Beginning and Ending Week" form was 13 for the beginning week and 27 for the ending week.

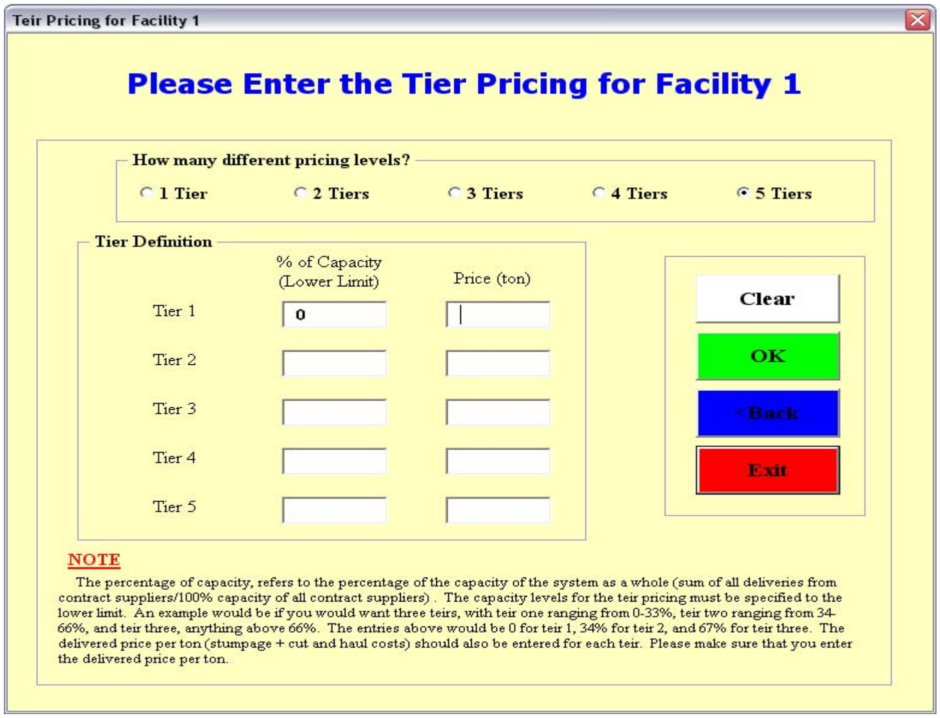


Figure D20. “Tier Pricing for Facility1” form.

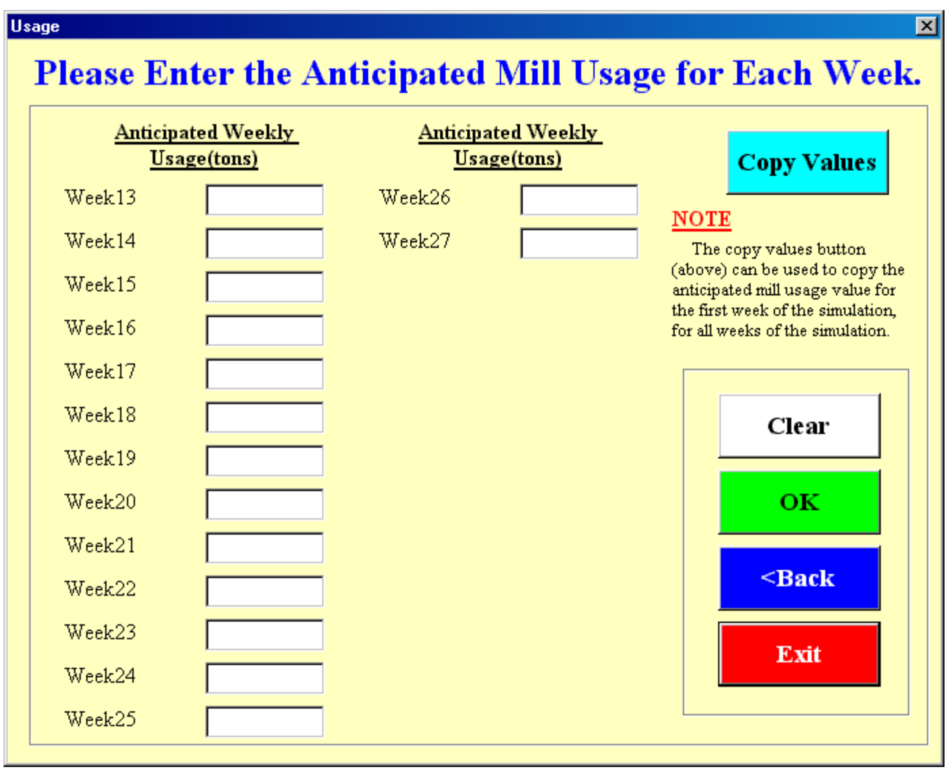


Figure D21. “Tier Pricing for Gatewood Quarter1” form.

Within this form you are given the option to copy the value in the first text box to all of the remaining text boxes.

Option: Copy Values. This option allows you to enter the same value for mill usage for every week. If you wish to specify the same value for every week, enter a value in the first week's text box and press the "Copy Values" button (Figure D22). This will fill in every text box with the value that you specified for the first week.

Upon completion of this form press "OK" and the "Target Inventory" form will be displayed.

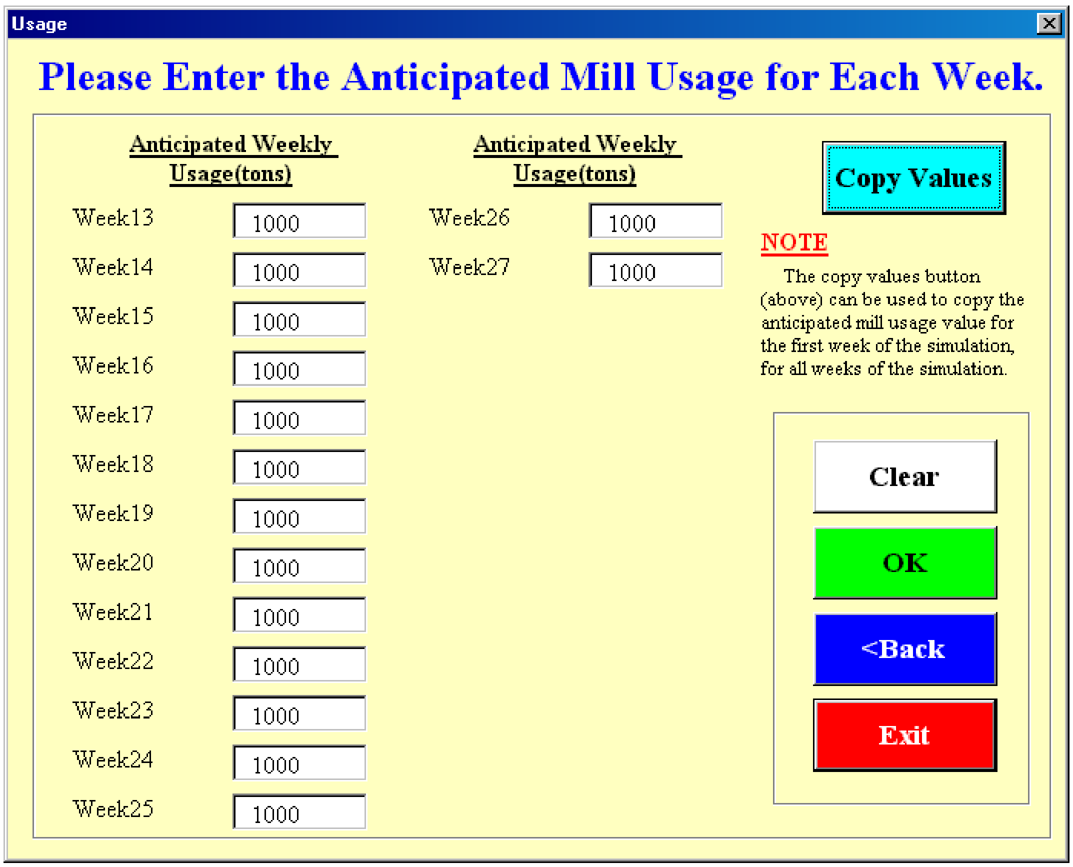


Figure D22. The "Mill Usage" form as seen after the “Copy Values” option button is pressed.

Target Inventory

The "Target Inventory" form is very similar to the "Mill Usage" form (p. 99), and allows you to enter a positive numeric value greater than or equal to zero for target inventory levels within each week of the simulation (Figure D23). One text box is displayed for every week of the simulation. This allows you to vary the target inventory so as simulate the building and liquidating of inventory from week to week. Within this form you are also given an option to copy the value in the first text box to all of the remaining text boxes. Upon completion of this form press "OK" and the "Number of Iterations" form will be displayed.

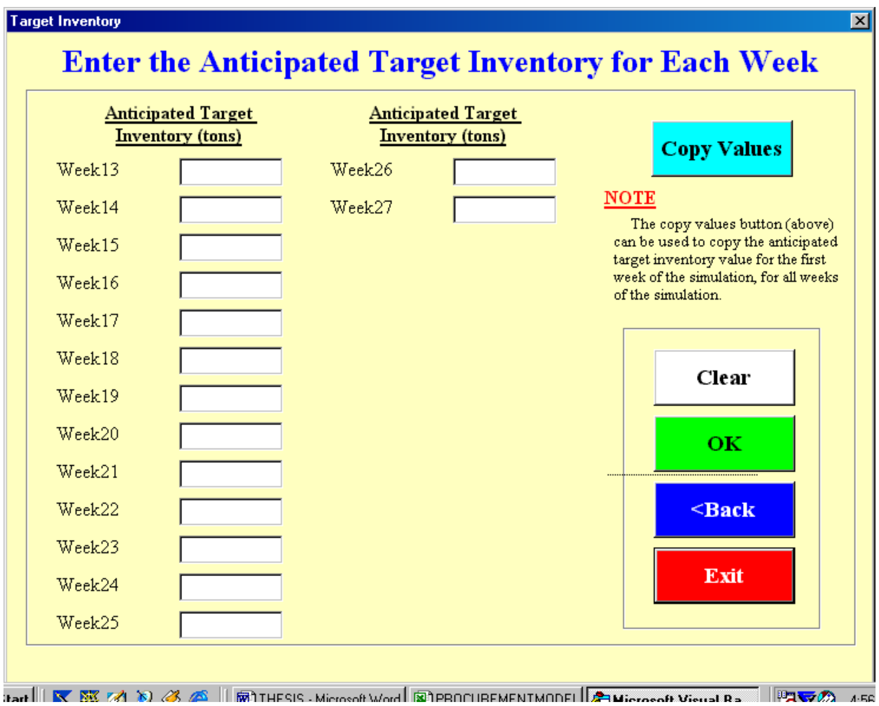


Figure D23. “Target Inventory" form.

Number of Iterations

The "Number of Iterations" form allows you to specify the number of iterations that you wish the simulation to conduct (Figure D24). This number has to be between 1 and 10,000. Please note that the more iterations that you specify, the longer it will take to complete the simulation. Upon entering the number of iterations, press "OK" and the "Random Number Generator Seed" form will be displayed.

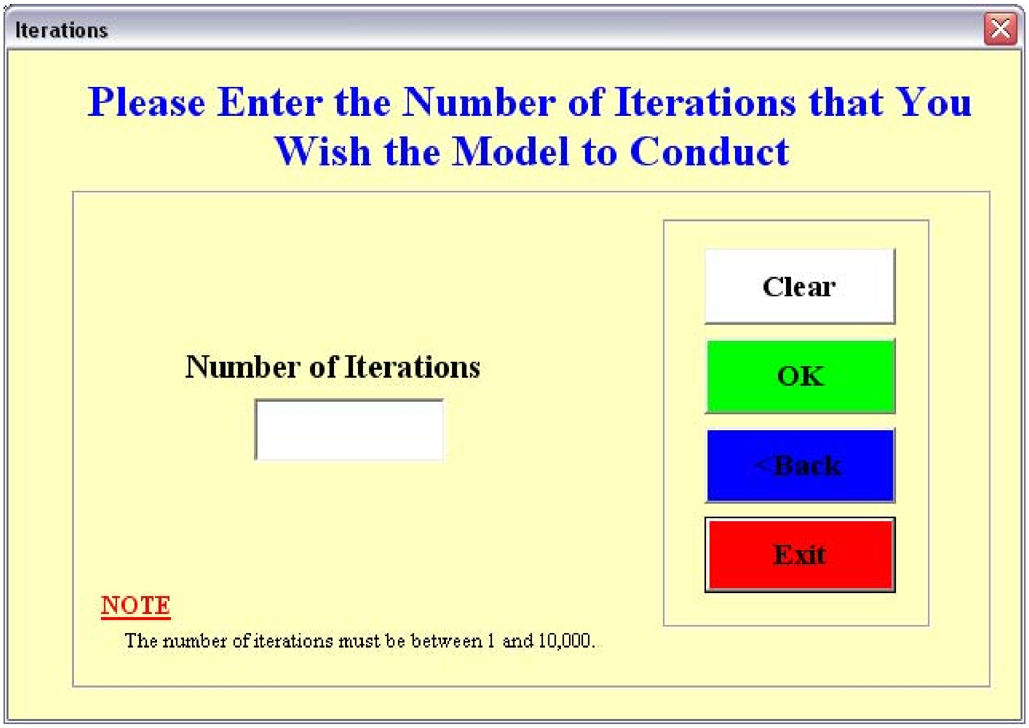


Figure D24. “Number of Iterations" form.

Random Number Generator Seed

The "Random Number Generator Seed" form allows you to enter the random number seed that you wish the simulation to use (Figure D25). If you want to obtain the same results for a given simulation, then you must use the same random number seed. By using the same random number seed, the simulation starts generating random numbers using the same sequence as the previous simulation. If you do not wish to specify a random number seed, enter zero in the text box and the computer will choose the random number seed to be used. Upon completion press the "OK" button and the "Run Simulation" form will be displayed.

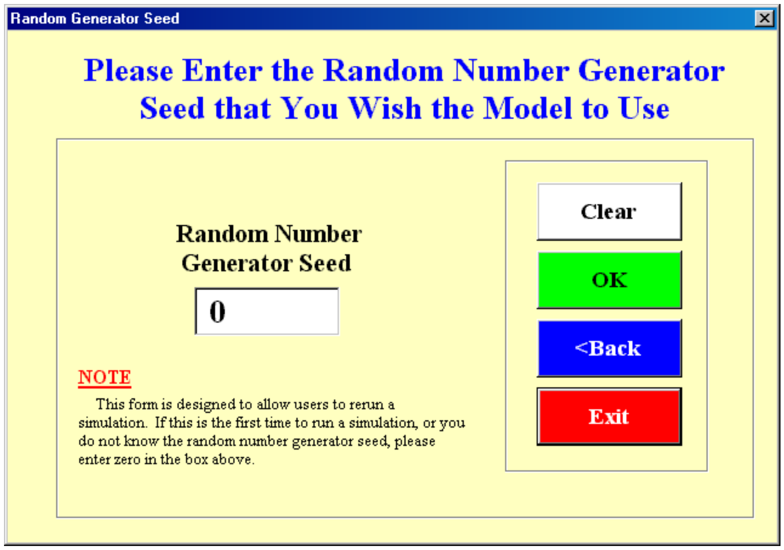


Figure D25. Random Number Generator Seed" form.

Run Simulation

The "Run Simulation" form contains the button to start the simulation phase (Figure D26). Before starting the simulation, make sure that all inputs have been entered correctly, for when the simulation starts no corrections can be made to the inputs. To make corrections use the "Back" button to go to the desired form, and correct the errors. To start the simulation phase press the "Run Simulation" button, and proceed to Chapter 4 for details.

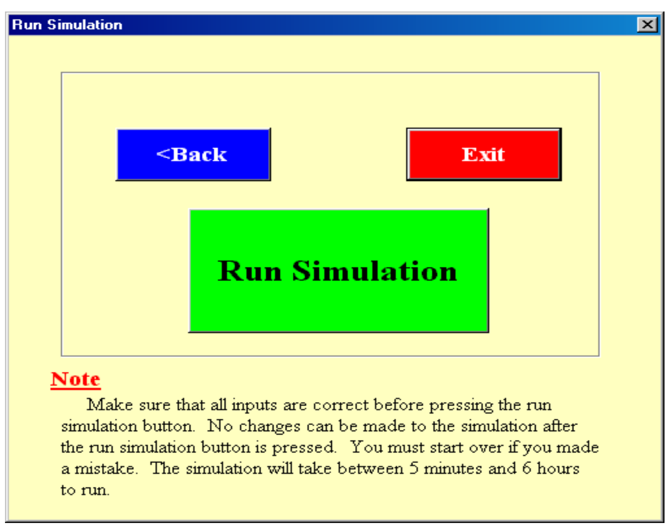


Figure D26. “Run Simulation" form.

CHAPTER 4. SIMULATION

The simulation phase begins immediately after you press the "Run Simulation" button contained within the "Run Simulation" form (Figure D26). This phase of the model takes between 5 minutes and 6 hours to complete, depending on the number of contract suppliers, length of simulation, and the speed of your computer. During the simulation stage two steps take place, 1) the creation and completion of several worksheets; and 2) the simulation.

The first step in the simulation phase is the completion of several worksheets that were created when the model was started. During this process the "Run Simulation" form will be displayed, and will appear as nothing is happening. Don't worry; the GWPM is creating the procurement systems for the four different procurement strategies, based on your inputs.

The second step will start when the procurement systems for the four different strategies have been created. You will know when this step begins, because the @Risk® "Simulating…" box will appear in the lower left hand corner of the screen. This box will display the progress of the simulation. Upon completion of this process, the GWPM will complete the “Summary” worksheet based on the results from the @Risk® simulation, and unload all of the user forms, displaying to you the "SummaryReport" worksheet. For details on interpreting the results, see Chapter 5.

CHAPTER 5. RESULTS

You have just completed a simulation of your facility's wood procurement system. Contained within the "PROCUREMENTMODEL" workbook should be nine new worksheets, listed in order from left to right:

1) Input
2) Tables
3) Production_Force
4) Split_Evenly
5) Split_Fixed_Costs
6) Split_Ave_Wk_Production
7) Full_Capacity
8) Summary
9) SummaryReport.

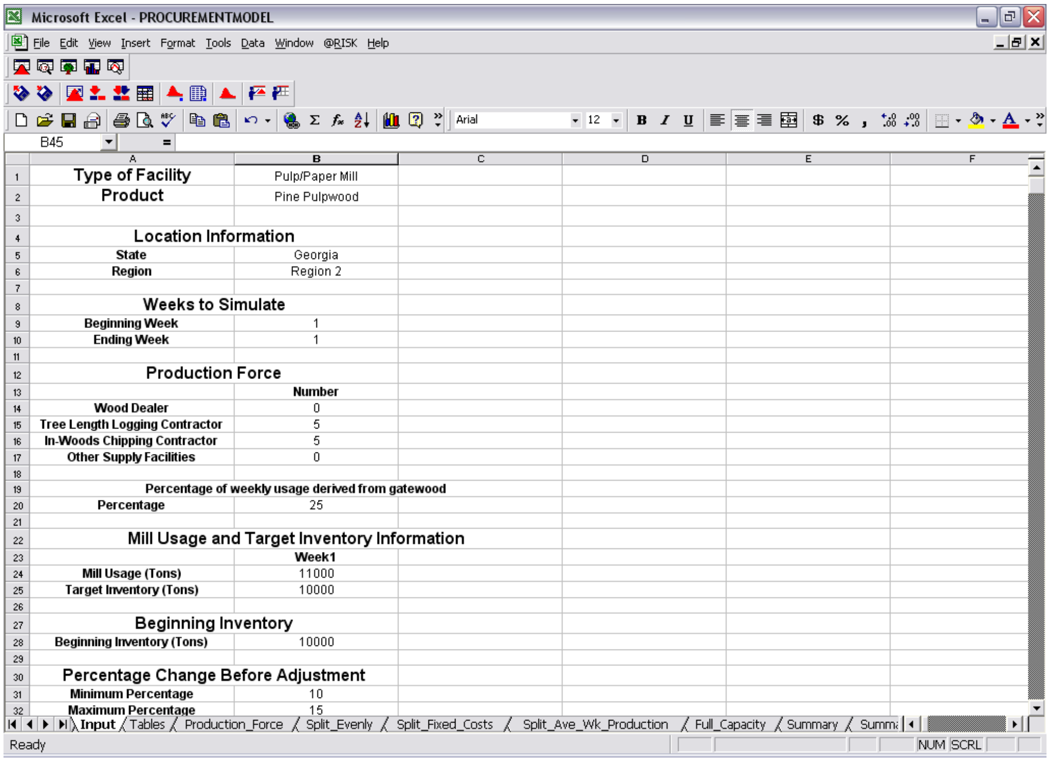
This chapter will describe and interpret in detail the contents of each worksheet.

Input

The "Input" worksheet contains a list of many of the inputs provided during the input phase of the model (Figure D27). Those inputs not contained within this worksheet, are contained within the "Tables" and "Summary" worksheets.

Tables

The "Tables" worksheet contains inputs not contained within the "Input" worksheet. Included within this worksheet are stumpage prices, gatewood tier pricing, and average production, fixed costs per week, and variable cost per ton for each tree-length logging and in-woods chipping crew (Figure D28). In addition to containing some of the inputs, this worksheet also contains a table entitled "Gatewood Production Adjustments."

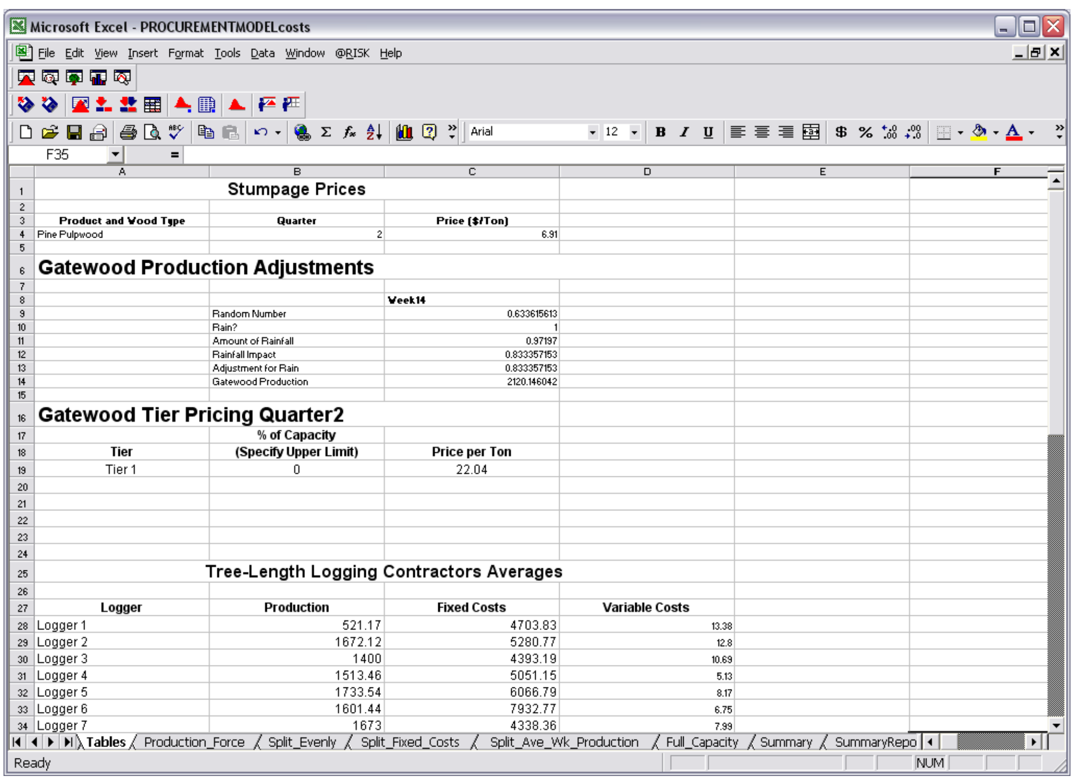


Microsoft Excel - PROCUREMENTMODEL

	A	B
1	Type of Facility	Pulp/Paper Mill
2	Product	Pine Pulpwood
3		
4	Location Information	
5	State	Georgia
6	Region	Region 2
7		
8	Weeks to Simulate	
9	Beginning Week	1
10	Ending Week	1
11		
12	Production Force	
13		Number
14	Wood Dealer	0
15	Tree Length Logging Contractor	5
16	In-Woods Chipping Contractor	5
17	Other Supply Facilities	0
18		
19	Percentage of weekly usage derived from gatewood	
20	Percentage	25
21		
22	Mill Usage and Target Inventory Information	
23		Week1
24	Mill Usage (Tons)	11000
25	Target Inventory (Tons)	10000
26		
27	Beginning Inventory	
28	Beginning Inventory (Tons)	10000
29		
30	Percentage Change Before Adjustment	
31	Minimum Percentage	10
32	Maximum Percentage	15

Input / Tables / Production_Force / Split_Evenly / Split_Fixed_Costs / Split_Ave_Wk_Production / Full_Capacity / Summary / Summ

Figure D27. “Input” worksheet.



Microsoft Excel - PROCUREMENTMODELcosts

Stumpage Prices

Product and Wood Type	Quarter	Price ($/Ton)
Pine Pulpwood	2	6.91

Gatewood Production Adjustments

	Week14
Random Number	0.633615613
Rain?	1
Amount of Rainfall	0.97197
Rainfall Impact	0.833357153
Adjustment for Rain	0.833357153
Gatewood Production	2120.146042

Gatewood Tier Pricing Quarter2

Tier	% of Capacity (Specify Upper Limit)	Price per Ton
Tier 1	0	22.04

Tree-Length Logging Contractors Averages

Logger	Production	Fixed Costs	Variable Costs
Logger 1	521.17	4703.83	13.38
Logger 2	1672.12	5280.77	12.8
Logger 3	1400	4393.19	10.69
Logger 4	1513.46	5051.15	5.13
Logger 5	1733.54	6066.79	8.17
Logger 6	1601.44	7932.77	6.75
Logger 7	1673	4338.36	7.99

Tables / Production_Force / Split_Evenly / Split_Fixed_Costs / Split_Ave_Wk_Production / Full_Capacity / Summary / SummaryRepo

Figure D28. “Tables” worksheet.

The "Gatewood Production Adjustments" table displays the weather affects on gatewood production for each week of the simulation. Below is a detailed description of the table.

Row 9 (Random Number)

This is the first line of the “Gatewood Production Adjustments” table. This row contains a random number, between zero and one, generated by Microsoft Excel®. The random number is used to determine if it rains within each week.

Row 10 (Rain?)

This row determines if it rains within the week, with a 1 representing rainfall and a 0 representing no rain for the week.

Row 11 (Amount of Rainfall)

Lists the amount rainfall for the week. Rainfall is shown for each week, whether it rains or not, with the rainfall line only being used when the "Rain?" line is 1.

Row 12 (Rainfall Impact)

Lists the affects that the rainfall had on gatewood production for the week.

Row 13 (Adjustment for Rain)

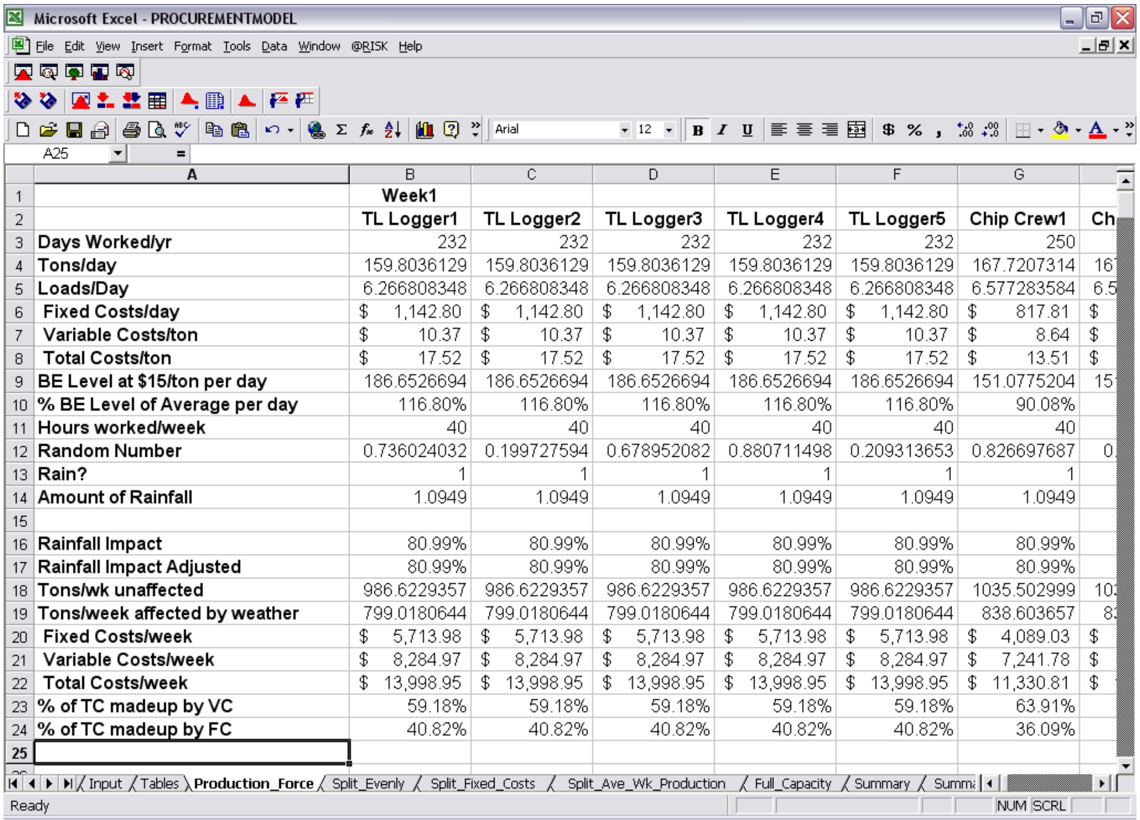
List the adjusted percentage of production allowed when the impact of rainfall is considered. This row constrains the impact of rainfall so that over- and negative production is not allowed.

Row 14 (Gatewood Production)

Lists the amount of gatewood deliveries (tons) supplied to the mill for each week.

Production_Force

The “Production_Force” worksheet contains information about every contract supplier for every week, assuming that the contract suppliers were working at full capacity levels, or 40 hours per week (Figure D29). In Figure D29, only logging contractors were used. The information contained in this worksheet is used in all of the following worksheets. Below is a detailed description of this worksheet.



	A	B	C	D	E	F	G	
1		Week1						
2		TL Logger1	TL Logger2	TL Logger3	TL Logger4	TL Logger5	Chip Crew1	Ch
3	Days Worked/yr	232	232	232	232	232	250	
4	Tons/day	159.8036129	159.8036129	159.8036129	159.8036129	159.8036129	167.7207314	16
5	Loads/Day	6.266808348	6.266808348	6.266808348	6.266808348	6.266808348	6.577283584	6.5
6	Fixed Costs/day	$ 1,142.80	$ 1,142.80	$ 1,142.80	$ 1,142.80	$ 1,142.80	$ 817.81	$
7	Variable Costs/ton	$ 10.37	$ 10.37	$ 10.37	$ 10.37	$ 10.37	$ 8.64	$
8	Total Costs/ton	$ 17.52	$ 17.52	$ 17.52	$ 17.52	$ 17.52	$ 13.51	$
9	BE Level at $15/ton per day	186.6526694	186.6526694	186.6526694	186.6526694	186.6526694	151.0775204	15
10	% BE Level of Average per day	116.80%	116.80%	116.80%	116.80%	116.80%	90.08%	
11	Hours worked/week	40	40	40	40	40	40	
12	Random Number	0.736024032	0.199727594	0.678952082	0.880711498	0.209313653	0.826697687	0.
13	Rain?	1	1	1	1	1	1	
14	Amount of Rainfall	1.0949	1.0949	1.0949	1.0949	1.0949	1.0949	
15								
16	Rainfall Impact	80.99%	80.99%	80.99%	80.99%	80.99%	80.99%	
17	Rainfall Impact Adjusted	80.99%	80.99%	80.99%	80.99%	80.99%	80.99%	
18	Tons/wk unaffected	986.6229357	986.6229357	986.6229357	986.6229357	986.6229357	1035.502999	10
19	Tons/week affected by weather	799.0180644	799.0180644	799.0180644	799.0180644	799.0180644	838.603657	8
20	Fixed Costs/week	$ 5,713.98	$ 5,713.98	$ 5,713.98	$ 5,713.98	$ 5,713.98	$ 4,089.03	$
21	Variable Costs/week	$ 8,284.97	$ 8,284.97	$ 8,284.97	$ 8,284.97	$ 8,284.97	$ 7,241.78	$
22	Total Costs/week	$ 13,998.95	$ 13,998.95	$ 13,998.95	$ 13,998.95	$ 13,998.95	$ 11,330.81	$
23	% of TC madeup by VC	59.18%	59.18%	59.18%	59.18%	59.18%	63.91%	
24	% of TC madeup by FC	40.82%	40.82%	40.82%	40.82%	40.82%	36.09%	
25								

Figure D29. “Production_Force” worksheet.

<u>Row 1</u>

Lists the week number.

<u>Row 2</u>

Lists the type of contract supplier.

<u>Row 3 (Days Worked/yr)</u>

Lists the average number of days worked per year by the type of contract supplier.

<u>Row 4 (Tons/day)</u>

Lists the number of tons produced per day by each supplier, assuming a five-day work week.

<u>Row 5 (Loads/Day)</u>

Lists the number of loads produced per day by each supplier. These numbers were determined by dividing the tons produced per day for a given supplier by 25.5 tons per load.

Row 6 (Fixed Costs/day)

Lists the fixed costs per day for each supplier. These numbers are found by dividing the fixed costs per week by five.

Row 7 (Variable Costs/ton)

Lists the variable costs per ton for each supplier and week. These numbers are based on either the number entered for average variable costs or the default values.

Row 8 (Total Costs/ton)

Lists the total costs per ton for each supplier and week. The total cost per ton is found by dividing total costs for the week and supplier by the number of tons produced in the week by the given supplier.

Row 9 (BE Level at $15/ton per day)

Lists for each supplier and week the break-even level of production, assuming a pay rate of $15 per ton.

Row 10 (% BE Level of Average per day)

Lists for each supplier and week the percentage of total daily production comprised by the break-even amount, assuming a pay rate of $15 per ton.

Row 11 (Hours worked/week)

Lists forty hours worked per week. Forty hours is assumed to be the number of hours worked per week under full-capacity situations.

Row 12 (Random #)

Lists a randomly generated number between one and zero. These numbers are used to determine if it rains in the area for that supplier and week.

Row 13 (Rain?)

Lists whether or not it rained in the area for that supplier and week. The rainfall occurrence is determined for each supplier by using the randomly generated number and probabilities of rainfall occurrence derived from 103 years worth of National Climatic Data Center precipitation data. If it rained within a given week, one is displayed otherwise zero is displayed.

<u>Row 14 (Amount of Rainfall)</u>

Lists the amount of rainfall in the area for each supplier and week. An amount of rain appears for each supplier regardless of whether or not it rains. However, only if a one appears in the "Rain?" row will the model use the amount of rainfall for that week.

<u>Row 15 (blank)</u>

Designated as a separation between weekly and daily data.

<u>Row 16 (Rainfall Impact)</u>

List the percentage of production allowed when the impact of rainfall is considered.

<u>Row 17 (Rainfall Impact Adjusted)</u>

List the adjusted percentage of production allowed when the impact of rainfall is considered. This row constrains the impact of rainfall so that over- and negative production is not allowed.

<u>Row 18 (Tons/wk unaffected)</u>

Lists the amount of production for each supplier and week if there were no weather affects taken into consideration.

<u>Row 19 (Tons/wk affected by weather)</u>

Lists the amount of production for each supplier and week when weather affects are taken into consideration. These values are assumed to be the average weekly production for each supplier and week.

<u>Row 20 (Fixed Costs/week)</u>

Lists the fixed costs per week for each supplier and week. These numbers are based on either the numbers entered for average fixed costs per week or the default values.

<u>Row 21 (Variable Costs/week)</u>

Lists the variable costs per week for each supplier and week. These numbers are found by multiplying the total amount produced when considering weather affects by the variable cost per ton.

<u>Row 22 (Total Costs/week)</u>

Lists the total costs per week for each supplier and week. These numbers are found by adding fixed costs and variable costs per week.

<u>Row 23 (% of TC madeup by VC)</u>

Lists for each week and supplier the percentage of total costs comprised by variable costs.

<u>Row 24 (% of TC madeup by FC)</u>

Lists for each week and supplier the percentage of total costs comprised by fixed costs.

Note: If you have wood dealers or other facilities, the only rows completed within this worksheet are:

1) Row 12 (Random #)
2) Row 13 (Rain?)
3) Row 14 (Amount of Rainfall)
4) Row 16 (Rainfall Impact)
5) Row 17 (Rainfall Impact Adjusted)
6) Row 18 (Tons/wk Unaffected)
7) Row 19 (Tons/wk Affected by Weather)

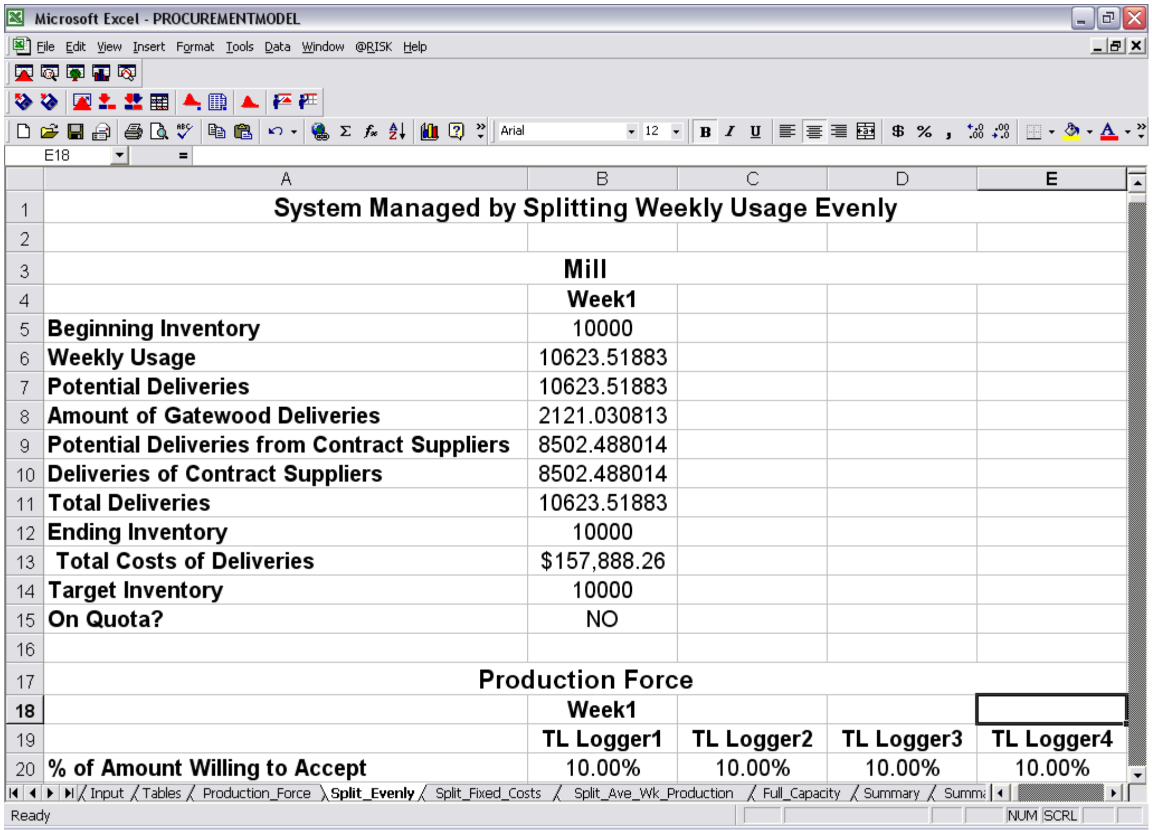
Few rows are completed because other facilities and wood dealers are assumed to only have variable costs, and wood dealers and other facilities may be comprised of multiple suppliers each with different costs. Therefore, the only detailed information that can accurately be portrayed is the adjustment of production due to weather.

Split_Evenly

The "Split_Evenly" worksheet contains your procurement system using the split evenly strategy. Therefore, if there were ten suppliers, then each supplier receives one tenth of the production accepted by the mill. This worksheet is divided into three parts, 1) mill, 2) production force and 3) summary. Contained below is a detailed description of each section.

<u>Mill</u>

This section of the "Split_Evenly" worksheet consists of mill usage, receipts, inventory levels and costs (Figure D30). In Figure D30, only one week was modeled, however, results are presented for every week of the specified simulation time. Below is a detailed description of the "Mill" section of the "Split_Evenly" worksheet.



	A	B	C	D	E
1	System Managed by Splitting Weekly Usage Evenly				
2					
3	Mill				
4		Week1			
5	Beginning Inventory	10000			
6	Weekly Usage	10623.51883			
7	Potential Deliveries	10623.51883			
8	Amount of Gatewood Deliveries	2121.030813			
9	Potential Deliveries from Contract Suppliers	8502.488014			
10	Deliveries of Contract Suppliers	8502.488014			
11	Total Deliveries	10623.51883			
12	Ending Inventory	10000			
13	Total Costs of Deliveries	$157,888.26			
14	Target Inventory	10000			
15	On Quota?	NO			
16					
17	Production Force				
18		Week1			
19		TL Logger1	TL Logger2	TL Logger3	TL Logger4
20	% of Amount Willing to Accept	10.00%	10.00%	10.00%	10.00%

Figure D30. Mill section of the “Split_Evenly” worksheet.

Row 1

Lists the title of the system.

Row 3

Lists the section of the worksheet.

Row 4

Lists the week

Row 5 (Beginning Inventory)

Lists the beginning inventory for each week. The beginning inventory for the first week is the amount that was specified in the “Beginning Inventory” form. The beginning inventory for the remaining weeks of the simulation is the ending inventory from the previous week.

Row 6 (Weekly Usage)

Lists the amount (tons) the mill used per week. These values are based on the amount specified for each week of the simulation in the “Mill Usage” form and derived probability distributions. Mill usage is considered to be a stochastic variable in this model.

Row 7 (Potential Deliveries)

Lists the total amount of deliveries accepted by the mill. These values are found by adding target inventory and mill usage, and then subtracting beginning inventory.

Row 8 (Amount of Gatewood)

Lists the amount of gatewood delivered to the mill. These values are found by multiplying mill usage by the amount enter in the “Percentage of Gatewood” form.

Row 9 (Potential Deliveries from Contract Suppliers)

Lists the amount the mill wishes to accept from contract suppliers. These values are the amount willing to accept minus gatewood deliveries.

Row 10 (Deliveries of Contract Suppliers)

Lists the actual amount delivered by contract suppliers. These values should match the “Potential Deliveries from Contract Suppliers,” except for when the “Potential Deliveries from Contract Suppliers” is greater than the amount that all of the contract suppliers can physically produce (greater than 150% logging production capacity levels).

Row 11 (Total Deliveries)

Lists the total deliveries accepted by the mill. These values are the total of the “Deliveries of Contract Suppliers” plus “Amount of Gatewood.”

Row 12 (Ending Inventory)

Lists the ending inventory for each week. These values are found by adding “Beginning Inventory” plus “Total Deliveries” minus “Mill Usage.”

Row 13 (Total Costs of Deliveries)

Lists for a given week the total costs of the deliveries to the mill. These values are found by adding for each week the costs of all of the contract suppliers plus the costs for gatewood. The costs for gatewood are found by multiplying the amount of gatewood (tons) by the difference between delivered price and stumpage price per ton for supplying gatewood.

Row 14 (Target Inventory)

Lists the target inventory level for each week. These values were specified on the "Target Inventory" form.

Row 15 (On Quota?)

Lists whether or not the contract suppliers were working at reduced logging production capacity levels. Where "Yes" means that suppliers were working at reduced capacity levels and "No" means that suppliers were not working at reduced logging production capacity levels.

Production Force

This section of the "Split_Evenly" worksheet consists of information about every individual contract supplier for each week, including amount of production allocated, logging production capacity, production, and costs for each supplier (Figure D31). In Figure D31, there were ten tree-length logging crews that comprised the production force, however, only four are shown. Below is a detailed description of the "Production Force" section of the "Split_Evenly" worksheet.

Row 17

Lists the section of the worksheet.

Row 18

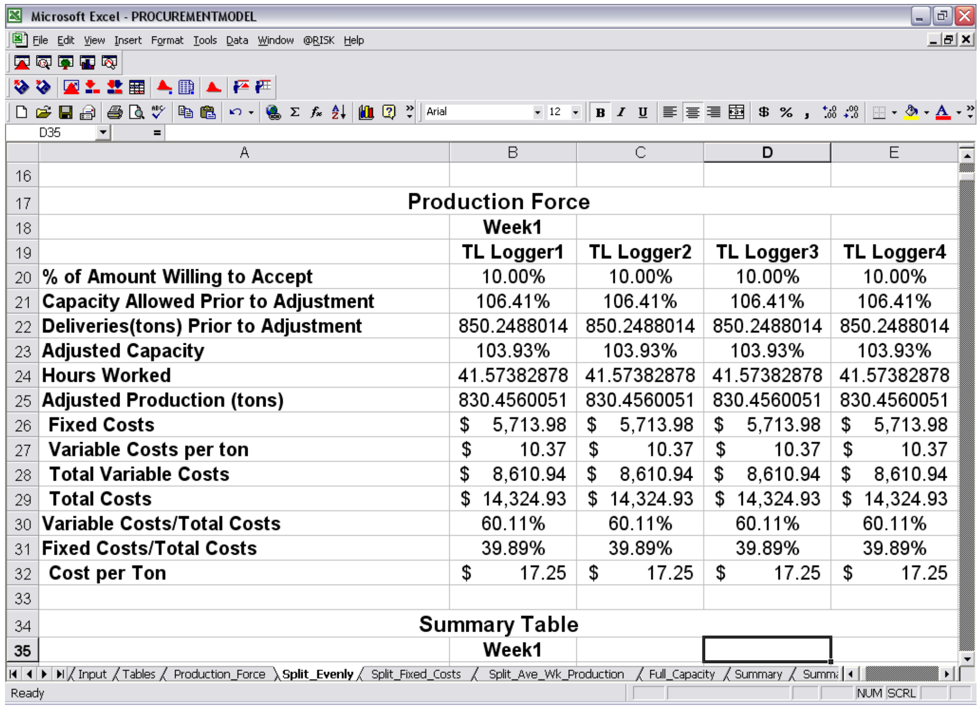
Lists the week.

Row 19

Lists the type of contract supplier.

Row 20 (% Amount Willing to Accept)

Lists the percentage of production allocated to each contract supplier. In Figure D31 the value for all of the suppliers was 10.00% because production was allocated evenly among suppliers and there were ten suppliers. If a given supplier is affected by weather to the extent that they cannot produce anything in a given week then 0.00% is displayed.



	A	B	C	D	E
16					
17	Production Force				
18		Week1			
19		TL Logger1	TL Logger2	TL Logger3	TL Logger4
20	% of Amount Willing to Accept	10.00%	10.00%	10.00%	10.00%
21	Capacity Allowed Prior to Adjustment	106.41%	106.41%	106.41%	106.41%
22	Deliveries(tons) Prior to Adjustment	850.2488014	850.2488014	850.2488014	850.2488014
23	Adjusted Capacity	103.93%	103.93%	103.93%	103.93%
24	Hours Worked	41.57382878	41.57382878	41.57382878	41.57382878
25	Adjusted Production (tons)	830.4560051	830.4560051	830.4560051	830.4560051
26	Fixed Costs	$ 5,713.98	$ 5,713.98	$ 5,713.98	$ 5,713.98
27	Variable Costs per ton	$ 10.37	$ 10.37	$ 10.37	$ 10.37
28	Total Variable Costs	$ 8,610.94	$ 8,610.94	$ 8,610.94	$ 8,610.94
29	Total Costs	$ 14,324.93	$ 14,324.93	$ 14,324.93	$ 14,324.93
30	Variable Costs/Total Costs	60.11%	60.11%	60.11%	60.11%
31	Fixed Costs/Total Costs	39.89%	39.89%	39.89%	39.89%
32	Cost per Ton	$ 17.25	$ 17.25	$ 17.25	$ 17.25
33					
34	Summary Table				
35		Week1			

Figure D31. Production Force section of the "Split_Evenly" worksheet.

<u>Row 21 (Capacity Allowed Prior to Adjustment)</u>

Lists the logging production capacity utilized by the system for each supplier. These values were based on the amount of production allocated to them in row 20. Suppliers having 100.00% displayed in this row indicate that they are producing at full capacity levels (working 40-hours per week). If a given supplier is affected by weather to the extent that they cannot produce anything in a given week then 0.00% is displayed.

<u>Row 22 (Deliveries (tons) Prior to Adjustments)</u>

Lists the tons each supplier must produce based on the amount of production allocated to them in row 20. If a given supplier is affected by weather to the extent that they cannot produce anything in a given week then zero is displayed.

<u>Row 23 (Adjusted Capacity)</u>

Lists the logging production capacity of each supplier after adjustments have been made. This is the actual logging production capacity for each supplier being utilized by the system. The adjusted logging production capacity makes sure that: 1) no one supplier is working over capacity unless all suppliers are working over capacity; 2) all excess production for a given supplier is redistributed among the remaining suppliers evenly;

and 3) no one supplier is working over 150 percent of their logging production capacity (physically impossible). The process of adjusting capacity can be seen below the "Summary" section on this worksheet. The values in this row will range from 0-150 percent. If a given supplier is affected by weather to the extent that they cannot produce anything in a given week then 0.00% is displayed.

Row 24 (Hours Worked)

Lists the number of hours worked by each type of contract supplier. If the type of contract supplier is a wood dealer or other facility, then these cells are blank, for the number of hours worked by these types of suppliers is unknown. If a given supplier is affected by weather to the extent that they cannot produce anything in a given week then zero is displayed.

Row 25 (Adjusted Production (tons))

Lists the actual tons produced by each contract supplier. These values are found by multiplying the "Adjusted Capacity" values by the production of each supplier assuming full-capacity levels. If a given supplier is affected by weather to the extent that they cannot produce anything in a given week then zero is displayed.

Row 26 (Fixed Costs)

Lists the fixed costs for each contract supplier. For wood dealers and other facilities these cells are blank, because these producers are assumed to only have variable costs. If a given supplier is affected by weather to the extent that they cannot produce anything in a given week then zero is displayed.

Row 27 (Variable Costs per ton)

Lists the variable costs per ton for each contract supplier. If a given supplier is affected by weather to the extent that they cannot produce anything in a given week then zero is displayed.

Row 28 (Total Variable Costs)

Lists the total variable costs for each contract supplier. These values are found by multiplying "Variable Cost per ton" by "Adjusted Production (tons)."

Row 29 (Total Costs)

Lists the total costs for each contract supplier. These values are found by adding "Total Variable Cost" to "Fixed Costs."

Row 30 (Variable Costs/Total Costs)

Lists the percentage of total costs comprised by variable costs for each supplier and week. If a given supplier is affected by weather to the extent that they cannot produce anything in a given week then 0.00% is displayed.

Row 31 (Fixed Costs/Total Costs)

Lists the percentage of total costs comprised by fixed costs for each supplier and week. If a given supplier is affected by weather to the extent that they cannot produce anything in a given week then 0.00% is displayed.

Row 32 (Costs per ton)

Lists the average cost per ton for each supplier.

Summary

This section of the "Split_Evenly" worksheet contains a summary of the procurement system created, including the capacity of the system, average hours worked, whether or not the suppliers were working at reduced capacity levels and the average cost per ton (Figure D32). In Figure D32, only one week has been modeled, however, results are presented for every week of the specified simulation time period. Below is a detailed description of the "Summary" section of the "Split_Evenly" worksheet.

Row 34

Lists the section of the worksheet.

Row 35

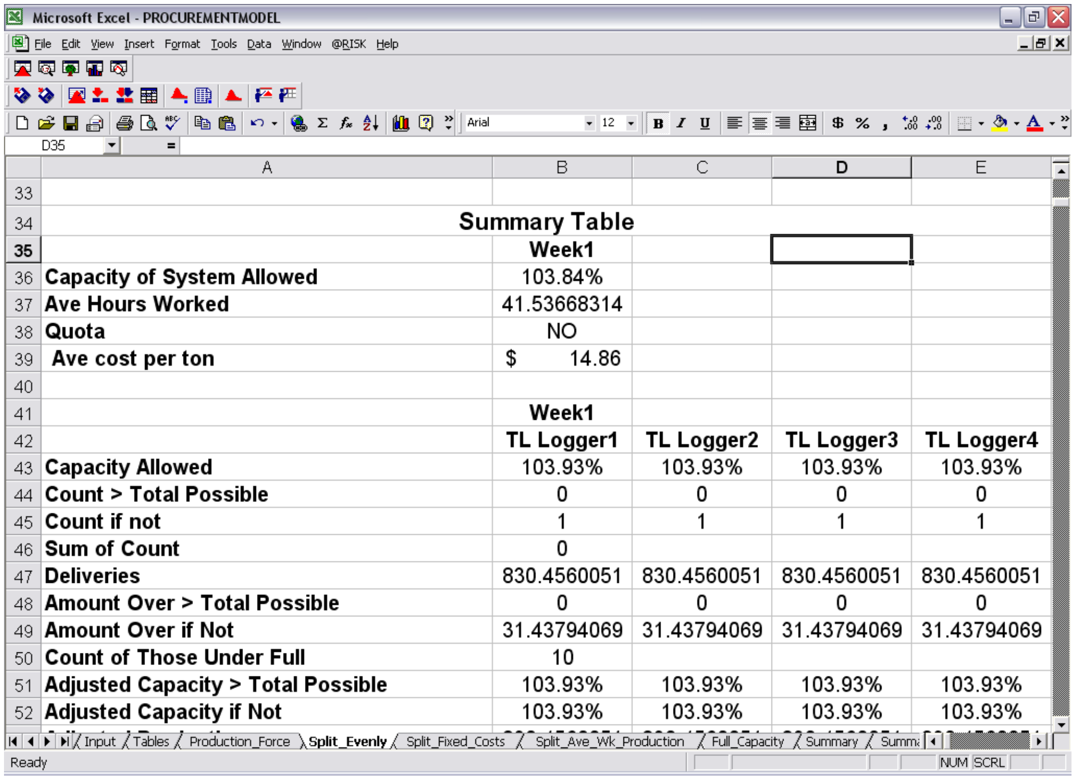
Lists the week.

Row 36 (Capacity of the System Allowed)

Lists the logging production capacity utilized by the mill. These values are found by dividing the "Deliveries of Contract Suppliers" by the total possible production of all of the contractor suppliers working at full capacity levels. If this value equals 100 percent, then the mill is fully utilizing all of logging production capacity of the system.

Row 37 (Ave Hours Worked)

Lists the average hours worked by tree-length logging and in-woods chipping crews.



	A	B	C	D	E
33					
34		Summary Table			
35		Week1			
36	Capacity of System Allowed	103.84%			
37	Ave Hours Worked	41.53668314			
38	Quota	NO			
39	Ave cost per ton	$ 14.86			
40					
41		Week1			
42		TL Logger1	TL Logger2	TL Logger3	TL Logger4
43	Capacity Allowed	103.93%	103.93%	103.93%	103.93%
44	Count > Total Possible	0	0	0	0
45	Count if not	1	1	1	1
46	Sum of Count	0			
47	Deliveries	830.4560051	830.4560051	830.4560051	830.4560051
48	Amount Over > Total Possible	0	0	0	0
49	Amount Over if Not	31.43794069	31.43794069	31.43794069	31.43794069
50	Count of Those Under Full	10			
51	Adjusted Capacity > Total Possible	103.93%	103.93%	103.93%	103.93%
52	Adjusted Capacity if Not	103.93%	103.93%	103.93%	103.93%

Figure D32. Summary section of the "Split_Evenly" worksheet.

<u>Row 38 (Quota)</u>

Lists whether or not the contract suppliers are working at reduced logging production capacity levels. Where "Yes" means that suppliers are working at reduced capacity levels and "No" means that suppliers are not working at reduced logging production capacity levels.

<u>Row 39 (Ave cost per Ton)</u>

Lists the average cost per ton for the wood procurement system.

Split_Fixed_Costs

The "Split_Fixed_Costs" worksheet contains the procurement system using the fixed cost strategy. This worksheet is divided into three parts just like the "Split_Evenly" worksheet. The difference between the "Split_Fixed_Cost" and the "Split_Evenly" worksheets are the manner in which: 1) production is allocated to each supplier; and 2) logging production capacity determined for each supplier. In this system suppliers are allocated production based on the amount of fixed costs they have compared to the other contract suppliers, with wood dealers and other facilities being excluded and allocated a fixed amount of production. For example, the total amount of fixed costs among all of the contract suppliers is $10,000, if one supplier has fixed costs of $2000, then they would be allocated two-tenths of the production for that week. In this system, suppliers with the highest fixed costs per week are allocated the most production. For a detailed description of this worksheet see the description given in the “Split_Evenly” worksheet, keeping in mind that production is allocated differently using this strategy (p.112).

Split_Ave_Wk_Production

The “Split_Ave_Wk_Production” worksheet contains the procurement system using the average weekly production strategy. This worksheet is divided into three parts just like the “Split_Evenly” worksheet. The difference between this worksheet and the previous worksheet are the manner in which: 1) production is allocated to each supplier; and 2) logging production capacity determined for each supplier. In this system, suppliers are allocated production based on the average weekly production they have compared to the other contract suppliers. For example, the total amount of average weekly production for all of the contract suppliers is 10,000 tons, if one supplier has an average weekly production of 2000, then they would be allocated two-tenths of the production for that week. In this system the supplier with the highest average weekly production is allocated the most production. For a detailed description of this worksheet see the description given in the “Split_Evenly” worksheet, keeping in mind that production is allocated differently using this strategy (p. 112).

Full_Capacity

The “Full_Capacity” worksheet contains the procurement system using the full capacity strategy. This worksheet is divided into three parts just like the “Split_Evenly” worksheet. The difference between the “Full_Capacity” and the “Split_Evenly” worksheets are that in a given week production is not allocated to suppliers but independent of mill usage. For a detailed description of this worksheet see the description given in the “Split_Evenly” worksheet, keeping in mind that production is not allocated using this strategy (p. 112).

Summary

The "Summary" worksheet contains summary information about all four procurement strategies, including average cost per ton, total receipts, logging production capacity of the system, ending inventory levels and the number of times each system ran out of wood (Figure D33). In Figure D33, only one week has been modeled, however, results are presented for every week of the specified simulation time period. Below is a detailed description of the "Summary" worksheet.

<u>Row1</u>

Lists the week.

<u>Row 2</u>

Lists the system.

<u>Row 3 (Total Number of Wood Dealers)</u>

Lists the total number of wood dealers used.

<u>Row 4 (Total Number of Tree Length Loggers)</u>

Lists the total number of tree length logging crews used.

<u>Row 5 (Total Number of In-Woods Chip Crews)</u>

Lists the total number of in-woods chipping crews used.

<u>Row 6 (Total Number of Other Facilities)</u>

Lists the total number of other facilities used.

<u>Row 7 (Average Tons of Gatewood Received)</u>

Lists the average amount of gatewood received (tons). These numbers and the following are based on the average for all of the iterations conducted by @Risk®.

<u>Row 8 (Average Tons Delivered from Contract Suppliers)</u>

Lists the average amount received from contract suppliers (tons).

<u>Row 9 (Average Total Receipts)</u>

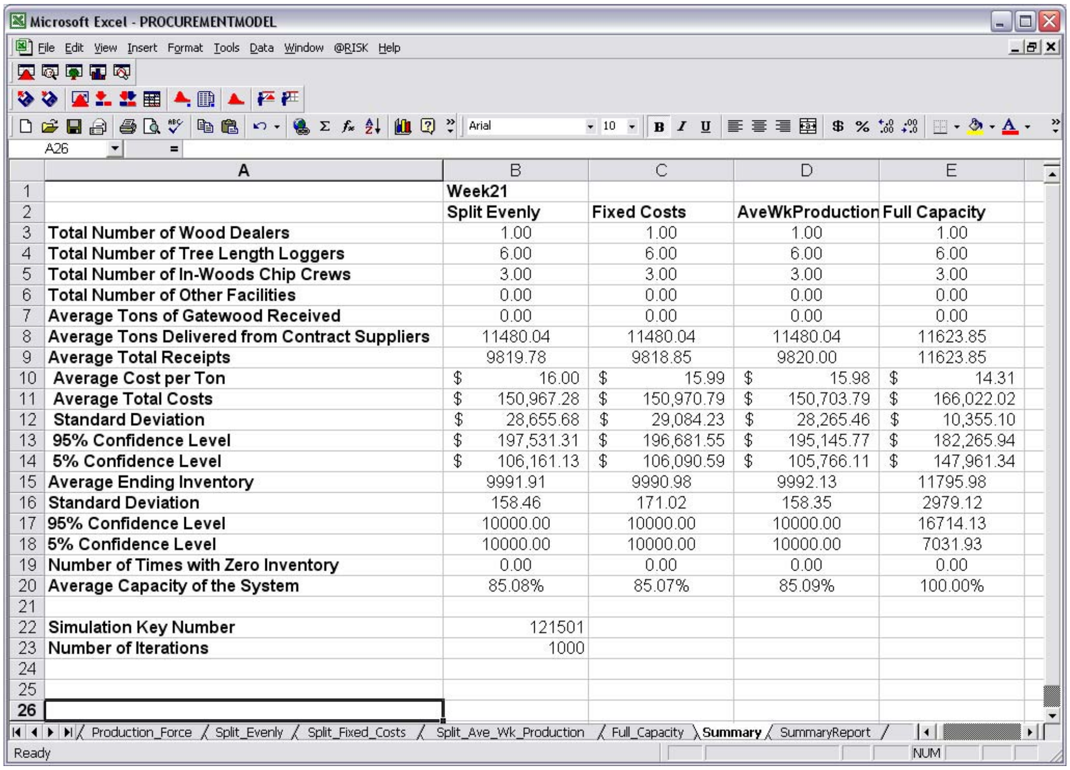
Lists the average amount (tons) received by the mill.

<u>Row 10 (Average Cost per Ton)</u>

Lists the average cost per ton for all deliveries received by the mill.

<u>Row 11 (Average Total Costs)</u>

Lists the average total costs for all deliveries received by the mill.



	A	B	C	D	E
1		Week21			
2		Split Evenly	Fixed Costs	AveWkProduction	Full Capacity
3	Total Number of Wood Dealers	1.00	1.00	1.00	1.00
4	Total Number of Tree Length Loggers	6.00	6.00	6.00	6.00
5	Total Number of In-Woods Chip Crews	3.00	3.00	3.00	3.00
6	Total Number of Other Facilities	0.00	0.00	0.00	0.00
7	Average Tons of Gatewood Received	0.00	0.00	0.00	0.00
8	Average Tons Delivered from Contract Suppliers	11480.04	11480.04	11480.04	11623.85
9	Average Total Receipts	9819.78	9818.85	9820.00	11623.85
10	Average Cost per Ton	$ 16.00	$ 15.99	$ 15.98	$ 14.31
11	Average Total Costs	$ 150,967.28	$ 150,970.79	$ 150,703.79	$ 166,022.02
12	Standard Deviation	$ 28,655.68	$ 29,084.23	$ 28,265.46	$ 10,355.10
13	95% Confidence Level	$ 197,531.31	$ 196,681.55	$ 195,145.77	$ 182,265.94
14	5% Confidence Level	$ 106,161.13	$ 106,090.59	$ 105,766.11	$ 147,961.34
15	Average Ending Inventory	9991.91	9990.98	9992.13	11795.98
16	Standard Deviation	158.46	171.02	158.35	2979.12
17	95% Confidence Level	10000.00	10000.00	10000.00	16714.13
18	5% Confidence Level	10000.00	10000.00	10000.00	7031.93
19	Number of Times with Zero Inventory	0.00	0.00	0.00	0.00
20	Average Capacity of the System	85.08%	85.07%	85.09%	100.00%
21					
22	Simulation Key Number	121501			
23	Number of Iterations	1000			
24					
25					
26					

Figure D33. "Summary" worksheet.

Row 12 (Standard Deviation)

Lists the standard deviation for total costs.

Row 13 (95% Confidence Level)

Lists the 95-percent confidence level for total costs.

Row 14 (5% Confidence Level)

Lists the 5-percent confidence level for total costs.

Row 15 (Average Ending Inventory)

Lists the average ending inventory for all deliveries received by the mill.

Row 16 (Standard Deviation)

Lists the standard deviation for ending inventory.

Row 17 (95% Confidence Level)

Lists the 95-percent confidence level for ending inventory.

Row 18 (5% Confidence Level)

Lists the 5-percent confidence level for ending inventory.

Row 19 (Number of Times with Zero Inventory)

Lists the number of times @Risk® reported an iteration when ending inventory was zero or less.

Row 20 (Average Capacity of the System)

Lists the average logging production capacity utilized by the mill.

Row 22 (Simulation Key Number)

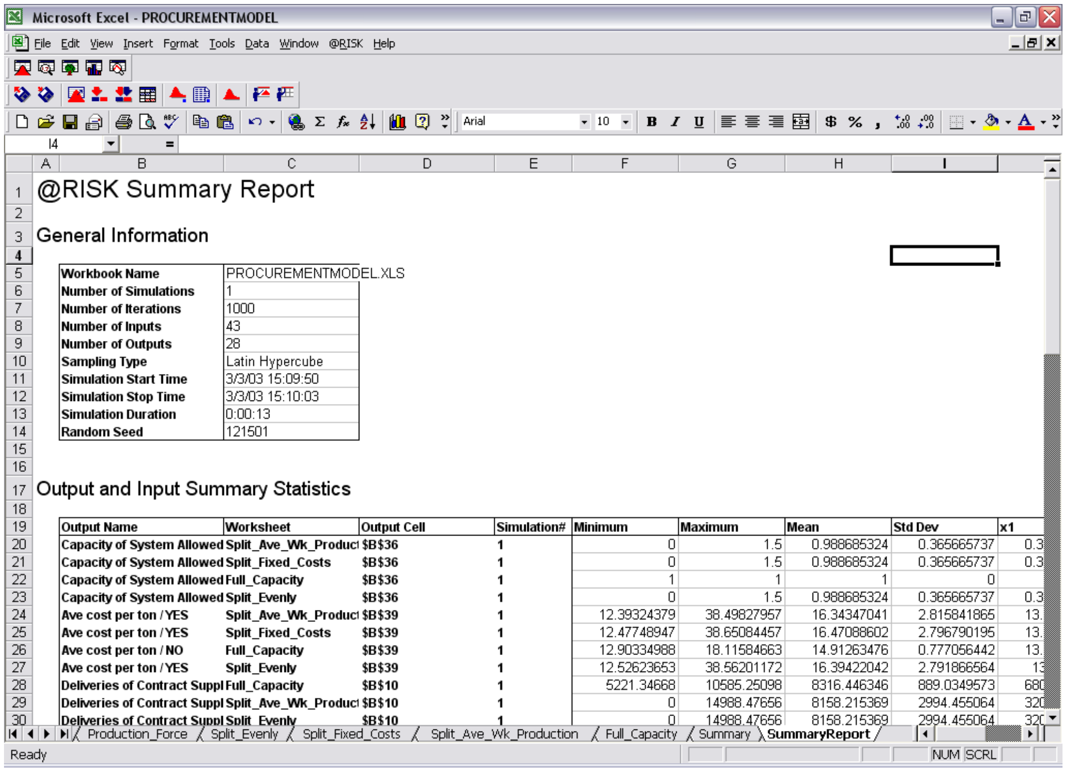
Lists the number that @Risk® used to start its random number generator. If you wish to create the same simulation and results, then you must use this number. If you specified a number in the "Random Number Generator Seed" form, then that number should be listed here.

Row 23 (Number of Iterations)

Lists the number of iterations that @Risk® used to determine the results.

SummaryReport

The "SummaryReport" worksheet is an @Risk® generated report (Figure D34). This report gives a summary of the simulation, including run time of the simulation, type of sampling, number of inputs and outputs, number of iterations, random number key, and statistics on all of the inputs and outputs used in the model. The contents in this worksheet will vary based on the number of suppliers and length of the simulation. For a detailed description of this report see the "@Risk® Operators Manual."



@RISK Summary Report

General Information

Workbook Name	PROCUREMENTMODEL.XLS
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	43
Number of Outputs	28
Sampling Type	Latin Hypercube
Simulation Start Time	3/3/03 15:09:50
Simulation Stop Time	3/3/03 15:10:03
Simulation Duration	0:00:13
Random Seed	121501

Output and Input Summary Statistics

Output Name	Worksheet	Output Cell	Simulation#	Minimum	Maximum	Mean	Std Dev	x1
Capacity of System Allowed	Split_Ave_Wk_Product	B36	1	0	1.5	0.988685324	0.365665737	0.3
Capacity of System Allowed	Split_Fixed_Costs	B36	1	0	1.5	0.988685324	0.365665737	0.3
Capacity of System Allowed	Full_Capacity	B36	1	1	1	1	0	
Capacity of System Allowed	Split_Evenly	B36	1	0	1.5	0.988685324	0.365665737	0.3
Ave cost per ton / YES	Split_Ave_Wk_Product	B39	1	12.39324379	38.49827957	16.34347041	2.815841865	13.
Ave cost per ton / YES	Split_Fixed_Costs	B39	1	12.47748947	38.65084457	16.47088602	2.796790195	13.
Ave cost per ton / NO	Full_Capacity	B39	1	12.90334988	18.11584663	14.91263476	0.777056442	13.
Ave cost per ton / YES	Split_Evenly	B39	1	12.52623653	38.56201172	16.39422042	2.791866564	13
Deliveries of Contract Suppl	Full_Capacity	B10	1	5221.34668	10585.25098	8316.446346	889.0349573	680
Deliveries of Contract Suppl	Split_Ave_Wk_Product	B10	1	0	14988.47656	8158.215369	2994.455064	320
Deliveries of Contract Suppl	Split_Evenly	B10	1	0	14988.47656	8158.215369	2994.455064	320

Figure D34. "SummaryReport" worksheet.

APPENDIX: DEFAULT VALUES

Table D1. LIST OF DEFAULT PRODUCTION, FIXED COSTS AND VARIABLE COSTS FOR TREE-LENGTH LOGGING CREWS.

Crew Number	Production (tons)	Fixed Costs ($/week)	Variable Costs ($/ton)
1	521.17	4,703.83	13.38
2	1,672.12	5,280.77	12.80
3	1,400.00	4,393.19	10.69
4	1,513.46	5,051.15	5.13
5	1,733.54	6,066.79	8.17
6	1,601.44	7,932.77	6.75
7	1,673.00	4,338.36	7.99
8	840.87	8,387.69	3.92
9	1,123.40	2,283.96	10.95
10	1,397.58	9,845.04	9.65
11	1,137.23	7,011.77	6.57
12	1,527.02	5,238.65	9.07
13	1,310.50	7,035.08	17.30
14	1,323.15	6,345.08	10.47
15	1,262.50	3,709.04	10.59
16	1,198.56	8,387.69	3.93
17	1,203.85	8,387.69	3.98
18	1,395.51	6,875.54	10.27
19	1,217.31	2,123.15	6.63
20	1,076.44	5,845.00	10.69
21	521.17	4,703.83	13.38
22	1,672.12	5,280.77	12.80
23	1,400.00	4,393.19	10.69
24	1,513.46	5,051.15	5.13
25	1,733.54	6,066.79	8.17
26	1,601.44	7,932.77	6.75

Table D2. LIST OF DEFAULT PRODUCTION, FIXED COSTS AND VARIABLE COSTS FOR IN-WOODS CHIPPING CREWS.

Crew Number	Production (tons)	Fixed Costs ($/week)	Variable Costs ($/ton)
1	1,179.98	5,860.37	8.08
2	1,299.52	5,515.65	12.48
3	1,395.51	6,875.54	10.27
4	1,217.31	2,123.15	6.63
5	1,076.44	5,845.00	10.69
6	1,275.64	5,841.08	8.83
7	1,179.98	5,860.37	8.08
8	1,299.52	5,515.65	12.48
9	1,395.51	6,875.54	10.27
10	1,217.31	2,123.15	6.63
11	1,076.44	5,845.00	10.69
12	1,275.64	5,841.08	8.83
13	1,179.98	5,860.37	8.08
14	1,299.52	5,515.65	12.48
15	1,395.51	6,875.54	10.27
16	1,217.31	2,123.15	6.63
17	1,076.44	5,845.00	10.69
18	1,275.64	5,841.08	8.83
19	1,179.98	5,860.37	8.08
20	1,299.52	5,515.65	12.48
21	1,395.51	6,875.54	10.27
22	1,217.31	2,123.15	6.63
23	1,076.44	5,845.00	10.69
24	1,275.64	5,841.08	8.83
25	1,179.98	5,860.37	8.08
26	1,299.52	5,515.65	12.48

Table D3. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR ALABAMA REGION 1.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	5.32	5.14	5.40	6.73
Pine	Sawtimber	41.53	40.29	44.51	43.30
Pine	Chip'N'Saw	27.13	27.33	26.22	27.33
Pine	Plylogs	35.00	34.30	37.25	37.50
Hardwood	Roundwood	7.15	6.18	6.40	7.33
Hardwood	Plylogs	35.00	34.30	37.25	37.50

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Assumed Hardwood Plylogs and Pine Plylogs are the same stumpage, because they are used for the same product.

Table D4. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR ALABAMA REGION 2.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	7.02	5.50	5.50	6.72
Pine	Sawtimber	47.12	46.28	43.98	45.44
Pine	Chip'N'Saw	30.88	28.31	25.31	27.48
Pine	Plylogs	48.38	44.24	39.34	44.25
Hardwood	Roundwood	8.22	6.79	6.88	8.37
Hardwood	Plylogs	48.38	44.24	39.34	44.25

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Assumed Hardwood Plylogs and Pine Plylogs are the same stumpage, because they are used for the same product.

Table D5. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR ARKANSAS REGION 1.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	5.18	4.86	4.61	4.57
Pine	Chips	5.18	4.86	4.61	4.57
Pine	Sawtimber	38.04	38.51	34.07	35.84
Pine	Chip'N'Saw	20.50	21.71	18.00	22.13
Pine	Plylogs	34.68	35.08	32.00	33.70
Hardwood	Roundwood	6.05	6.27	5.26	5.00
Hardwood	Chips	6.05	6.27	5.26	5.00
Hardwood	Plylogs	34.68	35.08	32.00	33.70

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.
* Assumed Hardwood Plylogs and Pine Plylogs are the same stumpage, because they are used for the same product.

Table D6. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR ARKANSAS REGION 2.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	4.73	4.68	4.62	4.58
Pine	Chips	4.73	4.68	4.62	4.58
Pine	Sawtimber	30.25	30.70	34.05	34.48
Pine	Chip'N'Saw	17.97	18.90	17.98	18.48
Pine	Plylogs	39.33	34.27	30.67	35.47
Hardwood	Roundwood	4.80	4.13	4.00	3.96
Hardwood	Chips	4.80	4.13	4.00	3.96
Hardwood	Plylogs	39.33	34.27	30.67	35.47

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.
* Assumed Hardwood Plylogs and Pine Plylogs are the same stumpage, because they are used for the same product.
* Pine Plylog prices are based on 2000 Timber Mart-South Quarterly Reports.

Table D7. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR FLORIDA REGION 1.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	8.95	7.80	8.56	8.26
Pine	Chip'N'Saw	27.03	25.26	26.16	26.88
Pine	Plylogs	35.87	38.86	39.81	36.90
Hardwood	Roundwood	4.61	3.61	4.01	3.98

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.

Table D8. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR FLORIDA REGION 2.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	7.14	6.75	6.95	7.23
Pine	Chip'N'Saw	23.29	21.31	20.92	22.83
Pine	Plylogs	42.44	39.97	38.94	44.23
Hardwood	Roundwood	4.93	5.51	6.31	6.57

* Based on Average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as Roundwood.

Table D9. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR GEORGIA REGION 1.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	5.40	4.50	5.17	5.61
Pine	Chips	5.40	4.50	5.17	5.61
Pine	Sawtimber	32.55	30.43	34.15	32.27
Pine	Chip'N'Saw	22.57	21.66	23.99	23.04
Pine	Plylogs	35.86	35.72	39.85	36.11
Hardwood	Roundwood	5.21	4.95	5.81	6.42
Hardwood	Chips	5.21	4.95	5.81	6.42
Hardwood	Plylogs	35.86	35.72	39.85	36.11

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.
* Assumed Hardwood Plylogs and Pine Plylogs are the same stumpage, because they are used for the same product.

Table D10. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR GEORGIA REGION 2.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	7.10	6.91	6.54	6.98
Pine	Chips	7.10	6.91	6.54	6.98
Pine	Sawtimber	46.00	44.62	44.35	45.11
Pine	Chip'N'Saw	31.42	28.96	28.52	28.81
Pine	Plylogs	41.46	46.26	42.05	43.10
Hardwood	Roundwood	7.20	7.33	6.75	7.62
Hardwood	Chips	7.20	7.33	6.75	7.62
Hardwood	Plylogs	41.46	46.26	42.05	43.10

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.
* Assumed Hardwood Plylogs and Pine Plylogs are the same stumpage, because they are used for the same product.

Table D11. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR LOUISIANA REGION 1.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	6.48	5.19	5.35	6.20
Pine	Chips	6.48	5.19	5.35	6.20
Pine	Sawtimber	39.09	36.25	33.71	38.05
Hardwood	Roundwood	4.33	4.57	5.19	7.45
Hardwood	Chips	4.33	4.57	5.19	7.45

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.

Table D12. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR LOUISIANA REGION 2.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	5.75	6.87	6.42	6.63
Pine	Chips	5.75	6.87	6.42	6.63
Pine	Sawtimber	37.75	36.75	36.42	37.65
Hardwood	Roundwood	4.88	4.80	5.20	6.43
Hardwood	Chips	4.88	4.80	5.20	6.43

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.

Table D13. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR MISSISSIPPI REGION 1.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	6.59	4.95	4.62	6.99
Pine	Chips	6.59	4.95	4.62	6.99
Pine	Sawtimber	44.60	41.41	41.62	47.50
Pine	Chip'N'Saw	28.60	29.13	24.75	28.76
Pine	Plylogs	43.73	39.60	38.40	36.00
Hardwood	Roundwood	6.79	3.44	3.46	6.20
Hardwood	Plylogs	43.73	39.60	38.40	36.00

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.
* Assumed Hardwood Plylogs and Pine Plylogs are the same stumpage, because they are used for the same product.
* Pine Plylog prices are based on Region 2 Timber Mart-South Quarterly prices in 2000.

Table D14. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR MISSISSIPPI REGION 2.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	7.69	6.35	6.63	7.96
Pine	Chips	7.69	6.35	6.63	7.96
Pine	Sawtimber	44.97	48.05	42.31	46.53
Pine	Chip'N'Saw	28.51	28.84	26.53	31.52
Pine	Plylogs	43.73	39.60	38.40	36.00
Hardwood	Roundwood	4.23	4.28	4.45	5.06
Hardwood	Plylogs	43.73	39.60	38.40	36.00

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.
* Assumed Hardwood Plylogs and Pine Plylogs are the same stumpage, because they are used for the same product.
* Pine Plylog prices are based on Region 2 Timber Mart-South Quarterly prices in 2000.

Table D15. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR NORTH CAROLINA REGION 1.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	4.48	4.42	4.24	4.54
Pine	Chips	4.48	4.42	4.24	4.54
Pine	Sawtimber	29.27	30.60	34.73	32.21
Pine	Chip'N'Saw	18.21	17.98	19.54	19.13
Pine	Plylogs	26.33	25.88	24.63	24.50
Hardwood	Roundwood	4.65	4.85	5.15	4.37
Hardwood	Chips	4.65	4.85	5.15	4.37
Hardwood	Plylogs	26.33	25.88	24.63	24.50

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.
* Assumed Hardwood Plylogs and Pine Plylogs are the same stumpage, because they are used for the same product.

Table D16. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR NORTH CAROLINA REGION 2.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	6.01	5.61	5.43	5.72
Pine	Chips	6.01	5.61	5.43	5.72
Pine	Sawtimber	41.43	41.90	43.32	42.31
Pine	Chip'N'Saw	25.94	24.85	23.50	24.87
Pine	Plylogs	43.23	42.88	41.70	41.00
Hardwood	Roundwood	3.10	2.05	2.28	3.19
Hardwood	Chips	3.10	2.05	2.28	3.19
Hardwood	Plylogs	43.23	42.88	41.70	41.00

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.
* Assumed Hardwood Plylogs and Pine Plylogs are the same stumpage, because they are used for the same product.

Table D17. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR SOUTH CAROLINA REGION 1.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	5.45	5.52	4.95	6.38
Pine	Chips	5.45	5.52	4.95	6.38
Pine	Sawtimber	35.07	39.34	37.38	38.25
Pine	Chip'N'Saw	21.60	19.48	18.41	21.08
Pine	Plylogs	38.36	38.94	34.31	39.50
Hardwood	Roundwood	5.83	5.37	5.06	5.86
Hardwood	Chips	5.83	5.37	5.06	5.86

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.

Table D18. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR SOUTH CAROLINA REGION 2.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	6.85	5.88	5.51	6.32
Pine	Chips	6.85	5.88	5.51	6.32
Pine	Sawtimber	41.40	41.68	41.85	39.03
Pine	Chip'N'Saw	24.24	22.11	21.55	22.03
Pine	Plylogs	40.52	41.17	42.63	41.84
Hardwood	Roundwood	6.72	6.21	5.87	6.25
Hardwood	Chips	6.72	6.21	5.87	6.25

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.

Table D19. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR TEXAS REGION 1.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	5.30	5.55	4.88	6.25
Pine	Chips	5.30	5.55	4.88	6.25
Pine	Sawtimber	34.86	37.25	34.81	34.74
Pine	Plylogs	32.59	33.17	32.00	33.58
Hardwood	Roundwood	5.69	6.60	5.33	5.50
Hardwood	Chips	5.69	6.60	5.33	5.50

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.

Table D20. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR TEXAS REGION 2.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	5.52	4.24	4.48	3.96
Pine	Chips	5.52	4.24	4.48	3.96
Pine	Sawtimber	35.32	40.73	34.16	36.22
Pine	Plylogs	43.00	37.95	35.45	35.85
Hardwood	Roundwood	4.55	4.38	4.31	4.48
Hardwood	Chips	4.55	4.38	4.31	4.48

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.

Table D21. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR VIRGINIA REGION 1.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	7.88	8.25	7.83	8.00
Pine	Chips	7.88	8.25	7.83	8.00
Pine	Sawtimber	25.40	24.83	30.30	31.05
Pine	Plylogs	33.08	30.78	30.40	31.15
Hardwood	Roundwood	2.92	3.24	2.47	4.00
Hardwood	Chips	2.92	3.24	2.47	4.00
Hardwood	Plylogs	33.08	30.78	30.40	31.15

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.
* Assumed Hardwood Plylogs and Pine Plylogs are the same stumpage, because they are used for the same product.

Table D22. LIST OF DEFAULT STUMPAGE VALUES BY WOODTYPE, PRODUCT AND QUARTER FOR VIRGINIA REGION 2.

		Price in Dollars per Ton			
Wood Type	**Product**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
Pine	Roundwood	7.09	7.50	7.85	7.92
Pine	Chips	7.09	7.50	7.85	7.92
Pine	Sawtimber	32.00	32.96	29.89	35.52
Pine	Plylogs	34.00	33.60	33.33	33.70
Hardwood	Roundwood	2.22	2.27	2.88	3.45
Hardwood	Chips	2.22	2.27	2.88	3.45
Hardwood	Plylogs	34.00	33.60	33.33	33.70

* Based on average price per ton reported in 2002 Timber Mart-South Quarterly Reports.
* Chips are considered to be the same stumpage price as roundwood.
* Assumed Hardwood Plylogs and Pine Plylogs are the same stumpage, because they are used for the same product.

APPENDIX E. LIST OF DISTRIBUTIONS AND PROBABILITIES OF RAINFALL BY WEEK, STATE, AND REGION

LIST OF TABLES

TABLE E1. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR ALABAMA REGION 1.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	1.3907	0.11292
2	Exponential	1.1350	0.15503
3	Exponential	1.1376	0.12098
4	Exponential	1.2535	0.07908
5	Exponential	1.0117	0.20306
6	Exponential	1.2258	0.13350
7	Exponential	1.3490	0.12521
8	Exponential	1.2800	0.12290
9	Exponential	1.4008	0.12352
10	Exponential	1.3053	0.15004
11	Exponential	1.4070	0.13770
12	Exponential	1.3608	0.13511
13	Exponential	1.3214	0.17866
14	Exponential	1.3485	0.15953
15	Exponential	1.2293	0.23658
16	Exponential	0.91063	0.29723
17	Exponential	1.1735	0.22007
18	Exponential	0.96715	0.26271
19	Exponential	0.91792	0.20687
20	Exponential	0.93693	0.30892
21	Exponential	0.91588	0.18787
22	Exponential	0.78089	0.23410
23	Exponential	0.81977	0.17399
24	Exponential	0.99753	0.12723
25	Exponential	0.91239	0.11092
26	Exponential	0.99834	0.09854
27	Exponential	1.1485	0.07445
28	Exponential	1.0790	0.10822
29	Exponential	1.0608	0.04971
30	Exponential	1.0896	0.07504
31	Exponential	0.83738	0.08703
32	Exponential	0.94219	0.08600
33	Exponential	0.92514	0.11740
34	Exponential	0.71070	0.15759
35	Exponential	0.61884	0.20339
36	Exponential	0.78353	0.17553
37	Exponential	0.81651	0.25839
38	Exponential	0.84651	0.26555
39	Exponential	0.95231	0.21429
40	Exponential	0.74532	0.36984

41	Exponential	0.56809	0.40936
42	Exponential	0.62249	0.40352
43	Exponential	0.69774	0.44547
44	Exponential	0.60680	0.35004
45	Exponential	0.87835	0.28476
46	Exponential	0.87832	0.36432
47	Exponential	1.1656	0.19899
48	Exponential	0.90018	0.25340
49	Exponential	1.0819	0.21321
50	Exponential	1.2778	0.13131
51	Exponential	1.0819	0.15572
52	Exponential	1.2356	0.16582

Probability density function for an exponential distribution.

$$\boxed{f(x) = \frac{\exp\left(-\frac{x}{\beta}\right)}{\beta}}$$

Where,

x = the amount of rainfall in a given week
β = decay constant and mean
exp = the base of the natural logarithm

TABLE E2. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR ALABAMA REGION 2.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	1.3338	0.06651
2	Exponential	1.0798	0.11685
3	Exponential	1.1558	0.08090
4	Exponential	1.2621	0.05180
5	Exponential	0.98961	0.16327
6	Exponential	1.2584	0.14447
7	Exponential	1.2478	0.10158
8	Exponential	1.3074	0.07710
9	Exponential	1.4665	0.10455
10	Exponential	1.3346	0.11261
11	Exponential	1.5460	0.11461
12	Exponential	1.2710	0.10112
13	Exponential	1.3624	0.12329
14	Exponential	1.2510	0.17045
15	Exponential	1.4293	0.19545
16	Exponential	0.79726	0.23982
17	Exponential	1.0497	0.20091
18	Exponential	1.0514	0.20862
19	Exponential	1.0023	0.22348
20	Exponential	1.0201	0.26304
21	Exponential	1.0468	0.16253
22	Exponential	1.0440	0.20862
23	Exponential	1.0402	0.19820
24	Exponential	1.1985	0.12727
25	Exponential	1.1994	0.10959
26	Exponential	1.0832	0.12073
27	Exponential	1.4777	0.06711
28	Exponential	1.6373	0.09502
29	Exponential	1.6426	0.01810
30	Exponential	1.5129	0.03579
31	Exponential	1.3337	0.09663
32	Exponential	1.3352	0.07589
33	Exponential	1.2466	0.12584
34	Exponential	0.92408	0.14640
35	Exponential	0.86066	0.21461
36	Exponential	1.1047	0.13667
37	Exponential	1.1587	0.19773
38	Exponential	0.95662	0.23649
39	Exponential	1.2523	0.23198
40	Exponential	0.96257	0.33559

41	Exponential	0.52669	0.46847
42	Exponential	0.47955	0.42247
43	Exponential	0.54213	0.38565
44	Exponential	0.73426	0.26786
45	Exponential	0.97897	0.22098
46	Exponential	0.88072	0.29821
47	Exponential	1.1410	0.15299
48	Exponential	0.80908	0.23649
49	Exponential	1.0415	0.16216
50	Exponential	1.3728	0.11338
51	Exponential	0.96105	0.12073
52	Exponential	1.1279	0.13242

TABLE E3. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR ARKANSAS REGION 1.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	0.85973	0.22363
2	Exponential	0.66430	0.25400
3	Exponential	0.80054	0.18354
4	Exponential	0.73647	0.17406
5	Exponential	0.75401	0.24306
6	Exponential	0.64456	0.25254
7	Exponential	0.99785	0.13904
8	Exponential	0.81977	0.15492
9	Exponential	0.90943	0.12859
10	Exponential	1.0815	0.15966
11	Exponential	0.91800	0.14559
12	Exponential	0.95400	0.12189
13	Exponential	0.95603	0.16370
14	Exponential	1.0182	0.13451
15	Exponential	1.0344	0.11579
16	Exponential	1.0843	0.12752
17	Exponential	1.1835	0.09742
18	Exponential	1.2755	0.13382
19	Exponential	1.2716	0.10816
20	Exponential	0.98564	0.18363
21	Exponential	1.2576	0.10835
22	Exponential	0.81086	0.21839
23	Exponential	0.92359	0.23918
24	Exponential	0.98144	0.17878
25	Exponential	0.86678	0.20667
26	Exponential	0.95874	0.21470
27	Exponential	0.77087	0.23968
28	Exponential	0.65831	0.28416
29	Exponential	0.84844	0.24514
30	Exponential	0.94548	0.14917
31	Exponential	0.65530	0.26811
32	Exponential	0.70675	0.24027
33	Exponential	0.89238	0.24181
34	Exponential	0.56941	0.29345
35	Exponential	0.66202	0.28613
36	Exponential	0.75343	0.26025
37	Exponential	0.88493	0.27844
38	Exponential	0.82783	0.24810
39	Exponential	0.98495	0.26046
40	Exponential	0.73296	0.33779

41	Exponential	0.66762	0.36525
42	Exponential	0.76203	0.31340
43	Exponential	0.82830	0.28959
44	Exponential	0.89347	0.23642
45	Exponential	0.83444	0.24031
46	Exponential	1.0107	0.24317
47	Exponential	1.1588	0.19077
48	Exponential	0.72383	0.28537
49	Exponential	1.0910	0.14895
50	Exponential	0.93044	0.21934
51	Exponential	0.69895	0.28717
52	Exponential	0.84965	0.24526

TABLE E4. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR ARKANSAS REGION 2.

Week	**Distribution of Rainfall**		**Probability of Zero Rainfall**
	Type	**Beta**	
1	Exponential	0.98479	0.15868
2	Exponential	0.88248	0.21521
3	Exponential	0.93838	0.13942
4	Exponential	0.95331	0.14133
5	Exponential	1.0276	0.20690
6	Exponential	0.82290	0.18750
7	Exponential	1.0647	0.12243
8	Exponential	1.0024	0.13062
9	Exponential	1.1294	0.11991
10	Exponential	1.1164	0.14987
11	Exponential	1.0754	0.12945
12	Exponential	1.0052	0.07946
13	Exponential	1.0409	0.13593
14	Exponential	1.0187	0.15364
15	Exponential	1.0682	0.13402
16	Exponential	1.0927	0.14737
17	Exponential	1.6326	0.09531
18	Exponential	1.5423	0.11662
19	Exponential	1.1733	0.13076
20	Exponential	1.1247	0.22319
21	Exponential	1.1404	0.21694
22	Exponential	0.91717	0.18971
23	Exponential	0.94709	0.24877
24	Exponential	0.96208	0.20707
25	Exponential	0.72759	0.23127
26	Exponential	0.88258	0.19389
27	Exponential	0.81521	0.24650
28	Exponential	0.75679	0.27266
29	Exponential	0.84844	0.22660
30	Exponential	1.0939	0.15915
31	Exponential	0.59197	0.27881
32	Exponential	0.75863	0.22806
33	Exponential	0.69048	0.28582
34	Exponential	0.59987	0.31986
35	Exponential	0.66667	0.29943
36	Exponential	0.73323	0.26248
37	Exponential	0.93413	0.27009
38	Exponential	0.87049	0.25546
39	Exponential	0.80509	0.32290
40	Exponential	0.78020	0.33409

41	Exponential	0.69456	0.38357
42	Exponential	0.84324	0.31015
43	Exponential	0.94855	0.29202
44	Exponential	0.88573	0.23618
45	Exponential	0.98424	0.22353
46	Exponential	1.1438	0.23815
47	Exponential	1.2347	0.17210
48	Exponential	0.81732	0.23782
49	Exponential	1.3045	0.15285
50	Exponential	1.2226	0.18901
51	Exponential	0.74505	0.22977
52	Exponential	1.0101	0.11471

TABLE E5. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR FLORIDA REGION 1.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	1.0426	0.08267
2	Exponential	1.1085	0.14567
3	Exponential	0.77624	0.09804
4	Exponential	1.1676	0.05098
5	Exponential	0.74819	0.18876
6	Exponential	1.2325	0.11553
7	Exponential	1.1988	0.11811
8	Exponential	1.0025	0.05929
9	Exponential	1.3131	0.11067
10	Exponential	1.3324	0.17829
11	Exponential	1.1253	0.15058
12	Exponential	0.88957	0.15116
13	Exponential	1.1425	0.18504
14	Exponential	1.1138	0.15234
15	Exponential	1.0296	0.22745
16	Exponential	0.53409	0.29528
17	Exponential	0.85693	0.27953
18	Exponential	0.59617	0.25806
19	Exponential	0.89949	0.19291
20	Exponential	0.81024	0.34646
21	Exponential	0.99193	0.23622
22	Exponential	0.76466	0.24701
23	Exponential	1.3680	0.14173
24	Exponential	1.3076	0.10671
25	Exponential	1.4591	0.05929
26	Exponential	1.5583	0.03571
27	Exponential	1.6100	0.03488
28	Exponential	1.6044	0.04669
29	Exponential	1.9546	0.02344
30	Exponential	1.8732	0.03516
31	Exponential	1.6591	0.03150
32	Exponential	1.5796	0.01563
33	Exponential	1.6367	0.04331
34	Exponential	1.4499	0.07813
35	Exponential	1.2587	0.11155
36	Exponential	1.6478	0.09449
37	Exponential	1.3177	0.16078
38	Exponential	1.2413	0.22656
39	Exponential	1.5592	0.17717
40	Exponential	1.0720	0.29688

41	Exponential	0.69411	0.41085
42	Exponential	0.49202	0.37984
43	Exponential	0.45735	0.42412
44	Exponential	0.75174	0.32411
45	Exponential	0.70813	0.26563
46	Exponential	0.61551	0.38189
47	Exponential	0.78043	0.15686
48	Exponential	0.66575	0.22835
49	Exponential	0.85438	0.18359
50	Exponential	1.0839	0.12891
51	Exponential	0.72611	0.11284
52	Exponential	1.0426	0.14397

TABLE E6. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR FLORIDA REGION 2.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	0.69660	0.18762
2	Exponential	0.70699	0.22266
3	Exponential	0.56778	0.21042
4	Exponential	0.73280	0.17215
5	Exponential	0.59558	0.29630
6	Exponential	0.85792	0.19231
7	Exponential	0.81208	0.22374
8	Exponential	0.75681	0.20921
9	Exponential	0.81752	0.20703
10	Exponential	0.85975	0.19186
11	Exponential	0.92068	0.22824
12	Exponential	0.73492	0.21154
13	Exponential	0.81016	0.23092
14	Exponential	0.86453	0.26550
15	Exponential	0.69537	0.33008
16	Exponential	0.49010	0.35271
17	Exponential	0.60212	0.32308
18	Exponential	0.61521	0.32485
19	Exponential	0.72488	0.24319
20	Exponential	0.73141	0.31467
21	Exponential	0.96076	0.20196
22	Exponential	0.92577	0.21032
23	Exponential	1.4913	0.12157
24	Exponential	1.5256	0.06214
25	Exponential	1.8093	0.05039
26	Exponential	1.1364	0.03143
27	Exponential	1.6258	0.05078
28	Exponential	1.6444	0.04086
29	Exponential	1.7165	0.03516
30	Exponential	1.7671	0.04752
31	Exponential	1.5381	0.04573
32	Exponential	1.7306	0.04892
33	Exponential	1.6545	0.05098
34	Exponential	1.6161	0.04902
35	Exponential	1.3363	0.10059
36	Exponential	1.7754	0.05347
37	Exponential	1.4107	0.11485
38	Exponential	1.4652	0.12795
39	Exponential	1.5318	0.09091
40	Exponential	0.73280	0.20881

41	Exponential	1.1137	0.23654
42	Exponential	1.0916	0.28046
43	Exponential	0.45483	0.39335
44	Exponential	0.46933	0.27112
45	Exponential	0.56553	0.30368
46	Exponential	0.41088	0.37743
47	Exponential	0.52639	0.24172
48	Exponential	0.39397	0.31238
49	Exponential	0.47371	0.31429
50	Exponential	0.68240	0.20229
51	Exponential	0.50625	0.27220
52	Exponential	0.68525	0.19057

TABLE E7. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR GEORGIA REGION 1.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	1.3704	0.07381
2	Exponential	1.1854	0.09393
3	Exponential	1.2159	0.07061
4	Exponential	1.2445	0.04480
5	Exponential	1.0569	0.16619
6	Exponential	1.1841	0.13056
7	Exponential	1.3479	0.07902
8	Exponential	1.1511	0.07781
9	Exponential	1.3698	0.05180
10	Exponential	1.3573	0.08120
11	Exponential	1.2847	0.09815
12	Exponential	1.3264	0.07681
13	Exponential	1.2512	0.11286
14	Exponential	1.3437	0.11949
15	Exponential	1.0295	0.14468
16	Exponential	0.79821	0.20626
17	Exponential	1.0881	0.11111
18	Exponential	1.0485	0.16212
19	Exponential	0.88659	0.10369
20	Exponential	0.88654	0.20680
21	Exponential	0.89728	0.16170
22	Exponential	0.83445	0.19886
23	Exponential	0.94775	0.15363
24	Exponential	0.97515	0.11380
25	Exponential	0.95472	0.11206
26	Exponential	1.0130	0.12000
27	Exponential	1.1073	0.10541
28	Exponential	1.0536	0.17730
29	Exponential	1.0729	0.11473
30	Exponential	1.1648	0.11048
31	Exponential	0.85090	0.13409
32	Exponential	1.0310	0.12199
33	Exponential	1.1147	0.15767
34	Exponential	0.91660	0.19203
35	Exponential	0.70863	0.26174
36	Exponential	0.85295	0.23011
37	Exponential	0.75113	0.25106
38	Exponential	0.91533	0.28187
39	Exponential	1.1229	0.22080
40	Exponential	0.91704	0.33759

41	Exponential	0.79236	0.35876
42	Exponential	0.71572	0.29178
43	Exponential	0.75119	0.31870
44	Exponential	0.78963	0.26000
45	Exponential	0.82380	0.18414
46	Exponential	0.76973	0.24716
47	Exponential	1.0697	0.11857
48	Exponential	0.87963	0.18286
49	Exponential	1.0690	0.13901
50	Exponential	1.1264	0.09714
51	Exponential	0.95783	0.13019
52	Exponential	1.2656	0.07824

TABLE E8. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR GEORGIA REGION 2.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	1.0949	0.11292
2	Exponential	0.97881	0.15503
3	Exponential	0.88713	0.12098
4	Exponential	1.0111	0.07908
5	Exponential	0.77481	0.20306
6	Exponential	1.1776	0.13350
7	Exponential	1.1479	0.12521
8	Exponential	0.97166	0.12290
9	Exponential	1.1763	0.12352
10	Exponential	1.1535	0.15004
11	Exponential	1.0489	0.13770
12	Exponential	1.0439	0.13511
13	Exponential	0.96197	0.17866
14	Exponential	0.97194	0.15953
15	Exponential	0.94663	0.23658
16	Exponential	0.63673	0.29723
17	Exponential	0.85593	0.22007
18	Exponential	0.74847	0.26271
19	Exponential	0.73817	0.20687
20	Exponential	0.74974	0.30892
21	Exponential	0.90706	0.18787
22	Exponential	0.81011	0.23410
23	Exponential	1.0041	0.17399
24	Exponential	1.0628	0.12723
25	Exponential	1.1150	0.11092
26	Exponential	0.90109	0.09854
27	Exponential	1.2999	0.07445
28	Exponential	1.2824	0.10822
29	Exponential	1.4150	0.04971
30	Exponential	1.3286	0.07504
31	Exponential	1.1109	0.08703
32	Exponential	1.2097	0.08600
33	Exponential	1.1264	0.11740
34	Exponential	0.99262	0.15759
35	Exponential	0.78619	0.20339
36	Exponential	1.0455	0.17553
37	Exponential	0.82718	0.25839
38	Exponential	0.85691	0.26555
39	Exponential	1.1341	0.21429
40	Exponential	0.71647	0.36984

41	Exponential	0.58488	0.40936
42	Exponential	0.54154	0.40352
43	Exponential	0.47210	0.44547
44	Exponential	0.50043	0.35004
45	Exponential	0.51722	0.28476
46	Exponential	0.54255	0.36432
47	Exponential	0.69497	0.19899
48	Exponential	0.63992	0.25340
49	Exponential	0.80474	0.21321
50	Exponential	1.0007	0.13131
51	Exponential	0.75709	0.15572
52	Exponential	0.89853	0.16582

TABLE E9. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR LOUISIANA REGION 1.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	1.3754	0.08300
2	Exponential	1.0806	0.15551
3	Exponential	1.1088	0.13281
4	Exponential	1.1982	0.10309
5	Exponential	1.0945	0.17397
6	Exponential	1.1347	0.14258
7	Exponential	1.2163	0.10644
8	Exponential	1.2551	0.11170
9	Exponential	1.2130	0.09278
10	Exponential	0.95511	0.13836
11	Exponential	1.0968	0.13251
12	Exponential	1.0429	0.12105
13	Exponential	1.4081	0.12353
14	Exponential	1.0273	0.18194
15	Exponential	1.3143	0.18383
16	Exponential	1.0147	0.20871
17	Exponential	1.3633	0.17057
18	Exponential	1.5674	0.13255
19	Exponential	1.0820	0.20888
20	Exponential	1.2383	0.26223
21	Exponential	0.89337	0.23266
22	Exponential	0.93286	0.25979
23	Exponential	0.91356	0.30619
24	Exponential	0.99173	0.23499
25	Exponential	0.90029	0.24003
26	Exponential	1.1314	0.15884
27	Exponential	0.95409	0.21961
28	Exponential	0.93074	0.19635
29	Exponential	0.90783	0.16140
30	Exponential	1.1348	0.14951
31	Exponential	0.68888	0.27285
32	Exponential	0.77031	0.25408
33	Exponential	0.69096	0.27557
34	Exponential	0.74489	0.24559
35	Exponential	0.68472	0.26680
36	Exponential	0.79800	0.22251
37	Exponential	0.96716	0.26832
38	Exponential	0.93883	0.28412
39	Exponential	0.64430	0.35256
40	Exponential	0.62365	0.37958

41	Exponential	0.68590	0.44233
42	Exponential	0.71137	0.40382
43	Exponential	0.90669	0.34512
44	Exponential	0.84997	0.27231
45	Exponential	0.99003	0.21164
46	Exponential	1.1026	0.26024
47	Exponential	1.2735	0.17616
48	Exponential	0.87331	0.23522
49	Exponential	1.2243	0.14191
50	Exponential	1.4836	0.13241
51	Exponential	1.1014	0.10861
52	Exponential	1.1328	0.17791

TABLE E10. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR LOUISIANA REGION 2.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	1.3187	0.07661
2	Exponential	1.1153	0.12827
3	Exponential	1.1773	0.15053
4	Exponential	1.2518	0.07754
5	Exponential	1.0036	0.16084
6	Exponential	1.1619	0.17057
7	Exponential	1.3043	0.10569
8	Exponential	1.2640	0.11479
9	Exponential	1.1670	0.11066
10	Exponential	0.85427	0.16558
11	Exponential	1.0764	0.16166
12	Exponential	1.0066	0.19789
13	Exponential	1.0521	0.16205
14	Exponential	1.0580	0.19082
15	Exponential	1.3400	0.21319
16	Exponential	1.0548	0.31541
17	Exponential	0.98732	0.24658
18	Exponential	1.0684	0.21665
19	Exponential	1.2128	0.20408
20	Exponential	1.1402	0.28803
21	Exponential	1.0474	0.23625
22	Exponential	0.91914	0.27229
23	Exponential	1.0221	0.20276
24	Exponential	1.2817	0.15883
25	Exponential	1.2779	0.15777
26	Exponential	1.1515	0.12368
27	Exponential	1.4256	0.07922
28	Exponential	1.5466	0.06726
29	Exponential	1.4778	0.05811
30	Exponential	1.5209	0.04295
31	Exponential	1.2829	0.09416
32	Exponential	1.4024	0.09327
33	Exponential	1.1354	0.09528
34	Exponential	1.3629	0.10976
35	Exponential	1.0319	0.13785
36	Exponential	1.4177	0.09099
37	Exponential	1.5868	0.16937
38	Exponential	1.1018	0.22213
39	Exponential	0.77606	0.33037
40	Exponential	0.76352	0.33658

41	Exponential	0.79681	0.44758
42	Exponential	0.60267	0.42203
43	Exponential	0.84827	0.39597
44	Exponential	0.86836	0.25689
45	Exponential	0.94896	0.24453
46	Exponential	0.92911	0.28537
47	Exponential	1.1391	0.18476
48	Exponential	0.83382	0.23027
49	Exponential	1.2257	0.14587
50	Exponential	1.3003	0.10445
51	Exponential	1.1865	0.09829
52	Exponential	1.0864	0.15102

TABLE E11. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR MISSISSIPPI REGION 1.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	1.4566	0.09018
2	Exponential	1.1020	0.11906
3	Exponential	1.0546	0.06804
4	Exponential	1.2085	0.05467
5	Exponential	1.0987	0.17661
6	Exponential	1.0701	0.14432
7	Exponential	1.3102	0.06791
8	Exponential	1.2164	0.11489
9	Exponential	1.3338	0.07714
10	Exponential	1.2750	0.10333
11	Exponential	1.3819	0.10362
12	Exponential	1.1753	0.07453
13	Exponential	1.0993	0.11015
14	Exponential	1.2377	0.11514
15	Exponential	1.3583	0.15718
16	Exponential	1.1079	0.14375
17	Exponential	1.3662	0.10852
18	Exponential	1.3699	0.15744
19	Exponential	1.1028	0.12275
20	Exponential	0.97476	0.26637
21	Exponential	1.0264	0.15247
22	Exponential	0.97269	0.18254
23	Exponential	0.88900	0.29709
24	Exponential	0.97903	0.16573
25	Exponential	0.84845	0.20630
26	Exponential	0.93900	0.18764
27	Exponential	0.90154	0.19213
28	Exponential	0.91225	0.22800
29	Exponential	0.84247	0.19313
30	Exponential	1.1324	0.12950
31	Exponential	0.66810	0.27092
32	Exponential	0.77123	0.20859
33	Exponential	0.73810	0.26832
34	Exponential	0.59295	0.30208
35	Exponential	0.59702	0.32043
36	Exponential	0.68624	0.22750
37	Exponential	0.77121	0.29956
38	Exponential	0.82689	0.29768
39	Exponential	0.82417	0.29112
40	Exponential	0.67769	0.31440

41	Exponential	0.61389	0.41441
42	Exponential	0.60669	0.35533
43	Exponential	0.81499	0.31898
44	Exponential	0.62840	0.24614
45	Exponential	1.0461	0.20508
46	Exponential	1.0281	0.21663
47	Exponential	1.3821	0.09370
48	Exponential	1.0573	0.19184
49	Exponential	1.3113	0.12408
50	Exponential	1.3369	0.11652
51	Exponential	1.0704	0.11859
52	Exponential	1.2529	0.16383

TABLE E12. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR MISSISSIPPI REGION 2.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	1.3258	0.07029
2	Exponential	1.1138	0.11579
3	Exponential	1.2728	0.11729
4	Exponential	1.4287	0.05697
5	Exponential	1.1100	0.16300
6	Exponential	1.3087	0.13578
7	Exponential	1.3776	0.09894
8	Exponential	1.2998	0.09947
9	Exponential	1.5032	0.08864
10	Exponential	1.1450	0.13417
11	Exponential	1.3712	0.14275
12	Exponential	1.1893	0.11550
13	Exponential	1.3445	0.13034
14	Exponential	1.2257	0.14807
15	Exponential	1.5986	0.17136
16	Exponential	0.99913	0.27279
17	Exponential	1.1417	0.20549
18	Exponential	1.2610	0.19790
19	Exponential	1.1071	0.23626
20	Exponential	1.1196	0.30432
21	Exponential	0.99097	0.22530
22	Exponential	0.87529	0.26133
23	Exponential	0.85863	0.27468
24	Exponential	1.0883	0.17673
25	Exponential	1.0202	0.15022
26	Exponential	1.0199	0.13715
27	Exponential	1.2113	0.10304
28	Exponential	1.2634	0.13893
29	Exponential	1.3094	0.07926
30	Exponential	1.3864	0.06250
31	Exponential	1.1142	0.13373
32	Exponential	1.0306	0.15904
33	Exponential	0.97627	0.18610
34	Exponential	0.89501	0.18601
35	Exponential	0.81596	0.19507
36	Exponential	1.1015	0.18263
37	Exponential	1.0856	0.23937
38	Exponential	0.90128	0.29638
39	Exponential	0.81641	0.31222
40	Exponential	0.73826	0.36573

41	Exponential	0.66926	0.47255
42	Exponential	0.56268	0.45481
43	Exponential	0.68052	0.38290
44	Exponential	0.72922	0.27581
45	Exponential	0.94913	0.20074
46	Exponential	0.93542	0.30758
47	Exponential	1.2707	0.18012
48	Exponential	0.93421	0.23313
49	Exponential	1.2612	0.14603
50	Exponential	1.4531	0.09591
51	Exponential	1.2126	0.09403
52	Exponential	1.1544	0.13278

TABLE E13. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR NORTH CAROLINA REGION 1.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	0.91820	0.09633
2	Exponential	0.87453	0.13333
3	Exponential	0.86499	0.08914
4	Exponential	0.87219	0.09573
5	Exponential	0.7300	0.19633
6	Exponential	0.85053	0.16572
7	Exponential	1.0170	0.09507
8	Exponential	0.85171	0.09443
9	Exponential	1.0334	0.09480
10	Exponential	0.87021	0.07014
11	Exponential	0.98840	0.09173
12	Exponential	1.0160	0.05862
13	Exponential	0.88844	0.12401
14	Exponential	0.92012	0.12318
15	Exponential	0.81708	0.13393
16	Exponential	0.71083	0.18701
17	Exponential	0.84162	0.12768
18	Exponential	0.79375	0.15593
19	Exponential	0.79986	0.13205
20	Exponential	0.85392	0.14337
21	Exponential	0.91174	0.10550
22	Exponential	0.84264	0.17079
23	Exponential	0.96613	0.11384
24	Exponential	1.0547	0.10887
25	Exponential	0.87585	0.11435
26	Exponential	0.85757	0.11918
27	Exponential	0.94561	0.10538
28	Exponential	1.1300	0.10181
29	Exponential	1.0560	0.09326
30	Exponential	1.1087	0.09955
31	Exponential	0.92989	0.11751
32	Exponential	1.0518	0.12176
33	Exponential	1.1098	0.12344
34	Exponential	0.87464	0.17926
35	Exponential	0.71468	0.23663
36	Exponential	1.0593	0.19340
37	Exponential	0.69723	0.29605
38	Exponential	0.86047	0.23616
39	Exponential	0.99485	0.21053
40	Exponential	0.84728	0.27559

41	Exponential	0.77370	0.35658
42	Exponential	0.75310	0.25393
43	Exponential	0.69212	0.28266
44	Exponential	0.61610	0.26286
45	Exponential	0.62768	0.18007
46	Exponential	0.59830	0.26196
47	Exponential	0.74771	0.14335
48	Exponential	0.69409	0.21609
49	Exponential	0.82057	0.19069
50	Exponential	0.86899	0.12159
51	Exponential	0.64548	0.15464
52	Exponential	0.86691	0.12571

TABLE E14. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR NORTH CAROLINA REGION 2.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	0.86345	0.09285
2	Exponential	0.85814	0.10065
3	Exponential	0.87337	0.08495
4	Exponential	0.89095	0.05140
5	Exponential	0.70496	0.17521
6	Exponential	0.86516	0.12465
7	Exponential	0.92968	0.07607
8	Exponential	0.80831	0.08824
9	Exponential	1.0474	0.07922
10	Exponential	0.85763	0.08783
11	Exponential	0.86740	0.07176
12	Exponential	0.89441	0.07713
13	Exponential	0.71220	0.16651
14	Exponential	0.79316	0.11284
15	Exponential	0.81383	0.13462
16	Exponential	0.66620	0.20146
17	Exponential	0.78318	0.13163
18	Exponential	0.77740	0.12420
19	Exponential	0.75614	0.16438
20	Exponential	0.83874	0.14090
21	Exponential	1.0189	0.09716
22	Exponential	0.81433	0.17804
23	Exponential	0.94406	0.15731
24	Exponential	0.99105	0.14038
25	Exponential	1.1016	0.07952
26	Exponential	0.93775	0.07948
27	Exponential	1.1772	0.07956
28	Exponential	1.4221	0.09016
29	Exponential	1.2495	0.08668
30	Exponential	1.3946	0.06100
31	Exponential	1.1672	0.08700
32	Exponential	1.1432	0.09936
33	Exponential	1.3770	0.10065
34	Exponential	1.1497	0.15688
35	Exponential	0.85577	0.21895
36	Exponential	1.2869	0.16529
37	Exponential	0.97775	0.27615
38	Exponential	0.97103	0.24081
39	Exponential	1.0496	0.19213
40	Exponential	0.81620	0.27413

41	Exponential	0.64469	0.38944
42	Exponential	0.77300	0.27864
43	Exponential	0.60721	0.26990
44	Exponential	0.61731	0.25508
45	Exponential	0.65314	0.18450
46	Exponential	0.55631	0.26606
47	Exponential	0.69242	0.18006
48	Exponential	0.59360	0.19403
49	Exponential	0.70175	0.15963
50	Exponential	0.84616	0.09108
51	Exponential	0.62710	0.13838
52	Exponential	0.79307	0.12570

TABLE E15. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR SOUTH CAROLINA REGION 1.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	1.2390	0.07656
2	Exponential	1.0566	0.11594
3	Exponential	1.0453	0.08824
4	Exponential	0.99852	0.06220
5	Exponential	0.90663	0.19231
6	Exponential	1.0577	0.12195
7	Exponential	1.1492	0.07692
8	Exponential	1.0331	0.09662
9	Exponential	1.1664	0.10194
10	Exponential	1.1162	0.05854
11	Exponential	1.0918	0.13592
12	Exponential	1.2073	0.10784
13	Exponential	1.1097	0.14778
14	Exponential	0.99846	0.10577
15	Exponential	0.87381	0.14762
16	Exponential	0.69654	0.23077
17	Exponential	0.96422	0.13270
18	Exponential	0.96156	0.20000
19	Exponential	0.87343	0.13527
20	Exponential	0.70637	0.26471
21	Exponential	0.90043	0.16346
22	Exponential	0.73654	0.20976
23	Exponential	0.94428	0.14904
24	Exponential	0.86282	0.12621
25	Exponential	0.81447	0.14078
26	Exponential	0.98865	0.14904
27	Exponential	0.89580	0.14976
28	Exponential	0.90763	0.18357
29	Exponential	1.0214	0.14706
30	Exponential	1.0597	0.13107
31	Exponential	0.96317	0.16337
32	Exponential	0.89930	0.18593
33	Exponential	0.98130	0.17874
34	Exponential	0.80296	0.19903
35	Exponential	0.64291	0.29126
36	Exponential	0.92550	0.20574
37	Exponential	0.70848	0.27962
38	Exponential	0.75781	0.32857
39	Exponential	0.96028	0.22275
40	Exponential	0.83110	0.34928

41	Exponential	0.84419	0.39524
42	Exponential	0.59384	0.30806
43	Exponential	0.67225	0.33493
44	Exponential	0.67367	0.27536
45	Exponential	0.67859	0.18049
46	Exponential	0.70307	0.29268
47	Exponential	0.89778	0.14493
48	Exponential	0.79311	0.19417
49	Exponential	0.96028	0.14423
50	Exponential	1.0436	0.16098
51	Exponential	0.84150	0.12560
52	Exponential	1.0500	0.08738

TABLE E16. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR SOUTH CAROLINA REGION 2.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	0.89113	0.08627
2	Exponential	0.87994	0.12136
3	Exponential	0.85119	0.09587
4	Exponential	0.89311	0.06553
5	Exponential	0.70343	0.16848
6	Exponential	0.95126	0.15049
7	Exponential	0.88468	0.10788
8	Exponential	0.81771	0.11206
9	Exponential	1.0212	0.10662
10	Exponential	0.98088	0.10909
11	Exponential	0.90614	0.09235
12	Exponential	0.97511	0.11004
13	Exponential	0.78757	0.19539
14	Exponential	0.80603	0.14027
15	Exponential	0.82213	0.19468
16	Exponential	0.56134	0.27316
17	Exponential	0.73274	0.18380
18	Exponential	0.76223	0.19807
19	Exponential	0.67584	0.21437
20	Exponential	0.65648	0.22596
21	Exponential	0.93797	0.14440
22	Exponential	0.78842	0.18841
23	Exponential	1.1466	0.12107
24	Exponential	1.1167	0.13631
25	Exponential	1.0454	0.11793
26	Exponential	0.92208	0.11353
27	Exponential	1.1836	0.06010
28	Exponential	1.1897	0.12411
29	Exponential	1.3950	0.08213
30	Exponential	1.3784	0.07758
31	Exponential	1.1339	0.10172
32	Exponential	1.1870	0.10964
33	Exponential	1.3529	0.10361
34	Exponential	1.1559	0.12727
35	Exponential	0.92815	0.21618
36	Exponential	1.3576	0.15840
37	Exponential	0.93878	0.24517
38	Exponential	0.91687	0.27349
39	Exponential	1.0459	0.21034
40	Exponential	0.70842	0.36527

41	Exponential	0.70960	0.40361
42	Exponential	0.75054	0.35671
43	Exponential	0.52852	0.34499
44	Exponential	0.51335	0.30147
45	Exponential	0.52520	0.22619
46	Exponential	0.52389	0.33857
47	Exponential	0.64137	0.18226
48	Exponential	0.57483	0.21220
49	Exponential	0.68005	0.20241
50	Exponential	0.85676	0.13664
51	Exponential	0.65547	0.15515
52	Exponential	0.87297	0.14061

TABLE E17. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR TEXAS REGION 1.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	0.70057	0.24481
2	Exponential	0.71744	0.28040
3	Exponential	0.80201	0.23762
4	Exponential	0.68161	0.25719
5	Exponential	0.76655	0.25530
6	Exponential	0.69838	0.25023
7	Exponential	0.85818	0.20322
8	Exponential	0.94113	0.18141
9	Exponential	0.86675	0.20036
10	Exponential	0.77463	0.23440
11	Exponential	0.77172	0.21696
12	Exponential	0.7220	0.19893
13	Exponential	0.82335	0.20848
14	Exponential	0.77719	0.28673
15	Exponential	0.93965	0.17349
16	Exponential	0.96930	0.21333
17	Exponential	1.5475	0.15631
18	Exponential	1.3014	0.16071
19	Exponential	1.2055	0.21233
20	Exponential	1.1271	0.26960
21	Exponential	0.90525	0.23165
22	Exponential	0.89448	0.25314
23	Exponential	0.92273	0.27743
24	Exponential	0.96417	0.31640
25	Exponential	0.78550	0.30563
26	Exponential	0.79006	0.33213
27	Exponential	0.63806	0.37021
28	Exponential	0.61596	0.41829
29	Exponential	0.66452	0.38222
30	Exponential	0.74710	0.36600
31	Exponential	0.39672	0.48685
32	Exponential	0.54074	0.37232
33	Exponential	0.48878	0.40410
34	Exponential	0.56657	0.38324
35	Exponential	0.64250	0.37996
36	Exponential	0.75288	0.33927
37	Exponential	0.92231	0.33779
38	Exponential	0.80870	0.33988
39	Exponential	0.69382	0.41234
40	Exponential	0.67809	0.41786

41	Exponential	0.81012	0.41800
42	Exponential	0.89766	0.38201
43	Exponential	0.99230	0.33810
44	Exponential	0.91629	0.33032
45	Exponential	0.85488	0.30749
46	Exponential	0.90729	0.30667
47	Exponential	0.99630	0.28762
48	Exponential	0.69495	0.37156
49	Exponential	0.96306	0.25135
50	Exponential	1.1178	0.22958
51	Exponential	0.70969	0.26763
52	Exponential	0.76578	0.29208

TABLE E18. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR TEXAS REGION 2.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	0.92844	0.12428
2	Exponential	0.89871	0.18722
3	Exponential	0.99836	0.15233
4	Exponential	0.77583	0.17145
5	Exponential	0.80623	0.18573
6	Exponential	0.83802	0.16730
7	Exponential	0.82487	0.14657
8	Exponential	0.95715	0.16160
9	Exponential	0.72625	0.15494
10	Exponential	0.52582	0.20381
11	Exponential	0.77964	0.19275
12	Exponential	0.76304	0.21146
13	Exponential	0.76602	0.21447
14	Exponential	0.71984	0.25996
15	Exponential	0.98116	0.24256
16	Exponential	0.85002	0.28081
17	Exponential	1.0674	0.23106
18	Exponential	1.1001	0.20091
19	Exponential	1.0759	0.25144
20	Exponential	1.1953	0.26073
21	Exponential	0.82071	0.27004
22	Exponential	0.93019	0.29587
23	Exponential	0.91710	0.32383
24	Exponential	0.96945	0.29949
25	Exponential	1.0998	0.25032
26	Exponential	0.90984	0.22949
27	Exponential	0.82015	0.24588
28	Exponential	0.83525	0.27210
29	Exponential	0.82347	0.24952
30	Exponential	0.92202	0.27735
31	Exponential	0.59253	0.33333
32	Exponential	0.75885	0.27944
33	Exponential	0.73208	0.29090
34	Exponential	0.89788	0.22258
35	Exponential	0.95583	0.22086
36	Exponential	1.0970	0.18662
37	Exponential	1.1938	0.24348
38	Exponential	1.1354	0.26667
39	Exponential	0.86528	0.37516
40	Exponential	0.67548	0.41640

41	Exponential	0.87734	0.40499
42	Exponential	1.0142	0.36184
43	Exponential	0.87392	0.32674
44	Exponential	0.93576	0.27249
45	Exponential	0.87624	0.22568
46	Exponential	0.95187	0.24713
47	Exponential	1.0635	0.23350
48	Exponential	0.72639	0.28222
49	Exponential	0.96430	0.16751
50	Exponential	1.1465	0.17591
51	Exponential	0.97405	0.17756
52	Exponential	0.80838	0.21009

TABLE E19. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR VIRGINIA REGION 1.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	0.67475	0.12748
2	Exponential	0.69603	0.11667
3	Exponential	0.70931	0.08562
4	Exponential	0.81186	0.08317
5	Exponential	0.62752	0.18170
6	Exponential	0.69549	0.15355
7	Exponential	0.78882	0.07771
8	Exponential	0.69636	0.11806
9	Exponential	0.81734	0.08571
10	Exponential	0.74983	0.07775
11	Exponential	0.89169	0.09602
12	Exponential	0.92894	0.06940
13	Exponential	0.67396	0.11817
14	Exponential	0.82538	0.10075
15	Exponential	0.77058	0.13453
16	Exponential	0.66604	0.13894
17	Exponential	0.86455	0.05882
18	Exponential	0.83694	0.11391
19	Exponential	0.82444	0.08798
20	Exponential	0.96676	0.07430
21	Exponential	0.80760	0.06952
22	Exponential	0.92945	0.09856
23	Exponential	0.84975	0.15161
24	Exponential	0.94303	0.08002
25	Exponential	0.91198	0.08967
26	Exponential	0.75342	0.11327
27	Exponential	0.89057	0.10012
28	Exponential	0.99143	0.08390
29	Exponential	0.84455	0.09803
30	Exponential	1.0387	0.07410
31	Exponential	0.77320	0.10019
32	Exponential	0.93467	0.07669
33	Exponential	0.91862	0.10135
34	Exponential	0.81301	0.18249
35	Exponential	0.53731	0.27953
36	Exponential	0.90286	0.22508
37	Exponential	0.77784	0.20343
38	Exponential	0.82817	0.14347
39	Exponential	0.84391	0.16758
40	Exponential	0.77889	0.20122

41	Exponential	0.61990	0.31049
42	Exponential	0.79201	0.24526
43	Exponential	0.70107	0.23067
44	Exponential	0.65503	0.21620
45	Exponential	0.76715	0.13723
46	Exponential	0.47847	0.21398
47	Exponential	0.70165	0.12656
48	Exponential	0.70405	0.15447
49	Exponential	0.76074	0.13968
50	Exponential	0.77065	0.07147
51	Exponential	0.56778	0.13421
52	Exponential	0.69290	0.15312

TABLE E20. DISTRIBUTIONS AND PROBABILITIES OF ZERO RAINFALL BY WEEK FOR VIRGINIA REGION 2.

Week	Distribution of Rainfall		Probability of Zero Rainfall
	Type	Beta	
1	Exponential	0.80861	0.10838
2	Exponential	0.79170	0.10172
3	Exponential	0.75485	0.08550
4	Exponential	0.87666	0.08528
5	Exponential	0.66227	0.18008
6	Exponential	0.74046	0.16582
7	Exponential	0.82994	0.08227
8	Exponential	0.72343	0.12516
9	Exponential	0.88947	0.08013
10	Exponential	0.80424	0.08652
11	Exponential	0.89307	0.09446
12	Exponential	0.91697	0.06646
13	Exponential	0.71996	0.12138
14	Exponential	0.79972	0.10440
15	Exponential	0.74454	0.12028
16	Exponential	0.66426	0.19425
17	Exponential	0.81134	0.09623
18	Exponential	0.83455	0.11252
19	Exponential	0.74333	0.11772
20	Exponential	0.88574	0.11890
21	Exponential	0.88536	0.06717
22	Exponential	0.93769	0.11776
23	Exponential	0.79828	0.17405
24	Exponential	0.87179	0.14020
25	Exponential	0.88937	0.13114
26	Exponential	0.83590	0.09470
27	Exponential	0.90591	0.10338
28	Exponential	1.1413	0.10667
29	Exponential	0.92253	0.14286
30	Exponential	1.1405	0.08166
31	Exponential	0.89585	0.12327
32	Exponential	1.0449	0.10092
33	Exponential	1.1171	0.11931
34	Exponential	0.89991	0.19901
35	Exponential	0.66458	0.27424
36	Exponential	0.94714	0.23468
37	Exponential	0.88445	0.27083
38	Exponential	0.89413	0.16687
39	Exponential	0.89451	0.15667
40	Exponential	0.88039	0.21033

41	Exponential	0.59809	0.35222
42	Exponential	0.83163	0.26942
43	Exponential	0.75536	0.23300
44	Exponential	0.67430	0.21121
45	Exponential	0.76551	0.12316
46	Exponential	0.52844	0.24770
47	Exponential	0.74047	0.13399
48	Exponential	0.66317	0.16429
49	Exponential	0.74220	0.17284
50	Exponential	0.91682	0.05857
51	Exponential	0.61012	0.12500
52	Exponential	0.69102	0.16865