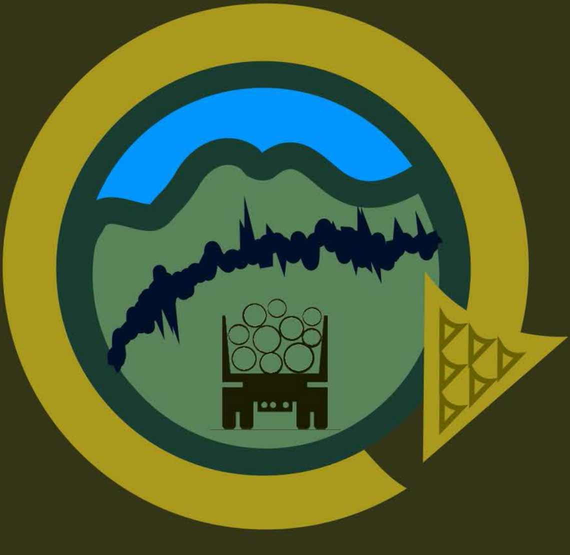
Continuous Improvement in Logging



Steven Bick

Jeffrey G. Benjamin

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in

Logging

Steven Bick

Jeffrey G. Benjamin

Forest
Enterprise
Institute

Thendara, NY

In Memory of Eric A. Johnson

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The desire to improve drives and sustains productive work. There is a proven theory behind this concept of continuous improvement, but plenty of people have found their way to using this approach without ever knowing this theory. Many of those who practice this approach are small business owners. Some of these small business owners are loggers.

There is a good chance of recognizing some of the concepts outlined here as standard practices. There is also a good chance that a lack of awareness means some loggers are not taking this approach far enough to realize all the benefits that can come from it. This publication will demonstrate how a continuous improvement approach can improve logging profits.

Continuous Improvement theory is easily explained and can be implemented without additional investment. This theory has been widely adopted in manufacturing, project management and other fields. Big businesses started to adopt this approach in the 1980's and have taken it to new levels. Small businesses have adopted this approach in a piecemeal fashion, or not at all.

Continuous Improvement theory is also known as the Theory of Constraints, or TOC (Goldratt, 1990). The Theory of Constraints was pioneered by Eliyahu M. Goldratt. Goldratt was a physicist by training. His work initially focused on simplifying complicated systems. This in turn led to simplifying production processes in many different industries.

The theory states in any productive enterprise, the rate of production is dictated by a constraint, or bottleneck. Eliminating a constraint will then reveal another.

Repeating this process will eventually reveal the primary constraint in a system. Exploiting this constraint to its fullest capacity will maximize the production in a system.

Loggers and other forestry professionals are particularly sensitive to the idea of exploitation. The term "exploit" is used here as a verb, in its most literal sense, meaning:

> *to make full use of and derive benefit from (a resource).*

As used in continuous improvement theory, "exploit" refers to enhancing the productive process through full use of the slowest step. It does not mean to overuse or degrade natural resources.

There is a natural tendency for people and organizations to complicate things, but how often do complications improve thing? In logging, the work itself is difficult enough.

The natural complications of the terrain, timber and weather are all surmountable. Add in the complexities introduced by landowners, foresters and public agencies and the challenges mount. Any action that simplifies matters is welcome.

Goldratt came up with a very effective means of spreading his ideas. Rather than relying heavily on academic journals or other technical publications, he worked with author Jeff Cox to present his theory as a novel. *The Goal – a Process of On-going Improvement* - was first published in 1984. Since that time is has been re-issued four more times, is widely used in business schools and inspired a new genre of writing for business training.

The novel follows the working of a fictional factory, where the plant manager and his team learn and implement continuous improvement methods. A failing business is saved from financial ruin and each of the important concepts behind continuous improvement theory is explained in practical terms. The book is well worth reading (or listening to during long commutes), but the logging audience will need to think carefully about how to apply it.

Goal of a Logging Business

Continuous improvement theory is based on the idea that the goal of any business is as follows:

> *To make money, both now and in the future.*

When pressed, individual small business owners, including loggers, may state their goal somewhat differently, using terms like *"to make money that sticks"*, *"make more money"* or *"get a return on investment and not just turn over dollars"*. All these expressions are consistent with the idea of making money. A logger's underlying investment in equipment that takes years to pay off lends weight to the importance of making money in the future.

Accepting the goal of making money, now and in the future, is the first important simplification in the move toward continuous improvement. Although most business owners know this, the idea can be carelessly overlooked in day-to-day decision making. In logging, it is very easy for common tasks to become goals themselves, rather than serve the business's financial goal.

Every business decision should be judged on whether it contributes to the underlying goal of making money. Loggers must ask themselves "why do this?". If the action doesn't make money or protect and promote opportunities for making money in the future, why do it?

With the goal of making money firmly in place, continuous improvement theory pinpoints the following three ways of meeting this goal:

- increase revenue;
- decrease investment; and
- decrease operating expenses.

These financial measurements are discussed in detail in the next chapter and applied specifically to logging businesses.

Key Concepts in Continuous Improvement

Improvement implies change. Continuous improvement means on-going changes. People generally do not like change, yet changes occur all the time.

A handful of key assumptions underlie the continuous improvement approach. Chief among these is that a system is only as productive as its slowest part. If constraints control production, elimination of one constraint will reveal another. The production process should be arranged to maximize utilization of the limiting constraint to take full advantage of these realities.

Is a system only as productive its slowest part? How about in logging? If a crew can fell and skid three loads a day, but the equipment on the header is only capable of delimbing, slashing and loading two loads, what is the total daily production for this system?

Suppose this crew found that by switching operators, the header was now capable of processing four loads per day. Does the system's daily production jump to four loads, or is it limited to the three loads the rest of the crew is capable of felling and skidding?

How can system capacity be increased? The new constraint in this system is the skidding.

How will this logger find a way to make sure the skidder is used to its full capacity? Would a longer shift for the skidder work? What about a bigger skidder or the addition of a second skidder? Are their ways to shorten the skidding cycle time?

Productive operations have the following three characteristics:

- there are dependent productive resources;
- there is a general direction of work flow; and
- anything that can go wrong, will go wrong (Murphy's law).

In logging, productive work depends on advance preparation, movement of equipment and then establishment of a site-specific process for the harvesting system. To process wood and load it onto a truck for delivery, it must first be skidded to a landing or header. Before it can be skidded, the trees must first be felled. Even a single-person operation is captive to dependent events.

In logging the general direction of work flow is from the forest to the mill. In the operation itself, a better description might be from the stump to the truck.

Just when a process is established and working well, Murphy's law weighs in and something goes wrong. The preparedness and responses to such mishaps determine how much of an impact Murphy's law has on production.

Five Step Process

Goldratt states there are five focusing steps in the continuous improvement process:

1. Identify the constraint;
2. Exploit the constraint;
3. Subordinate everything to the constraint;

4. Elevate the constraint; and
5. Prevent inertia from becoming the constraint.

These steps work for solving individual problems and as an approach to overall improvement of a business. In logging, these steps might be applied to existing production methods, moving equipment and establishing methods for an individual harvesting site, or finding the ideal mix of equipment for business expansion.

Identification of the constraint is the starting point. There may be a bit of trial an error in this doing this. Loggers (and most small businesses) excel at pinpointing mechanical difficulties. A more difficult diagnosis may involve admitting limitations and personnel problems that have been previously tolerated or ignored.

A constraint in production is known as a bottleneck. If a suspected bottleneck is eliminated or used to its fullest capacity, the rate of production will increase. If not, it was not a bottleneck.

Once a bottleneck is identified, it must be **exploited**. For example, if a piece of equipment is a bottleneck, it must be used to its full capacity. This might mean scheduling repairs and maintenance to minimizes down time, creating longer shifts for the operator or perhaps putting a better operator in place.

Once the bottleneck is identified and exploited (used to its fullest capacity) other aspects of the production process and business must be **subordinated** to this decision. This might mean halting other machines so operators can help with emergency repairs, or training a substitute operator who can step in when the primary operator is unavailable.

Since the slowest step in a production process dictates the rate of production for the entire system, it is important that the entire production crew and support team are aware of the primary constraint. This sort of operational awareness ensures that everyone is ready to take any steps necessary to keep production flowing smoothly. No operator is an island, so it's essential that everyone knows this.

Elevation of the system's constraints is the next step after subordinating everything to exploiting a known bottleneck. This will go beyond simple procedural changes and involve changes to increase the actual capacity of the constraint. Some re-alignment of the actual production process may be in order. The owner will have to decide if further investment is warranted.

Decisions on further investment in capacity should not be made lightly. Continuous improvement theory suggests that in most productive enterprises, up to 30 percent more production is possible without any significant increase in investment. Field observations of logging companies bear this out. Does every logger with the same mix of equipment, working in the same timber, produce an equal amount each week? Are some crews more productive than others? Are some bottleneck function operators more productive than others?

Goldratt's last step is do not let **inertia** cause a constraint. Inertia can be defined in several ways, including *"a tendency to do nothing or to remain unchanged"* and *"a property of mater by which it continues in a uniform motion in a straight line"*. From a continuous improvement standpoint, think of it is the strong tendency of people to resist change.

As noted at the opening of this section, improvement and change come as a package. Continuous improvement means changes going forward that people are inclined to dislike. Purposeful changes that are dictated by logging business owners will often encounter resistance by the crew. Involving crew members in decisions to make changes that impact their day to day activities is a good way to get them to buy into the process.

If a bottleneck has been identified and fully exploited, it will result in an increase in production. As constraints are exploited, new ones should become evident. That is why this is a continuous process. Return to step one and find the next constraint to the process. This continuous approach is shown in Figure 1-1.

Elimination of smaller interfering bottlenecks that constrain the true potential of a logging operation will eventually expose the controlling bottleneck in an operation.

It is in this area that investment in increased capacity has the greatest potential to have positive financial results.

Bottlenecks that are specific to logging businesses are the subject of Chapter 3. Common interfering bottlenecks that hamper logging business potential are discussed, as are the controlling bottlenecks common to each of the primary logging systems used in the Northeast.

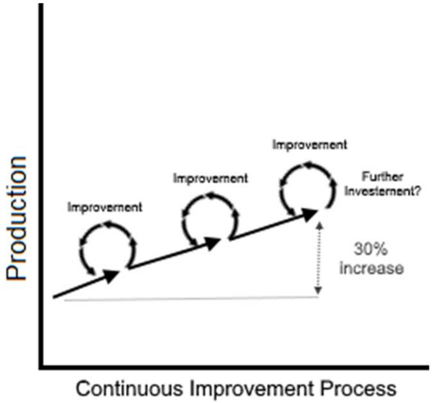


Figure 1-1. The continuous improvement process and production.

Rules for Optimizing Production

Goldratt has several useful rules for optimizing production while using the continuous improvement process. Several of these rules (bold sections) are presented here and then discussed in the content of a logging operation.

Full utilization of a non-bottleneck resource is a waste. Utilization of a resource and activation of a resource are not quite the same. Activation is what should be done (in other words, use as needed).

There has traditionally been pressure in any work place to “look busy”. Keeping busy is a poor excuse for making wasteful efforts. Production should be aligned so the bottleneck step in the process is fully activated. This necessarily dictates having enough capacity in other steps in the process to ensure this. For example, if the grapple skidders in an operation can pull enough wood in 30 hours to keep the landing supplied for 40 hours, there is little reason to keep skidding beyond 30 hours (unless there is ample landing room and the skidders can finish and be employed on another job). Even worse would be skidding the same amount of wood over a greater number of hours, just to look busy (more on the pitfalls of this in later chapters).

The utilization of a non-bottleneck function, then, is dictated not by its own potential, but by the needs of the production system. System-wide production is dictated by the bottleneck function, so this function determines the use of all others.

In some cases, extra capacity in non-bottleneck functions can be employed elsewhere in other ways that help the business.

Logging businesses with multiple crews often move equipment between jobs, as needed. Excess capacity in a larger feller-buncher is common. Some loggers have found it advantageous to hire these machines (operator included) to smaller loggers who cannot justify owning one themselves.

Time lost in the bottleneck function means a loss in system-wide production. This is the reason for exploiting the bottleneck to its fullest capacity and for subordinating all other aspects of the operation to this function.

In practice, time lost in a logging bottleneck can often be made up or minimized, but this requires prompt decision making and action. Logging equipment break downs are common. Time lost during a bottleneck breakdown might mean staying late (what choice is there when a truck is waiting to be loaded?). This might also mean a conscious decision to work on a weekend, even if it means the boss is the operator that day.

Time saved at a non-bottleneck is a mirage, at least in terms of the system’s output on an individual logging job.

In logging, processing the same amount of wood in one fewer hour means less wear on a machine. This, in turn, slightly lowers the level of investment (more on this in another chapter). This higher rate of production also contributes to adding potential days of production to the year, which can result in significant financial gains.

Capacity and priority of the production system should be considered simultaneously, not sequentially.

Capacity refers to how much wood each piece of logging equipment can process as part of its function in the overall system. Priority refers to the allocation of time and other resources to each step in the process. If full capacity operation of the bottleneck function is given the highest priority, it follows that the capacity of the other machines in the system must be sufficient to ensure uninterrupted operation of the bottleneck.

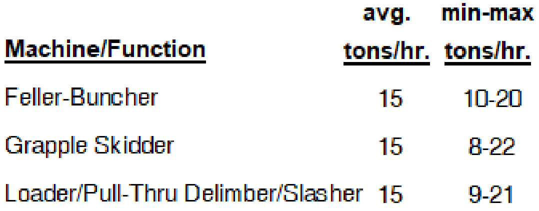
Balance the flow through the system, rather than the system's capacity.

The capacity of each machine must be sufficient to create a continuous flow of material that keeps the bottleneck fully engaged in production. It follows that the flow through the system must be balanced, rather than the capacity of each machine. Why?

The answer to this question lies in the three characteristics of productive systems that were discussed earlier:

- there are dependent productive resources;
- there is a general direction of work flow; and
- anything that can go wrong, will go wrong (Murphy's law).

Balancing the capacity of all machines in each stage of production results in a system that never reaches its full productive capacity. Consider the following whole tree harvesting system:



Machine/Function	avg. tons/hr.	min-max tons/hr.
Feller-Buncher	15	10-20
Grapple Skidder	15	8-22
Loader/Pull-Thru Delimber/Slasher	15	9-21

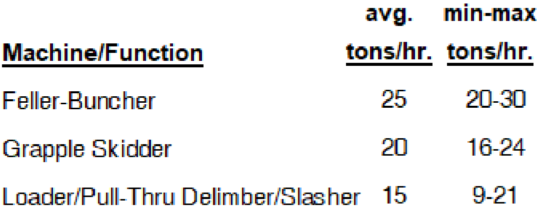
Each step in the process can process 15 tons per hour, on average. Will the average production of the entire system be 15 tons? Almost never.

The general direction of work flow is one of felling and bunching, followed by skidding and then processing on the landing. Each function depends on the on that proceeds it.

Suppose the feller-buncher is working in a stand of smaller, scattered wood and averages just 11 tons per hour. Or suppose the timber conditions are average and everything about the site is normal, what happens if Murphy pays a visit and time is lost to repairs? How can the skidder possibly average 15 tons per hour if only 11 tons per hour are available?

If the landing only receives 11 tons per hour, it will be unable to process 15 tons. Suppose further that this logger knows the landing is the bottleneck function on the job. Is this system capable of working to its full capacity when the upstream functions are insufficient to ensure this bottleneck is never idled?

Consider the following whole tree harvesting system:



Machine/Function	avg. tons/hr.	min-max tons/hr.
Feller-Buncher	25	20-30
Grapple Skidder	20	16-24
Loader/Pull-Thru Delimber/Slasher	15	9-21

If only capacity is considered, this system appears to be imbalanced. Using flow as the criteria, however, reveals that the feller-buncher can almost always supply at least 20 tons per hour. The grapple skidder, in turn, can almost always supply at least 16 tons per hour. The result is that the landing functions performed by the loader/delimber/slasher combination will have enough material to reach its average production potential of 15 tons per hour.

In practice, assigning the right priorities can make up for some of the potential shortfalls in capacity. It would be difficult for a logger to own sufficient equipment to always have everything that is needed for every possible job. The art of the production process comes in scheduling the production steps in such as way that each of the non-bottleneck functions has what it needs to ensure the bottleneck is never idled. More is coming on this topic in the chapter on bottlenecks in logging.

2 Financial Measurements

Measurements are necessary in determining if improvement is taking place. Financial measurements are the correct way of gauging success when the goal is to make money, both now and in the future. Throughput accounting methods were developed by Goldratt as an uncomplicated way of measuring financial results. Throughput accounting methods were first adapted to logging in the PATH (Planning and Analysis in Timber Harvesting) spreadsheet (Bick, 2017).

Logging is difficult to compare to a brick-and-mortar business, with fixed production facilities or a storefront. Traditional accounting rules treat logging like any other business. Monthly or quarterly profit and loss statements can be useful, but they do not reveal much about the types of harvesting jobs that are profitable.

Financial measurements in logging should be made for each individual harvesting job. In this way, the measurements serve as a guide for operational decision making, such as what jobs types best suit the harvesting system.

Profit and Return on Investment

Throughput accounting uses two straightforward but powerful financial measurements - *net profit* and *return on investment* (ROI). Some standard bookkeeping is necessary to make these financial measurements. These bookkeeping measurements include *throughput, operational expense* and *investment*.

Throughput is the rate at which a business generates net revenue. Calculation of throughput is a simple matter of multiplying the amount of each product produced (sawlogs, pulpwood, chips, etc.) by the appropriate net price (removing stumpage and/or trucking costs) and then adding all the totals together.

Operational expense is the amount spent to harvest the timber. This includes the costs of owning and operating equipment, overhead, and any job-specific costs (e.g. moving, gravel, seeding, etc.). This accounting can be tedious, but fortunately (at least from an accounting standpoint!), most of the information is already summarized annually on an income tax return (Form 1040, Schedule C, in most cases). This information can be used to determine the average daily costs for overhead. Overhead can be thought of as fixed business costs not directly related to individual jobs.

Investment is the most difficult of these measures to grasp. A logging business is largely an investment in equipment. These machines enable production, but almost never appreciate in value. The investment is consumed during production through a process known as depreciation.

The proceeds from logging cover operational expenses first, recover the investment next and provide a profit last. It follows that a logger's investment in an individual timber harvesting job is the depreciation that occurs there. The most convenient way to measure this is hourly, used the productive machine hours (PMH) shown on each machine's hour meter. Multiply the cumulative number of PMH on a job for each machine by the appropriate depreciation rate. Summing the total or each machine results in the amount of invest on the job.

The practice of throughput accounting has shown that there is an additional element of investment that must be considered in the depreciation approach. Most machines have a core value that they retain through their useful lives. Some consider this a salvage value, but this is not entirely accurate. Quite a few loggers have a small business model that involves machines (especially cable skidders) that are so old that annual depreciation is minimal.

The core value of the machine (whether it is band new or 30 years old) represents a recurring portion of a logger's investment and requires an annual return. This portion of the investment is incorporated in the calculations by dividing the core value of each machine by the number of hours of expected annual use.

The resulting hourly rate is combined with hourly depreciation to arrive at an hourly rate for investment calculations. The cumulative machine hours on each harvesting site are multiplied by the appropriate rate to determine the total investment for the job.

Profit is simply revenue minus expenses. Any calculation of profit in an owner-operated business must include deducting a wage for the owner in the expense category (no one can turn a profit without first making a living). Often the next best paying alternative the owner has for employment is used in calculating this wage (alternatively, some businesses simply include the owner in the payroll). In this way, the return on the actual investment – the reward for taking the risk – is separated from payment for the owner’s time.

Return on Investment (ROI) is the rate of profit in relation to the investment needed to produce it. Loggers are reluctant to share their target return on investment rates, so it is difficult to identify benchmarks for comparison. An individual business can compare the ROI from one harvesting job to the next. While a logger might be unable to target only the most profitable jobs, knowing how individual jobs compare to one another will help in avoiding the least profitable ones.

Cash flow must not be overlooked in financial calculations. Sufficient cash flow is necessary to meet obligations and operate continuously. If the combination of cumulative income and cash on hand exceeds cumulative costs, cash flow will not be a problem.

Throughput Accounting Example

An example of throughput accounting for a harvesting job is shown in Table 2-1. This is a job that was completed over 25 days by a cut-to-length system (harvester & forwarder). Daily overhead is $250. Moving and water quality best management practices costs were $800.

In this example, the business recorded a $595 profit (over and above the expense of a reasonable wage for the owner/operator) for this harvesting job, representing a 4.5 percent return on its investment. This is a narrow margin – so much so that dropping the price of pulpwood by $1 per ton results in a net loss for the job!

In practice, many small changes in input and product prices can have a significant impact on financial results.

Table 2-1. Throughput accounting example.

Operational Expense			
general	days	$/day	cost
daily overhead	25	$ 250	$ 6,250
job costs (moving, seeding)			$ 800
machine costs	hours	$/hour	
CTL harvester	175	$ 125	$ 21,875
forwarder	150	$ 104	$ 15,600
total costs			**$ 44,525**
Throughput			
product	volume	price*	
sawlogs (MBF)	156	$ 120	$ 18,720
pulpwood (tons)	1,200	$ 22	$ 26,400
total throughput			**$ 45,120**
* price on landing; no trucking involved			
Investment			
machine	hours	$/hour	
CTL harvester	175	$ 45	$ 7,875
forwarder	150	$ 35	$ 5,250
			$ 13,125
Profit	= $45,120 - 44,535 = **$595**		
ROI	= $595 / $13,125 = **4.5%**		

Measurements and Decision Making

Using these financial measurements for each harvesting job allows a logger to make objective comparisons among them. While additional factors (weather, relationships, prospect of future work) often go into job selection, throughput accounting can bolster these choices with cold hard facts.

Throughput accounting allows for straightforward decision making by keeping financial measurements to a minimum. In choosing a course of action (harvest layout, number of machines, time of year, utilization mix, etc.) every decision can be judged in terms of its impact on throughput, return on investment and operational expense.

Increasing throughput in relation to the current reality of a logging business has the greatest potential to increase the well-being of the business. Loggers have limited influence on the price of their service or products. In situations where a switch in markets will increase price, such changes are often made rapidly, and then the focus shifts back to working on the production side of the equation to increase profits.

Return on investment is improved by increasing profits, reducing investment, or both. Increasing profits goes back to throughput. If, on average, more system-wide production per day can be achieved, profits go up. Increasing throughput under current conditions might mean modest increases in variable costs, but fixed costs remain the same.

Reducing investment on a logging job essentially means maintaining or improving throughput with fewer hours of equipment use each day. In some cases, this might mean changes to the harvesting process that allows fewer pieces of equipment to be used. It might also mean less use of equipment that must still be on site. Permanent removal of equipment that provides the occasional sprint or protective capacity can be tempting but it will not improve the return on investment. Keeping this capacity is necessary to keep the bottleneck fully operational at times.

Operating expenses are the easy scapegoat when it comes to figuring how to improve a business. This focus can be misguided and some mistakenly view it as a goal. Though wasteful spending (spending that does no help increase to throughput) should be always be cut, reduction of operational expenses has the least potential to improve the well-being of a business.

It is doubtful that any established logging business could make substantial (greater than 10-15%) reduction in operating expenses and still retain the necessary productive capacity.

The concepts behind throughput accounting are not difficult, but measuring them can be. The busy life of a logger, when coupled with a positive cash flow, can make critical measurements easy to overlook. PATH 2.1 (Planning & Analysis in Timber Harvesting) is a free spreadsheet utility that was recently updated to include throughput accounting measures for loggers. A link to a free download of PATH is shown in the resource section of this publication.

Note and Commentary on Logging Costs

Logging costs is a category of thought that have occupied foresters and others for generations. As a forest management and planning activity, there is nothing wrong with this. "What will it cost to harvest this timber?" is a question a forest management entity might rightly ask and then set out to determine.

The problem is that the forestry profession has had a large hand in logger training efforts and emphasis and, as a result, they have taken a perfectly good concept and used it as if it is interchangeable with the notion of a logger's cost of doing business. This has caused problems in two areas:

Treating "logging costs" the same as they if they were a "logger's costs" has institutionalized the notion that they are mathematically equivalent. The cost of having some timber harvested is not equal to the logger's cost of doing the work. Equating the two somehow removes the understanding that a logger invested money in a business with the expectation of realizing a profit.

Carrying the whole logging cost theme into the training world has placed an undue influence on controlling operational expenses as a means of improving a business. As noted earlier, throughput accounting places the emphasis where it belongs – on increasing revenue and improving ROI.

A common dilemma in a business is the seeming conflict between short-term tactics and long-term strategy. While the business exists to turn a profit, a local focus over-emphasizes curbing operating expenses, placing it in conflict with actions taken to increase throughput. Increasing throughput will increase profit and enhance ROI. Lowering operating expenses, while desirable, has a limited impact on profit. There are often very good reasons for safeguarding operating expenses, but blanket policies or inclinations against increasing this expense for any reason will not further the goal of the business. Cost inputs are an essential part of making money.

Suppose that a logger has a broken loader that can easily be repaired with a single part. Logs are on the landing and trucks are waiting to be loaded. Standard shipping will cost $50 and take two days. Overnight shipping will cost $100. Sending an employee and a pickup truck on a 200-mile round trip to retrieve the part will cost $250, but the loader will be fixed in time to send a load that same day.

This logger typically produces three loads each day and throughput on each load is $800. The best course of action is clearly to send the employee to retrieve the part – especially if this person is typically working in felling or skidding and there is buffer capacity in these areas. Nevertheless, quite a few loggers would naturally opt for the overnight shipping and a few might even choose standard shipping. Cost control can dominate thinking to the point where it undermines the true goal of making money.

3 Bottlenecks in Logging

Bottlenecks are constraints in any productive endeavor. As demonstrated in the first chapter, the bottlenecks dictate the rate of production for the entire system. Elimination of one bottleneck will eventually reveal another. Once a logging business has eliminated enough of these constraints, the primary bottleneck to the system will eventually be revealed. Once production is aligned to fully exploit this bottleneck, the business can decide if further investment in capacity is warranted.

Bottlenecks are not a bad thing or a negative force – they are simply the reality of a productive process. By definition, one part of the process must be the slowest and least productive. Find the slowest part and figure out how to get the most out of it.

Loggers frequently grapple with and subdue bottlenecks, both over the course of an individual job and throughout a career. Elimination of unnecessary bottlenecks allows a business to reach its full potential. Control and management of a primary bottleneck allows a logger to optimize production.

This chapter will examine some of the bottlenecks that can limit logging businesses unnecessarily. Potential solutions for each are discussed. Bottlenecks for each of the primary harvesting systems used in the Northeast (tree-length, cut-to-length and whole-tree) are examined. Finally, bottlenecks to overall management of a logging businesses are explored, along with their financial consequences.

Bottlenecks that Interfere with Logging

Factors outside the actual logging operation will often limit production. A business must plan around, respond to, properly schedule or outright avert these factors to ensure production flows smoothly.

Logging system productivity can be diminished or rendered irrelevant by common conditions and occurrences. These factors include trucking, weather, foresters, landowners, repairs, employee behavior and even the habits of the business owners themselves. The good news is that these actors can be minimized or overcome.

Trucking is essential to harvesting wood products. Logging businesses often struggle with trucking arrangements. Some choose to own and operate trucks and others hire out all their trucking. Often it is a combination of the two. While there is no industry-wide universal solution, there is often a best approach for an individual business.

Trucking is a bottleneck if it idles a logging business. This can occur if trucking is unreliable or a landing is too full to work, or equipment cannot be moved to the next job.

Ownership of trucks for some or all a business's transportation allows greater control of scheduling, though this comes with additional risks and responsibilities. Others achieve this same level of control by being the most important customer to a trucking company.

Owning excess trucking capacity can be wasteful, unless there are opportunities to offer trucking to other businesses. Some businesses have found that owning enough trucking capacity to handle all their moving needs and up to 80 percent of their wood deliveries gives them enough control avoid production delays.

Weather is a limiting factor that cannot be controlled. A logger's response to less than ideal weather is controllable. Planning and preparation go a long way toward minimizing lost productive time when weather does not cooperate.

Job scheduling is one of the ways of limiting the impact of weather on production. Certain times of the year have a much higher risk of work shutdowns for weather, such as most of the spring and the second half of the fall. Other sites require winter conditions for work. Sites should be judged and scheduled accordingly. For example, fine-textured soils give way to rain more readily than coarse-textured soils. These site characteristics are now easy to investigate in advance, using the National Resource Conservation Service's online soil mapper or various GPS based soil identification apps for smartphones.

While some sites should clearly be avoided at the wrong time of year, others are less easily judged. If the only work available is on a less than ideal choice, the logger must make the best of it.

Skidding is usually the function that is most weather dependent. It is advisable to get as much skidding done as possible in the higher risk locations while conditions are good. Saving higher and drier location for skidding after a rain can be worthwhile. If the landing has sufficient material to keep going, it is often possible to produce during poor weather, even if skidding and felling are curtailed temporarily.

Loggers in the northeast report working from 170 to 240 days per year. While the higher number often puts loggers at risk of violating water quality best management practices, it is possible to move toward the upper end of this range with careful planning. Late winter and early spring jobs on well-drained, coarse-textured soils along roadways without weight restrictions are best for this. These harvesting sites are not easy to find, which is a good reason to save them for parts of the year when other sites are inoperable.

Foresters are known for providing both a lot of work for loggers and a lot of headaches. Landowners can provide similar challenges. Since foresters and landowners control much of the resource, productive working relationships benefit all parties. Foresters have ability to schedule and design harvests and then suspend operations. These responsibilities give foresters a lot of influence on the logger's production, making them a bottleneck. Some loggers simply avoid working on harvests that involve foresters. This strategy has some merit, but it also excludes a lot of harvesting opportunities.

One logger, when asked about working with foresters, offered this comment:

"Oh, I like working with foresters. I'm training a new forester right now."

This guy is clearly on to something. He was developing a good working relationship and helping the young forester understand the considerations that go into logging. Loggers who find foresters they can work with can develop good long-term productive relationships.

People being as they are, every logger-forester combination will not be a perfect match. Loggers should cultivate work relationships with foresters who have the best combination of work habits, interpersonal skills, landowner clients and prescription tendencies to match the logger's operation. Avoid those who are difficult to work with. Managing these relationships well prevents foresters and ultimately procurement of work from becoming bottlenecks.

Breakdowns and subsequent repairs can be bottlenecks that wipe out entire weeks of potential production. Even a breakdown in a non-bottleneck function can eventually halt an entire operation. Loggers won't know exactly when a breakdown will happen, but should not be surprised when one does.

Regular maintenance is this first safeguard against breakdowns. This includes both a daily routine by the operator and scheduled maintenance by a mechanic. This work is both preventative and diagnostic. Noticing wear on allows parts to be ordered and on hand before breakdowns happen. One logger even suggests that daily maintenance be performed early enough in the day that parts can be ordered and on hand by the next day if they are needed.

There are any number of routine repairs that crop up regularly and can be handled on site. The key to minimizing the impact of these repairs on production is to have the parts, tools and skills on hand. Some loggers accomplish this with a parts and tools truck or trailer that is kept on the job site.

One logger observed that:

"80 percent of my repairs involve 20 percent of the parts I need."

This in turn dictated the things he kept on hand. For example, it is common to have hydraulic hoses pre-made to length and ready to install. Having a full set of hand tools, an air compressor and a welder on site are other important time savers.

Beyond parts, tools and preventative maintenance, loggers need the mechanical skills to use them. These are part of a larger set of problem-solving skills that are well-suited to adversity. The nature of the logging business tends to funnel those who have these skills into this life and weed out those who do not.

Just as mechanical and problem-solving skills can be learned and cultivated over time, so can responses to emergency situations. Logging is risky in many ways, including the physical risk of being injured or killed. It is easy enough to relate injuries to production losses, but the human costs are much greater.

Emergency response preparation requires both items on hand a crew-wide plan for what do if something goes wrong. Logger rescue innovator Dana Hinkley has suggested that each crew member have a personal first aid kit. Included in this kit is a “keep it with you” or KIWY form that includes that person’s private medical information so it can be provided to emergency responders and the hospital.

A one-page safety plan is essential. This plan has contact information for all the emergency responders for the location and a carefully worded set of directions that can be relayed on a 911 call. Regular safety discussion among crew members fosters a sense of readiness in case someone is injured.

Loggers invest in equipment, but must then rely on employees to operate it productively. Employees who show up late or not at all become a bottleneck to both production and potential growth. Disengaged employees who are present but are not focused on their work pose a similar problem. Most loggers only tolerate such behaviors when that is all the labor force offers. If paying a higher wage will attract better employees it is almost always worth the cost. One logger put it this way:

"I don't miss all the halfwits and misfits. I've got four guys now who are just outstanding."

The owner is sometimes the bottleneck in a logging operation. When this is the case it can be very difficult for them to see it, though it is usually obvious to others.

Owners of smaller logging operations who built their business slowly over time seem to be more prone toward this. Few of them got into logging because they wanted to manage people, but they soon find that any growth requires this. Those who do not learn to trust employees with certain duties or to make minor decisions (e.g. keep skidding vs. stop for a small repair) are placing limits on production.

A good test of this 'boss-as- the-bottleneck" limitation is whether the owner can leave the rest of the crew to work to go look at another potential job. Apart from safety concerns, a business owner who is unable to trust the crew to work during an occasional absence either has the wrong crew or the wrong approach.

In a single-person operation, the owner will always be the bottleneck. Successful loggers of this type almost always realize this and allocate their time accordingly. Those who wonder why they are not doing as well as some of their peers can always find the answer in how they spend their time. Improvements can be made by simply by avoiding things that do not contribute to their goals. More on this in the discussion of tree-length harvesting systems.

Whole-Tree Harvesting Bottlenecks

Whole tree harvesting systems are those that employ a feller-buncher to cut trees, grapple skidders for moving bunches of trees to the landing and then equipment for some mix of sorting, delimbing, slashing and chipping on the header or landing. Leon and Benjamin

(2013) found that this system is the dominant system in the Northeast, in terms of total timber harvested.

Several potential bottlenecks can limit the output of a whole tree system. Most of these involve the type of the machine and the size and stocking of the timber being harvested.

The feller-buncher becomes the bottleneck if the type of machine is insufficient to keep the rest of the system supplied with wood. This could depend on its locomotion (wheeled vs. tracked) or cutting head (hot vs. intermittent; saw vs. saw bar). Some trial and error is usually involved in getting the right feller-buncher in place, but most loggers avoid this bottleneck and figure it out. Some smaller operations have found it easier to hire out the felling to a subcontractor who has the right machine for the job, rather than own one themselves.

The size and spacing of trees for harvest can cause a bottleneck in the felling and bunching. These variables are often dictated by a forester's harvest prescription. Feller-bunchers can efficiently harvest small diameter trees, though the smaller sizes may cause problems further down the production line. Widely spaced harvest trees slow down the felling and bunching process considerably, regardless of tree size. If the size and spacing of tree is such that the skidder or skidders are idled waiting for wood, then the feller-buncher becomes the bottleneck.

Occasional harvesting jobs of this type mean that the logger or perhaps the forester have made a mistake in putting the wrong harvesting system on the site. Frequent occurrences of this type of bottleneck means that the logger has the wrong feller-buncher (or perhaps the wrong system entirely) for the work that is available. Both situations are correctable.

Skidding in a whole-tree system becomes a bottleneck when the processing functions on the landing become idle while waiting for hitches of wood. Skidding is a bottleneck that has plagued many operations, but it is also one that has been eliminated by many successful loggers. Important grapple skidding variables are capacity (size of the machine or number of machines), tree size, terrain and distance. These factors all interact with one another.

A single grapple skidder capable of pulling hitches of up to five tons is adequate for many whole-tree operations, providing the skidding distance is not too far. In general, on uniform terrain, with average skidding distances that do not exceed one half mile, a single skidder is adequate to keep up with one feller-buncher and feed a landing with a single loader or stroke delimber (other operations run multiple sets of equipment in a single crew).

When distances exceed a half mile (or when both distance and terrain serve to create cycle times exceeding 30 minutes or so), added skidding capacity is necessary to prevent skidding from becoming a bottleneck. This problem has been addressed in several ways.

It is possible to make gains in skidding capacity without adding more equipment. This approach should precede any new investment. Significant gains are usually possible by improving methods.

Longer skidding shifts can create a larger advance processing inventory on the landing. This approach is particularly useful for short term needs on a single harvesting site. Improving operator practices is another possibility. The skidder operator should have the situational awareness to know when the closest hitches are needed to the keep the landing in operation. Conversely, this operator must know the best times to target the farthest hitches. A similar awareness is needed in picking the correct time to fuel and grease the machine.

Improved operator practices can be supported in several ways. The complexity of whole-tree operations has motivated many loggers to install two-way radios in each machine. This fosters better and safer communication. Operators need both the training and the leeway to make sound decisions on hitch and distance choices throughout their shifts.

One approach is to have a single, larger skidder, capable of pulling larger hitches. A few operations even employ six-wheeled grapple skidders, capable of pulling up to 12 tons.

Other operations add a second skidder. This approach is particularly useful when an older machine can serve as sprint capacity on jobs where it is needed and idled in other situations. Sometimes only a newer full time second skidder will solve the problem.

Tree sizes – both diameter and height – impact the sizes of the hitches that are skidded to the landing. Some of this can be addressed by both job selection and bunching practices. More often it is an issue that is addressed by adding skidding capacity.

If felling and skidding bottlenecks have been overcome or avoided, the logical controlling bottleneck for a whole tree harvesting system will emerge. In general, this bottleneck will be in the handling and processing on the landing or header.

Processing practices vary considerably around the region. The simplest system is a stroke delimber with a cut off saw. Limbs are removed and stem sections are sorted by species groups and product potential, with further processing being handled off site or perhaps by a separate flail chipping crew.

The more species and products involved, the greater the complexity on the landing. The higher the sawtimber content, the more additional sorting and handling is needed for proper utilization. Roundwood crews will have either a stroke delimber or a lower capacity pull-through delimber that is operated in conjunction with the loader and slasher. Once the limbs are off, logs and pulpwood are cut to length with the slasher and sorted into piles (or loaded directly on to trucks). Grapple skidders remove the limbs and tops, taking them back to the woods and filling in low spots in the trails.

Chippers in a whole-tree system add an additional layer of processing. Flail chippers are truly a value-added step, taking roundwood suitable for pulp (and perhaps some smaller material) and sending it to the mill as a clean chip. Some of the flail debris may be processed further in a grinder and used in an electrical plant or for mulch.

The more common chipper in a whole-tree operation is a so called dirty chipper (disk, drum, or cone), using tops, limbs and stems not suitable for anything else to create a low-value chip for energy. A portion of the roundwood material is inevitably mixed in, especially when pulpwood markets are inadequate. These same chippers can also produce a somewhat higher quality chip for wood heating plants, using only roundwood.

A first step in fully exploiting this bottleneck for whole-tree systems is to simplify the process. Sorting and processing on the landing for proper utilization can get bogged down in complexity, and yet loggers have found ways to streamline the process to the point of maximizing the flow of materials onto trucks for delivery.

Adequate landing space and alignment serve to maximize flow through the system. Grapple skidders are sometimes employed in moving processed stems from a delimber and on to a loader/slasher combination.

Some operations have longer shifts on the landing, even to the point of having substitute operators (usually from other job function) stop in to operate machines during lunch breaks.

One means of minimizing handling has been to slash and pile directly onto trailers, with no slashing taking place unless a trailer is available. This procedure can cut up to one full productive machine hour out of the process.

Once procedures are completely streamlined to maximize the flow of wood, loggers will consider increasing the capacity of the landing. This might mean the addition of a larger loader, or perhaps a second loader that is operated as needed in loading stockpiled logs. In this case an operator is diverted from a non-bottleneck function whenever necessary.

The addition of a full time second loader in a chipping operation can add capacity to the entire system. The primary machine delimbs (pull through), slashes and sorts stems and tops. This machine is never taken from this task for other duties. The second loader (often tracked) handles all loading of trucks and chipping. This system works very well when the second operator prioritizes truck scheduling, loading and chipping correctly.

Whole-tree harvesting systems sometimes incorporate a CTL processor on the landing, especially when there is no chipping involved. A processing head is capable of delimbing and bucking. This situation is most desirable when it allows a single machine and operator to replace two pieces of equipment (such as a stroke-delimber and loader/slasher).

Cut-to-Length Bottlenecks

A standard cut-to-length (CTL) system is a two-piece operation, including a processor and a forwarder. The bottleneck in this straightforward system will always be one function or the other. Cut-to-length systems in the northeast are sometimes hybridized in combination with whole-tree and even tree-length systems. These hybrid systems are discussed at the end of this section.

Cut-to-length systems are governed by a bottleneck in the forwarding function if the forwarder is too small or the forwarding distance (or cycle time is too great). Hiesl and Benjamin's (2013) *Harvesting Equipment Cycle Time and Productivity Guide for Logging Operations in Maine* is a useful reference for determining when this is the case.

A smaller forwarder (100 logs per load) becomes the bottleneck when production drops below 16 tons per hour (using 8-inch diameter softwoods and a moderate harvesting intensity as a benchmark). On uniform terrain, this will happen at all but the very closest distance.

A medium-sized forwarder capable of carrying 150 logs per load will also become a bottleneck when production drops below 16 tons per load. On uniform terrain, this will happen at distances of 1,000 feet or more.

Larger forwarders lengthen the distance required to make forwarding he bottleneck. For those capable of carrying 200 logs, distances of approximately 1,700 feet create the bottleneck.

Terrain will limit the production of a forwarder more than distance in many locations in the northeast.

A forwarding bottleneck can be exploited or broken by any action that reduces cycle time. Several procedures can help in this. Adding greater sorting responsibility to the processor is one of them. Reducing or eliminating the road front sorting and loading responsibilities are another. This can be accomplished by adding a loader to the road front and assigning loading responsibilities to the trucker.

On some sites, the chains can be removed from forwarder wheels. This will increase their speed and reduce their fuel consumption, resulting in increased hourly production.

Capacity can be added to solve a forwarding bottleneck, but this will usually take additional investment. Switching to a larger forwarder is one possibility. Adding a second forwarder is another. As with skidding, no more capacity should be added than is necessary. This might mean adding a used machine for occasional use or adding a new full-time machine. In practice, second forwarders are seldom added to CTL systems, largely due to their expense.

The harvester is the logical controlling bottleneck in a CTL system. If the effect of this bottleneck is too pronounced, it is usually due to stem size and spacing. These two variables can be combined and expressed as harvest intensity in tons (or loads) per acre.

Hiesl and Benjamin (2013) documented wide ranges of hourly production potential, ranging from 5 tons per hour in excessively small timber to 259 tons per hour in larger timber. Excessively high levels of production are an occasional bonus. The normal effective operating range of these machines is much narrower.

The harvester bottleneck is exploited through operator skill and practices, effective communication with the forwarder operator and by having the correct machine for the average working conditions. Sizes and models of processers vary – with both tracked and wheeled carriages and fixed and dangling processing heads.

Time can be diverted from sorting and bunching by the harvester by leaving this responsibility to the forwarder. Species and product sorts are then made as the forwarder is loaded or unloaded, effectively shifting this duty to a non-bottleneck function.

Older harvesters are sometimes supplemented with additional felling. Hand felling may be used for occasional stems that are too large for the processor. Some loggers with older processors have observed that the felling is more difficult than the processing. Having a feller-buncher cutting the trees in advance and pointing the tops uphill is one means of making an older harvester more effective.

It has been suggested that, if average forwarding distances are too far, (more than 2,500 feet, or cycle times exceeding 2.5 hours, for example) CTL systems are not viable. The history of the use of these systems in the Northeast is that they work very well in well-stocked harvests on moderate terrain, but do not work well for harvesting more scattered stems on difficult terrain.

While CTL systems are commonly associated with harvesting in softwood plantations, they perform well in both hardwoods and softwood, provided the harvest intensity is high enough and the average stems size is not too small or too large.

Hybrid harvesting systems sometimes incorporate either a forwarder or CTL harvester.

A hand felling operation combined with a forwarder is still a CTL system. The focus in this case is usually on low-impact results, rather than high production. Considerations for this system are like those discussed in the tree-length system bottleneck section.

Tree-Length System Bottlenecks

Tree-length systems have a niche in most locations throughout the northeast region.

These operations are sometimes called conventional logging or cable-skidding logging.

These systems are uncomplicated, involving hand felling and delimbing with a chainsaw and skidding to a landing or header with a cable skidder. Landing functions can be handled with just a chainsaw and push pile, or may be more advanced with a loader and slasher or mechanized sawbuck.

Tree-length systems work best in harvesting larger stems. When harvest stems are scattered, this system may be the only option.

Tree-length systems are far less expensive than both whole-tree and cut-to-length operations. The tree-length approach has served as an entry-level opportunity for many loggers, many of whom continue to use this system throughout their careers.

One of the advantages of this system, from a business standpoint, is that it is well-suited to a sole-proprietor, owner-operator. It can also be scaled up with additional hand fellers, skidders and a loader-slasher combination.

A long-standing rule-of-thumb in tree-length systems is that one person, both felling and skidding, can produce one load per day. Two people, with one felling, the other skidding and both cooperating and communicating well, can produce two loads per day. Adding a third person, without additional equipment, will not result in a third load, as there are declining returns to scale.

In any sole owner-operator business, the owner is the bottleneck. Logging is no exception. The emphasis and time allocations made by this person will dictate the rate of production.

In practice, a sole operator might logically spend a portion of the day felling and a portion skidding. Often this means felling and delimbing enough stems to create one hitch for the cable skidder and then skidding it to a landing and processing it further. When the complicating wrinkles of weather and truck scheduling are added, deviation from this model may be necessary. In general, felling can continue to take place in weather that is unsuitable for skidding, especially when water quality best management practices are followed. This might motivate the logger to have sufficient stems felled and limbed out to ensure that skidding can take place whenever ground conditions permit.

The addition of one employee to a tree-length operation with a single cable skidder shifts the bottleneck into the system itself. This bottleneck must logically fall into the felling and delimbing, skidding, or processing on the landing.

If harvest stems are of the size and spacing that the system is best suited to work with, felling and delimbing will seldom be the bottleneck. Occasional harvests or partial harvests where tree size is smaller or spacing is greater can create a bottleneck. A two or three-person operation has the option of shifting capacity into felling to fully exploit these situations.

Wang, et al (2004) found that, on average, a single cable skidder produced about 20 percent less than a hand feller per productive machine hour (289 cubic feet vs. 363 cubic feet). Processing on the landing was not studied. The strong implication of this finding is that skidding will be the bottleneck in this situation. Factor in situations when it is possible to fell and delimb but not skid due to weather conditions and the bottleneck becomes more pronounced.

When skidding is the bottleneck in a tree-length operation, the entire operation must focus on ensuring skidding takes place whenever possible. Skidding will not be possible in two situations:

- no trees are felled and limbed, and
- ground conditions or contractual obligations prevent skidding.

The first situation is easy enough to remedy, though this sometimes means a longer shift or weekend work to ensure felled wood is available to skid. Some loggers split crews during job transitions to ensure the landing is in place and felled trees are available when the cable skidder is moved to the job site.

Avery, et al (2003) found that the addition of a remote-control winch to the cable skidder reduced cycle time by 22.6 percent. This effectively increases hourly production by 29 percent. A gain of this type in a bottleneck function is a gain for total system productivity. This is one way of increasing capacity with a modest increase in investment

It is possible to increase the processing capacity of the landing site for a tree-length operation with the addition of a better loader, a slasher, better procedures and improved trucking. Investments and improvement efforts that increase landing capacity to the point of exceeding felling and skidding capacity require upgrades in those areas to be financially sound.

If a hand-felling operation grows to the point where processing on the landing is the logical bottleneck, the discussion in the whole-tree harvesting bottlenecks section applies here as well. In practice, this type of growth has resulted into a gradual shift toward whole-tree harvesting in many cases around the northeast.

4 Logging Productivity

Productivity is a ratio of output to effort. Productivity is often touted as a good thing, without ever defining it or quantifying it in a meaningful way. Increasing productivity is the standard advice from those who are unwilling to raise prices. Understanding the differences between production and productivity is a good starting point in examining how productivity relates to the financial success of a logging business.

Production is a quantifiable amount. Loads, board feet, tons and cords are common measurements of production. The wide range of products that may come from an individual logging site makes standardizing measurements of production a challenge. Many loggers solve this problem by discussing production in terms of loads.

While load sizes vary around the region, they can be standard to a business, based on legal limits and the size of trailer used.

Productivity is a ratio, rather than an amount. Loggers often keep tabs on a shorthand version of productivity, such as loads per day or loads per week. This is a quick ratio that is easily grasped by both the crew and by outsiders. The drawback to this method is that time (days, weeks, months) is not really a measurement of effort. If each day or each week had an equal amount of effort, this might be the case. Fluctuations in weekly effort and the number of hours and type of equipment used make time a less than ideal measurement.

Time remains an important measurement of potential, however. There are a fixed number of days in the year, a smaller set of which will be employed in production. Every productive day saved provides an opportunity for achieving greater annual profits.

How can logging effort be measured? Productive machine hours (PMH) is the most objective measurement readily available to most loggers. Hour meters in the machines make this possible – but only if someone keeps track of them for each job site. As discussed in an earlier chapter, productive machine hours are also a very good way to keep track of depreciation, which is the key to throughput accounting in logging.

Productivity and Financial Results

As shown earlier, there are just a few variables in financial results. Production times price equals revenue. Revenue less costs equals profit. In situations where there is very little flexibility in the price of forest products and important inputs such as fuel, parts and labor, production is the primary avenue for a logger to increase profits.

Increasing production in a linear way that simply keeps pace with the cost of inputs will not increase profits. Increasing production with minimal increases in costs will increase profits. This is the essence of productivity. Producing more wood with the same amount of effort is an increase in productivity. Both profits and return on investment (ROI) increase when this happens.

Increasing system-wide productivity should be the primary focus of improvement efforts. System-wide productivity is dictated by the productivity of the bottleneck, so that is where improvements can have the greatest financial impact.

Normal re-investment in replacement machines must take place to ensure non-bottleneck functions continue to feed the bottleneck function. Major investments in improvements to non-bottleneck functions will not increase the flow through the system and could instead have a negative impact on profit and ROI.

Improvements in non-bottleneck functions have a positive financial impact when they serve to lower the overall level of investment. This is true because investment in individual jobs is measured by the amount of functional depreciation that takes place in operating the machines on each job. If fewer productive machine hours are used, productivity increases and the level of investment decreases.

Site Productivity

Loggers should understand the productive potential of their harvesting system as it applies to the range of harvesting opportunities available to them. Many loggers have developed an intuitive sense of the situations that are best for them. This sense is often born of experience and the result from some financially unpleasant trial and error.

One useful measure of productive potential is the size of the stems that will be harvested (both diameter and height). Stem size by itself requires further investigation to put it into productive terms. The number of stems of various sizes required to produce several sizes of truckloads is shown in Table 4-1.

The productive potential of an individual harvesting site can be gauged, in part, by the amount of timber that is slated for removal. This variable can be quantified efficiently by measuring the average basal area per acre of the marked or designated trees and noting the average total tree height.

Tables 4-2, 4-3 and 4-4 show the number of loads per acre, based on the basal area being removed and tree height. Loads weights of 29, 34 and 39 tons are shown. Custom tables for other loads weights can be created by dividing the load weight by any of the three weights shown and then multiplying the result by the contents of the table.

The tables were constructed from weights established by Monteith (1979) for combined hardwood species in New York. Similar tables of loads per acre were created for softwood species weights. The differences between hardwood and softwood loads in the resulting tables were found to be negligible.

Productivity expectations naturally vary between harvesting system types. Several productivity tables are provided in the sections that follow as general references for each of the three major harvesting system types.

For very detailed productivity tables for whole-tree and cut-to-length equipment, see Hiesl and Benjamin's (2013) *Harvesting Equipment Cycle Time and Productivity Guide* *for Logging Operations in Maine*. A link to this guide is included in the resource section of this publication.

An extensive set of productivity tables or various aspects of each of the three main harvesting systems is provided in Appendix A.

Table 4-1. Number of trees per load (combined hardwoods 50′ tall*; all products – logs, pulpwood & chips)

DBH (")	tons per tree	trees per ton	trees per load (29 tons)	trees per load (34 tons)	trees per load (39 tons)
4	0.08	12.5	363	425	488
5	0.12	8.3	242	283	325
6	0.18	5.6	161	189	217
7	0.24	4.2	121	142	163
8	0.31	3.2	94	110	126
9	0.39	2.6	74	87	100
10	0.48	2.1	60	71	81
11	0.58	1.7	50	59	67
12	0.69	1.4	42	49	57
13	0.81	1.2	36	42	48
14	0.93	1.1	31	37	42
15	1.07	0.9	27	32	36
16	1.21	0.8	24	28	32
17	1.36	0.7	21	25	29
18	1.53	0.7	19	22	25

* for 60′ tall trees, reduce numbers by 21%

Table 4-2. Number of 29-ton loads per acre (all products – logs, pulpwood & chips*) based on basal area to be removed and tree height.

basal area per acre	**Tree Height**			
	30'	**50'**	**65'**	**80'**
30	0.6	0.9	1.2	1.9
40	0.8	1.2	1.6	2.5
50	0.9	1.5	1.9	3.1
60	1.1	1.8	2.3	3.7
70	1.3	2.1	2.7	4.3
80	1.5	2.4	3.1	5.0
90	1.7	2.7	3.5	5.6
100	1.9	3.0	3.9	6.2
110	2.1	3.3	4.3	6.8
120	2.3	3.6	4.7	7.4
130	2.5	3.9	5.1	8.1
140	2.7	4.2	5.5	8.7
150	2.8	4.6	5.8	9.3

* chipwood can be excluded from the totals above by reducing them by 15%

Table 4-3. Number of 34-ton loads per acre (all products – logs, pulpwood & chips*) based on basal area to be removed and tree height.

basal area per acre	**Tree Height**			
	30'	**50'**	**65'**	**80'**
30	0.5	0.8	1.0	1.6
40	0.6	1.0	1.3	2.1
50	0.8	1.3	1.7	2.6
60	1.0	1.6	2.0	3.2
70	1.1	1.8	2.3	3.7
80	1.3	2.1	2.7	4.2
90	1.5	2.3	3.0	4.8
100	1.6	2.6	3.3	5.3
110	1.8	2.8	3.7	5.8
120	1.9	3.1	4.0	6.4
130	2.1	3.4	4.3	6.9
140	2.3	3.6	4.7	7.4
150	2.4	3.9	5.0	7.9

* chipwood can be excluded from the totals above by reducing them by 15%

Table 4-3. Number of 34-ton loads per acre (all products – logs, pulpwood & chips*) based on basal area to be removed and tree height.

basal area per acre	**Tree Height**			
	30'	**50'**	**65'**	**80'**
30	0.4	0.7	0.9	1.4
40	0.6	0.9	1.2	1.8
50	0.7	1.1	1.4	2.3
60	0.8	1.4	1.7	2.8
70	1.0	1.6	2.0	3.2
80	1.1	1.8	2.3	3.7
90	1.3	2.0	2.6	4.2
100	1.4	2.3	2.9	4.6
110	1.6	2.5	3.2	5.1
120	1.7	2.7	3.5	5.5
130	1.8	2.9	3.8	6.0
140	2.0	3.2	4.1	6.5
150	2.1	3.4	4.3	6.9

* chipwood can be excluded from the totals above by reducing them by 15%

5 Start Improving

Readers who have made it this far in the publication are clearly interested in making improvements. The good news is that continuous improvement theory can be applied to any productive situation and the very nature of this approach means there is always more to d. Starting to improve is not difficult.

Applying the continuous improvement process simply relies on a focus on eliminating constraints, as outlined in the five-step process from Chapter 1 (***identify, exploit, subordinate, elevate & avoid inertia***). These steps must be coupled with a technical knowledge of logging, business and the forest that comes from first-hand experience. Anyone brave enough to go into business for themselves and clever enough to solve the day-to-day problems that come with logging also has what it takes to figure out how to make on-going improvements to their business.

A solid first step in 1) grasping the continuous improvement process and 2) contemplating how to apply it, is to read *The Goal – A Process of Ongoing Improvement*. Even better is to get a copy of the audiobook to listen to it on a long commute or in an equipment cab. Encourage a friend, colleague or key employee to do the same so there is someone to discuss it with. These discussions are sometimes necessary in grasping how the factor setting in the novel apply to logging operations in the woods.

Implement Change

Goldratt (1999) explains that the Theory of Constraints helps to answer three fundamental questions:

1. What to change?
2. What to change to?
3. How to cause the change?

The first question, what to change, is often easily answered by intuition, built on experience. Admitting previously unacknowledged problems may be necessary. Many systems contain an imbalance, with as a few small items having a disproportionate impact. Pinpoint the issues and items that have the biggest impact on the entire system or organization.

What to change is the second of the three questions. Recall that the goal of the business is to make money, now and in the future. Therefore, the change must be something that improves profit and return on investment, either by increasing revenue, lowering expenses or lowering the investment or some combination of all three.

Using the financial measurements outlined in Chapter 2 as decision making criteria will make it easy to determine what to change to make the operation more profitable. This approach requires good record keeping (especially machine hours). Accurate calculation of profit and ROI after a job is complete is the only way to know what is working and what is not.

How to change is the third question. There is no textbook reference for this question, but there are a few suggestions for common logging bottlenecks in Chapter 3 and some useful productivity references in Chapter 4.

Loggers are adept at both innovating and adapting machinery, tools and methods of doing things better. Many of the problems a logger will face have already been solved by someone before them. In other cases, past solutions are a starting point for further innovation.

Despite the hallmark independence of the small business person, there are many peers to draw from as role models. Long-term friendships among loggers who may appear to competitors are common.

Established loggers have pursued and enjoyed cooperative relationships with peers for decades. Those who are newer in the business should take advantage of regional meetings and training sessions as way of getting to know their peers better. The best of the logger training programs in the region foster group discussions on relevant topics and offer ample opportunities for networking with others.

Start Now

Following a few steps can begin or enhance continuous improvement efforts by loggers.

Recall from chapter one that the process involves identifying a constraint, exploiting it, subordinating everything to this constraint, elevating the constraint and then preventing inertia from undoing this solution.

Solve one small problem as a proof of concept exercise. This effort will probably be somewhat consistent with past problem-solving efforts. Solving one problem should then reveal another and then the continuous nature of this approach is underway.

> Read *The Goal* and think about how to apply it to logging

Incorporate throughput accounting, including job-specific measurements of profit and return on investment. It is difficult to measure results and progress without knowing the results of individual logging jobs. Download a free copy of the latest version of PATH (link provided in the Appendix B of this publication).

Use the PATH spreadsheet to create a template for forecasting individual jobs and benchmarking results. If possible, attend one of the PATH training sessions that are periodically offered around the northeast region. This is the quickest way of setting up a system for measuring job-level results.

Conclusion

Continuous improvement methods have great potential for helping logging businesses achieve financial goals. Similarities between in-house and intuitive problem-solving methods and those presented here are not a coincidence. Goldratt's Theory of Constraints is a formal presentation of ideas that many people have stumbled onto in their work. His genius was in simplifying things that others thought were complex and then disseminating a structured approach that has been widely adopted in many fields.

Logging is hard and challenging work. Significant investments are necessary in equipment that frequently breaks down. Costs of inputs and price for harvested wood products are usually beyond the logger's control. Forest conditions and the requirements of landowners and foresters can seem inflexible. Weather is often uncooperative. Thriving under all these conditions requires nimble internal operations and continued productivity that keeps pace with change. Continuous improvement provides a focusing mechanism to guide the business forward.

"The first step towards change is awareness."

Nathaniel Branden

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Appendix A: Harvesting System Productivity Tables

Productivity tables for various aspects of whole-tree, cut-to-length and tree-length harvesting systems are included here. A brief description precedes each set of tables.

Whole-Tree Harvesting System Tables

Whole-tree harvesting system productivity and profitability is influenced by the size and spacing of the timber to be harvested, along with the skidding distance and terrain.

Hiesl and Benjamin (2013) provide an approximation of feller-buncher productivity for various stem sizes and numbers of stems per acre in Maine. A graph showing this productivity variance was used to construct Table A-1, which approximates feller-buncher productivity in loads per hour.

Grapple skidder productivity can be calculated using bunch sizes. This was done in creating Tables A-2, A-3 and A-4, showing the number of loads of various size loads skidded per productive machine hour.

A timber harvesting productivity index for whole tree harvesting systems in Maine is shown in Table A-5. This index was built using Hiesl and Benjamin’s productivity information for a feller-buncher, grapple skidder and stroke delimber. The number of combined machine hours necessary for producing 1,000 tons was calculated, for various tree sizes and skidding distances. An average harvest situation (4-ton bunch, 1,200′ skidding distance) was assigned an index value of one. The number of combined machine hours for every other combination was divided by the hours necessary for this combination to populate the index.

A harvesting situation with an index number of 2 would take twice as many productive machine hours as the average. A harvesting situation with an index number of 0.5 would take half as many productive machine hours as the average.

Table A-1. Feller buncher productivity in loads per productive machine hour.*

DBH (")	tons per Hour	loads per hour (29 tons)	loads per hour (34 tons)	loads per hour (39 tons)
4	13.5	0.5	0.4	0.3
6	18.5	0.6	0.5	0.5
8	29.5	1.0	0.9	0.8
10	45.5	1.6	1.3	1.2

* Tons per machine hour shown in the table were derived from Hiesl and Benjamin's (2013) graph of simulated feller buncher productivity. Approximate values were selected from the range shown.

Table A-2. Grapple skidder productivity in 29-ton loads per productive machine hour for various cycle times.

bunch	29-ton loads			
size		cycle	time	
(tons)	15'	30'	45'	60'
3	0.4	0.2	0.1	0.1
4	0.6	0.3	0.2	0.1
5	0.7	0.3	0.2	0.2
6	0.8	0.4	0.3	0.2
(6-wheel)				
10	1.4	0.7	0.5	0.3
12	1.7	0.8	0.6	0.4

29-ton loads

Table A-3. Grapple skidder productivity in 34-ton loads per productive machine hour for various cycle times.

bunch	34-ton loads			
size		cycle	time	
(tons)	15'	30'	45'	60'
3	0.4	0.2	0.1	0.1
4	0.5	0.2	0.2	0.1
5	0.6	0.3	0.2	0.1
6	0.7	0.4	0.2	0.2
(6-wheel)				
10	1.2	0.6	0.4	0.3
12	1.4	0.7	0.5	0.4

34-ton loads

Table A-4. Grapple skidder productivity in 39-ton loads per productive machine hour for various cycle times.

bunch size (tons)	39-ton loads			
		cycle	time	
	15'	30'	45'	60'
3	0.3	0.2	0.1	0.1
4	0.4	0.2	0.1	0.1
5	0.5	0.3	0.2	0.1
6	0.6	0.3	0.2	0.2
(6-wheel)				
10	1.0	0.5	0.3	0.3
12	1.2	0.6	0.4	0.3

39-ton loads

Table A-5. A whole tree harvesting system productivity index for Maine (derived from Hiesl & Benjamin, 2013)

skid distance (feet)	light stocking (4" DBH)	bunch	size (tons)	heavy stocking (10" DBH)
	3.0	**4.0**	**5.0**	**6.0**
200	1.2	0.8	0.7	0.5
400	1.3	0.8	0.7	0.5
600	1.3	0.9	0.7	0.5
800	1.4	0.9	0.7	0.5
1000	1.4	1.0	0.8	0.5
1200	1.5	1.0	0.8	0.6
1400	1.6	1.1	0.8	0.6
1600	1.6	1.1	0.9	0.6
1800	1.7	1.2	0.9	0.7
2000	1.8	1.2	1.0	0.7
2200	1.9	1.3	1.0	0.7
2400	2.1	1.4	1.1	0.8

* average conditions have an index of 1, all are a multiple of this; multiply the combined machine hours needed to fell, skid & delimb any quantity under average conditions by the index number to determine the number of hours needed

Cut-to-Length System Tables

Cut-to-length system productivity and profitability is influenced by the size and spacing of the timber to be harvested, along with the forwarding distance and terrain.

Hiesl and Benjamin (2013) developed cycle time equations for CTL harvesters in Maine. This allowed them to calculate the number of tons harvested per machine hour, based on the average diameter of the stems being harvested. The results of this work were used in creating Table A-6, showing the number of loads (various sizes) per productive machine hour that a harvester can produce.

Forwarder productivity can be calculated using load capacity and cycle time. This was done in creating Table A-7, which shows loads per productive machine hour for two forwarder sizes.

Table A-6. Cut-to-length harvester productivity in loads per productive machine hour for various tree sizes (derived from Hiesl & Benjamin, 2013).

hardwoods

DBH (")	tons per hour	loads per hour (29 tons)	loads per hour (34 tons)	loads per hour (39 tons)
6	6.3	0.2	0.2	0.2
8	11.7	0.4	0.3	0.3
10	21.6	0.7	0.6	0.6
12	40.2	1.4	1.2	1.0
14	74.5	2.6	2.2	1.9
16	138.2	4.8	4.1	3.5

softwoods

DBH (")	tons per hour	loads per hour (29 tons)	loads per hour (34 tons)	loads per hour (39 tons)
6	8.6	0.3	0.3	0.2
8	16.0	0.6	0.5	0.4
10	29.7	1.0	0.9	0.8
12	55.1	1.9	1.6	1.4
14	102.3	3.5	3.0	2.6
16	189.8	6.5	5.6	4.9

Table A-7. Forwarder productivity in loads per productive machine hour for various cycle times.

cycle time (min)	smaller forwarder (3 turns per load)	larger forwarder (2 turns per load)
15	1.32	2.00
30	0.66	1.00
45	0.44	0.67
60	0.33	0.50
75	0.26	0.40
90	0.22	0.33
120	0.17	0.25

Tree-Length Productivity Tables

Tree-length harvesting productivity is influenced by the size and spacing of the timber to be harvested, along with the skidding distance and terrain.

Wang, et al (2004) developed a regression formula for chainsaw productivity from empirical observations. This formula was used in constructing Table A-8. This table shows productivity in loads per productive hour for various timber sizes. Loads are defined as 1,000 cubic feet of any product – sawlogs, pulpwood or firewood logs.

Cable skidder productivity is shown in Table A-9. This table is also based on research by Wang, et al (2004).

Table A-10 shows tree-length felling, delimbing and skidding productivity in terms of the number of combined productive hours needed to produce one load of 1,000 cubic feet in size. Various hitch sizes and skidding cycle times are shown. Single-person operations should pay attention to situations in which one load cannot be produced in a single day.

Table A-8. Chainsaw productivity in number of 1,000 cubic foot loads per hour (harvest stocking of 15 trees per acre).

DBH		tree height	
(")	50'	60'	70'
10	0.52	0.57	0.62
11	0.54	0.60	0.65
12	0.57	0.63	0.68
13	0.60	0.65	0.70
14	0.62	0.68	0.73
15	0.64	0.70	0.74
16	0.66	0.72	0.76
17	0.68	0.74	0.77
18	0.70	0.75	0.78
19	0.72	0.76	0.79
20	0.73	0.77	0.80
21	0.74	0.78	0.80
22	0.76	0.79	0.80

* loads can be any combination of sawlogs, pulpwood and firewood

Table A-9. Cable skidder productivity in number of 1,000 cubic feet loads per hour

cycle time (minutes)	hitch size (cubic feet)			
	50	100	150	200
15	0.20	0.40	0.60	0.80
30	0.10	0.20	0.30	0.40
45	0.07	0.13	0.20	0.27
60	0.05	0.10	0.15	0.20
75	0.04	0.08	0.12	0.16
90	0.03	0.07	0.10	0.13
105	0.03	0.07	0.10	0.13
120	0.03	0.05	0.08	0.10

* loads can be any combination of sawlogs, pulpwood and firewood

Table A-10. Tree-length felling, delimbing and skidding PMH per 1000 cubic ft. load for various timber sizes and cycle times.

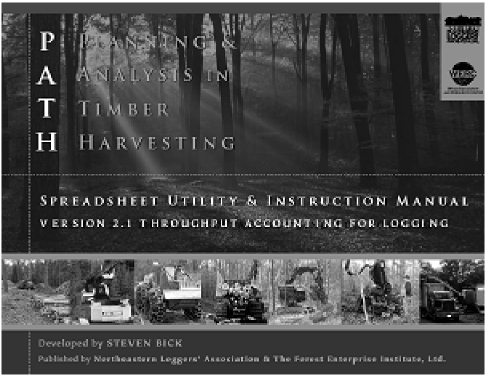
cycle time (minutes)	10 hitches per load PMH	6-7 hitches per load PMH	5 hitches per load PMH
15	3.9	3	2.6
30	6.4	4.6	3.8
45	8.9	6.3	5.1
60	11.4	8	6.3
75	13.9	9.6	7.6
90	16.4	11.3	8.8
105	18.9	13	10.1
120	21.4	14.6	11.3

* loads can be any combination of sawlogs, pulpwood and firewood

Appendix B: Additional Resources

Several useful publications are included in here. There is a brief description of each, along with a download link. All these are free publications, intended for distribution throughout the logging community.

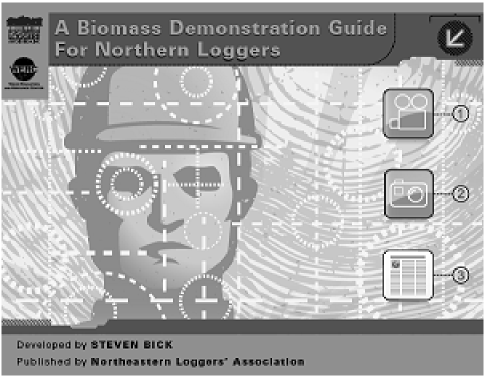
PATH v. 2.1



Download link:

bit.ly/PATHv2-1

A Biomass Demonstration Guide for Northern Loggers



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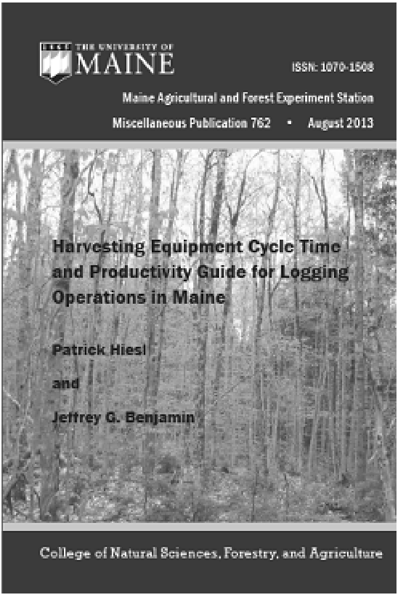
Harvesting Equipment Cycle Time and Productivity Guide for Logging Operations in Maine



THE UNIVERSITY OF MAINE

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Harvesting Equipment Cycle Time and Productivity Guide for Logging Operations in Maine

Patrick Hiesl

and

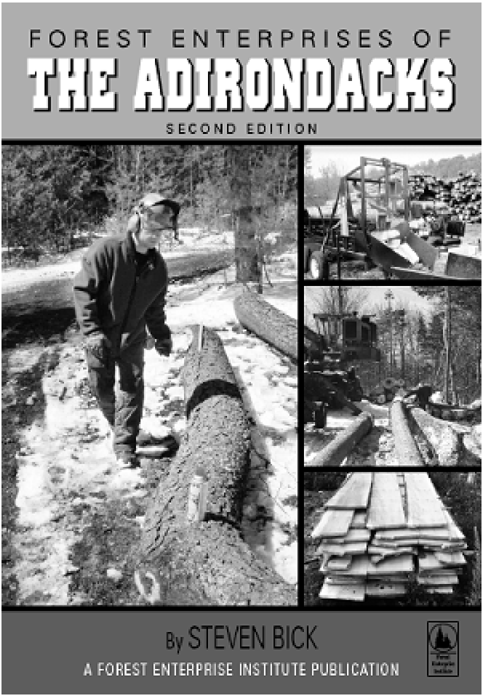
Jeffrey G. Benjamin

College of Natural Sciences, Forestry, and Agriculture

Download link:

bit.ly/LogOpME

Forest Enterprises of the Adirondacks



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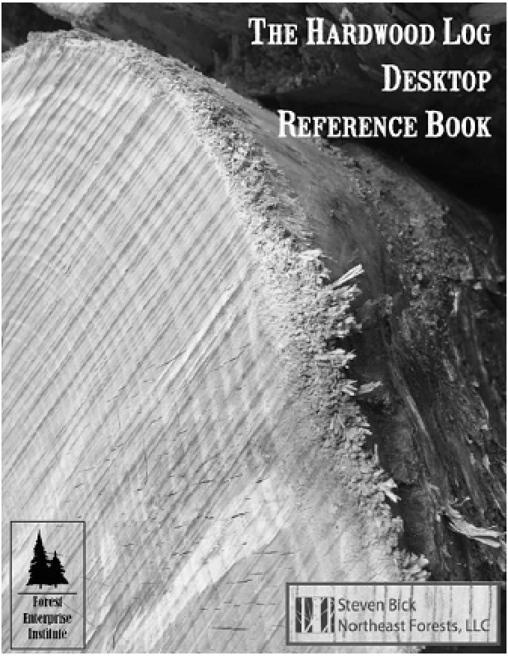
The Hardwood Log Desktop Reference Book



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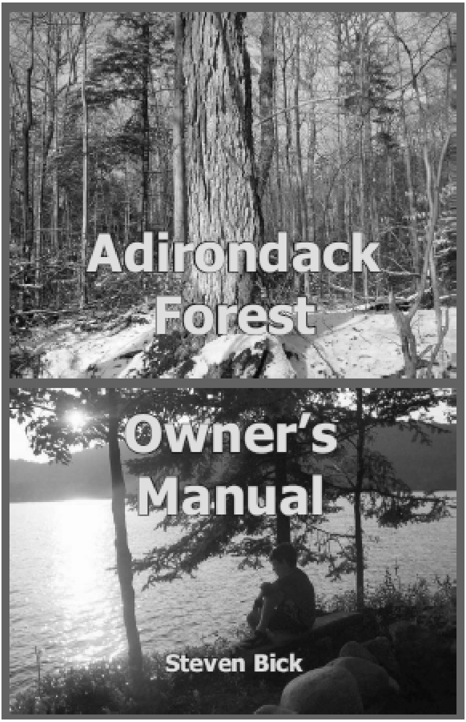
Adirondack Forest Owner's Manual



Download link:

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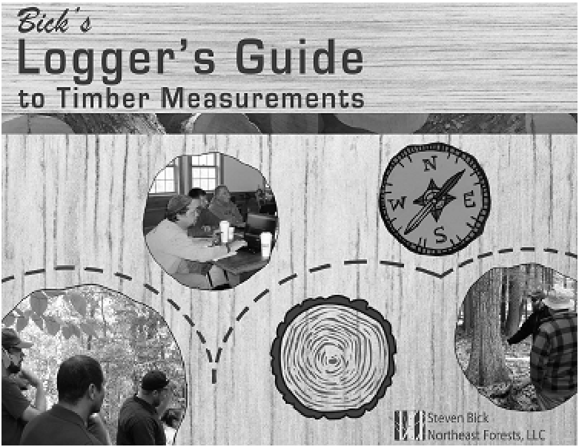
Logger’s Guide to Timber Measurements



Download link:

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Steven Bick is a forestry consultant and principal in Northeast Forests, LLC. He provides stewardship, training and research services to clients throughout the northeast. Steve has taught or co-taught over 200 workshops for loggers, foresters and landowners. He is the author of seven books on topics ranging from woody biomass to conservation easements. Steve has a PhD in Forest Economics and Management from Virginia Tech, along with a BS and MS from SUNY College of Environmental Science and Forestry, where he is currently an adjunct professor. Steve is an SAF Certified forester and has informal affiliations with institutions and landowners throughout the country.

Jeffrey G. Benjamin is a Senior Research Associate with the Forest Enterprise Institute. For almost a decade, he served at the University of Maine as an associate professor of forest operations in the School of Forest Resources and as a Cooperating Scientist with the Cooperative Forestry Research Unit. During that time, he authored (or co-authored) over 50 articles for the forest operations community and he has delivered even more professional presentations on a variety of topics. Jeff now serves as Head of School at a private Christian school in central Maine. His passion for the logging industry keeps him engaged in continuous improvement efforts.

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