An Analysis of Log Truck Turn Times at Harvest Sites and Mill Facilities

Tripp N. Dowling

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M. Chad Bolding
W. Michael Aust
Thomas R. Fox

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ABSTRACT

The raw forest products transportation sector is inherently unique when compared to other transportation industries. The loggers and contractors who transport raw forest products are at a competitive disadvantage. Older equipment is also commonly used by the raw forest products transportation industry in harsh working environments. The average log truck age is 9.7 years while all trucks average only 3.9 years. Nineteen percent of log trucks are 15 years old or older while only 5.9% of all trucks are older than 8 years. Log trucks are regulated by both the Federal Motor Carrier Safety Administration and the state that the truck operates in, thus making interstate transportation more difficult. In addition to these challenges, there is a lack of information concerning efficiency and productivity improvement opportunities related to transporting forest products. This study evaluated truck turn times at both the harvesting site and mill facilities in order to identify important trucking productivity factors and efficiency improvement opportunities. Regression equations were created to estimate truck turn times at harvesting sites and mill facilities. Gross level studies found that 1268 truck turns at the tract scale averaged 1.40 hours while 576 truck turns at the mill scale averaged 0.56 hours. Elemental time studies at four harvesting locations found that log trucks were idle 32% of the time. Trucks spent 29% of time being loaded and 26% of the

time waiting. Elemental time studies at mill facilities found that trucks were idle 27% of the time. Trucks spent the greatest amount of time unloading while unbinding was the second greatest contributor to turn times. Reductions in loading and waiting times can have significant effects on the overall turn time.

Harvesting contractors could benefit from maintaining balanced harvesting crews. Estimates indicate that harvesting contractors could earn an additional profit of $106,500 over a period of five years by purchasing an additional skidder for those crews whose production is limited due to a lack of skidding capacity. It is estimated that if adding an additional trailer to harvesting crews would allow an additional 2 loads to be transported to the mill each day, harvesting crews could earn an additional $22,100 per year of profit. Road construction can also affect harvesting contractors profits. By minimizing road construction through the use of easements and improved pre-harvest planning, harvesting contractors could reduce road construction costs by as much as $14,000 per tract.

With tools available to estimate truck turn around times, harvesting contractors, fleet managers, and truck drivers will be able to make more informed decisions regarding fleet management. This will enable those owning and operating trucks to operate in more efficient and profitable manners. The models created during this study will allow managers to estimate tract and mill turn times so as to better allocate trucking resources.

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Chapter 1 INTRODUCTION

1.1 Background Information and Study Objectives

The wood supply system of the Southeastern United States links forest landowners, harvesting contractors, and processing mills (Sun and Zhang 2006 and Rönnqvist 2003). Truck drivers, who transport raw forest products to consuming mills, are either employed directly by the harvesting contractors or have transportations contracts with the harvesting contractors. Following transport, the consuming mills process the raw forest products (Figure 1.1)

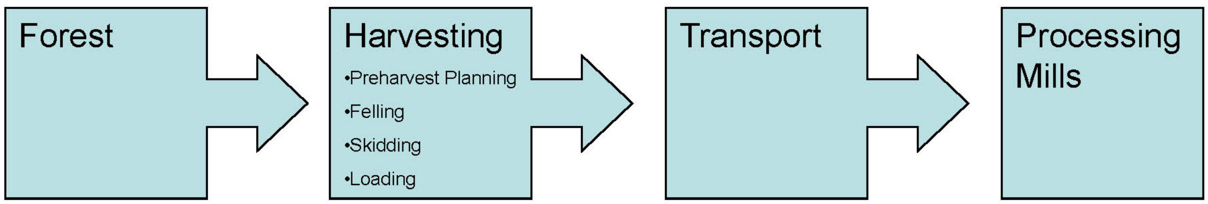

Figure 1.1: Idealized wood supply chain for the Southeastern United States.

The United States is dependent on trucks to move the majority of freight. As of 2002 a total of 12.5 billion tons of freight were transported in the United States. Of this, 8.7 billion tons (70%) were transported by truck alone, up from 67% in 1997. Considering freight that was transported partially by truck and rail the truck total increases to 73% (Bureau of Transportation Statistics and U.S. Census Bureau 2009). The wood supply chain of the United States is even more dependent on trucks for transportation. As of 1997, approximately 94% of the raw forest products delivered to processing facilities, in the United States, was transported by truck (Bureau of Transportation Statistics and U.S. Census Bureau 2009). According to Smith et al. (2004), in 2001 approximately 221 million tons of roundwood were transported by truck in the Southern United States.

The transportation of raw forest products is often different from transportation of other commodities. Log trucks routinely operate in dusty, muddy, or other rough terrain as opposed to trucks which transport freight across hard surfaced roads. These demanding operating conditions can necessitate more frequent, and expensive, preventative maintenance as well as increasing the likelihood of damage to log trucks, trailers, electrical wiring, or air lines (Shaffer and Stuart 1998). Log trucks are more prone to lose opportunities to work due to weather conditions than other trucking industries as well. Due to the variability of the raw forest products that log trucks haul and the infrequent use of in-woods scales, log trucks are frequently either underloaded (lost potential payload) or overloaded (risk of fines) as opposed to other trucking industries (Shaffer et al.1987, Gallagher et al. 2005). Log trucks are also generally older than over-the-road trucks. Many log trucks were previously used as over-the-road trucks which were converted to log trucks (Gallagher et al. 2005, ATA 2009).

Reliance on road/truck transportation has increased due to the closure of rail lines, changes in rail/road freight costs, and an improvement in hard surfaced road infrastructure. However, costs associated with the harvest and transportation of forest products have increased by 14% from 1995 through 2003 while prices paid during the same period increased by only 8% (Stuart et al. 2004). Trucking is often the most expensive phase of a timber harvesting operation, accounting for as much as 40-60% of total harvesting cost (Shaffer and Stuart 1998). Difficulties associated with the transportation of harvested materials stem from high capital investments, low profit margins, high fuel costs, and strict governmental regulations (Shaffer et al. 1987). Therefore, modest efficiency gains could produce meaningful cost savings.

There is a profit margin in today's forest products industry. Therefore, it is imperative that each operation of the wood fiber supply chain operate at full capacity, safely and efficiently.

Thus, the objectives of this research were to:

1. Conduct a literature review comparison of the raw forest products transportation industry with other trucking industries,
2. Evaluate truck turn around times at the tract scale to identify important trucking productivity factors and efficiency improvement opportunities,
3. Evaluate truck turn around times at the mill scale to identify important trucking productivity factors and efficiency improvement opportunities,
4. Create models to estimate truck turn around times at the tract scale, and
5. Create a model to estimate truck turn around times at the mill scale.

1.2 Literature Cited

American Trucking Association Department of Research and Transport Economics (ATA) 2009. American Trucking Trends 2008-2009.

Bureau of Transportation Statistics (BTS) and U.S. Census Bureau (USCB). 2009. 2007 United States Commodity Flow Survey. Bureau of Transportation Statistics. http://www.bts.gov/publications/commodity_flow_survey/index.html (Accessed 27 Jan. 2010).

Bureau of Transportation Statistics (BTS) and U.S. Census Bureau (USCB). 1999. 1997 United States Commodity Flow Survey. U.S. Census Bureau. EC97TCF-US. 169 p.

Rönnqvist, Mikael. 2003. Optimization in forestry. Mathematical Programming. 97: 267-284.

Shaffer, R.M. and W.B. Stuart. 1998. A checklist for efficient log trucking. Virginia Cooperative Extension. Virginia Tech. 17. http://www.ext.vt.edu/pubs/forestry/420-094/420-094.html (Accessed 9 March 2010.)

Shaffer, R.M., J.F. McNeel, and J. O'Rourke. 1987. On-board log truck scales: application to southern timber harvesting. South. J. Appl. For. 11(1987):112-116.

Smith, W.B., P.D. Miles, J.S. Vissage, and S.A. Pugh. 2004. Forest resources of the United States, 2002. USDA For. Serv. Gen. Tech. Rep. NC-241. 137 p.

Stuart, W., L. Grace, and C. Altizer. 2004. Preliminary 2003 logging cost indices. Wood Supply Research Institute and the Forest and Wildlife Research Center- Mississippi State University, FWRC FO 415. 18 P.

Sun, C. and D. Zhang. 2006. Timber harvesting margins in the Southern United States: a temporal and spatial analysis. Forest Science 52(3): 273-280.

Chapter 2 A COMPARISON BETWEEN THE TRANSPORTATION OF RAW FOREST PRODUCTS AND OTHER TRANSPORTATION INDUSTRIES

2.1 Introduction

The transportation of raw forest products is an important component of any timber harvesting or wood supply system. As of 1997 approximately 94% of the round wood delivered to United States processing facilitiess was transported by truck (BTS and USCB 1999). According to Smith et al. (2004), in 2001 approximately 221 million tons of roundwood were transported by truck in the southern United States. The reliance on truck transportation for raw forest products stems from a variety of causes, including; the improvement in hard surface road infrastructure, the closure of rail lines, and changes in relative rail/road freight costs. Costs associated with the harvest and transportation of forest products increased by 14% from 1995 through 2003 while wood delivered prices paid during the same period increased by only 8% (Stuart et al. 2004). Trucking is often the most expensive phase of a timber harvesting operation, accounting for as much as 40-60% of total delivered cost (Shaffer and Stuart 1998) and over one-third of the delivered cost of wood in the cases of lower valued products such as pulpwood (Mendell and Haber 2006).

A survey by Luppold et al. (1998) found that loggers in West Virginia identified trucking as frequently limiting production and a survey by Baker and Greene (2008) found that trucking was the 5th highest ranked problem facing logging businesses. Concerns associated with trucking costs and profitability have spurred several investigations into log trucking efficiency. However, the majority of these studies have been concerned with reducing load weight variability and maximizing gross vehicle weight (GVW). To date, little information can be found comparing the transportation of unmanufactured forest products to other commodities or transportation industries. A comparison between the raw forest products transportation industry, other commodities, and interstate trucking reveals the diversity, segmentation, and disadvantages of the raw forest product transportation industry.

2.2 Employment

As of April 30, 2009, there were approximately 1.3 million truck drivers employed in the United States under the North American Industry Classification System (NAICS) (BLS 2009a). Under NAICS all truck drivers were included in the NAICS 484 category. This category includes any occupation that provides over-the-road transportation of cargo using motor vehicles. The category has two classes, general freight trucking and specialized freight trucking. General freight trucking handles a wide variety of commodities, generally palletized, that are transported in a container or van trailer. Specialized freight trucking transports cargo that requires specialized equipment for transportation due to size, weight, shape, or other inherent characteristics. The transportation of agricultural products, including raw forest products, is classified under the specialized freight trucking category.

The Standard Occupation Classification (SOC) further separates NAICS 484 into three categories of truck driver: 1) driver/sales workers (SOC 53-3031), 2) truck drivers, light or delivery services (SOC 53-3033), and 3) truck drivers, heavy and tractor trailer (SOC 53-3032). In 2008, approximately 1.7 million individuals were employed under SOC 53-3032 in the United States (BLS 2009a). In 2002, there were approximately 1.8 million truck drivers employed in the SOC-53-3032 category. Of these approximately 183,000 were categorized as specialized freight trucking (Global Insight Inc. 2005). According to the 2002 Economic Census (DOC and USCB 2004), approximately 70% of all truck drivers are associated with long haul/over the road trucking while 30% are associated with local trucking and storage. Of the 1.8 million truck drivers, approximately 0.06% were associated with NAICS 4842202, specialized freight trucking agricultural products without storage, and approximately 0.04%were associated with NAICS 4842302, specialized freight trucking agricultural products, long distance. Although the exact number of trucks that transport raw forest products is unknown, less than 1% of all trucks in the United States hauled raw forest products in 2002.

2.3 Employee Retention and Wages

Quality-of-life issues are most frequently cited as the primary consideration for worker retention in the over-the-road trucking industry. Major irritants for drivers are extended periods on the road away from home and unpredictable schedules for getting home (Global Insights Inc. 2005). In this regard many log trucking firms have the advantage of being short haul operations. Drivers can return home each night and essentially functioning as equipment operators.

In 2008, the average hourly wage for truck drivers, heavy and tractor trailer (SOC 53-3032) was $18.62 and the mean annual wage was $38,720 (BLS 2009b). However, drivers in the truck transportation industry (predominantly long distance heavy-duty truck drivers) earned about 25 percent more than truck drivers in all other industries (Global Insight Inc. 2005). This corresponds with work by Gallagher et al. (2005) which found that on average commercial haulers receive 25% more pay than log truck drivers. Based on this assumption, the mean hourly wage of log truck drivers is approximately $13.97 and the annual wage is approximately $29,040.

The construction industry, which is relatively comparable with the trucking industry in terms of pay and educational requirements, is often identified as a competitor for labor (Global Insights Inc 2005). As of 2008, construction was broken into 54 categories. Of these, construction laborers, operating engineers, and other construction equipment operators were selected for comparison. On average construction laborers earn $15.51 per hour and $32,250 annually while equipment operators averaged $20.97 per hour and $43,650 annually (BLS 2009b). Logging equipment operators earn on average $15.76 hourly and $32,780 annually, while log graders and scalers earn on average $16.51 hourly and $34,330 annually (BLS 2009b). While laborer wages are lower than the average for truck drivers, heavy and tractor trailer (SOC 53-3032), they were higher than the estimated wages of log truck drivers while construction equipment operator wages were higher than both (**Table 2.1**).

Log transportation appears to be at a disadvantage in regards to driver recruitment and retention, due to the lower compensation relative to other trucking industries. A 2004 survey of log truck drivers in the states of Alabama, Mississippi, North Carolina, South Carolina, and Texas found that an average of 41% of truck drivers were dissatisfied with their wages (Gallagher et al. 2005). Furthermore, many regulations imposed on transportation industries may cause other occupations to be more appealing to potential employment candidates. For example, entering the construction industry as a laborer or logging as an equipment operator requires less certification, training, licensing, and background checks than required to obtain a Commercial Drivers License (CDL) (Global Insights Inc.).

2.4 Regulations

In 1935 Congress enacted the Motor Carrier Act, which extended regulation to interstate trucking. This regulation made it challenging for new trucking firms to enter the market during the period of 1940-1980 as well as significantly increasing costs and rates (Moore 2009). Trucking remained regulated until the Motor Carrier Act of 1980 deregulated trucking; however, the Federal Motor Carrier Safety Administration is still responsible for federal laws affecting truck transportation.

One of the areas of strictest regulation is the Hours-of-Service (HOS) regulation (49 Code of Federal Regulations Part 395), which limits the time commercial motor vehicle (CMV) drivers may drive. These regulations apply to vehicles weighing 10,001 lbs or more. The regulations also apply to vehicles used to transport 16 or more passengers (including the driver) not for compensation or 9 or more passengers (including the driver) for compensation, or for vehicles involved in interstate or intrastate commerce and transportion hazardous materials in a quantity requiring placards. For vehicles carrying freight, HOS regulations allow truckers to drive for 11 hours following 10 consecutive hours off and stipulate that they may not drive beyond the 14th consecutive hour after coming on duty, following 10 consecutive hours off duty. Furthermore drivers may not drive after 60/70 hours on duty in 7/8 consecutive days. A driver may restart a 7/8 consecutive day period after taking 34 or more consecutive hours off duty (Federal Motor Carrier Safety Administration 2008).

Interstate and intrastate truck drivers are also required to create and maintain a record of duty status in his or her own handwriting for each 24-hour period. The only exemption to this is the 100 air-mile radius exemption. Under this exemption, drivers are exempt from maintaining the daily log if they meet the following requirements: 1) the driver operates within a 100 air-mile radius of the normal work reporting location, and 2)the driver returns to the work reporting location, and is released from work within 12 consecutive hours. Additionally, employers must maintain and retain records for a period of 6 months of times that the driver reports for duty each day, the total number of hours the driver is on duty each day, the time the driver is released from duty each day, and the total time for the preceding 7 days for first-time or intermittent drivers (Federal Motor Carrier Safety Administration 2008).

On all federal interstate highways an 80,000 lbs (36,287 kg) GVW limit is enforced. However, many states have higher weight limits on state maintained roads or allow a certain tolerance for some agricultural products, such as raw forest products. Legal weights in Southern states range from 80,000 lbs (36,287 kg) to 88,000 lbs (39,916 kg) as well as having various load flagging and warning light requirements (Janna Sakowitz, personal communication, Hermitage Safety Consultants, January, 28, 2009) (**Table 2.2**). These variations in regulations affecting log trucks, in addition to interstate weight limits, can make hauling raw forest products across state lines difficult.

2.5 Haul Distances and Conditions

Average haul distance is a concern for the entire trucking industry. In 1993, the Bureau of Transportation Statistics and the Census Bureau began collecting information across the United States for all commodities including average distance per shipment by mode of transportation, weight by mode, and value by mode and is repeated every four years (Bureau of Transportation Statistics and U.S. Census Bureau 2008). Examination of reported haul distances indicates that the average haul distances for finished wood products and all commodities have increased. Data for the raw forest products industry are not as reliable. Many of the survey results were so variable they were not published or information was collected from only one firm and was subsequently not reported.

Moldenhauer and Bolding (2009) reported that 56% of logging firms in South Carolina have average haul distances between 40 and 60 miles, while 26% hauled between 20 and 40 miles during the year 2008. Timber Mart-South (2009) reported an average haul distance of 55 miles (89 km) during the 1st quarter of 2009 for the states of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia.

Log trucks and other trucks differ in their conditions of operation. While over-the-road trucks and many other trucking industries haul primarily on interstates or other improved roads, log trucks spend a significant amount of time on low standard in-woods roads. The wide variety of road surfaces encountered during log hauling is a particular problem for loggers, not shared by traditional transport operations (McCormack 1990). SAE (2003) states that dry dirt roads can require twice the power of paved roads while sandy or muddy roads can require up to 13 times more power and subsequently lead to much higher fuel consumption and vehicle wear. McCormack (1990) found that sandy roads can have 2-3 times more fuel consumption than paved road while gravel roads can require nearly 2 times as much fuel consumption.

2.6 Truck Driver Demographics

Logging industry employees are aging and the same is true for truck drivers. In 1994, the average age of drivers in the trucking industry was 40.4 years while the average age in 2002 was 43.4 years. During the same time the average age of the entire workforce was 38.1 and 39.8

years, respectively (Global Insights Inc 2005). A study conducted in Georgia by Greene et al. (2001) found that the average age of logging contractors was 45.7 ±1.6 years. This study also found that workers in the age class of 60-64 years accounted for approximately 8% of the workforce while workers 65-69 years old accounted for approximately 5%. A similar study conducted in 2007 by Baker and Greene (2008) found that the average age had increased to 50.1 ±1.5 years. This study also found that workers in the age class of 60-64 years had doubled to approximately 16% of the workforce while those in the age class 65-69 years had also nearly doubled to approximately 9%. While neither study was conducted exclusively on truck drivers, harvesting contractor firms included truck drivers among their employees. Gallagher et al. (2005) reported that 86% of log truck drivers were 30 years old and older and 66% of all drivers had more than 10 years experience driving log trucks. This 86% is comparable to the 90% of truck drivers that are 30 years old and older in all trucking industries (Global Insights Inc. 2005). While the age classes 45 years old and older have increased, all of the younger age classes have decreased (Figure 2.1). A reason for the low numbers reported in the 21-24 years of age category is because the Federal Motor Carrier Safety Administration requires individuals to be 21 years old in order to qualify for a CDL. Additionally, many trucking firms require drivers to be at least 25 years old due to lower insurance premiums and some trucking firms will hire only "experienced" drivers, which reduce to recruitment new truck drivers.

Truck driver and other industries education levels for the year 2000 were relatively similar as shown in Table 2.3 (Global Insights Inc. 2005). Georgia logging contractor employee education levels during 1997 were reported by Greene et al. (1998) **(Table 2.3).** Logging contractor employees were not exclusively log truck drivers but were represented in the survey. Truck driver education levels were similar to those of all industries, but there were differences in education levels between logging employees, including truck drivers, and truck drivers and all other industries. Logging employees have approximately 3% more individuals with less than high-school diplomas than all truck drivers and 18.3% fewer individuals with some college or college degree than all truck drivers. Logging employees also have 22.6% fewer with some college or college degree than all other industries.

2.7 Fleet Demographics

The American Trucking Association (2009) reported that during 2008 there were more than 600,000 carriers operating in the United States. Of these, 47% were private carriers while for-hire carriers represented just over 35%. A private carrier is any company owning a fleet of trucks to support its main business. As of June 2008, there were over 214,000 for hire motor carriers and 276,000 private fleets registered with the Department of Transportation (ATA 2009). Of these 490,000+ firms, the vast majority are small businesses with 87.3% operating 6 or fewer trucks, 8.6% operating 7-20 trucks, and only 4.1% operating more than 20 trucks. Gallagher et al. (2005) found that the average log truck fleet size was 5.4 trucks. Baker and Greene (2008) found that the majority of logging contractors who employed truck drivers employed between 2 and 3 truck drivers.

A 1988 Georgia survey found that nearly 50% of logging contractors used some level of contract hauling (Greene et al. 1988). A survey distributed to timber producers in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia found that 66% owned and operated their own trucks (Munn et al. 1998). Greene et al. (2001) found that in 1997 logging contractors delivered 55% of their wood using company owned and operated trucks and 45% by contract trucks. Milauskas and Wang (2006) found that 61% of hauling in West Virginia was done by privately owned trucks. The most recent survey conducted in South Carolina in 2008 found that 48% of loggers own and operate trucks, 13% exclusively use contract trucks, and 38% use a combination of company and contract trucks (Moldenhauer and Bolding 2009). In comparison, a survey of the Appalachian forest products industry found that 35% of forest product manufacturers use a combination of company and contract trucks. Meanwhile, 57% of Appalachian region hardwood sawmills report exclusive use of contract haulers, 33% use a combination of company and contract trucks, and 10% exclusively use their own trucks (Miller et al. 2005).

As of 2006 there were approximately 2 million truck-tractors registered in the United States (ATA 2009). The number of new registrations each year, beginning in 1998, and each year's contribution to the total number of registered trucks as of 2006 are shown in **Figure 2.2**. As of 2006 the average age of all truck-tractors registered in the United States was 3.9 years.

Gallagher et al. (2005) conducted a survey in the states of Alabama, Mississippi, North Carolina, South Carolina, and Texas and found that the average log truck age was 9.7 years in 2004. Milauskas and Wang (2006) found that the average age for log trucks in West Virginia was 8.8 years. The percentage of log trucks in the states of Alabama, Mississippi, North Carolina, South Carolina, and Texas that were 15 years old and older ranged from 11% to 20%. Interestingly an average of 19% of log trucks are15 years old or older as of 2006, while only 5.9% of trucks registered in all industries were older than 8 years.

Ada et al. (1985) correlated truck age and failure. In this study trucks were separated into 3 age classes based on mileage: 67,580 - 81,220 miles, 229,400-255,440 miles, and 299,460-336,040 miles. The average distance interval between breakdowns for the three categories of trucks was 1077, 777, and 569 miles with average repair times of 9.74, 12.23, and 13.29 hours, respectively (**Table 2.4**).

As of 2006 there were a total of 5.59 million trailers and semitrailers registered in the United States (ATA 2009). **Figure 2.3** illustrates the number of new registrations each year starting in 1998 and each year's contribution to the total number of registered trailers and semitrailers as of 2006.

Gallagher et al. (2005) found trailer ages ranged from 1 to 38 years old in the states of Alabama, Mississippi, North Carolina, South Carolina, and Texas. Of these surveyed trailers, 55% were ≤ 10 years. When compared to approximately 36% of trailers in all trucking industries that are ≤ 10 years old, this appears to be an instance where log truck drivers posses newer and better equipment than other industries. However, this is possibly a reflection of trailers wearing out earlier due to harsh working conditions.

2.8 Conclusions

A review of the literature reveals some of the challenges of the raw forest products transportation industry. During 2002, of the approximately 1.8 million truck drivers employed in the United States, less than 1% were associated with transporting raw forest materials (DOC and USCB 2004). Log truck drivers earn an estimated 25% less than other, predominately over-the-road, truck drivers. Log truck drivers can often be viewed as equipment operators due to their somewhat more reliable work schedule in terms of returning home each night. However, log truck drivers earn less than construction laborers and construction equipment operators, which are fields frequently viewed as competitors with the trucking industry for employment. Forty-one percent of surveyed log truck drivers in five southern states reported being unhappy with their wages.

While all trucks are regulated by the FMCSA, log trucks are also regulated to some extent by the state in which they operate. States often have varying regulations on log trucks, for example in the southern 13 states the GVW limit ranges from 80,000 lbs to 88,000 lbs with a total of 7 different GVW limits within these 13 states. A review of the literature also found little information concerning average haul distances of raw forest products. While the average haul distance for finished wood products and all commodities is increasing, data pertaining to average haul distance of raw wood products are extremely segmented and unreliable to draw conclusions.

Currently the trucking industry as a whole is an aging workforce. In 1994, the average age for all trucking employees was 40.4 years while the entire work force was 38.1 years. In 2002, the average age for the trucking industry had increased by 3 years to 43.4 while the average age for entire workforce had only increased by 1.7 years to 39.8 (Global Insights Inc. 2005). A study conducted in Georgia found the average age for logging employees, including truck drivers was 45.7 ±1.6 years (Greene et al. 2001). When replicated in 2007 the average age had increased to 50.1 ±1.5 years (Baker and Greene 2008). In 2006, the average age for all truck-tractors registered in the United States was 3.9 years with trucks over 8 years old only making up 5.9% of the total (ATA 2009) while the average age of log trucks in southern states in 2004 was 9.7

years with trucks over 15 years old comprising 19% of the total (Gallagher et al. 2005). In regards to trailers, the raw forest products transportation industry appears to use newer and better equipment than other industries however, this is likely a reflection of trailers wearing out earlier due to harsh working conditions. The general lack of reliable information further extends to how tract and mill turn times affect trucking efficiency and costs in the Southeastern United States.

2.9 Literature Cited

Ada, N.R., I.S. Ferguson and D.M. Stodart. 1985. Modeling log truck breakdowns. Australian Forest Research (15):85-93.

American Trucking Association Department of Research and Transport Economics (ATA) 2009. American Trucking Trends 2008-2009.

Baker, S.A. and W.D. Greene. 2008. Changes in Georgia's logging workforce, 1987-2007. South. J. Appl. For. 32 (2): 60-68.

Bureau of Labor Statistics (BLS). 2009a. *Industries at a Glance.* Available online at www.bls.gov; last accessed May 19, 2009.

Bureau of Labor Statistics (BLS). 2009b. *Occupational Employment and Wages, 2008.* Bureau of Labor Statistics. USDL 09-0457. 30 p.

Bureau of Transportation Statistics (BTS) and U.S. Census Bureau (USCB). 1999. *1997 United States Commodity Flow Survey*. U.S. Census Bureau. EC97TCF-US. 169 p.

Bureau of Transportation Statistics (BTS) and U.S. Census Bureau (USCB). 2008. Bureau of Transportation Statistics. Available online at http://www.bty.gov/programs/commodity_flow_survry/, last accessed Dec. 5, 2008.

Gallagher, T., M. Smidt, R. Tufts, and T. McDonald. 2005. *How to Improve Transportation Efficiency and Costs.* Wood Supply Research Institute. 44 p.

Global Insight Inc. 2005. *The U.S. Truck Driver Shortage: Analysis and Forecasts*. Available online at http://www.truckline.com/StateIndustry/Pages/default.aspx; last accessed Apr. 10, 2009.

Greene, W.D., B.D. Jackson and D.C. Woodruff. 1998. Characteristics of logging contractors and their employees in Georgia. Forest Prod. J. 48 (1): 57-53.

Greene, W.D., B.D. Jackson, and J.D. Culpepper 2001. Georgia's logging businesses, 1987-1997. Forest Prod. J. 51 (1): 25-28.

Greene, W.D., F.W. Cubbage, and J.F. McNeel. 1988. Characteristics of independent loggers in Georgia. Forest Prod. J. 38 (7/8): 51-56.

Federal Motor Carrier Safety Administration (FMCSA). 2008. *Rules and Regulations.* Available online at www.fmcsa.dot.gov; last accessed Oct. 7, 2008.

Luppold, W.G., C.C. Hassler, and S. Grushecky. 1998. An examination of West Virginia's logging industry. For. Prod. J. 48(2): 60-64.

McCormack, Robert J. 1990. Measuring and evaluating log truck performance in a variety of operating conditions. PhD. dissertation, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 138 p.

Milauskas, S.J. and J. Wang. 2006. West Virginia logger characteristics. Forest Prod. J. 56 (2): 19-24.

Miller C., R. Smith, O. Parhizkar, and B. Stich. 2005. *Analysis of the transportation needs of the wood products industry in distressed Appalachian regions.* Virginia Polytechnic Institute and State University. 50 p.

Moldenhauer, M.C., and M.C. Bolding. 2009. Parcelization of South Carolina's private forestland: loggers' reaction to a growing threat. For. Prod. J. 59(6): 37-43.

Moore, T.G. 2009. Truck Deregulation. Available online at http://www.econlib.org/library/Enc1/TruckingDeregulation.html; last accessed Mar. 12, 2009.

Munn, I.A., J.B. Cutshall, and D.G. Hodges. 1998. 1993 pulpwood logging contractor survey. Forest Prod. J. 48 (7/8): 47-53.

Society of Automotive Engineers (SAE). 2003. Commercial truck and bus SAE recommended procedure for vehicle performance prediction and charting. Soc. of Automotive Eng. SAE J2188.

Smith, W.B., P.D. Miles, J.S. Vissage, and S.A. Pugh. 2004. *Forest resources of the United States, 2002.* USDA For. Serv. Gen. Tech. Rep. NC-241. 137 p.

Stuart, W., L. Grace, and C. Altizer. 2004. Preliminary 2003 logging cost indices. Wood Supply Research Institute and the Forest and Wildlife Research Center. Mississippi State University, FWRC FO 415. 18 p.

Timber Mart-South, Inc. 2009. Logging Rates. The Journal of Southern Timber Prices. 34 (1): 14-15.

U.S. Department of Commerce (DOC) and U.S. Census Bureau (CB). 2004. Truck Transportation: 2002. U.S. Census Bureau. ECO2-481-09. 13 p.

2.10 Table and Figure Captions

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Table 2.3: Education characteristics of truck drivers and all other industries in 2000 and logging contractors in 1997

Table 2.4: Average distance between breakdowns and repair times by truck mileage (Ada 1984).

Figure 2.1: Truck drivers in the truck transportation industry by age during the years 2004 and 2000 (Global Insights Inc. 2005)

Figure 2.2: Number of new truck-tractor registrations by year (thousands) and in service in 2006 (ATA 2009)

Figure 2.3: Number of new trailer registrations by year (thousands) (ATA 2009)

Table 2.1: Average hourly and annual wage for individuals employed in construction, logging, and trucking as of 2008.

	Mean Hourly Wage	Mean Annual Wage
Construction Laborers[1]	$15.51	$32,250
Construction Equipment Operators[1]	$20.97	$43,650
Logging Equipment Operators[1]	$15.76	$32,780
Log Graders/Scalers[1]	$16.51	$34,330
Heavy Truck and Trailer (all)[1]	$18.62	$38,720
Log Truck and Trailer[2]	$13.97	$24,090

[1]BLS 2009a
[2]BLS 2009a and Gallagher et al. 2005

Table 2.2: Weight limits, load flagging, and warning light requirements for log trucks by southern state[1].

State	Gross Weight Limit Including Tolerance	Load Flagging[2] Number of Flags	Over Hang[4]	Warning Lights[3]
Alabama	88,000 lbs	Two	Two 4ft or over	Two red after dark
Arkansas	85,000 lbs	Two	Two 4ft or over	Red after dark
Florida	80,000 lbs	One	One 4ft or over	Amber Strobe all times Light bar after dark
Georgia	84,000 lbs	Two	Two 4ft or over	Amber Strobe all times
Kentucky	88,000 lbs	Two	Two 4ft or over	Red after dark
Louisiana	88,000 lbs	Two	Two 4ft or over	Red after dark
Mississippi	83,000 lbs	One	One 4ft or over	Red after dark
North Carolina	84,000 lbs	One	One at all times	Red or amber after dark
Oklahoma	84,000 lbs	One	One 4ft or over	Red after dark
South Carolina	84,272 lbs	One	One 4ft or over	Amber strobe at all times
Tennessee	88,000 lbs	One	One 4ft or over	Red Strobe after dark
Texas	86,000 lbs	Two	Two at all times	Amber after dark – can not haul tree length after dark
Virginia	84,000 lbs	One	One 4ft or over	Red on double bunk – can not haul tree length after dark

[1]Janna Sakowitz, personal communications, Hermitage Safety Consultants, Janurary, 28th, 2009)
[2] Red or orange 18 inch square fluorescent warning flags affixed to the log or tree stem which protrudes the furthest off of a loaded log trailer
[3] Projecting load lamps affixed to the log or tree stem which protrudes the furthest off of a loaded log trailer
[4]Distance that product must extend beyond the rear of the trailer before load flagging is required.

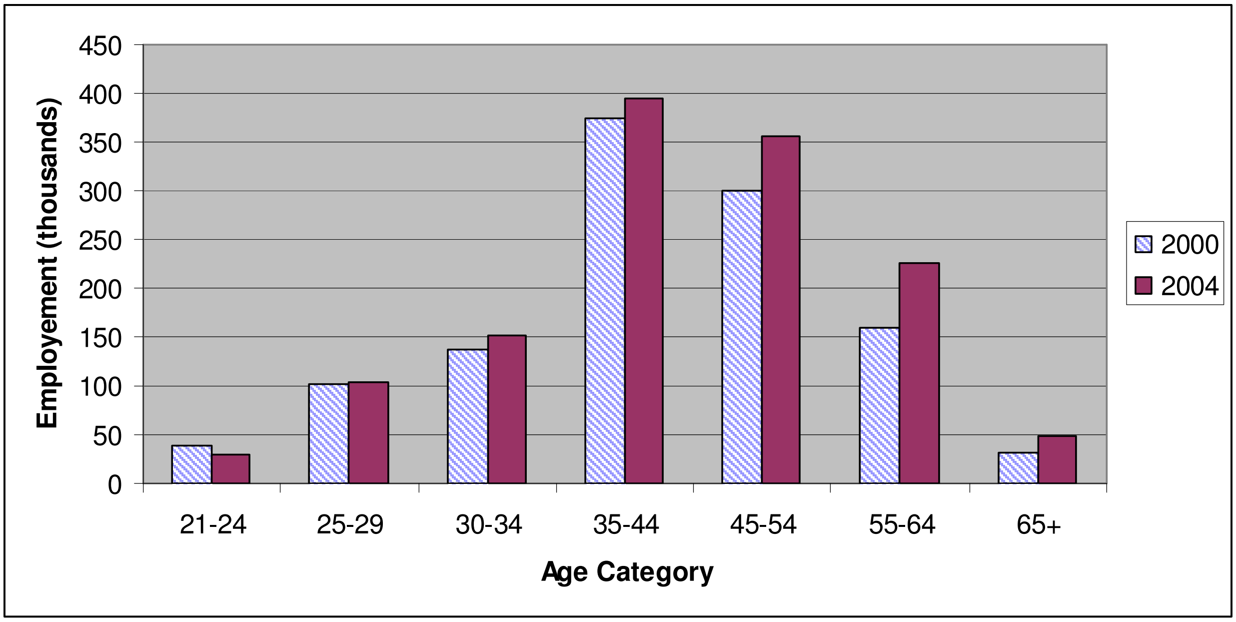


Figure 2.1: Truck drivers in the truck transportation industry by age during the years 2000 and 2004 (Global Insights Inc. 2005).

Table 2.3: Education characteristics of truck drivers and all other industries in 2000 and logging contractors in 1997.

	Truck Drivers [1]	All Other Industries [1]	Logging Contractors [2]
Less than high-school diploma	25.7%	24.7%	28.6%
High-school diploma	47.6%	44.3%	46.0%
Some colllege or college degree	26.7%	31.0%	8.4%

[1] (Global Insight Inc. 2005)

[2] (Greene et al. 1998)

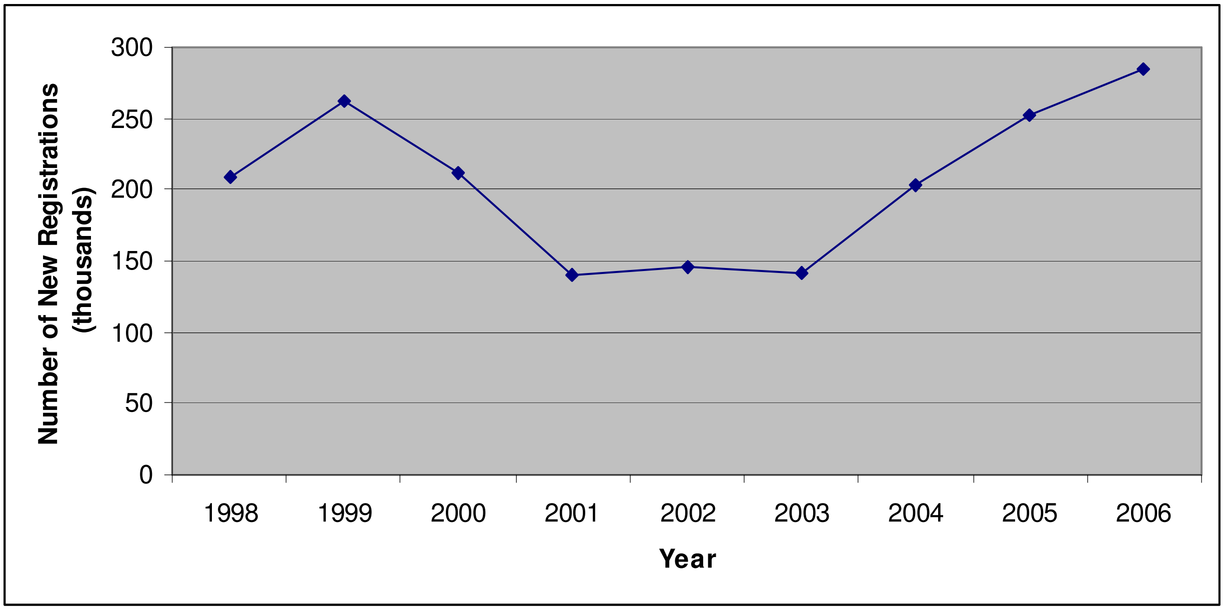


Figure 2.2: Number of new truck-tractor registrations by year (thousands) and in service in 2006 (ATA 2009).

Table 2.4: Average distance between breakdowns and repair times by truck mileage (Ada 1984).

Truck Mileage	Average Distance Between Breakdowns (Miles)	Average Repair Times (Hours)
67,590 - 81,220	1,077	9.74
229,400 - 255,440	777	12.23
299,460 - 336,040	569	13.29

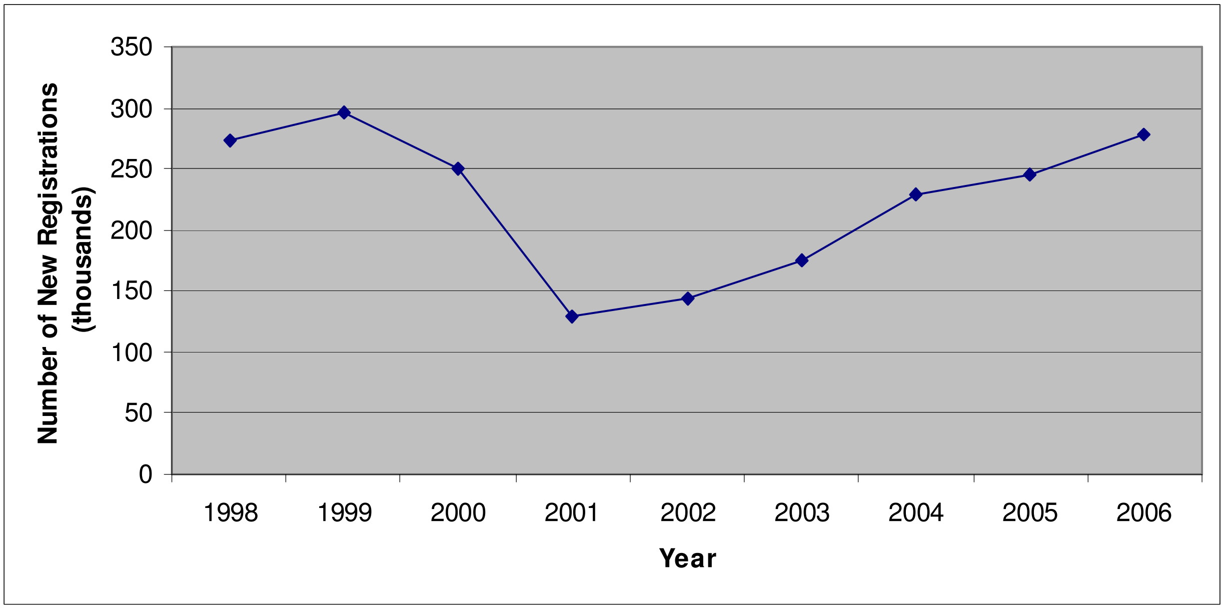


Figure 2.3: Number of new trailer registrations by year (thousands) (ATA 2009).

Chapter 3 AN ANALYSIS OF LOG TRUCK TURN AROUND TIMES AT BOTH THE TRACT AND MILL SCALES

3.1 Abstract

Log truck turn around times affect overall trucking efficiency and logging costs. This study evaluated log truck turn times at both the tract and mill scales using both gross and elemental time studies to identify important trucking productivity factors and efficiency improvement opportunities. The gross level study was conducted from July 13th until November 17th 2009. Seventeen truck drivers were randomly assigned to record mill turn times starting when the truck entered a mill facility and ending when the truck exited the mill facility. The remaining 17 drivers recorded tract turn times starting when the truck exited a state or county maintained road to enter a harvesting location and ending when the truck reentered a state or county maintained road. During this phase, both groups recorded date, weather, product, road length, time in/out, crew number, and destination. During the elemental time study 50 in-woods truck turns were observed at each of the four harvesting crews for a total of 200 turns. A turn was defined as beginning when the log truck exited a state or county maintained road entering a harvesting location and ending when the truck returned to the state or county maintained road. Regression equations were also created to further interpret truck turn times at both the tract and mill scales. Gross level studies found that 1,268 truck turns at the tract scale averaged 1.40 hours while 576 truck turns at the mill scale averaged 0.56 hours. Elemental time studies at harvesting locations (tract scale) found that log trucks were idle 32% of the time. Trucks spent the greatest amount of time being loaded while waiting was the second greatest contributor to turn times. Elemental time studies at mill facilities found that trucks were idle 27% of the time. Trucks spent the

greatest amount of time being unloaded while unbinding was the second greatest contributor to turn times. Results indicate that reductions in loading and waiting times can have significant effects on the overall turn time.

3.2 Introduction

The transportation of raw forest products is an important component of any timber harvesting or wood supply system. As of 1997, approximately 94% of the round wood delivered to processing facilities, across the United States, was transported by truck (BTS and USCB 1999). According to Smith et al. (2004), in 2001 approximately 221 million tons, of roundwood were transported by truck in the southern United States. The reliance on truck transportation for raw forest products stems from a variety of causes, including the improvement in hard surfaced road infrastructure, the reduction of rail lines, and changes in relative rail/road freight costs. Costs associated with the harvest and transportation of forest products increased by 14% from 1995 through 2003 while delivered wood prices paid during the same period increased by only 8% (Stuart et al. 2004).

Trucking is often the most expensive phase of a timber harvesting operation, accounting for as much as 40-60% of total harvesting cost (Shaffer and Stuart 1998) and over one-third of the delivered cost of wood for lower valued products such as pulpwood (Mendell and Haber 2006). Expenses associated with the transportation of harvested materials stems from high capital investments, high fuel and operating costs, and strict governmental regulations (Shaffer et al. 1986). As a result, modest transportation efficiency gains could produce meaningful cost savings.

A survey by Luppold et al. (1998) found that loggers in West Virginia identified trucking as frequently limiting production. Similarly, a survey by Baker and Greene (2008) found that trucking was the 5^{th} highest ranked problem facing logging businesses. Concern associated with trucking costs and profitability has spurred several investigations into log trucking efficiency. The majority of these studies have been focused on reducing load weight variability (Shaffer et al. 1987, Overboe et al. 1998, Gallagher et al. 2004), maximizing gross vehicle weights (Shaffer and Stuart 1998, Gallagher et al. 2004, Bolton 2007), and improving truck scheduling (Weintraub1996, Murphy 2003, McDonald et al. 2005, Mendell et al. 2006).

Overboe et al. (1998) reported that hauling costs are generally minimized when log truck weights approach the maximum legal limit. As a result, several studies have investigated methods to reduce gross vehicle weight and to maximize potential payload weights, while reducing variability. Two case studies conducted in Georgia and Virginia investigated the effects of on-board log truck scales on load weight variability. After adding the on-board truck scales the net load weight standard deviation decreased by 0.52 tons while the mean cost of overweight fines decreased from $92.69 to $57.64 (Shaffer et al. 1987). Gallagher et al. (2004) found that the use of in-woods platform scales generally increased payload and reduced load weight variation. These improvements effectively reduced the number of light loads and minimized overweight loads which could be subject to fines. Another, potentially cheaper, method to control load weight variability is a simple reporting and feedback technique with loggers who have target load weights. Overboe et al. (1998) found that by simply informing loader operators about previous load weights it is possible to significantly reduce the number of overweight loads and increase the number of loads within each logger's target range. A 1% decrease in GVW variability yielded a 0.22 to 0.73 ton increase in payload at individual mills; however, GVW targets must balance cost, risk, and liability.

One approach to reduce costs and increase profits associated with trucking is to reduce tare (empty) weight of log trucks and trailers. Due to GVW restrictions imposed by state and federal regulations, reductions in tare weight translate into more payload that can be legally transported. It has been estimated that every pound added to a truck's tare weight can decrease a logger's profit by $5 (Shaffer and Stuart 1998). This conclusion has led many logging and trucking contractors to explore ways to reduce their fleet's tare weight. Bolton (2007) found that a combination of methods, including using super single truck and trailer tires, lighter engines, and eliminating dual exhausts, could reduce tare weights by approximately 2,680 lbs per truck.

Consolidating truck resources, as well as improving truck scheduling, can positively affect the efficiency of a trucking fleet. Weintraub et al. (1996) reported that fleet reductions of 32% were possible with improved truck scheduling. Fleet reductions of 25 to 50% in New Zealand had reported cost savings as high as 47% (Murphy 2003). A 2005 Georgia study tracked 18 log trucks from three independent logging companies and six logging sites to 15 destinations over five days. A simulation of a centralized dispatch system used the actual inventory and loading/unloading data from the field study and constraints to model hours worked and truck flows per tract. Simulation results indicated that the same volume of wood could be delivered with 55 fewer minutes per truck per day and 36 fewer miles driven per truck per day. Estimated daily cost savings for the 18-truck system were $759/day or $42/truck per day (Mendell et al.

2006). In addition McDonald et al. (2005) found that the use of a pooled trucking resource could reduce the number of trucks required to deliver a volume of wood by 20%, as well as reduce unloaded miles by 10%.

Tract and mill turn times can potentially affect trucking efficiency and logging costs. Deckard et al. (2003) conducted a study in eight southern states in which 9,576 loads of roundwood were delivered and mill turn times were recorded. The sample was then divided into a desired target group and a rest-of-sample (ROS) group. The desired target group turn times ranged from 33 to 74 minutes. The ROS group turn times ranged from 58 to 137 minutes. If the ROS group could match the BM group turn times, an estimated \$0.24 - \$0.48 per ton of delivered wood could be saved for a system savings of \$44.1 - \$87.1 million annually at the 95th percentile.

Using computer simulation Barrett, (2001) found that longer turn times at mill locations do not necessarily increase logging contractor costs. However, if longer mill turn times cause a reduction in the average loads delivered per day, trucking can become the limiting factor for logging contractors and increase costs. It was also determined that increasing haul distances and in-woods turn times can have a similar effect on trucking costs.

Log trucks routinely operate in harsh working conditions including dusty, muddy, or other rough terrain. These working conditions, especially log landing to state/county maintained roads, can necessitate more frequent and expensive preventative maintenance due to increased likelihood of damage to the truck, trailer, electrical systems, air lines (Shaffer and Stuart 1998). These rough haul roads can cause an increase in truck fuel consumption (McCormack 1990). Log trucks are prone to lose potential work opportunities due to natural weather conditions as well as load availability, which can vary not only day to day but minute to minute.

Previous research indicates the importance of transportation efficiency with regard to profitability of the logging contractors and trucking industry. Tract and mill turn times are potential areas where transportation gains can be made.

Therefore, the four objectives of this study were to:

1. Evaluate truck turn around times the tract scale to identify important trucking productivity factors and efficiency improvement opportunities,
2. Evaluate truck turn around times at the mill scale to identify important trucking productivity factors and efficiency improvement opportunities,
3. Create models to estimate truck turn around times at the tract scale, and
4. Create a model to estimate truck turn times at the mill scale.

3.3 Methods

3.3.1 Study participants and harvest prescriptions

This study was conducted with the assistance of one logging business that operates four separate harvesting crews and approximately 34 log trucks, of which 14 truck drivers were company employees and 20 truck drivers were independent contractors. Each harvesting crew operated primarily in the Piedmont of Virginia while products were delivered as far away as Pennsylvania. Each crew had unique equipment configurations and operated on different forest stands under differing harvest prescriptions. Forest roads observed during the course of the study included both class permanent and temporary forest roads that were not part of county, state, or federal road systems.

Crew one consisted of one TigerCat 724E feller-buncher paired with one TigerCat 635B rubber-tired grapple skidder as well as one Timbco 820E rubber-tired grapple skidder. This crew also utilized one Barko 495M knuckleboom loader with a CTR delimber and one Barko 595 knuckleboom loader. Crew one also employed one deck hand who was responsible for delimbing loaded trucks using a pole saw as well as moving set out trailers. This crew also utilized platform scales and one bunk saw. Crew one was working on a 100 acre loblolly pine plantation receiving the first thinning. Crew one utilized a class three road with a total length of 1,330 feet and an average width of 22 feet. During the course of the study the weather remained clear and the road stayed dry.

Crew two consisted of one TigerCat 720D feller-buncher paired with one TigerCat 630C rubber-tired grapple skidder. This crew utilized two Barko 495M knuckleboom loaders, one of which was equipped with a CTR delimber. Crew two also employed one deck hand who was responsible for delimbing loaded trucks using a pole saw as well as moving set out trailers. This crew was also equipped with platform scales and one bunk saw. Crew two was working on a 60 acre loblolly pine plantation receiving its first thinning. Crew two utilized a class three road with a total length of 3,168 feet with an average width of 14 feet. During the study the weather was clear with dry roads with the exception of one morning Friday which received less than 1 inch of rain. During this half day the road became impassable for loaded log trucks and work was not resumed until the following Monday.

Crew three consisted of one TigerCat 724E feller-buncher paired with one TigerCat 635B rubber-tired grapple skidder. This crew utilized one Barko 495M knuckleboom loader with a CTR delimber and one Barko 595 knuckleboom loader which was paired with a bunk saw. Crew three also employed one deck hand who was responsible for delimbing loaded trucks and moving set out trailers. Crew three was working on a 600 acre loblolly pine plantation clear cut harvest. Crew three utilized a class three road with a total length of 5,808 feet with an average width of 16.5 feet. The weather remained clear and the road remained dry during the study.

Crew four consisted of one TigerCat 720D feller-buncher paired with one TigerCat 630C rubber-tired grapple skidder. This crew also utilized one Barko 495M knuckleboom loader paired with a CTR delimber. Crew four was working on a 400 acre loblolly pine plantation receiving its first thinning. Crew four utilized a class four road with a total length of 11,088 feet and an average width of 15 feet. During the course of the study the weather remained clear and the road remained dry.

This study was further assisted by three wood receiving mills. These mills consisted of one pulp mill, one chip mill, and one saw mill. The pulp mill received an average of 277 truck loads per day of both pine and mixed hardwoods. Wood was delivered to the pulp mill by a variety of truck types including tandem trucks, tandem trucks with auxiliary trailers, and trucks with double bunk trailers. Trucks were unloaded at the mill by front end loaders. The chip mill received an average of 92 truck loads per day of both pine and mixed hardwoods. This mill also receives wood from a variety of truck types including tandem trucks, tandem trucks with auxiliary trailers, and trucks with double bunk trailers. Trucks at the chip mill are unloaded by overhead cranes. The saw mill received an average of 52 truck loads per day of southern yellow pine. This mill receives wood from a wide variety of trucks including trucks with double bunk trailers, tandem trucks, tandem trucks with auxiliary trailers, as well as an occasional dump truck from land clearing companies. Trucks at the saw mill are unloaded by front end loaders.

3.3.2 Experimental design, data collection, and analysis

The first phase of data collection consisted of a gross time study which began on July 13th and continued until November 17th 2009. A gross time study deals with gross production, total elapsed time, and typically involves those responsible for production to record these values (Miyata et al. 1992). During this phase, 34 truck drivers recorded data in the gross time study. Seventeen truck drivers were randomly assigned to record mill turn times starting when the truck entered a mill facility and ending when the truck exited the mill facility. The remaining 17 drivers recorded tract turn times starting when the truck exited a state or county maintained road to enter a harvesting location and ending when the truck reentered a state or county maintained road. During this phase, both groups recorded date, weather, product, road length, time in/out, crew number, and destination. A total of 1268 tract turn times were recorded as well as 576 mill turn times during this gross time study.

The second phase of data collection consisted of an elemental time study which was conducted at each of the four harvesting locations as well as at each of the three mill facilities. Elemental time studies utilize stopwatches in observing, measuring, and recording well-defined phases of operations for an entire day or over many days or weeks (Miyata et al. 1992). Fifty in-woods truck turns were observed at each of the four harvesting crews for a total of 200 turns. A turn was defined as beginning when the log truck exited a state or county maintained road entering a harvesting location and ending when the truck returned to the state or county maintained road. Crew specific information, including the number of employees and specific equipment mixes, was recorded for each harvesting crew. Stand specific information was also recorded for each location including tract size and harvest prescription.

A combination of general information and various time elements were gathered for each truck turn. General information consisted of date, crew number, road length, road width, road condition, weather, time of day, load type, product, and loading method. Time elements covered all possible tasks that a log truck can be involved in during one turn. Time elements are shown in detail in **Table 3.1**.

During the mill phase of the elemental time study, 50 truck turns were observed at each of the three mills. A turn was defined as beginning when the log truck exited a state or county maintained road entering a mill owned road or property and ending when the truck returned to the state or county maintained road. Mill specific information was recorded at each of the three receiving mills. This information included road length, road width, and unloading procedure (i.e. overhead crane vs. front end loader). General information was recorded for each turn including time of day, weather, load type, and product. In addition to general information, various time elements were recorded for each turn. The time elements covered possible tasks that a log truck can be involved in during a turn and are presented in **Table 3.2**.

Two people were required to record data for both the tract and mill scale. The first person was positioned near the state or county maintained road. The second person was positioned near the logging deck during the tract scale data collection and near the unloading area during the mill scale data collection. Each individual was positioned to be able to keep the log trucks in sight. Additionally, the two individuals remained in radio contact throughout each recorded turn. Both individuals used tally sheets to record turn information and each individual was able to monitor up to three trucks at a time. Stop watches were used to record values for the various time elements as well as total turnaround time.

Statistical analysis consisted of developing stepwise multiple linear regression models for predicting truck turn times at both the tract and mill levels. Models were evaluated using the multiple R-squared, the standard deviation of the residuals ($S_{y.x}$), and the F-statistic. Comparisons between company and contract trucks were completed using a Kruskal-Wallis One-Way Analysis of Variance (ANOVA). Comparisons between turn times during the morning and afternoons, at both mill and tract levels, were completed using Kruskal-Wallis One-Way ANOVA and ANOVA, respectively.

3.4 Results and Discussion

3.4.1 Gross Level Time Study

Results of the gross level time study are shown in **Table 3.3.** Contract trucks make up approximately 60% of the studied truck fleet yet accounted for less than 49% of the 1,844 recorded loads. The majority of the loads delivered by contract trucks were delivered to a receiving mill in Pennsylvania. However, company owned trucks never transported raw forest products to the Pennsylvania mill. This resulted in contract trucks often only delivering one load per day as opposed to company trucks which delivered multiple loads. Due to these differences, a Kruskal-Wallis (ANOVA) with $\alpha=0.05$ was conducted to determine if there were significant differences between company and contract truck turn times at both the tract and mill level. Both tests indicated that there were no significant differences between company and contract truck turn times (tract p=0.70, mill p=0.44).

Tract turn times, with company and contract truck turn times combined, ranged from 0.11 to 6.50 hours with an average turn time of 1.40 hours and a median of 1.0 hours. The minimum turn times reflect the shortest turn times that were recorded for setout trailers while the longest turn times were associated with hot loading. Each crew worked from 7:00 am until 5:00 pm and took a 30 minute lunch break at 12:00 pm. Using the recorded starting time of each turn it was determined that of the 1,268 recorded tract turn times 60% occurred before 12:00 pm while the remaining turns occurred after the crew's lunch break. The average morning turn time was 1.15 hours while the average afternoon turn time increased to 1.55 hours. A Kruskal-Wallis ANOVA with $\alpha=0.05$ determined that there was a significant difference between morning and afternoon turn times (0.028).

Mill turn times, with company and contract truck turn times combined, ranged from 0.13 to 6.65 hours with an average turn time of 0.56 hours and a median of 0.42 hours. Using the recorded starting time of each turn it was determined that of the 576 recorded mill turn times approximately 55% occurred in the morning while the remaining turns occurred in the afternoon. The average morning turn time was 0.60 hours while the average afternoon turn time increased to 0.70 hours which was a significant difference (p=0.03).

3.4.2 Tract Turn Times

Descriptive statistics **(Table 3.4)** were summarized for the total turn time for each crew. The longest turn times were recorded for crew four. This crew also had the longest haul road distance with a total distance of 2.1 miles from the state maintained road to the logging deck. Each of the four crews used a combination of setout trailers and hot loading during the course of the study. Hot loading is used on logging operations in which the stems are not decked and stored for extended periods of time but loaded onto a truck as soon as a truck is available. Setout trailers are trailers that are loaded and prepared for transport in the absence of available trucks for hot loading. The shortest turn times recorded during the elemental time study were those of the setout trailers while the longest recorded turn times are associated with hot loading. The relationship between haul road distance and total travel time is illustrated in **Table 3.5**.

In all harvesting systems, the use of setout trailers resulted in shorter turn times versus hot loading. As shown in **Table 3.4** the average setout turn time was 0.59 hours while the average hot loading turn time was 1.69 hours. The longest setout trailer turn times reflect times in which trucks arrived to the harvesting location when no setout trailers were available but were being loaded. In this situation, trucks often waited for the setout trailer to be completely loaded and then took that load. This situation contributed to the longest setout trailer turn times. Given the difference in average turn times between setout trailers and hot loading, tract turn times for harvesting contractors could potentially be reduced if setout trailers were more commonly incorporated.

Of the 136 tract turn times which were identified as hot loading, 86 or 63% occurred in the morning while the remaining 37% occurred in the afternoon. The average turn time recorded in the morning was 1.65 hours while the average afternoon turn time was 1.67 hours. Using an ANOVA test with α=0.05 it was determined that there was no significant difference between hot loading which occurred in the morning or afternoon. Of the 64 tract turn times which were identified as setout trailers, 70% occurred in the morning while the remaining 30% occurred in the afternoon. The median morning turn time was 0.38 hours while the afternoon turn time increased to approximately 0.51 hours. Using a Kruskal-Wallis ANOVA with α=0.05 it was determined that there was no significant difference between morning and afternoon setout turn times (p=0.17). A comparison was also made between tract turn times for both the gross and elemental time study. Using an ANOVA with α=0.05 it was determined that there was no significant difference between gross and elemental tract turn times (p=0.83).

Figure 3.1 shows the contribution of time elements to the average turn time by crew. Loading and waiting contribute the most to tract turn times. Average loading time for all crews was 0.39 hours and average waiting time for all crews was 0.34 hours. Time spent loading contributed approximately 29% of total tract turn time while time spent waiting contributed approximately 26% percent of total tract turn time. For comparison, the next highest contributor to total tract turn time was preparing the load with an average of 0.16 hours and approximately 12% of total tract turn times.

Non-productive tract turn time can be defined as time a log truck spent idle such as waiting, mechanical delays, and non-mechanical delays. This non-productive time can be a large contributor to total tract turn time. By this definition non-productive time contributes an average of 32% of total tract turn time.

3.4.3 Mill Turn Times

Descriptive statistics **(Table 3.6)** were also summarized for the total turn time at each receiving mill. The longest turn times were recorded for the chip mill with a maximum turn time of 1.60 hours and an average of 0.47 hours. This mill also had the highest standard deviation at 0.21 hours. The shortest turn times were obtained by the pulp mill with a minimum turn time of 0.17 hours and an average turn time of 0.33 hours. This mill also had the lowest standard deviation at 0.08 hours.

For each of the mill locations, truck turn times were separated into two categories, those which occurred in the morning and those which occurred in the afternoon. At the saw mill, 73% of recorded turns occurred in the morning with an average turn time of 0.37 hours. During the afternoon turn times increased to 0.38 hours. At the pulp mill, 67% of recorded turns occurred in the morning with an average turn time of 0.33 hours. Afternoon turn times at the pulp mill remained at an average of 0.33 hours. At the chip mill 60% of recorded turn times occurred in the morning with an average turn time of 0.49 hours. During the afternoon the average turn time decreased to 0.46 hours. As a whole, 66% of recorded mill turn times occurred in the morning with turn times averaging 0.40 hours. The average afternoon turn time remained at an average of 0.40 hours. There were no significant differences between morning and afternoon turn times at the three mills separately or as a whole.

A comparison was also made between mill turn times for both the gross and elemental time study. Using a Kruskal-Wallis ANOVA with $\alpha=0.05$ it was determined that there was a significant difference between gross and elemental mill turn times (p=0.003). During the course of the gross level time study a large number of loads were delivered to mills which were not studied during the elemental time study. Additionally, the saw mill which was involved with the elemental time study was not visited by trucks during the course of the gross level time study. In all likelihood, the differences in recorded truck turn times are the result of different mills being studied.

The contribution of time elements to the average turn times for each mill is shown in **Figure 3.2**. Unloading and unbinding contributed the greatest amount of time to overall mill turn times. Average unloading time for the three mills was approximately 0.10 hours and average unbinding time was 0.072 hours. Time spent unloading consisted of approximately 24% of total mill turn time while unbinding contributed to approximately 18%. Traveling empty was the third highest contributor to total turn time averaging 0.068 hours and accounting for approximately 16% of total time. The difference between average time unloading and average time unbinding was just under 1.50 minutes while the difference in the average time unbinding and average time traveling empty was 30 seconds per turn.

Non-productive mill time can be defined as time a log truck spent idle such as waiting, mechanical delays, and non-mechanical delays. While non-productive mill time was not as great a factor for mills as it was for harvesting contractors it still accounts for an average of approximately 20% of mill turn times.

3.5 Regression Models for Predicting Turn Times

Three multiple linear regression models were developed for predicting tract turn times. These models were selected due to the differences in overall turn time for all loads, hot loading, and setout trailers. These models can be used to predict turn times for hot loading, using setout trailers, or a combination of the two. Descriptive statistics (**Table 3.7**) were summarized for the different time elements used in each of the following four models. For all loads at the tract scale, 200 total, the independent variables waiting (WT), loading (LD), and travel empty (TE) were significant. Tract turn time (hours) for all loads:

Model 1. (y = 0.29 +1.13 x LD + 1.87 x TE + 1.03 x WT)

R^2=0.92, F-ratio=741.87, $S_{y.x}$=0.06, p-value<0.001

In model one LD, TE, and WT represent time spent loading, traveling empty, and waiting respectively. All time elements are in hours as is the total estimated turn time. Turn times estimated using model one appear in **Figure 3.3**. To create these estimates, the average loading time of 0.40 hours and the average travel empty time of 0.13 hours were used. Waiting times varied from 0 to 2 hours which represented the range of observed waiting times for all loads. Using model one, errors for the estimate ranged from -2.10 to 0.94 hours with an average error for the estimate of 0.01 hours.

For hot loading at the tract scale, 135 loads total, the independent variables waiting (WT), loading (LD), and travel empty (TE) were significant. Tract turn time (hours) for hot loading:

Model 2. (y = 0.27 + 1.12 x LD + 1.99 x TE + 1.05 x WT)

R^2=0.90, F-ratio=418.66, $S_{y.x}$=0.05, p-value<0.001

In model two the variables LD, TE, and WT were once again used. As before, these variables represent time spent loading, traveling empty, and waiting, respectively. All time elements are in hours as is the total estimated turn time. Turn times estimated using model two appear in **Figure 3.4**. To create these estimates, the average loading time of 0.59 hours and the average travel empty time of 0.15 hours were used. Waiting times varied from 0 to 2 hours which represented the range of observed waiting times for all loads. Using model two, errors for the estimate ranged from -1.86 to 1.16 hours with an average error for the estimate of 0.01 hours.

For setout trailers at the tract scale, 65 loads total, the independent variables waiting (WT), delay non-mechanical (DNM), and travel loaded (TL) were significant. Tract turn time (hours) for setout trailers:

Model 3. (y = 0.21 + 1.06 x DNM + 2.33 x TL + 1.05 x WT)

R^2=0.95, F-ratio=396.80, $S_{y.x}$=0.09, p-value<0.001

In model three DNM, TL, and WT represent time spent in non-mechanical delays, traveling loaded, and waiting respectively. All time elements are in hours as is the total estimated turn time. Turn times estimated using model three appear in **Figure 3.5**. To create these estimates, the average non-mechanical delay time of 0.10 hours and the average travel loaded time of 0.07 hours were used. Waiting times were increased from 0 to 1.43 hours which represented the range of observed waiting times for all loads. Using model three, errors for the estimate ranged from -0.23 to -0.27 hours with an average error for the estimate of -0.006 hours.

In addition to those developed for tract turn times, one regression model was developed to predict mill turn times. This model can be used to predict turn times at any of the three study mills. For all loads at the mill scale, 202 loads total, scaling weight (SW), waiting (WT), and unloading (UL) were significant. Mill turn time for all mills (hours):

Model 4. ($y = 0.09 + 2.46 \times SW + 1.09 \times UL + 0.96 \times WT$)

R^2=0.82, F-ratio=302.78, $S_{y.x}$=0.05, p-value<0.001

In model four SW, UL, and WT represent time spent on the mill scales, unloading, and waiting respectively. All time elements are in hours as is the total estimated turn time. Turn times estimated using model four appear in **Figure 3.6**. To create these estimates, the average scaling weight time of 0.06 hours and the average unloading time of 0.10 hours were used. Waiting times were increased from 0 to 0.47 hours which represented the range of observed waiting times for all loads. Using model four, errors for the estimate ranged from -1.26 to 0.19 hours with an average error for the estimate of -0.003 hours.

3.6 Sensitivity Analysis

Loading and waiting times were the major contributors to tract turn times with a total of 29% and 26%, respectively. As such, reductions in time spent waiting and loading could significantly reduce tract turn times. If time spent waiting was reduced by 25%, average turn time would drop to 1.25 hours for a total reduction of 0.09 hours while if time spent loading was reduced by 25%, average turn time would drop to 1.24 hours for a total reduction of 0.10 hours. If time spent waiting was reduced by 50%, average turn times would drop to 1.17 hours for a total reduction of 0.17 hours while if time spent loading was reduced by 50% average turn time would drop to 1.14 hours for a total reduction of 0.24 hours.

During the study an average of 9 trucks were hot loaded per day. If the average turn time were reduced by 25%, a total of 81 minutes would be saved each day. This would allow enough time to load 3 more trucks or setout trailers while a 50% reduction would save 162 minutes allowing enough time to load 9 more trucks or setout trailers. A 25 or 50% reduction in waiting times would save 63 and 117 minutes, respectively. This saved time would allow 2 to 3 additional loads each day.

The majority of time spent waiting was due to two bottlenecks, the first being a lack of wood ready to be loaded onto a waiting truck and the second being one truck waiting to be loaded due to another truck currently being loaded. As such, it would not be unreasonable for reductions in loading time to cause reductions in waiting time. If time spent waiting and time spent loading were both reduced by 25% average turn time would fall to 1.16 for a total reduction of 0.18 hours. If time spent waiting and time spent loading were reduced by 50% average turn time would drop to 0.97 hours for a total reduction of 0.37 hours.

A 25% reduction in both loading and waiting times would save 144 minutes each day making it possible to load an additional 5 trucks or setout trailers. A 50% reduction in both loading and waiting times would save 279 minutes each day which would be enough time to load 15 additional trucks or setout trailers.

3.7 Conclusions

Results indicate that time spent loading and waiting are the greatest contributors to log truck turn times at the harvesting location. These two time elements are responsible for 55% of total tract turn time. Log trucks spend approximately 32% of their time at a harvesting location idle of which approximately 81% is spent waiting. Reductions in time spent waiting and loading could significantly reduce tract turn times. At the mill scale, time spent unloading and unbinding contribute to 24 and 18% of total turn time at the mill. However, the unloading and travel empty time elements are the best predictors of mill turn time.

The greatest impediment to truck turn time was keeping the loader supplied with enough wood to load trucks. This appeared to be caused by unbalanced logging crews. Harvest contractors should try to ensure that equipment mixes are suited for the harvest prescription and site on which they will be working. Crew one, which operates primarily on clear cuts, was operating on a young pine thinning with relatively small pulpwood. Had this crew been operating on a clear cut, the crew's production would have likely been much different. Both crew two and crew three identified skidding as their limiting factor. In both cases, the feller-buncher had more than enough wood on the ground to keep the skidder working; however, long skidding distances did not allow the skidder to work as efficiently as possible.

An average of 9 trucks were hot loaded each day. If an additional skidder was added to crews which indicated that skidding was their limiting factor, the loader would have enough available wood to load additional trucks each day. Timber Mart-South (2009) reported an average cut and haul rate of $17.68 per ton in the Piedmont region. This cut and haul rate would generate a revenue of $442 assuming that one truck load of delivered wood weighs 25 tons. If adding a skidder would allow crews to move an additional 6 loads per day, crews could move an additional 1,500 loads per year assuming a 5 day work week and 50 working weeks each year. This would lead to an increased revenue of $663,000 each year. Assuming a 10% profit margin, harvesting contractors could earn an additional $63,000 each year by adding an additional skidder. A rubber-tired grapple skidder would cost approximately $225,000. Brinker et al. (2002)

report that the life span of a rubber-tired grapple skidder is 5 years. Over the course of the 5 year life span, the harvesting contractor could earn and additional $106,500 after deducting the initial cost of purchasing a new skidder.

Another option to increase skidder productivity would be to minimize skidding distance through the use of more logging decks and better pre-harvest planning. If on a given tract the number of decks were increased from 2 to 4, skidding distances would be reduced which could allow for more loads to be moved each day. Adding more decks to a tract of land carries the associated costs of closing the additional decks. Increasing the number of decks also increases the likelihood of having to cross streams when skidding wood to the logging deck. Pre-harvest planning could minimize the number of stream crossings or avoid them entirely. Ultimately the number of logging decks must meet both the needs of the harvesting contractors and the wants of the landowners.

The in-woods roads on which log trucks travel can also affect trucking efficiency. Crew 2 was unable to work one day due to rain making in-woods roads impassable for loaded log trucks. The road which crew 2 was utilizing was a class 3 road and had an average width of 14 feet and a total length of 3,168 feet. However, the section of road which made the road impassable was only 50 feet in length. Using the AVLO road costing model (O'Neal et al. 2006) it was calculated that adding approximately 16 tons of gravel to this problem section would have been enough to allow the loggers to continue working that day. Assuming a cost of $10/ton of gravel this brings the total gravel cost to $160. This would have allowed crew 2 to potentially move 12 loads on that day. Assuming a cut and haul rate of $17.68 per ton and a profit margin of 10%, adding this gravel would have allowed the loggers to make an additional $370 after deducting the cost of gravel.

The road which crew 4 was utilizing was a class 4 road with an average width of 15 feet and a total length of 11,088 feet. Using the AVLO road costing model (O'Neal et al. 2006) a construction cost of $26,000 was estimated. It would cost an estimated $16,000 to upgrade this road to a class 3 road allowing all weather access. The tract of land on which crew 4 was operating was 400 acres in size and was shaped like a narrow rectangle. The in-woods road originated on one side of the rectangle and continued down the length of the tract. Often times the in-woods haul road was located within 100 feet of the property line. This tract of land was separated from the county maintained road by several tracts of land, most of which were approximately 1-11/2 acres in size. Road construction could have been greatly reduced if the logger had purchased easements from adjacent landowners allowing log trucks to travel across their lands in order to access the county road. If two easements had been purchased at opposite ends of the tract at a cost of $2500 each, road construction costs could have been reduced by an estimated $14,000.

While the overall variability of harvesting will keep some aspect of harvest production and trucking efficiency out of contractor control, any possible efficiency improvement opportunities should be fully explored and, when feasible, implemented. Harvest contractors have the greatest amount of control over in-woods trucking productivity. Harvest contractors should also take steps to reduce the amount of time that is wasted, not only during each truck turn, but throughout the harvesting system. During the course of the study the average non-mechanical delay time per turn was approximately 10 minutes. Non-mechanical delays typically occurred when truck drivers were using cellular phones. It is nearly certain that truck drivers are not the only employees employed by harvesting contractors who waste some portion of each day using cellular phones or other such activities. The control harvest contractors have over mill turn times is extremely limited. Realistically the only way to minimize mill turn times is to avoid mills at peak hours, if any, or for truck drivers to complete tasks such as unbinding in as efficient a manner as possible.

The use of setout trailers allowed these four crews to move an average of an additional three loads each day. This was accomplished by continually loading trailers while trucks are not in the woods. Currently the harvest contractors maintain approximately 70 trailers, distributed among the four crews, to allow trailers to be continuously loaded. In cold logging systems, which are prevalent in much of Scandinavia and Europe, tracts of timber are harvested and cut-to-length wood is forwarded and decked by the roadside. This cut timber can sit at the road side for several weeks before being loaded on transport trucks (Laestadius 1990). In cold logging systems, loggers are paid according to the volume of wood harvested while a separate trucking entity is paid based on the volume of wood they transport to the processing mill. In hot logging systems, which are prevalent in the Southeastern U.S., loggers are paid a cut and haul rate and do not receive payment until loads are delivered to processing mills. Transportation costs are typically lower in cold logging systems due to reduced idle times (Laestadius 1990).

The use of set out trailers allowed crews to increase their average loads per day from 9 to 12 by continuously loading trailers even when trucks were not available. The use of setout trailers could benefit loggers financially. For example, if a harvesting contractor purchased an additional trailer for $20,000 they may be able to move an additional 2 loads each day. This would allow the harvesting crew to move an additional 500 loads a year assuming a five day work week and 50 working weeks each year. Assuming a cut and haul rate of $17.48 per ton and 25 tons per load, this would generate an additional revenue of $221,000 each year. Assuming a 10% profit margin, the use of an additional trailer would generate an additional $22,100 each year. Gallagher et al. (2005) reported an average trailer age of 9.7 years in Southern states

When questioned about moving toward a cold logging system, where crews move onto a tract and load trailers before trucks arrive, the harvest contractor indicated that this approach had been tried before. Previously a crew would work 2-3 days loading trailers before trucks started to haul from that particular crew. As additional crews and mill destinations were added it became difficult to coordinate log trucks as well has keep enough trailers available to be loaded. There is no “best” solution for trucking raw forest products in terms of hot loading versus the use of setout trailers. Harvest contractors should balance the costs and benefits of each option and use the most appropriate approach as each harvesting site dictates.

More research is needed to explore efficiency improvement opportunities in order to supplement and broaden the information pool for truck efficiency improvement methods. This research includes:

1. truck turn time, at both tract and mill, effects on trucking costs,
2. methods to reduce truck tract and mill turn times,
3. improved truck scheduling.

3.8 Literature Cited

Baker, S.A. and W.D. Greene. 2008. Changes in Georgia's logging workforce, 1987-2007. South. J. Appl. For. 32 (2): 60-68.

Barrett, M. S. 2001. A computer simulation model for predicting the impacts of log truck turn-time on timber harvesting system productivity. M.Sc. thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 74 p.

Bolton, F. 2007. Truck and trailer weight reduction revisited. Forest Resource Association Technical Release 07-R-29.

Brinker, R.W., J. Kinard, B. Rummer, and B. Lanford. 2002. Machine rates for selected forest harvesting machines. Alabama Agricultural Experiment Station. Circular 296. 32 p.

Bureau of Transportation Statistics (BTS) and U.S. Census Bureau (USCB). 1999. 1997 United States Commodity Flow Survey. U.S. Census Bureau. EC97TCF-US. 169 p.

Deckard, D.L., R.A. Newbold, and C.G., Vidrine. 2003. Benchmark roundwood delivery cycle-times and potential efficiency gains in the southern United States. For. Prod. J. 53. (7/8):61-69.

Gallagher T., T. McDonald, M. Smidt, and R. Tufts. 2005. Let's talk trucking: Weights and loading methods. Forest Resources Association Tech. Pap. 05-P-2.

Hamsley, A.K., W.D. Greene, J.P. Siry, and B.C. Mendell. 2007. Improving timber trucking performance by reducing variability of log truck weights. South. J. Appl. For. 31 (1):12-16.

Laestadius, Lars. 1990. A comparative analysis of wood-supply systems from a cross-cultural perspective. PhD. dissertation, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 149 p.

Luppold, W.G., C.C. Hassler, and S. Grushecky. 1998. An examination of West Virginia's logging industry. For. Prod. J. 48(2): 60-64.

McCormack, Robert J. 1990. Measuring and evaluating log truck performance in a variety of operating conditions. PhD. dissertation, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 138 p.

McDonald, T., M. Smidt, R. Tufts, and T. Gallagher. 2005. Lets talk trucking: Improving log trucking logistics. Forest Resources Association Tech. Pap. 05-R-9.

Mendell, B.C. and J.A. Haber. 2006. Evaluating the potential for shared log truck resources in middle Georgia. South. J. Appl. For. 30(2): 86-91.

Miyata, E.S., H.M. Steinhilb, and S.A. Winsauer. 1992. Using work sampling to analyze logging operations. United States Department of Agriculture. Research paper Nc-213. 9 p.

Murphy, G. 2003. Reducing trucks on the road through optimal route scheduling and shared log transport services. South. J. Appl. For. 27(3): 198-205.

O'Neal, B.S., W.A. Lakell III, W. Aust, R.M. Viser. 2006. AVLO:A simplified cost analysis approach for estimating construction costs for forest roads. Council on Forest Engineering Annual Meeting, Boise, ID.

Overboe, P.D., R.M. Shaffer, and W.B. Stuart. 1998. A low-cost program to improve log truck weight control. For. Prod. J. 38(6): 51-54.

Shaffer, R.M., J.F. McNeel, and J. O'Rourke. 1987. On-board log truck scales: application to southern timber harvesting. South. J. Appl. For. 11(1987):112-116.

Shaffer, R.M. and W.B. Stuart. 1998. A checklist for efficient log trucking. Virginia Cooperative Extension. Virginia Tech. 17.Available online at http://www.ext.vt.edu/pubs/forestry/420-094/420-094.html; last accessed Nov. 7, 2008.

Smith, W.B., P.D. Miles, J.S. Vissage, and S.A. Pugh. 2004. Forest resources of the United States, 2002. USDA For. Serv. Gen. Tech. Rep. NC-241. 137 p.

Stuart, W., L. Grace, and C. Altizer. 2004. Preliminary 2003 logging cost indices. Wood Supply Research Institute and the Forest and Wildlife Research Center- Mississippi State University, FWRC FO 415. 18 P.

Timber Mart-South, Inc. 2009. Logging Rates. The Journal of Southern Timber Prices. 34 (1): 14-15.

Weintraub, A., R. Epstein, R. Morales, J. Seron, and P. Traverso. 1996. A truck scheduling system improves efficiency in the forest industries. Interfaces 26: 1-12.

3.9 List of Tables and Figures

Table 3.1: Description of all possible tract level time elements.

Travel Loaded (TL)- Time spent traveling loaded
Travel Empty (TE)- Time spent traveling empty
Delay Mechanical (DM)- Truck break downs, etc.
Delay Non-mechanical (DNM)-Talking, cell phones, etc.
Waiting (WT)- Time spent idle due to interactions or bottlenecks
Positioning (POS)- Time spent backing under a loader or trailer
Loading (LD)- Time spent under a loader
Preparing the load (PTL)- Time spent trimming the load, attaching flagging, and binding the load.
Drop off trailer (DOT)- Time spent disconnecting glad hands and dropping landing gear
Pick up trailer (PUT)- Time spent connecting glad hands and raising landing gear

Table 3.2: Description of all possible mill level time elements.

Travel Loaded (TL)- Time spent traveling loaded
Travel Empty (TE)- Time spent traveling empty
Delay Mechanical (DM)- Truck break downs, etc.
Delay Non-mechanical (DNM)-Talking, cell phones, etc.
Waiting (WT)- Time spent idle due to interactions or bottlenecks
Scaling Weight (SW)- Time spent weighing in or out of a mill
Positioning (POS)- Time spent backing under a loader or unloading area
Unloading (UL)- Time spent under a loader or in a unloading area
Unbinding (UB)- Time spent removing binders and flagging

Table 3.3: Gross level descriptive statistics at both the tract and mill scales.

	Count	Mean (hours)	Min (hours)	Max (hours)	Range (Hours)	SD	SE
Company							
Tract	606	1.32	0.11	6.50	6.39	0.91	0.03
Mill	340	0.61	0.13	6.65	6.52	0.67	0.04
Contract							
Tract	662	1.47	0.17	6.50	6.33	1.25	0.04
Mill	236	0.50	0.17	3.33	3.16	0.33	0.22
Combined							
Tract	1268	1.40	0.11	6.50	6.39	1.11	0.03
Mill	576	0.56	0.13	6.65	6.52	0.56	0.23

Table 3.4: Elemental tract descriptive statistics for all crews.

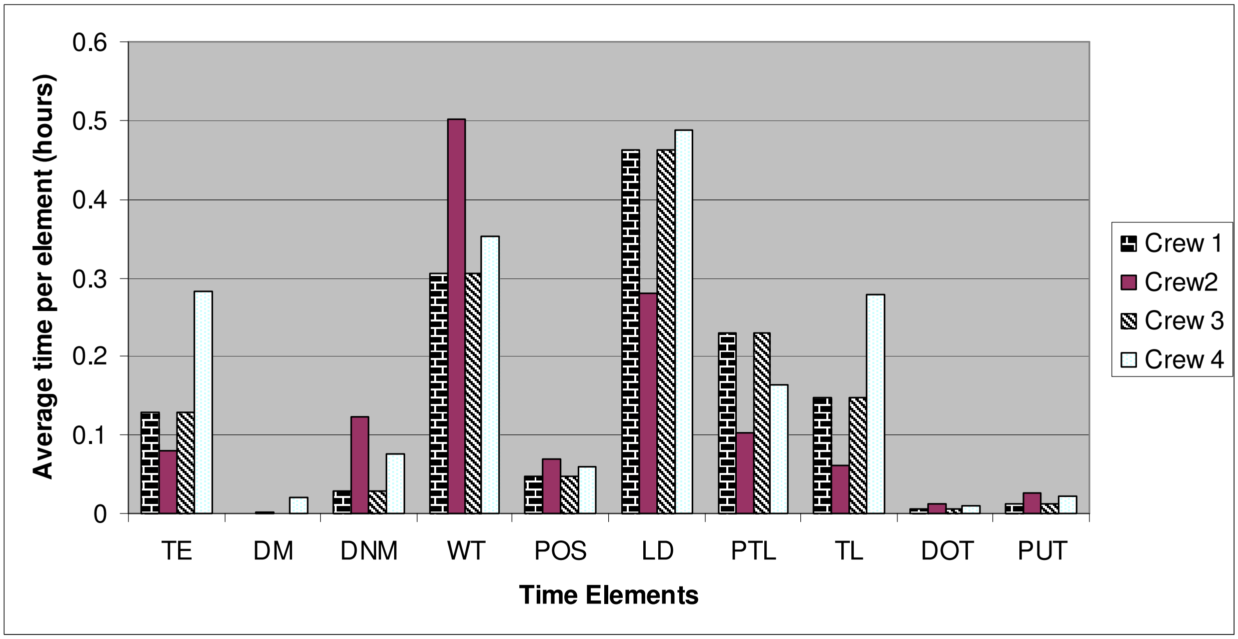
	Count	Mean (hours)	Min (hours)	Max (hours)	Range (hours)	SD	SE
Crew 1							
Hot	30	1.38	0.41	3.78	3.37	0.87	0.12
Setout	20	0.44	0.19	1.69	1.49	0.34	0.08
Crew 2							
Hot	27	1.81	0.58	3.4	2.82	0.81	0.16
Setout	23	0.64	0.18	1.74	1.56	0.53	0.11
Crew 3							
Hot	41	1.51	0.65	3.7	3.05	0.7	0.11
Setout	9	0.56	0.39	0.7	0.31	0.12	0.05
Crew 4							
Hot	37	2.08	1.26	3.95	2.69	0.56	0.09
Setout	13	0.76	0.21	1.52	1.31	0.38	0.12
Combined							
Hot	135	1.69	0.41	3.95	3.54	0.77	0.07
Setout	65	0.59	0.18	1.74	1.56	0.43	0.05
All	200	1.34	0.18	3.95	3.77	0.85	0.06

Table 3.5: Road class, average width, travel distance, and descriptive statistics for all observed in-woods travel.

Road Class	Average Width (Feet)	Travel Distance (Feet)	Count	Mean (Hours)	Min (Hours)	Max (Hours)	Range (Hours)	SD	SE
3	22	176	20	0.05	0.01	0.15	0.14	0.04	0.008
3	22	2660	30	0.10	0.09	0.23	0.19	0.05	0.009
3	14	300	3	0.06	0.01	0.10	0.09	0.04	0.020
3	14	2660	20	0.13	0.04	0.21	0.17	0.05	0.010
3	14	4224	14	0.12	0.07	0.31	0.24	0.05	0.010
3	14	6336	13	0.20	0.12	0.29	0.16	0.05	0.010
3	16.5	8448	9	0.22	0.19	0.32	0.13	0.04	0.020
3	16.5	11616	41	0.29	0.18	0.53	0.35	0.06	0.008
3	22	176	3	0.01	0.01	0.02	0.01	0.08	0.005
4	15	17952	10	0.42	0.40	0.50	0.10	0.04	0.010
4	15	22176	37	0.66	0.51	1.14	0.63	0.13	0.020

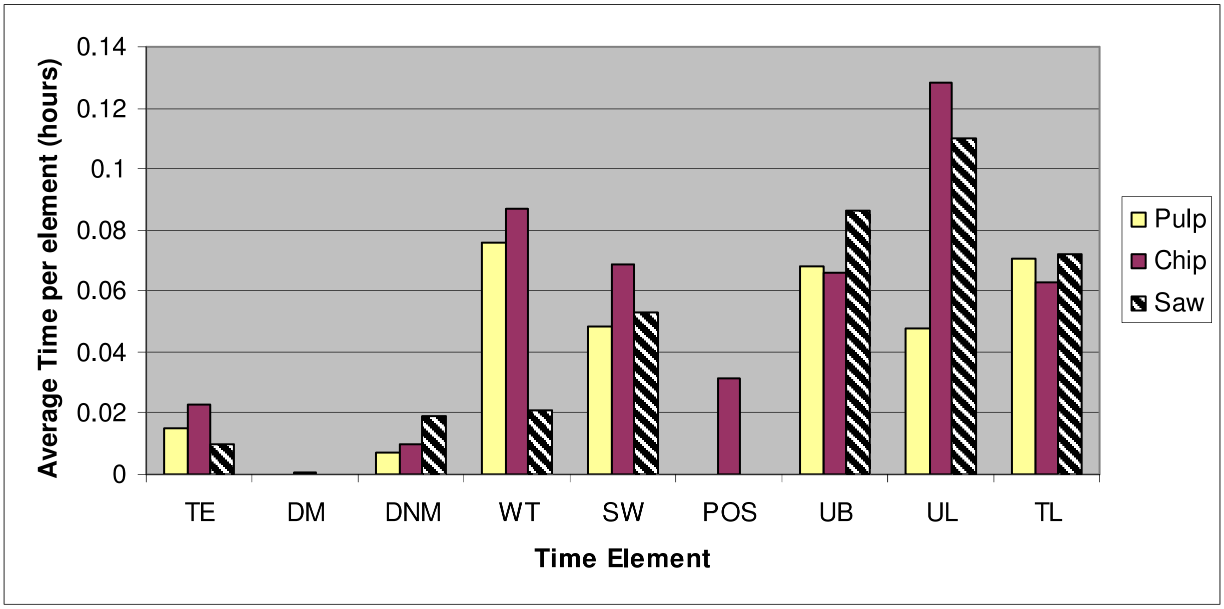
Table 3.6: Elemental mill descriptive statistics for all mills.

Mill	Count	Mean (hours)	Min (hours)	Max (hours)	Range (hours)	SD	SE
Pulp	61	0.33	0.17	0.55	0.38	0.08	0.01
Chip	85	0.47	0.22	1.60	1.37	0.21	0.02
Saw	56	0.37	0.23	0.72	0.49	0.09	0.01
All	202	0.40	0.17	1.60	1.43	0.16	0.01



TE (Travel Empty)- Time spent traveling empty
DM (Delay Mechanical)- Truck break downs, etc.
DNM (Delay Non-mechanical)- Talking, cell phones, etc.
WT (Waiting)- Time spent idle due to interactions or bottlenecks
POS (Positioning)- Time spent backing under a loader or trailer
LD (Loading)- Time spent under a loader
PTL (Preparing the load)- Time spent trimming the load, attaching flagging, and binding the load
TL (Travel loaded)- Time spent traveling loaded
DOT (Drop off trailer)- Time spent disconnecting glad hands and dropping the landing gear
PUT (Pick up trailer)- Time spent connecting glad hands and raising the landing gear

Figure 3.1: Contribution of time elements to total turn time for each crew.



TE (Travel Empty)- Time spent traveling empty
DM (Delay Mechanical)- Truck break downs, etc.
DNM (Delay Non-mechanical)- Talking, cell phones, etc.
WT (Waiting)- Time spent idle due to interactions or bottlenecks
SW (Scaling Weight) Time spent weighing in or out of a mill
POS (Positioning) Time spent backing under a loader or unloading area
UB (Unbinding)- Time spent removing binders and flagging
UL (Unloading)- Time spent under a loader or in an unloading area
TL (Travel Loaded)- Time spent traveling loaded

Figure 3.2: Contribution of time elements to total turn time for each mill.

Table 3.7: Descriptive statistics for all model inputs at both the tract and mill scales.

	Count	Mean (hours)	Min (hours)	Max (hours)	Range (hours)	SD	SE
Model 1							
LD	200	0.39	0	2.28	2.28	0.38	0.03
TE	200	0.13	0.01	0.55	0.54	0.11	0.008
WT	200	0.34	0	1.96	1.96	0.48	0.03
Model 2							
LD	135	0.59	0.12	2.28	2.16	0.33	0.03
TE	135	0.15	0.14	0.44	0.3	0.11	0.009
WT	135	0.44	0	1.96	1.96	0.49	0.04
Model 3							
DNM	65	0.09	0	1.33	1.33	0.2	0.03
TL	65	0.07	0.01	0.33	0.32	0.08	0.01
WT	65	0.11	0	1.43	1.43	0.32	0.04
Model 4							
SW	202	0.06	0.01	0.36	0.35	0.04	0.03
UL	202	0.1	0.08	0.3	0.22	0.05	0.003
WT	202	0.07	0	0.46	0.46	0.09	0.007

LD (Loading)- Time spent under a loader
TE (Travel Empty)- Time spent traveling empty
WT (Waiting)- Time spent idle due to interactions or bottlenecks
DNM (Delay Non-mechanical)- Talking, cell phones, etc.
TL (Travel Loaded)- Time spent traveling loaded
SW(Scaling Weight) Time spent weighing in or out of a mill
UL (Unloading)- Time spent under a loader or in an unloading area

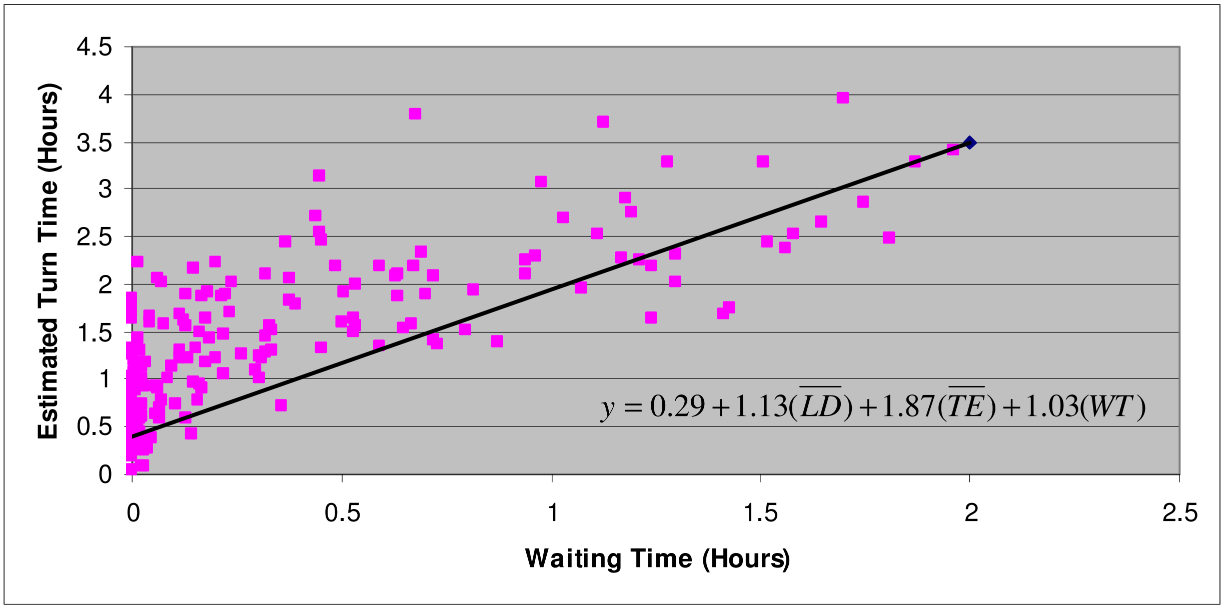


Figure 3.3: Estimated turn times for all loads with loading and travel empty held at the average observed value.

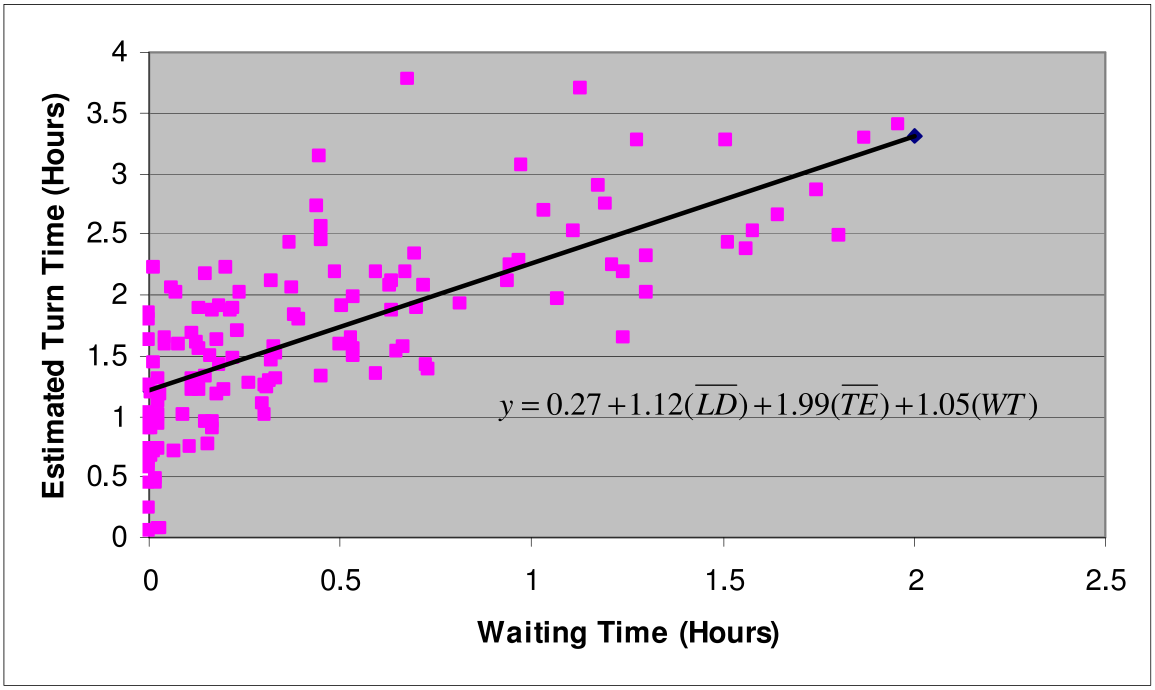


Figure 3.4: Estimated turn times for hot loading with loading and travel empty held at the average observed value.

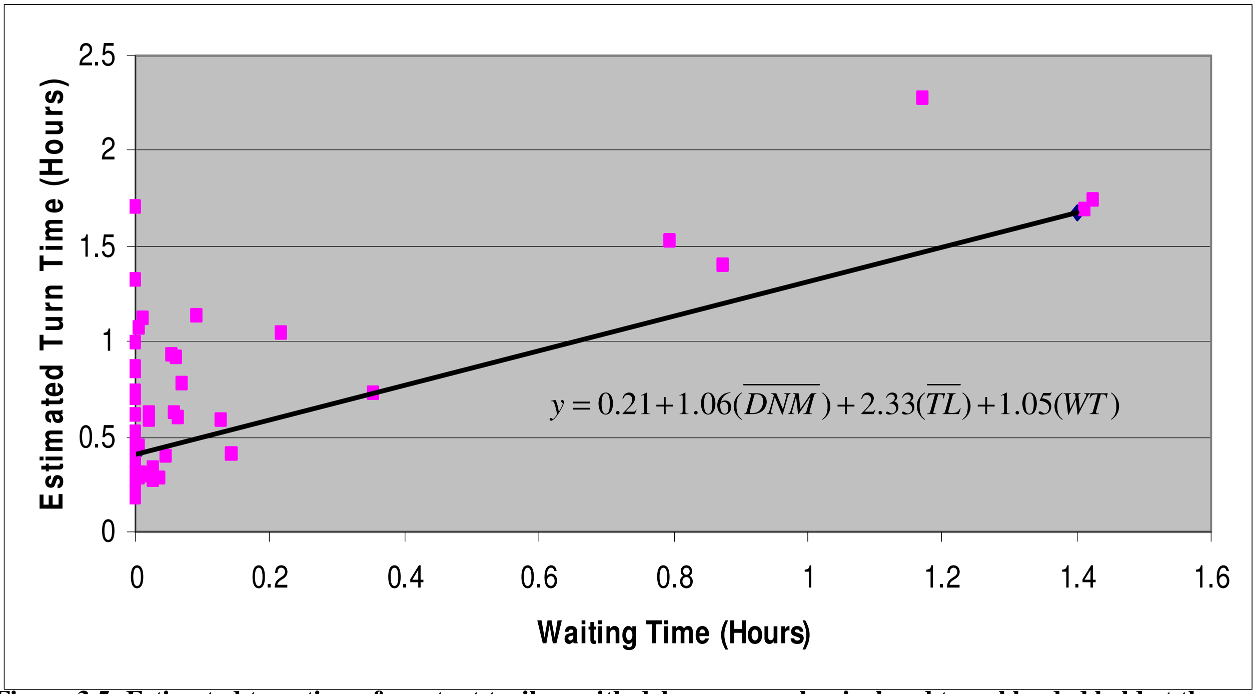


Figure 3.5: Estimated turn times for setout trailers with delay non-mechanical and travel loaded held at the average observed value.

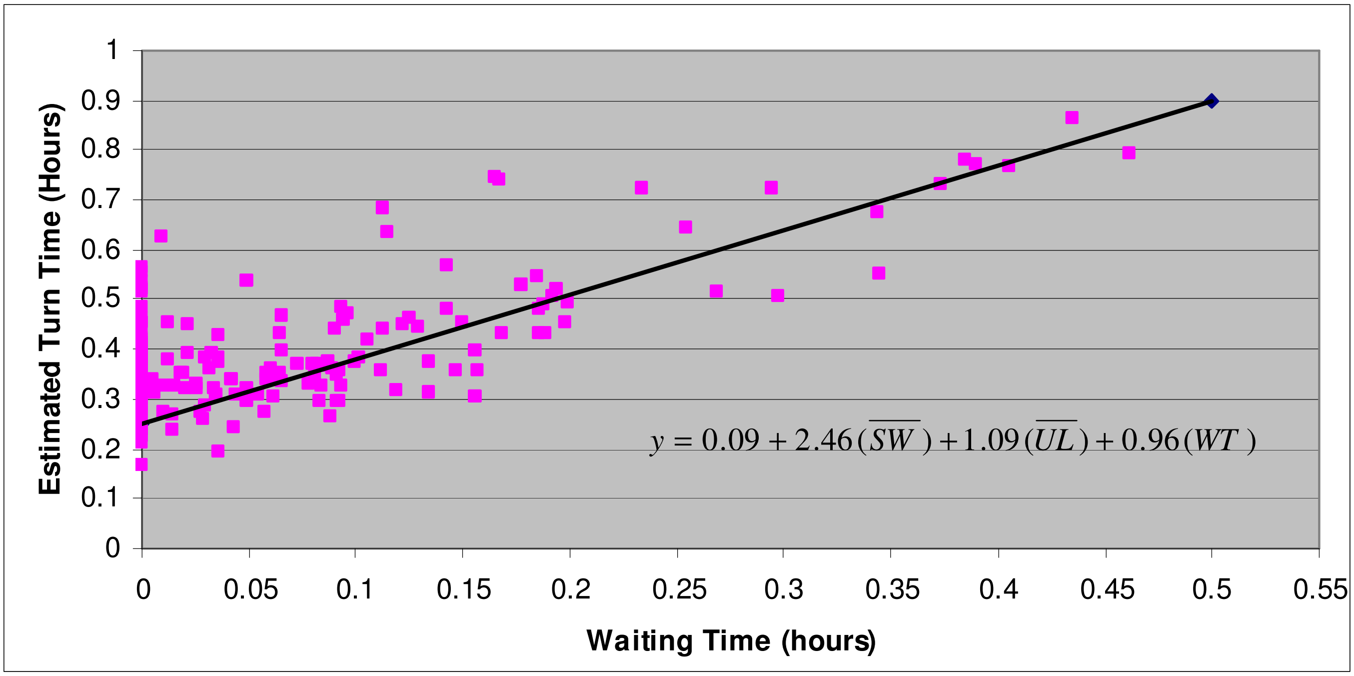


Figure 3.6: Estimated turn times for all mills with scaling weight and unloading held the average observed time.

Chapter 4 Summary and Conclusions

Five objectives were set for this research. The first was to conduct a literature review and analysis comparing the raw forest products transportation industry with other trucking industries. The second was to evaluate log truck turnaround times at the tract scale to identify important trucking productivity factors and efficiency improvement opportunities, the third was to evaluate log truck turn around times at the mill scale to identify important trucking productivity factors and efficiency improvement opportunities, the fourth was to create models to estimate truck turn around times at the tract scale, and the fifth was to create a model to estimate truck turn around times at the mill scales.

The literature review comparing the raw forest products transportation industry with other trucking industries illustrates several challenges that the raw forest products transportation industry faces. This is a relatively small industry employing less than 1% of all truck drivers in the United States. Two separate studies indicate that log truck drivers also earn on average 25% less than the average yearly wage of all truck drivers. Log truck drivers also earn on average less than construction laborers and construction equipment operators, a field frequently seen as competing with the trucking industry for employment, as well as logging employees. In addition, 41% of surveyed log truck drivers in five southern states are unhappy with their wages.

Log trucks are also older than trucks used in other transportation industries with an average age of nearly 10 years versus an average age of less than 4 years. Estimates indicate that log truck drivers are also older and less educated than employees in other transportation industries as well as national employee averages. Log trucking businesses are also further disadvantaged by the fact that they are regulated not only by the Federal Motor Carrier Safety Administration, but also to some extent by the state in which they operate. Furthermore, regulations imposed on log trucks are highly variable from state to state which can make transporting raw forest products across state lines costly, in terms of proper permitting.

Log trucks also routinely operate in harsh working conditions including dusty, muddy, or other rough terrain. These working conditions, especially log landing to state/county maintained roads, can necessitate more frequent and expensive preventative maintenance due to increased likelihood of damage to the truck, trailer, electrical systems, and air lines. These rough haul roads can also cause an increase in truck fuel consumption. Log trucks are also prone to lose potential work opportunities due to natural weather conditions as well as load availability, which can vary not only day to day but minute to minute.

The first phase of field data collection, the four month gross time study, produced 1844 truck turn times of which 1268 were tract turn times and 576 were mill turn times. Tract turn times ranged from a minimum of 0.11 to a maximum of 6.5 hours with an average turn time of 1.40 hours. Mill turn times ranged from a minimum of 0.11 to a maximum of 6.65 hours with an average turn time of 0.56 hours.

The second phase of data collection consisted of an elemental time study which followed 200 truck turns at the tract level, of which 135 were hot loaded and 35 used set out trailers. Data was also collected for 202 mill truck turns. Tract turn times for hot loading ranged from 0.41 to 3.95

hours with an average of 1.69 hours. Tract turn times for set out trailers ranged from 0.18 to 1.74 hours with an average of 0.59 hours. Mill turn times ranged from 0.17 to 1.60 hours with an average of 0.40 hours.

The greatest contributors to tract turn times was time spent being loaded followed by time spent waiting. Loading times averaged 0.39 hours or 29% of total turn time while time spent waiting averaged 0.34 hours or 26% of total turn times. Non-productive times, defined as time a log truck spent idle such as waiting, mechanical delays, and non-mechanical delays contributed to an average of 32% of tract turn times. The greatest contributors to mill turn times was time spent being unloaded and time spent waiting. Unloading times averaged 0.10 hours or 24% of total turn time while time spent unbinding averaged 0.072 hours or 18% of total turn time. Non-productive times contributed to an average of 20% of total mill turn times.

A logging contractor or truck driver's control over mill turn times is extremely limited. The only way that logging contractors or truck drivers can influence a mill's turn time is to avoid mills at peak hours, if any, or to perform tasks for which the truck driver is responsible, such as unbinding, in the most efficient manner possible. Logging contractors and truck drivers have much more control over truck turn times at the tract scale. Results indicate that the use of setout trailers versus hot loading can reduce average turn times by over one hour. While this undoubtedly will not hold true for all occasions, those in which it does will greatly improve tract turn times. Additionally, it is important that truck drivers work so as not to impede other truck drivers. Examples of this include moving a loaded truck from under the loader prior to delimbing and binding so that other trucks may be loaded at the same time.

4.1 Suggestions for Future Research

1. Further research comparing the transportation of raw forest products and other transportation industries is needed. Data collected from this investigation illustrates in greater detail the transportation of raw forest products industry's strengths and weaknesses compared to other transportation industries. This data could be used to further investigate efficiency improvement opportunities for our industry as well as the possibility of adopting current efficiency improvement methods currently used by other industries, such as improved truck scheduling and control over load weight variability.
2. Further research should also concentrate the effects of tract and mill turn times on trucking costs as well as strategies to reduce turn times at both the tract and mill scales. The reduction of turn times has the potential to reduce time spent idle as well as the possibility of allowing truck drivers to increase the number of loads delivered each day.
3. Another possible area for research is total truck turn times. Total truck turn times can be defined as the time spent not only picking up a load in the woods or unloading at the mill but also time spent in transit from harvest locations to receiving mills. This research could also be coupled with investigations into the effectiveness of improved truck scheduling on the efficiency of a trucking fleet.

LITERATURE CITED

Ada, N.R., I.S. Ferguson and D.M. Stodart. 1985. Modeling log truck breakdowns. Australian Forest Research (15):85-93.

American Trucking Association Department of Research and Transport Economics (ATA) 2009. American Trucking Trends 2008-2009.

Baker, S.A. and W.D. Greene. 2008. Changes in Georgia's logging workforce, 1987-2007. South. J. Appl. For. 32 (2): 60-68.

Barrett, M. S. 2001. A computer simulation model for predicting the impacts of log truck turn-time on timber harvesting system productivity. M.Sc. thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 74 p.

Bolton, F. 2007. Truck and trailer weight reduction revisited. Forest Resource Association Technical Release 07-R-29.

Bureau of Labor Statistics (BLS). 2009a. *Industries at a Glance.* Available online at www.bls.gov; last accessed May 19, 2009.

Bureau of Labor Statistics (BLS). 2009b. *Occupational Employment and Wages, 2008.* Bureau of Labor Statistics. USDL 09-0457. 30 p.

Bureau of Transportation Statistics (BTS) and U.S. Census Bureau (USCB). 1999. *1997 United States Commodity Flow Survey*. U.S. Census Bureau. EC97TCF-US. 169 p.

Bureau of Transportation Statistics (BTS) and U.S. Census Bureau (USCB). 2008. Bureau of Transportation Statistics. Available online at http://www.bty.gov/programs/commodity_flow_survry/, last accessed Dec. 5, 2008.

Bureau of Transportation Statistics (BTS) and U.S. Census Bureau (USCB). 2010. *2007 United States Commodity Flow Survey.* Bureau of Transportation Statistics. http://www.bts.gov/publications/commodity_flow_survey/index.html (Accessed 27 Jan. 2010).

Deckard, D.L., R.A. Newbold, and C.G., Vidrine. 2003. Benchmark roundwood delivery cycle-times and potential efficiency gains in the southern United States. For. Prod. J. 53. (7/8):61-69.

Federal Motor Carrier Safety Administration (FMCSA). 2008. *Rules and Regulations.* Available online at www.fmcsa.dot.gov; last accessed Oct. 7, 2008.

Gallagher, T., M. Smidt, R. Tufts, and T. McDonald. 2005. *How to Improve Transportation Efficiency and Costs.* Wood Supply Research Institute. 44 p.

Global Insight Inc. 2005. *The U.S. Truck Driver Shortage: Analysis and Forecasts*. Available online at http://www.truckline.com/StateIndustry/Pages/default.aspx; last accessed Apr. 10, 2009.

Greene, W.D., B.D. Jackson and D.C. Woodruff. 1998. Characteristics of logging contractors and their employees in Georgia. Forest Prod. J. 48 (1): 57-53.

Greene, W.D., B.D. Jackson, and J.D. Culpepper 2001. Georgia's logging businesses, 1987-1997. Forest Prod. J. 51 (1): 25-28.

Greene, W.D., F.W. Cubbage, and J.F. McNeel. 1988. Characteristics of independent loggers in Georgia. Forest Prod. J. 38 (7/8): 51-56.

Hamsley, A.K., W.D. Greene, J.P. Siry, and B.C. Mendell. 2007. Improving timber trucking performance by reducing variability of log truck weights. South. J. Appl. For. 31 (1):12-16.

Laestadius, Lars. 1990. A comparative analysis of wood-supply systems from a cross-cultural perspective. PhD. dissertation, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 149 p.

Luppold, W.G., C.C. Hassler, and S. Grushecky. 1998. An examination of West Virginia's logging industry. For. Prod. J. 48(2): 60-64.

McCormack, Robert J. 1990. Measuring and evaluating log truck performance in a variety of operating conditions. PhD. dissertation, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 138 p.

McDonald, T., M. Smidt, R. Tufts, and T. Gallagher. 2005. Lets talk trucking: Improving log trucking logistics. Forest Resources Association Tech. Pap. 05-R-9.

Mendell, B.C. and J.A. Haber. 2006. Evaluating the potential for shared log truck resources in middle Georgia. South. J. Appl. For. 30(2): 86-91.

Milauskas, S.J. and J. Wang. 2006. West Virginia logger characteristics. Forest Prod. J. 56 (2): 19-24.

Miller C., R. Smith, O. Parhizkar, and B. Stich. 2005. *Analysis of the transportation needs of the wood products industry in distressed Appalachian regions.* Prepared for: Appalachian Regional Commission. Virginia Polytechnic Institute and State University. 50 p.

Miyata, E.S., H.M. Steinhilb, and S.A. Winsauer. 1992. Using work sampling to analyze logging operations. United States Department of Agriculture. Research paper Nc-213. 9 p.

Moldenhauer, M.C., and M.C. Bolding. 2009. Parcelization of South Carolina's private forestland: loggers' reaction to a growing threat. For. Prod. J. 59(6): 37-43.

Moore, T.G. 2009. Truck Deregulation. Available online at http://www.econlib.org/library/Enc1/TruckingDeregulation.html; last accessed Mar. 12, 2009.

Munn, I.A., J.B. Cutshall, and D.G. Hodges. 1998. 1993 pulpwood logging contractor survey. Forest Prod. J. 48 (7/8): 47-53.

Murphy, G. 2003. Reducing trucks on the road through optimal route scheduling and shared log transport services. South. J. Appl. For. 27(3): 198-205.

O'Neal, B.S., W.A. Lakell III, W. Aust, R.M. Viser. 2006. AVLO:A simplified cost analysis approach for estimating construction costs for forest roads. Council on Forest Engineering Annual Meeting, Boise, ID.

Overboe, P.D., R.M. Shaffer, and W.B. Stuart. 1998. A low-cost program to improve log truck weight control. For. Prod. J. 38(6): 51-54.

Rönnqvist, Mikael. 2003. Optimization in forestry. Mathematical Programming. 97: 267-284.

Shaffer, R.M., J.F. McNeel, and J. O'Rourke. 1987. On-board log truck scales: application to southern timber harvesting. South. J. Appl. For. 11(1987):112-116.

Shaffer, R.M. and W.B. Stuart. 1998. A checklist for efficient log trucking. Virginia Cooperative Extension. Virginia Tech. 17.Available online at http://www.ext.vt.edu/pubs/forestry/420-094/420-094.html; last accessed Nov. 7, 2008.

Smith, W.B., P.D. Miles, J.S. Vissage, and S.A. Pugh. 2004. Forest resources of the United States, 2002. USDA For. Serv. Gen. Tech. Rep. NC-241. 137 p.

Society of Automotive Engineers (SAE). 2003. Commercial truck and bus SAE recommended procedure for vehicle performance prediction and charting. Soc. of Automotive Eng. SAE J2188.

Stuart, W., L. Grace, and C. Altizer. 2004. Preliminary 2003 logging cost indices. Wood Supply Research Institute and the Forest and Wildlife Research Center- Mississippi State University, FWRC FO 415. 18 P.

Timber Mart-South, Inc. 2009. Logging Rates. The Journal of Southern Timber Prices. 34 (1): 14-15.

U.S. Department of Commerce (DOC) and U.S. Census Bureau (CB). 2004. Truck Transportation: 2002. U.S. Census Bureau. ECO2-481-09. 13 p.

Weintraub, A., R. Epstein, R. Morales, J. Seron, and P. Traverso. 1996. A truck scheduling system improves efficiency in the forest industries. Interfaces 26: 1-12.