Improving Log Transportation with Data Based Monitoring and Analysis in Northern Wisconsin and Upper Peninsula of Michigan

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Authors:
Richard D. Stewart, Ph.D. University of Wisconsin–Superior, Pasi Lautala Ph.D. P.E. Michigan Technological University, Elizabeth Ogard MBA Prime Focus LLC, Student Researchers: Hamed Pouryousef, Janne Vartiainen, Alan Siers, Kenneth Chong

Principal Investigator:
Richard D. Stewart, Ph.D.
Transportation and Logistics Research Center
University of Wisconsin–Superior

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1. Executive Summary

Minimizing transportation cost is essential in the forest products industry. Logs and wood chips are relatively low value. Logs are a dense heavy weight product to transport, while chips are light and bulky. These handling characteristics along with low value create a supply chain where transportation cost represents a large portion of the final delivered product price. The Midwest forest products industry competes in a global market, and the region's value proposition is highly dependent on an affordable and efficient transportation system. Understanding of system efficiencies requires sufficient data, but while most individual forest products companies collect data on truck trip origin and destination, little is known about the actual daily truck activity within the region. One method to collect data on continuous truck movements is with Global Positioning Systems (GPS) data receivers. Since the cell phone coverage in the region is very sparse and unreliable, using satellite based GPS transponders is a logical alternative, but the use of such devices has been limited in the forest products industry, partially due to the high cost of devices and partially due to the fact that the financial benefits of these tracking systems haven't been demonstrated for many owner-operators, nor has this data been required for payment for freight invoices.

Transportation is a significant cost component in the global fiber supply chain business and specifically in the truck transportation of logs and chips in the Upper Peninsula of Michigan, Northern Wisconsin, and Minnesota. It is a challenging business due to the fact that the logging sites are widely dispersed in a large and rugged rural area. Many log loads originate on private roads that are off public road networks, making site identification difficult for trucking companies unfamiliar with the region. Specialized, self-loading equipment is needed to load trucks at the woods job site. Harvesting productivity is limited by road restrictions during freeze and thaw cycles. Trucking companies cite delays and process inefficiencies yet lack data to address these supply chain issues.

The primary objective of this research effort was to provide transportation time and movement data for actual shipments of logs and chips to gain insights on how to improve system efficiency. Data on actual movements can be used to identify and evaluate the choke points on the system and compare against the anecdotal data by industry stakeholders. While the objective of system improvements is to reduce costs and provide overall economic benefit to the supply chain, the research team was not provided with commercial rate data or cost information to make economic conclusions, but rather concentrated in technical analysis of actual truck movement data.

The research team worked with three companies to recruit a sample of volunteer operators to allow real-time data collection to document the day to day trucking operation in the region. It is estimated that there are 600-700 truckers in the region, most of them owner-operators (Green 2005). Despite efforts to secure participation by a statistically significant number of truckers, many truckers were hesitant to participate in the study for various personal reasons. The truckers in the region have been struggling to survive based on reduced freight volumes, increased operating costs, and increased regulatory activity. Comments from the drivers contacted for the study on why they were unwilling to participate included: concern about how the data would be used, downward rate pressure from wood processers, and the potential for regulatory repercussions.

GPS monitors were used to map and chart the routes used. This data was supplemented by driver activity log sheets to describe the daily operational events. After a pilot test, two data collection periods were undertaken. Eight trucks participated in the first data collection effort which spanned a four week period between October and November 2010, and five trucks participated in January and February 2011. A mix of log and chip trucks participated in both rounds of data collection. Due to the small sample size, the statistical validity of these findings cannot be considered significant, but the methodology is valid and this experiment could and should be replicated with a larger sample size to validate findings.

A literature review of alternative GPS devices available for tracking purposes was completed. A Trine XL data collector was selected as the GPS data collection device for this research effort because it is inexpensive, easy to use, and provided the necessary geospatial information to perform truck movement analysis. Industry funded the purchase of the units. Since this GPS system doesn’t have real-time activity recording capabilities, driver activity sheets were developed for truck drivers to complete to complement the geospatial data. Other more expensive GPS recorders allow function keys for the driver to code stop-time activities, but these units were beyond budget considerations. Using a combination of Trine XL GPS data and driver activity data sheets, the research team was able to make interpretations of truck movements and activities during stops or idling periods and was able to validate trends and to identify potential improvements and savings.

Findings:

1. This research effort concluded that there are significant similarities between log and chip truck movements.
2. It validated the fact that the main barrier to truck productivity involves the numerous truck stops required either for loading or unloading and short average length of haul.
3. Loading time amounted to 36-55% of total stop times.
4. Unloading time amounted to 16-28% of the stop times.
5. Technical, mechanical, and unknown stops represented 6-35% of the stop time.
6. There are differences between log and chip truck productivity.

7. Chip trucks had significantly shorter unloading times when compared to the log trucks and they recorded higher average daily mileage.
8. The research did not identify specific inefficiencies in the actions of truck drivers.
9. Data indicated that trucks experience extensive idle periods during operation due to process steps in other nodes in the supply chain.
10. There are uncontrollable factors such as weather that can impact wood fiber supply chain efficiencies.

Recommendations are problematic considering the validity questions raised with a small sample size. However, the methodology did provide insight into hourly log truck operations, structure to the research process, and the potential for replication on a larger scale. Data indicated that there may be opportunities to optimize the system by improved scheduling of truck arrivals at mills to minimize delays. Pooled dispatching or other methods could be used to coordinate transportation between multiple loggers and wood fiber owners. The system used in Finland has the potential to reduce total transportation miles, especially empty mileage. The stakeholders expressed a desire for optimization that is mutually beneficial in reducing the costs and increasing revenue for all participants in the wood fiber supply chain.

2. Introduction and Background

2.1 Research Background

The Midwest forest products industry functions in an extremely competitive global market, where most products are a pure commodity with little in the way to differentiate production. Transportation costs account for approximately half of the delivered cost of feedstock (logs) to the mill. The overall health and competitiveness of the industry is highly dependent on an affordable and efficient transportation system, in contrast to the competing plantation tree stands of the Southern United States and South America. The Midwest's forests are often harvested using selective cutting (Youngs 2007). Selective cutting of trees results in lower output per acre of forest land compared to plantation style forest management, but provides the area saw mills with high value saw and veneer logs which plantations cannot grow. This lower production per acre also results in logs traveling greater distances to the mill, further increasing the importance of an efficient transportation system. Trucks must make multiple stops to achieve a full truckload.

The industry recognizes these challenges. Lake State Shippers Association (LSSA) undertook an effort to tackle the problem of reducing empty miles (and costs) associated to the trucking movements by contracting a Third Party Logistics Company (3PL) to investigate the opportunities for collectively optimizing truck movements of the member companies, (Stewart, 2010). During the process, it became clear that one of the key deficiencies of the current system is the lack of accurate log truck movement data. According to a study conducted in 2005, it is estimated that there are approximately 600-700 log trucks in the Upper Peninsula of Michigan, most of them individually owned and operated (Green 2005). While most forest products companies collect data on origins and destinations of truck trips, little is known about the events in between those locations. Many delays can occur throughout the day, but until now, the actual travel time efficiency has not been investigated using a data based approach.

One of the most effective ways to monitor and to improve the understanding of the truck movements is to use Global Positioning System (GPS) devices. These are commonly used by the long haul trucking industry to continuously monitor the location of trucks and to document supply chain activities. For log transportation, the use of such devices has been limited, partially due to cost of devices and primarily due to the lack of communication networks. The recent development of inexpensive GPS receivers for about $100 each, such as the "Right Way Trine XL Data Logger," has greatly enhanced the possibility to expand the use of the technology for monitoring log truck transportation. While these devices do not provide real-time tracking activities, they can be extremely valuable in collecting actual truck movement data for later analysis.

Some initial trials have been conducted by individual companies, such as Plum Creek Timberlands L.P. in Minnesota, and the results have been promising. The main objective for Plum Creek Timberlands L.P. was to track log truck activity to identify the current state of transportation. However, with the data collected, other situations, such as excessive idle times, could be identified and actions were taken to improve the transportation process. Another test was conducted by Culp Lumber Company in North Carolina. Fourteen log trucks were monitored. After the first week of data collection the company identified process inefficiencies and safety issues, (Charest, 2009).

While individual companies have been successfully using the technology, independent owner-operators, who provide the majority of log transportation in the study area have not adopted this new technology. In a recent study which focused on optimizing log truck movements in the same region, it was found that cell phone coverage was very sparse and unreliable, (Stewart, 2010). This fact means that satellite-based GPS systems, which have a stronger signal in the remote areas, will be the best choice for data collection.

2.2 Project Stakeholders

The research was funded by the National Center for Freight & Infrastructure Research & Education (CFIRE). Dr. Richard Stewart from the University of Wisconsin-Superior was the principal investigator assisted by co-principal investigators Dr. Pasi Lautala from Michigan Technological University and Elizabeth Ogard from Prime Focus LLC. Student researchers at

Michigan Technological University and University of Wisconsin-Superior also joined the effort. Three private sector companies: J.M. Longyear, LLC, Plum Creek Timberlands L.P. and Carey Logging & Excavating, Inc. committed to working with the research team by providing their trucks and freight volumes, agreed to install the GPS instruments, and participated in a post movement analysis. A Professional Advisory Committee (PAC) provided guidance and feedback to the research team throughout the process.

2.3 Project Objectives, Scope, and Schedule

The objective of this research was to use data to improve the performance of log transportation systems in northern Wisconsin and the Upper Peninsula of Michigan. The study tested GPS technology to better understand the operational challenges and to illustrate time and motion activities for all stakeholders in the process.

The scope of the study included four tasks:

Task 1 – Select and Install GPS Devices and Develop Baseline Data: Review, select, and install data collection devices. Conduct a pilot test and collect baseline data. Assist users with system setup and training.

Task 2 – Data Collection and Analysis: Collect test data, analyze activities, identify trends, patterns, and potential inefficiencies. Review findings and suggest recommendations with industry stakeholders. Prepare charts, maps, and graphs for stakeholder review.

Task 3 – Repeat Data Collection Effort with Proposed Improvements: Based on input from Task 2's stakeholder meeting, conduct a second round of data collection. Review and analyze data, compare and contrast findings, examine productivity improvements, potential savings and barriers. Prepare maps, graphs, and analysis.

Task 4 – Summarize the Results and Develop Recommendations: Summarize and share findings with industry stakeholders. Develop a strategy for expanding the study to cover a larger portion of the log trucks in the Midwest. Present project analysis.

The research project started with GPS receiver calibration in September 2010. The final report was submitted in February 2012. The project schedule is shown in figure 1, followed by a short description of project activities.

Task s 2010-2012	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
Review literature																		
Task 1																		
Task 2																		
Task 3																		
Task 4																		
FINAL REPORT																		

Figure 1: Project Schedule

- **Literature Review**

An abbreviated literature review included articles featuring various configurations of GPS devices, used for tracking trucks or other vehicles.

- **Task 1: Pilot Study and First Round of Data Collection**

After initial investigation, a Trine XL GPS unit was purchased and field tested by the research team. Initial data collection and process instructions were developed and tested in log truck service over a four day pilot study. The test period provided valuable input. Study methods were modified for the first round of data collection accordingly. Four weeks of data collection from industry stakeholders was performed between October 18 and November 30, 2010. A total of eight trucks were monitored over a four week period, but individual truck data collection was staggered due to installation efforts, leading to a six week total period of data collection.

- **Task 2: Analysis of Baseline Data**

Baseline data analysis was completed and presented to the stakeholders in January 2011.

- **Task 3: Second Round of GPS Data Collection**

Data collection methods and instruments were modified based on the first round of data analysis. Six trucks collected data for a four week period in February, 2011. Data collection was curtailed due to an early spring thaw.

- **Task 4 & Final Report: Final Analysis and Conclusions Developed and Documented**

The final task summarized the findings and provided conclusions and recommendations.

3. Literature Review and Pilot Study

Scientific research on log and chip truck movements in the U.S. and abroad is fairly limited. According to Lake State Shippers Association (LSSA), one of the key deficiencies of the forest products transportation system in the Midwest is the high percentage of empty miles (and costs) associated to the trucking movements. Furthermore, one of the challenges to improve the current situation is the lack of accurate data of log truck movements, (Stewart, 2010), to identify where load optimization could occur or where and how delays impact productivity. According to another study completed in 2005, it is estimated that there are approximately 600-700 log trucks in the Upper Peninsula of Michigan, most of them individually owned and operated, (Green 2005). While most forest products companies collect data on origins and destinations of truck trips, little is known about the events in between those locations. Many delays can occur throughout the day, but the actual delays and inefficiencies haven't been investigated with data based approaches, (Stewart, 2010).

One of the most effective ways to improve the understanding of the truck movements is to monitor them with Global Positioning System (GPS) devices. These are commonly used by the over-the-road trucking industry to continuously monitor truck locations and to direct supply chain activities. For forest products transportation, the use of such devices has been limited, partially due to cost of devices and the lack of continuous coverage of communication networks.

Tracking systems can be classified as real time or passive. With real time tracking systems, users can monitor the vehicle location, by logging on to a website or another digital interface like smart phones to identify system issues, (Berney, 2008). Typically, there is a monthly subscription cost for real-time tracking systems, in addition to the initial purchase price of each unit. Passive tracking systems, such as GPS units, can be placed inside the vehicle or trailer and collect geographical information of the vehicle movements and store it in an internal memory space to be downloaded later. The passive tracking systems are usually less expensive than real-time systems and rarely include a monthly subscription cost.

There are various GPS models and commercial brands with different technical and operational specifications which can be used for tracking. Research conducted by H.W. Culp Lumber Company used an inexpensive passive tracking system, The RightWay Trine XL data Logger, for monitoring the performance of 14 log trucks in North Carolina, (Charest, 2009). In another study, University of Washington's TransNow Regional Center conducted research that tracked several truck movements with passive GPS devices and used geographic information system (GIS) technology to develop a freight database for Washington Department of Transportation (WSDOT). The research team analyzed the travel time, reliability, and access time of trucks and was able to determine main truck bottlenecks for bridge and highway segments within the research area, (Tabat, McCormack, 2010).

3.1 GPS Unit Selection and Review of Alternative Data Collectors

In order to track time and travel on a real-time basis the research team reviewed four GPS units with various capabilities at various prices. The units reviewed are described below. The selection criteria for the devices included:

- Ability to reliably connect to global positioning systems and accurately report vehicle location
- Simple to use and install with a minimum of driver input required
- Cost effectiveness
- Data storage to allow for prolonged data collection periods
- Ability to record stop time duration and reason codes for stops

Desirable features such as function keys to record stops or delay reason codes were examined in an effort to simplify driver inputs and improve reporting accuracy, yet were determined to be cost prohibitive. The research team determined that a mix of passive GPS tracking along with an easy to use driver activity data sheet was the most cost effective combination of technology and administrative effort.

The research group selected the **"Trine XL GPS"** unit (figure 2) manufactured by RightWay GPS for the project. The Trine XL unit was inexpensive, easy to use, and provided the necessary geospatial accuracy needed to document activity. The Trine XL provided navigation and data logging functions via Bluetooth or a USB connection and could be used with smart phones or Notebook PCs. Power could be supplied via USB from a computer, a cigarette lighter car adapter, or directly from the battery bank.

The horizontal accuracy of the unit is < 2.5m (<8.2 ft), the velocity accuracy is <0.01 m/s (< 0.02 mph) and data logging can be set by distance, time, or speed. The unit has a capacity of 131,000 points, or 364 hours for a ten second continuous recording interval. The data points can be exported in .csv table format and in map .kml format that can be read by Google Earth. Mapping data supports both concise path view and detailed point view and includes start and stop point information, as well as mileage summary for paths between each start and stop points.

The initial price of Trine XL GPS unit was approximately $100/unit with no monthly charge. The industry participants purchased the units used on the trucks and other units were purchased by the research universities. Trine XL functions almost as an independent unit, taking advantage of satellite coverage.

Figure 2: Trine XL GPS Unit and Supporting Hardware

3.2 Other GPS Device Options and Tools

3.2.1 InstaMapper

InstaMapper is a free service that allows a GPS-enabled cell phone to be tracked online in real-time (figure 3). The application periodically sends GPS coordinates to InstaMapper servers and the current location can be seen on Google map in little dots. The map updates automatically at a minimum of five second intervals. Every dot shows the coordinates, altitude, speed and heading direction in degrees. Historical data can be organized into tracks and exported in .kml (Google Earth) and .csv (Excel) formats. InstaMapper gives access to the last 30 days of location data (up to 100,000 locations per device). InstaMapper requires a cell phone network which makes it hard to be implemented in the Upper Peninsula of Michigan due to large areas with poor or nonexistent phone coverage.

Figure 3: InstaMapper 2010

3.2.2 Integrate GPS Insight

This unit, (figure 4), has been developed by GPS Insight Company and it is either based on cell phone network or satellite GPS coverage. For example, in GPSI-3900 or GPSI-4000 models, it is coupled with Garmin nüvi devices for real-time vehicle tracking. In addition to sending messages and route information to fleet vehicles, it can show a list of currently "dispatched" vehicles and individual driving/arrival status. Alerts, such as "turn off vehicle" or "you are speeding" may be sent to a driver's Garmin device. Dispatch/Navigation Reports allow the supervisors to easily see which vehicles were dispatched and how long it took to arrive at their destinations. When compared to the other devices and options, this unit was more expensive and included higher monthly service charges based on two minute interval updates.

Figure 4: GPS Insight 2010

3.2.3 m!Trace, m!Truck

m!Trace is a web-based application developed by Sycada, a European company based in the Netherlands, which specializes in managing mobility solutions, (Sycada Manage Mobility, 2011). The users have access to the m!Trace application via any PC with Internet connection. It provides real-time position information by:

- Direct access to position and status information of vehicles
- Easy to activate alerts
- Quick access to daily reports
- Geo-fence areas can be drawn on map to secure any desired area
- All movements of vehicles are accounted for and can be reported
- Active signaling and alerts are possible based on speed, location, date, time, and operating hours
- Each authorized user has a specific profile and user rights
- It is possible to restrict access to the system based on working hours and/or IP ranges per user

m!Truck adds a number of extra application features to m!Trace. It can provide access to driver registration, activities, expenses, two-way messaging, as well as work order management.

3.2.4 NetTrack

This software was developed by Track Your Truck Company and is based on real-time tracking by GPS devices and an internet connection, (NetTrack, 2011). Routes can be presented on Enterprise Google Maps. It also can be connected to a mobile phone or iPad with service providers like AT&T, Verizon, and T-Mobile to provide a screen shot, (figure 5). Some of the reporting features of NetTrack include:

- Full overview of all activity for each vehicle
- Tracking of time spent at each location – helping to minimize employee idle time

- Collection of detailed data including address, latitude/longitude, speed, and direction
- Reports can be downloaded in Excel, Word, and Adobe PDF formats

The NetTrack system can use either cellular or satellite coverage. Cellular is recommended for urban and suburban areas; satellite coverage is recommended for rural areas. Pure satellite GPS tracking systems for vehicles (called SkyRunner) offers detailed reporting and real-time GPS updates for companies that operate far from cellular network ranges. SkyRunner can keep track of vehicle location, speed, direction heading, and more. It updates on 10-minute intervals, but one, two, and five minute intervals are also available. The screen capture shown below illustrates the visual imagery which can be produced by this device.

Figure 5: NetTrack Software Screenshot

3.3 Pilot Study and Outcomes

Prior to giving out any Trine XL GPS units the research team had students operate their autos with the units in place to test readings and reliability. One of the student test units was used on a round trip from UW-Superior to Michigan Technological University and recorded data the entire trip. The initial assessment indicated that the units were functioning within acceptable parameters.

The research group then installed a single Trine XL GPS unit in one log truck, (figure 6), for a four day period between the dates of September 24-29, 2010. The purpose of the pilot study was to test the research methods and to ensure the GPS unit would be functional in the logging environment. The GPS unit recorded a data point every 200 meters (about 600 feet) and every stop of more than five minutes. The driver was asked to fill out daily activity sheets to provide additional information about the stops by writing in the stop and rationale for the stop, (figure 7).

Figure 6: Pilot Truck Leaving Loading Area (Photo: H. Pouryousef)

Action Codes:

1: Start to move, **2**: Stop for loading, **3**: Stop for unloading, **4**: Stop for something else,

Date:	Fuel consumption:

Time, (hh:mm)	Action code	Description (If 2 or 3, please insert the net tonnage; If 4, stop for something else, please describe the reason)	Engine off (✓)

Figure 7: Sample Driver Daily Activity Sheet

The GPS unit worked properly and the settings for the pilot study were appropriate. However, the driver daily activity sheet, (figure 7), turned out to be problematic for the drivers due to the lack of defined activities and the need for the driver to stop work activities in order to write up the report. Lack of clarity also increased time for the data analysis process by the research team. The driver daily activity sheet was modified prior to round one data collection. Modifications included more descriptive event categories to identify activities which included a check box system. This change was made due to feedback from the drivers requesting a less open ended form with less writing.

3.4 Modification for "Round I" Data Collection

The GPS unit settings were confirmed and retained after the pilot study. The driver activity data sheets were modified to describe general activities with check boxes for faster tabulation. Raw data was imported to a spreadsheet and each stop was categorized. Stop time, as well as loading and unloading operating times were automatically calculated. The categorization of each stop required manual review and comparison to the driver activity data sheet.

4. Review of First Round Data Collection

4.1 Participating Industry and Administrative Steps

Three companies committed to working with the research team in a data collection effort, using GPS tracking units. This was a select group of log and chip trucks, operating in Michigan. The research partners included J.M. Longyear LLC, Plum Creek Timberland L.P., J. Carey Logging, Inc., and volunteer drivers. Eleven GPS units were purchased. Michigan Tech. calibrated the equipment for uniformity prior to data collection. After setting up the units, the research team sent the units to the research partner companies along with driver activity data sheets. It was determined that driver activity data sheets would provide sufficient information to help describe unknown or unforeseen variables such as weather, breakdowns, or other operational interruptions. Sample driver activity data collection sheets and related installation instructions developed by the research team are shown in the Appendixes.

Each truck was requested to collect data for four consecutive weeks. After the first week of data collection, driver activity log sheets were returned to the research team for quality control. After data collection was completed, eight GPS units with corresponding driver activity log sheets were returned to the research team for analysis. Of the eight participant trucks, two were chip trucks and six were log trucks. The data represented 126 driver days of recorded information provided by the eight trucks between October 18 and November 30, 2010. Some trucks started earlier than others which resulted in a six week span of the whole set of data collection.

The objective of the project was to collect and analyze data on the movements of trucks, (not individual drivers), in addition to comparing the average performance of log trucks versus chip trucks. The GPS units were attached to the assigned trucks for the whole study period regardless of the number of driver changes during the days of operation. Some trucks may have had more than one operator. As the data was based on the movements of the specific trucks, the findings of the study cannot reliably be used to develop performance metrics on individual drivers based on the small sample size.

4.2 Review of Collected Data and Analytical Criteria

The GPS units were set to record a data point every 200 meters (about 600 feet) in order to easily spot stops and not to exceed the memory capacity of the GPS units within the four weeks of data collection. If there were any stops over five minutes with small movements of distance less than 50 meters (about 150 feet), the unit considered the truck to be “stopped” and recorded such events as a stopping point in Google Earth software. The data was saved in tabular format (.csv files) and also in file format used by Google Earth (.kml files). Each recorded point included the following raw data:

- Time: year, month, day, hour, minute, second
- Coordinates: latitude, longitude, altitude
- Speed of truck

Since speed analysis of truck movements was out the research scope, we didn't focus on the speed outputs derived from GPS units. Based on the raw data the research team was able to view the routes of the trucks, (figure 8), and calculate stop times. Figure 8 is an example of three truck operations on a single day with the stars indicating stopping locations. A stop was recorded if the time difference between two data points, 200 meters apart (about 600 feet), was over two minutes. This means that a stop was recorded when the truck was either completely stopped or moving slower than normal walking speed. Individual maps of each representative truck are shown in Appendix 2.

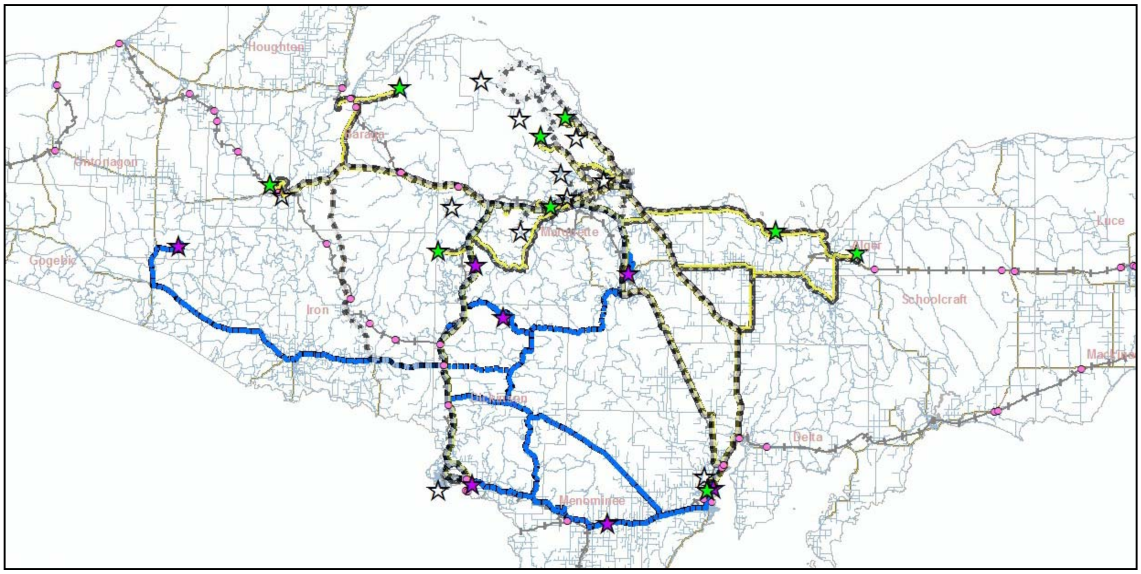


Figure 8: GIS Map of Three Truck's Activities - Round I

★ : Truck A (Company A) ☆ : Truck B (Company B) ★ : Truck C (Company C)

Since the raw GPS data did not include the reason for each stop, the research team asked the truck drivers to create an event to describe the delay on a driver activity data sheet to help understand the actual daily activities associated with the movements. By comparing the raw data with the driver data sheet information, the research team was able to categorize each stop and to estimate when the truck was empty and when it was loaded. The data analysis is based on the days the research team had both the raw data from the GPS units and the log sheets from the truck drivers. During the first round of data collection there were 12 days of operation that were recorded by the GPS units but lacked the log sheet information. Those days were removed from data analysis.

The following sections summarize the data collected and provide analysis of some of the key outcomes.

4.3 Data Analysis and Interpretations

4.3.1 General Review of Operation Days

The average (AVG) number of data collection days per truck in the first round of activities was 16 and varied between 12 and 22 per truck. The recorded operations were distributed fairly equally during weekdays, except on Thursdays, which saw somewhat less activity than other days. Weekend activities were limited with a total of six recorded days of operation during weekends, four on Saturday, and two on Sunday. Figure 9 shows the distribution of operating days divided between the days of the week for each individual truck, and further divided between log and chip trucks (chip trucks are highlighted in yellow with an *).

Days in Operation									
	Dates	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Total
Truck 1	10/21 - 11/12	0	2	3	2	2	3	0	12
Truck 2	10/27 - 11/12	1	2	2	3	3	3	1	15
Truck 3	10/21 - 11/8	0	3	2	2	3	3	0	13
Truck 4	10/18 - 11/12	0	4	4	4	4	4	2	22
Truck 5	10/18 - 11/12	0	4	3	4	3	3	0	17
Truck 6*	10/26 - 11/23	0	3	4	3	2	3	0	15
Truck 7*	10/22 - 11/30	0	3	3	4	2	4	1	17
Truck 8	10/25 - 11/21	1	3	3	3	2	3	0	15
Total	10/18 - 11/30	2	24	24	25	21	26	4	126
AVG days of Log Trucks		0.3	3	2.8	3	2.8	3.2	0.5	
AVG days of Chip Trucks*		0	3	3.5	3.5	2	3.5	0.5	

Figure 9: Operational Distribution between Days of the Week - Round I

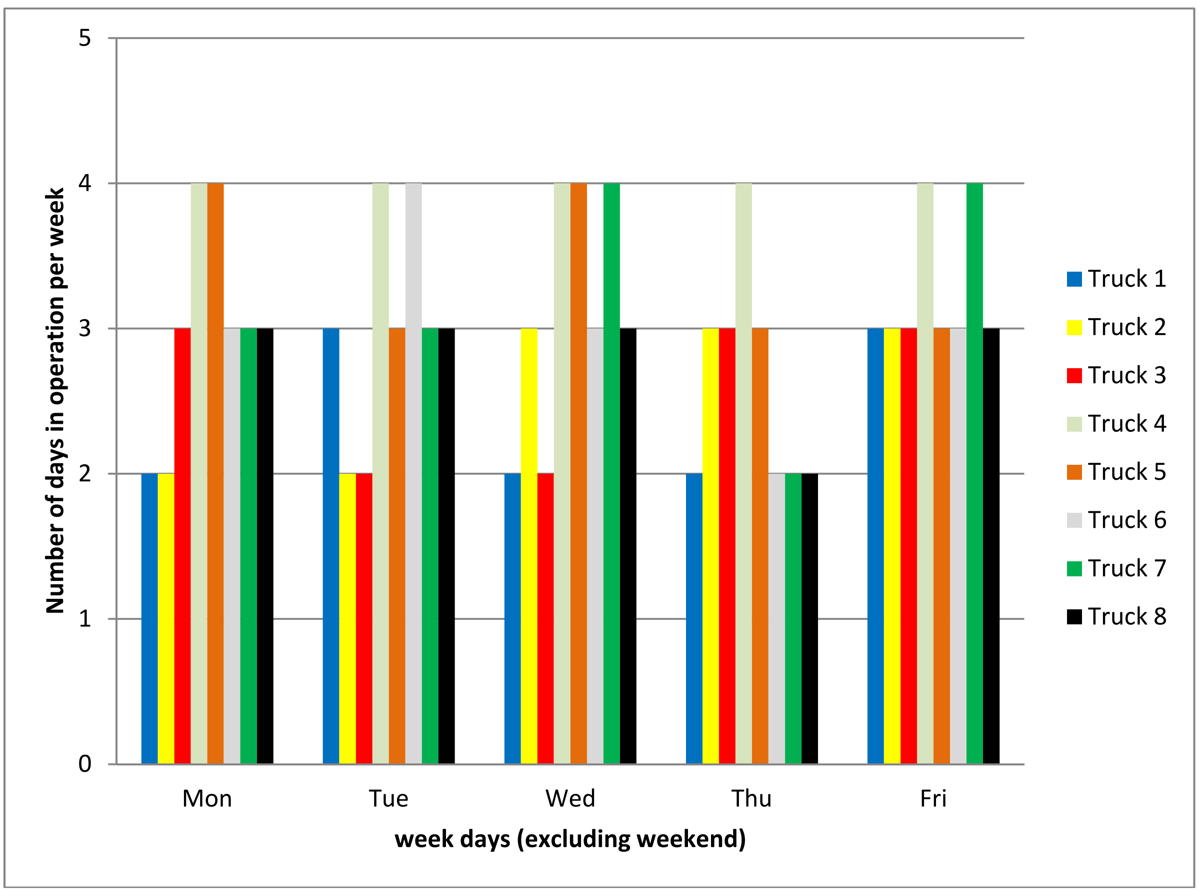


Figure 10: Weekly Operational Pattern - Round I

Truck usage can be measured by the frequency that a truck operated on a given day of the week and also by the hours that each truck operates on those days. Figure 10 represents the frequency that a truck is in operation during a Monday through Friday period for the multi-week study period in round II.

Monday and Friday had the most frequent truck operations per day with Wednesday very similar.

The research also captured the average hours per day of the week that a truck operated. The data in Figure 11 reflects the hours of operation on a particular day by truck. The data indicates that Monday was the day of the week with the most hours of operations per day. Trucks operations per hour per day were similar on Tuesday, Wednesday, and Thursday. Average hours of operation per day per truck was 11 hours with some of the trucks using two drivers.

The shortest weekday operating times were observed on Fridays, with a 10h 0m, average time. There were only six days of driver data collected. During the weekends the dispersion of operating times is notable, so Saturdays and Sundays were ignored in the averages. The average operating times on each day of the week per truck and per each company are respectively represented in figure 10: Weekly Operational Pattern and figure 11: Average Operating Time per Truck and Commodity.

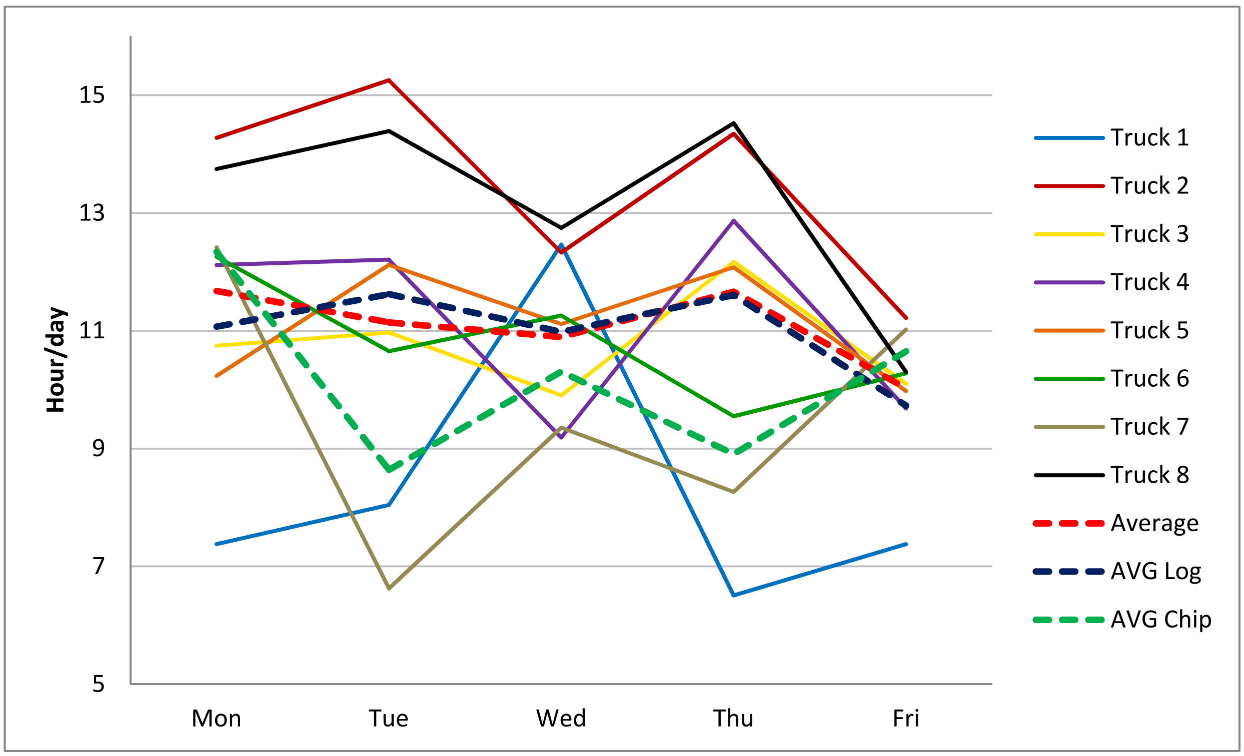


Figure 11: Average Operating Time per Truck and Commodity - Round I

Figure 12 represents a summary of average daily operating time by company of respective trucks. In general, companies' performance was similar to each other especially for daily loaded movements. However, small sample size reduced the reliability of such conclusions.

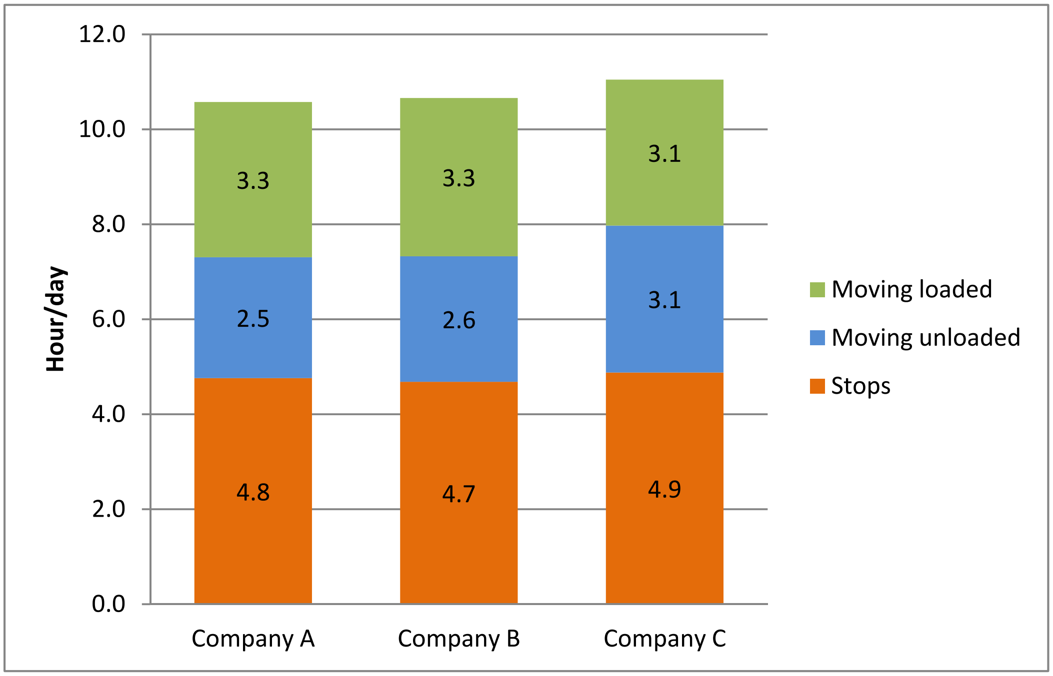


Figure 12: Average Daily Operating Time by Company - Round I

4.3.2 Stop Time Analysis

Stop time analysis is based on the information provided by the log sheets filled out by each driver. The drivers used a daily activity sheet to record stops and the most common reasons for stops, such as loading, unloading, detaching a "pup," hooking up "pup," stopping for fuel and stopping for coffee break. A pup is a second trailer usually shorter attached to the tractor behind the first trailer. There was also space for "other" stops, to identify any other reasons for the stops. The accuracy of the daily activity sheet comments varied among truck drivers and there were several stops that were not recorded, resulting in an "unknown" category. The unknown stops are discussed later in section 4.

When analyzing the data the stops were divided into seven different categories: administrative, technical, gas, idling, loading, unloading, and unknown.

Administrative stops included required paperwork, talking to customers or supervisors, as well as wait times at the mills and rail yards. The drivers did not separate waiting times at mills or rail yards from the actual loading or unloading times, but the research team made estimates based on the routes and stops displayed in Google Earth maps to identify location. Stops, usually short ones that were not clearly identifiable in the GPS data at the unloading or loading sites inside the mill or rail yard area were usually considered "administrative" stops.

Technical stops included time that was not directly related to logging operations, such as loading or unloading, but included mechanical work such as maintaining the equipment, detaching and hooking up pup, truck repairs, clearing obstacles from the road, working with a grinder and/or getting stuck on muddy roads or landings.

Gas stops included refueling the truck at gas stations.

Idling stops included reported stops that did not match any other category. Those stops included coffee breaks and waiting for other trucks in the woods. The label idling, recognized that truck engines were kept idling during all breaks throughout the days. Therefore, the research team decided to change this label for the second round of data collection (covered later in the report).

Loading stops mainly took place at log landing sites. Often the truck drivers mentioned only one stop for loading even though they made several short stops very close to each other in the woods. As this often reflected the fact that multiple piles were used to fill up the truck, all these stops which were close to each other were considered as a single "loading stop." Determining the actual stops for loading in the woods was sometimes difficult, because of the numerous intermediate stops in a short distance span.

Unloading stops included stops for unloading the truck at the mills, rail terminals, and areas in close proximity to these destinations. Stops in rail yards were usually made with several short stops in and around a central area. The additional stops were typically related to cleaning the truck, separating species of wood at the mills, and / or other unknown events.

Unknown stops included all the stops that were not mentioned in the driver activity sheets, but were recorded by the GPS units. Unknown stops are further discussed in more detail later in this chapter.

Stops for loading represented the largest share of the total stop times, ranging from 36% to 55% of the total stop times. Unloading represents the second largest share, from 16% to 28% and unknown stops represents the third largest group with the share ranging from 6% to 35%. The rest of the stops have a relatively small share of the total, excluding the two trucks with exceptionally high, 15% and 18% share of technical stops. These trucks had equipment failures which resulted in long repair times. Because of the relatively short period of the data collection, an individual, but long lasting technical issue can result in high percentage of the overall data set.

Loading took at least twice as much time as unloading which can be explained by the use of specialized high volume unloading equipment typically present at unloading sites (mainly mills) whereas the truck drivers usually load the trucks in the woods by themselves with self-loaders. The share of total stop times for each individual truck is shown in figure 13. On average, chip trucks 6 and 7 recorded shorter unknown, loading and unloading stops, while their technical and administrative stops were slightly higher than for log trucks (this may be due to better record keeping).

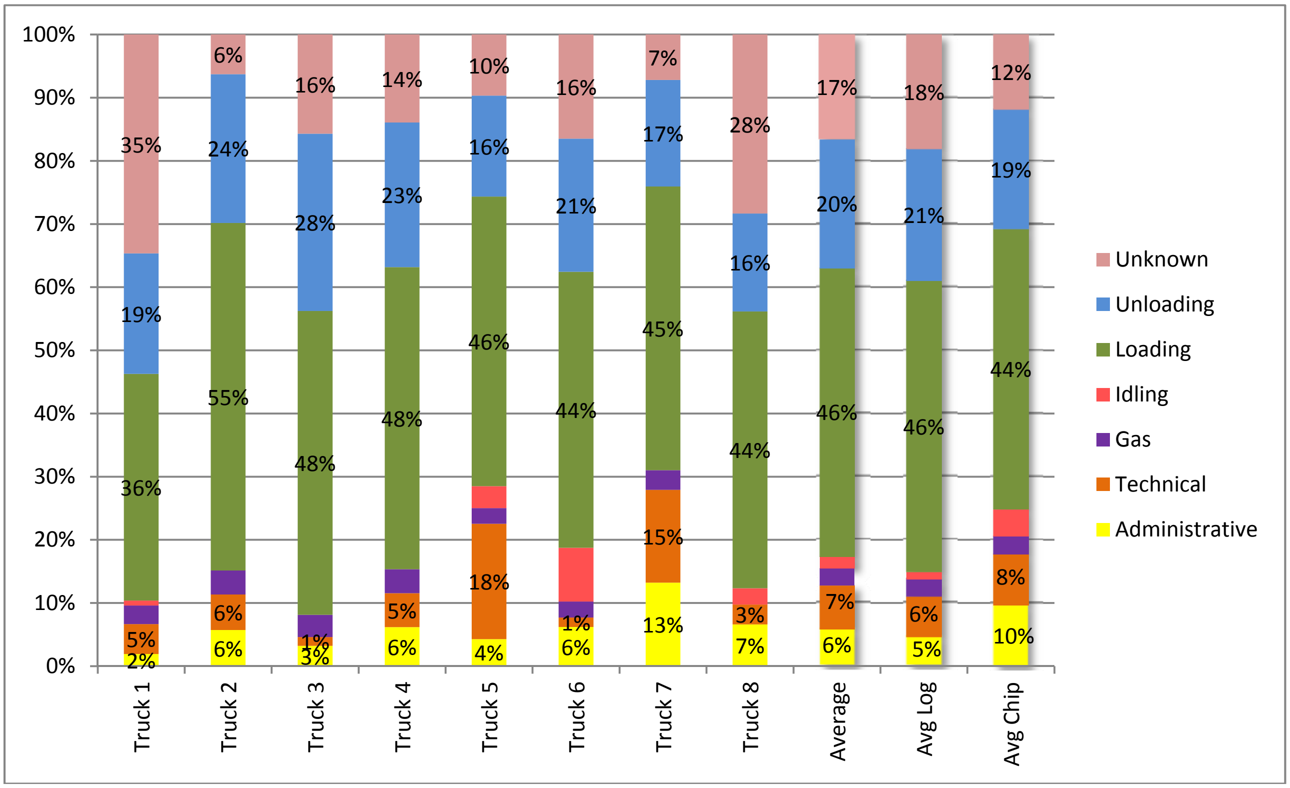


Figure 13: Percentage of Total Stop Times in Addition to Averages for Each Truck Type - Round I

An analysis of the collected data is presented in figures 14: Average Stop Times per Day for Each Truck Type and 15: Average stop times per day for each truck and chip/log trucks. From the observations it was determined that the total average time for loading varies from 1h 27min to 2h 53min per day, depending on the truck.

The results of the research indicated that unloading takes from 42min to 1h 20min per day. The analysis of the observed data reflected that unknown stops take from 18min to 1h 52 min a day. Of note is the fact that the average daily loading and unloading times per day for chip trucks 6 and 7 are 31 and 16 minutes, respectively, which is shorter than the average for log trucks.

Average Total Stop Times per Day (min)							
	Administrative	Technical	Gas	Idling	Loading	Unloading	Unknown
Truck 1	5	12	7	2	87	46	84
Truck 2	18	18	12	0	177	76	20
Truck 3	9	4	10	0	137	80	45
Truck 4	15	13	9	0	119	57	35
Truck 5	14	59	8	11	148	52	31
Truck 6	15	4	6	21	105	51	40
Truck 7	33	37	8	0	112	42	18
Truck 8	26	12	0	10	173	61	112
Average	17	20	8	5	132	58	48
AVG Log	15	20	8	4	140	62	54
AVG Chip	24	20	7	10	109	46	29

Figure 14: Average Stop Times per Day for Each Truck Type - Round I

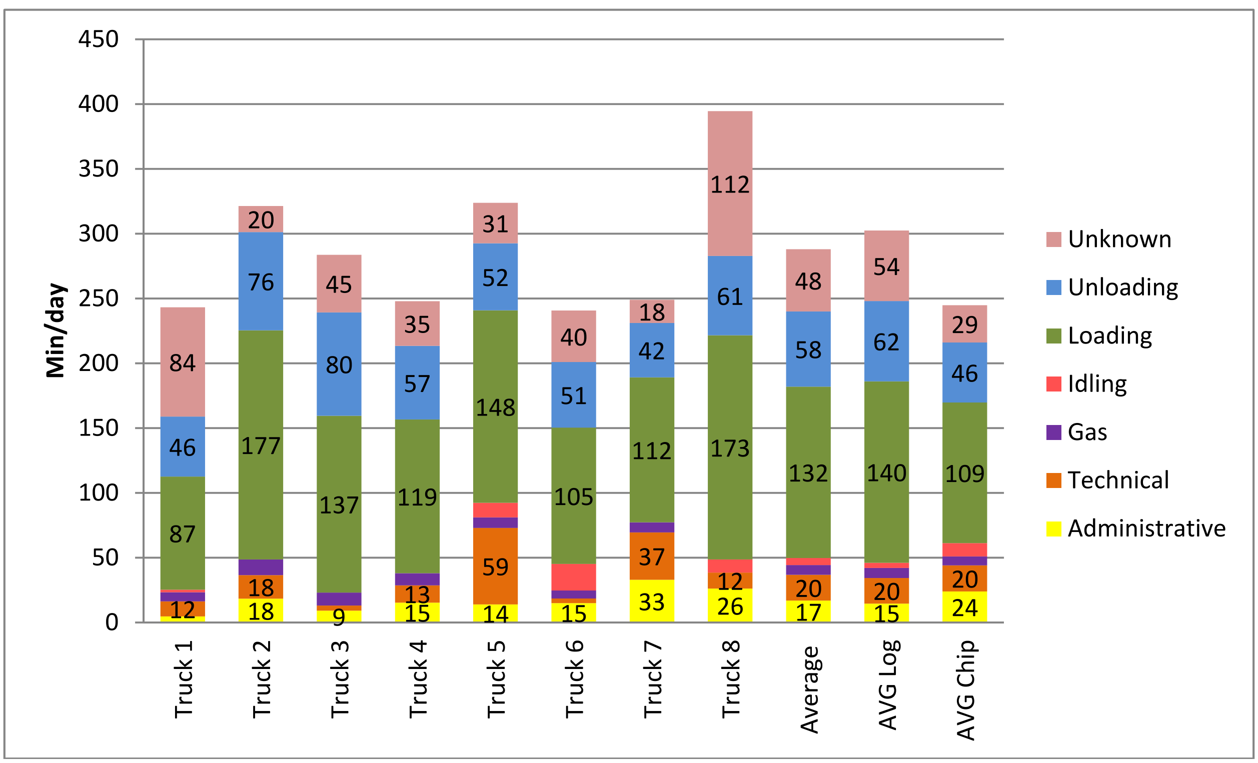


Figure 15: Average Stop Times per Day for Each Truck and Chip/Log Trucks, Discretely (minute) - Round I

The total stop times are very similar between the three companies ranging from 4 hours 41 minutes to 4 hours 53 minutes. Average daily total loading and unloading stop times are also similar between the companies. Average loading stops are within eight minutes, ranging from 2 hours 9 minutes to 2 hours 17 minutes. Unloading times range from 51 minutes to 1 hour 8 minutes. Larger variation is found in unknown, technical, and administrative stops. Average stop times per day for each company are shown in figure 16.

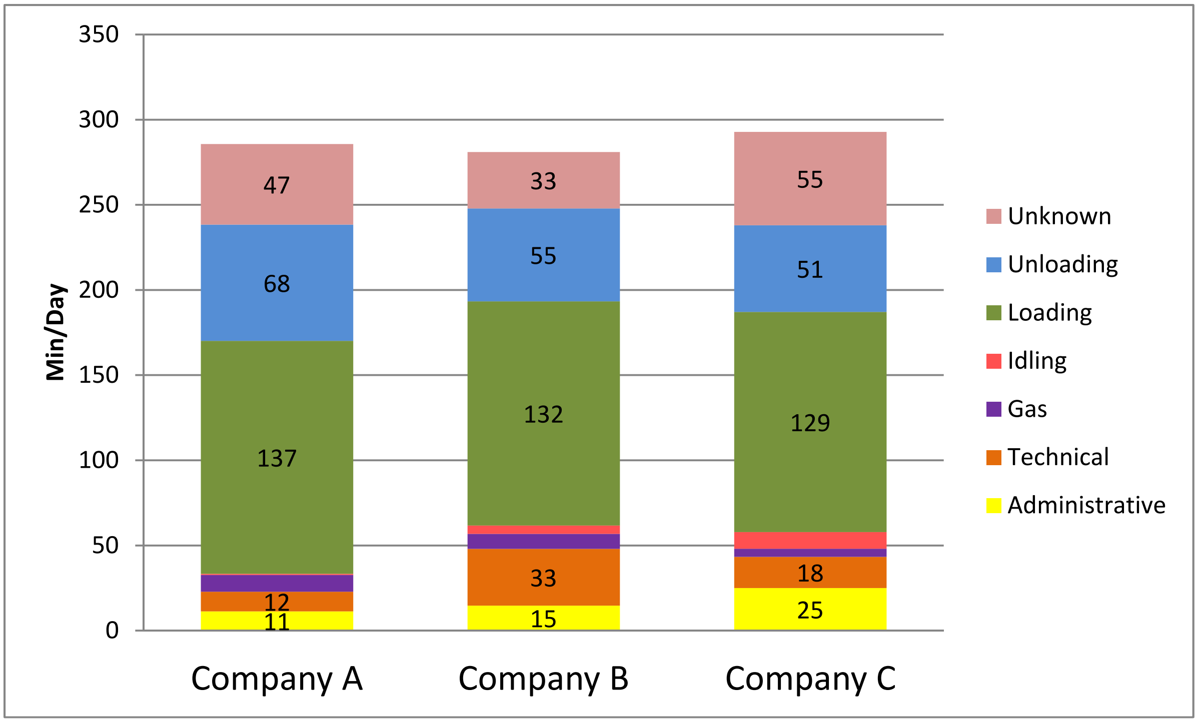


Figure 16: Average Stop Times per Day by Company - Round I

4.3.3 Unknown Stop Interpretation

Some of the stops logged by GPS units were not identified by drivers, leading to an establishment of a stop category labeled “unknown”. Unknown stops could be one of technical, administrative, gas station, idling, and even loading or unloading stops which drivers forgot to mention in the daily activity sheets. As presented in figure 17, unknowns stops were classified into four different categories based on the duration of each stop; less than 10 minutes, between 10 and 30 minutes, between 30 and 60 minutes, and more than 60 minutes.

Based on discussions with industry and research team members riding on the log trucks a heuristic was developed to apply in determining probable reasons for the “unknown” stops. A table was created to capture the application of the heuristic and graphed in figure 17. For unknown stops less than 10 minutes, the most likely reasons are administrative, technical issues, or idling; any loading activity would be very unlikely for this category due to short stop time. It is also possible to assume either a gas stop or unloading actions at a mill may be included in this category. For unknown stops between 10 and 30 minutes, all stop categories are possible, although administrative, gas stops, and unloading activities are expected to be the main reasons. For unknown stops with duration between 30 and 60 minutes, short stops, such as refueling are quite unlikely, but other reasons could be considered, especially loading activities in landing or harvesting areas that the driver forgot to mention in the log sheet. The last category of unknown stops, with duration more than 60 minutes, can be interpreted as either technical or idling stops, although a loading stop is also a possibility. The team was able to discount unloading, administrative or fueling as likely reasons for unknown stops of 60 minutes or greater based on input from industry. The table in figure 17 was reviewed by the industry advisory board and they felt it was a reasonable capture of probable rationales for unknown stops.

Unknown stop category	T<10 min	10<T<30 min	30<T<60 min	60<T min
Administrative	very high	high	low	none
Technical	high	moderate	moderate	moderate
Gas station	high	moderate	none	none
Idling	high	moderate	moderate	low
Loading	low	moderate	high	moderate
Unloading	low	high	moderate	none

Figure 17: Determination of Unknown Stops based on Different Categories of Stops and Time Duration - Round I

The research team then used the data to show the distribution pattern of unknown stops for each truck, based on stop duration, (figure 18). All trucks had some occurrences in the first two categories, less than 10 minutes, or between 10 and 30 minutes which formed the majority of total unknown stop times. For the third and fourth categories (30<T<60 minutes and more than 60 minutes), the total recorded times of unknown stops showed significant differences between trucks. Some of the trucks such as trucks 2, 3, 4, and 5 had no significant stop times in these categories. On the other hand, trucks 1 and 8 had significant amounts of stops in the third and fourth categories (30<T<60 and more than 60) which increased the total amount of their unknown stops and caused greater deviation between those and the rest of the trucks.

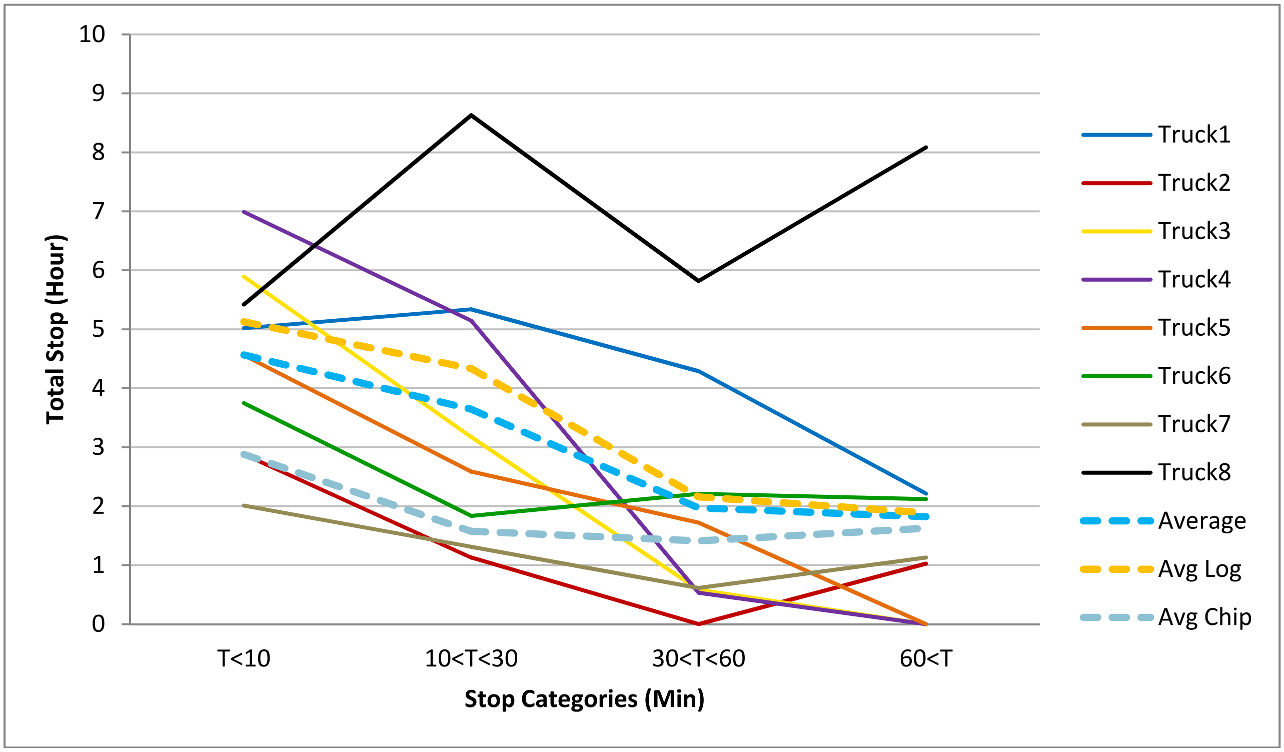


Figure 18: Classifications of Total Unknown Stops - Round I

According to the daily activity data sheets, it was determined that both truck drivers 1 and 8 had some technical issues, such as getting stuck in mud during several days. By comparing these dates and major unknown stop dates, it was clarified that most of their unknown times with duration more than 30 minutes happened in either the same day of a technical problem or immediately before or after them. For instance, truck 8 had one unknown stop with a 238 minute duration. After review of the data with the industry advisory board it was learned that this was due to an equipment breakdown.

By comparing average unknown stops between log trucks and chip trucks 6 and 7, it is clear that both types of trucks have similar records of unknown stops based on the classifications of stops. Therefore, it was concluded that there was no meaningful relationship between unknown stop and type of truck, but unknown stops were mainly dependent on the accuracy level and details of the driver activity data sheets filled out by truck drivers. The decision was made to revise the driver activity data sheets for round two in order to minimize the unknown stops.

5. Review of Second Round Data Collection

5.1 Participating Industry and Administrative Steps

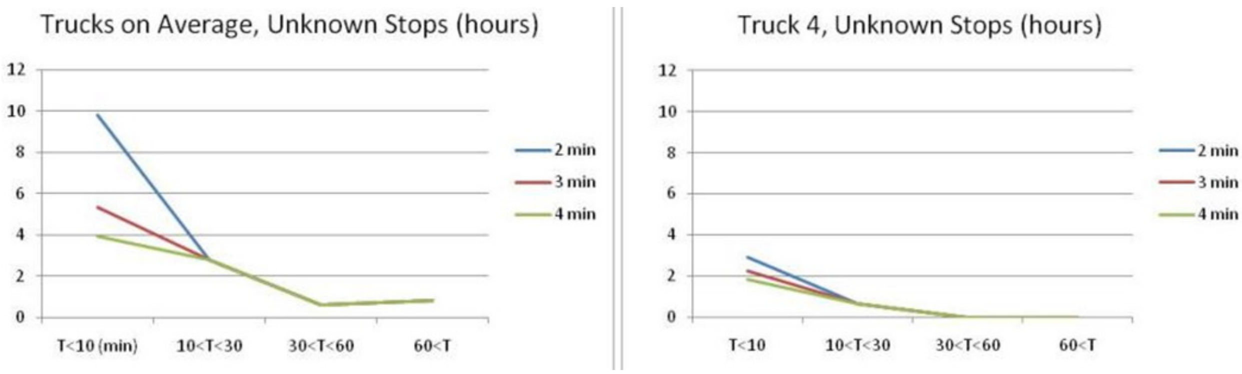
As in the first round, three companies, J. M. Longyear, LLC; Plum Creek Timberland L.P. and J. Carey Logging, Inc participated in the second round of data collection. In total, eleven GPS units were set up for the second round, but only six units were used for the data collection. The lack of data collection sites was due to the resistance on the part of the drivers to participate in the study. During interviews with log truck drivers several reasons were given for the reluctance to participate. Drivers believed that the data might be used to reduce their income level by companies. Drivers were concerned that the data might, despite assurances, be given to regulators and drivers felt that the added effort did not benefit them but companies. Support for the study had been given by the log truck drivers associations and one of the organization's officers was on the study's oversight committee but that fact and the rationale provided by the research team did not convince additional drivers to participate.

To compound the reduced data collection sites the team also discovered during data analysis that one of the six units had not recorded data consistently during the study period. This resulted in the final number of units with usable data for round II being only five units a reduction of three units from the round I experiment. The round II data collection units consisted of three log trucks and two chip trucks.

5.2 Review of Collected Data and Analytical Criteria

The settings of the units for the second round did not work as expected. For an unknown reason to the research team, four out of the five units (except truck no. 4) recorded data points in 600 meter (approximately 1,800 ft.) intervals instead of 200 meter (600 ft.) intervals used during the first round. The undesired settings were only detected after the data was collected and analysis started. The manufacturer of the units was contacted to clarify if there is an automatic default setting or some other software issue that would cause the units to reset automatically to a 600 meter interval. The manufacturer dismissed the possibility for such a reset, so the cause remains unknown.

The research team evaluated whether the change in settings would have significant impact on outcomes, and as a result decided to change the analytical criteria for stop time analysis from minimum of two minutes to four minutes, to make the results more comparable with the previous round. If a truck moved with an average speed of 11 mph, it would advance 600 meters in two minutes. As the trucks frequently drive less than 10 mph on small forest roads near loading sites, these would be considered stops with two minute intervals. The research team studied the truck movements in the logging roads to find out the appropriate minimum stop time for the analysis and recognized that four minute stop time provided more accurate interpretation by eliminating the slow movements near loading sites. However, it also eliminated the actual short stops between two and four minutes. After further analysis, it was determined that the possible loss of short stops did not have a major impact on the more critical results of the data analysis. Figure 19 shows how the total amount of unknown stop times fluctuates, as the minimum stop time changed from two to four minutes. Based on the figure, the total amount of time spent for short unknown stops increases significantly in trucks with 600 meter settings, when two minutes was considered a minimum stop time. The use of four minute minimum removes the majority of these stops, providing better overall accuracy.



Round II **Round I**

Figure 19: Change in Total Unknown Stop Times based on the Minimum Stop Time. On the left, the Average of Trucks with 600 m Interval and on the right, the Truck with 200 m Interval between Data Points

5.3 Outcomes of Data Analysis and Interpretations

5.3.1 General Review of Data and Operation Days

The second round of data collection took place between January 31 - February 26, 2011 with all five trucks collecting data during the same time period. Compared to the first round the overall data collection period was shorter even though more days per truck were recorded, making the data set temporally more homogenous. Trucks 1, 2, and 3 were log trucks and 4 and 5 chip trucks.

The average number of data collection days per truck in the second round was 19. The maximum number of operating days was 23 and minimum 16. Similar to the first round, the recorded operations seemed to be distributed equally on the weekdays. However, the days of Tuesdays and Thursdays which saw less activity in the first round now showed the most activity in the second round. Also, there was more activity on Saturdays (a total of eight recorded days). Figure 20 shows the distribution of operations by truck type between days for the second round of data collection. In comparison to the first round, log trucks significantly increased their operation times on Saturdays during the second round.

Days in Operation								
	Dates	Mon	Tue	Wed	Thu	Fri	Sat	Total
Truck 1 (log)	2/1 - 2/26	3	4	4	4	4	4	**23**
Truck 2 (log)	2/1 - 2/26	3	4	3	4	4	3	**21**
Truck 3 (log)	2/2 - 2/25	3	3	4	4	2	0	**16**
Truck 4 (chip)	2/1 - 2/25	3	4	3	3	3	0	**16**
Truck 5 (chip)	1/31 - 2/25	4	3	3	3	3	1	**17**
Total	1/31 - 2/26	16	18	17	18	16	8	93
AVG days of Log Trucks		3.0	3.7	3.7	4.0	3.3	2.3	
AVG days of Chip Trucks		3.5	3.5	3.0	3.0	3.0	0.5	

Figure 20: Number of Operating Days by Truck Type - Round II

The daily operating hours had large variations. The average difference between the maximum and minimum operation time per truck was 9.8 hours and the min. and max. operating times were very similar for each truck. The average daily operating time was 11.3 hours which was 30 minutes higher than on the first round. The minimum and maximum daily operating hours for each truck during the second round of data collection showed log trucks had higher minimum and maximum hours of operations in comparison to the chip trucks, (figure 21). It was also noticed that the number of operating hours consistently dropped after a day with high hours of operation.

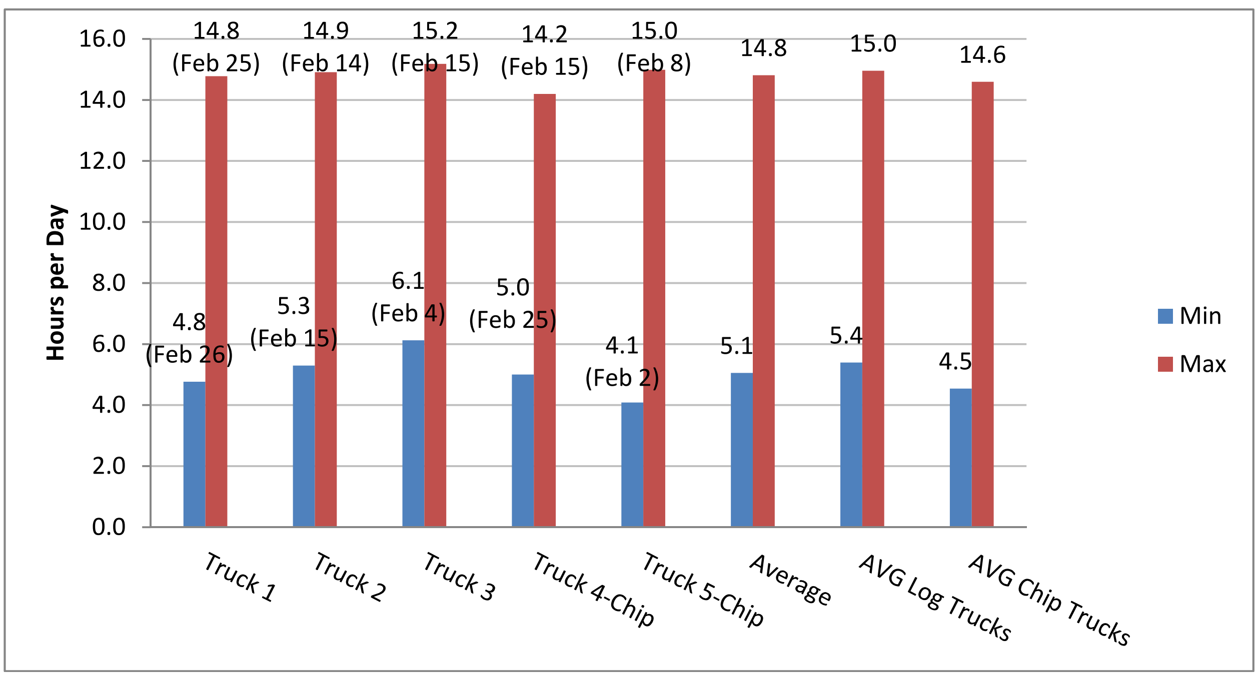


Figure 21: Operating Variances per Day per Truck - Round II (Hour/day)

The days for highest average operating hours were Mondays (12 hours), Tuesdays, and Thursdays (11.8 hours each). Many trucks carried two drivers. Similar to the first round, the shortest average weekday operating time of 10.7 hours were observed on Fridays. Saturday had the lowest average operating time and only some trucks were operating during weekends. The average number of operating hours, each day of the week per truck and per each company are represented in figures 22-25. According to figure 24, the chip truck operations (Company C) were on average one hour shorter than that of log trucks (Companies A and B) during week days (10.8 vs. 11.8).

Average Operating Time on Each Day of the Week (hours)							
	Mon	Tue	Wed	Thu	Fri	Sat	Work Day Avg
Truck 1 (log)	11.9	11.2	11.9	11.9	11.7	7.7	**11.7**
Truck 2 (log)	13.3	11.9	10.2	12.3	11.2	11.5	**11.8**
Truck 3 (log)	11.9	14.5	12.6	11.6	8.9		**12.1**
Truck 4 (chip)	12.8	10.1	10.9	11.1	9.5		**10.8**
Truck 5 (chip)	10.5	12.2	8.3	12.0	11.1	11.9	**10.8**
Average	**12.0**	**11.8**	**11.0**	**11.8**	**10.7**	**9.6**	**11.4**
AVG Log Trucks	12.4	12.5	11.6	11.9	10.6	9.6	11.8
AVG Chip Trucks	11.7	11.1	9.6	11.6	10.3	11.9	10.8

Figure 22: Average Operating Hours per Truck per Day - Round II

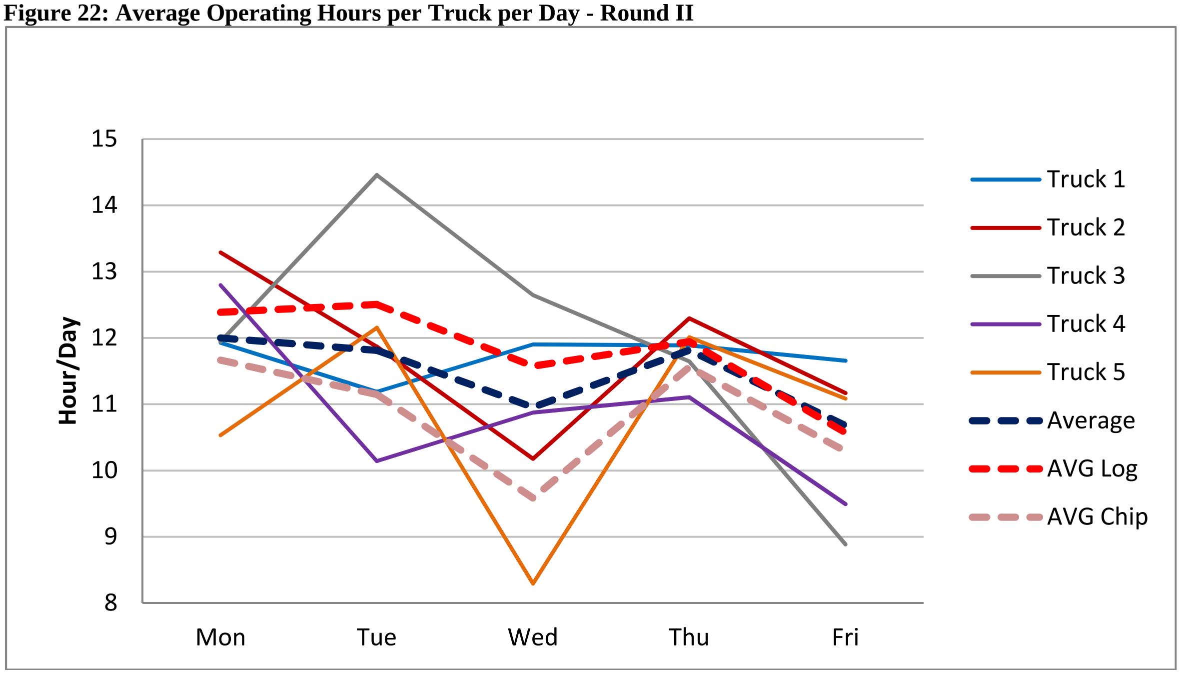


Figure 23: Average Operating Hours per Truck per Day - Round II

Average Operating Time on Each Day of the Week (hours)							
	Mon	Tue	Wed	Thu	Fri	Sat	Wkd Avg
Comp. A	11.9	11.2	11.9	11.9	11.7	7.7	11.7
Comp. B	12.6	13.0	11.6	12.0	10.4	11.5	11.9
Comp. C	11.5	11.0	9.6	11.6	10.3	11.9	10.8

Figure 24: Average Operating Hours by Company in Hours - Round II

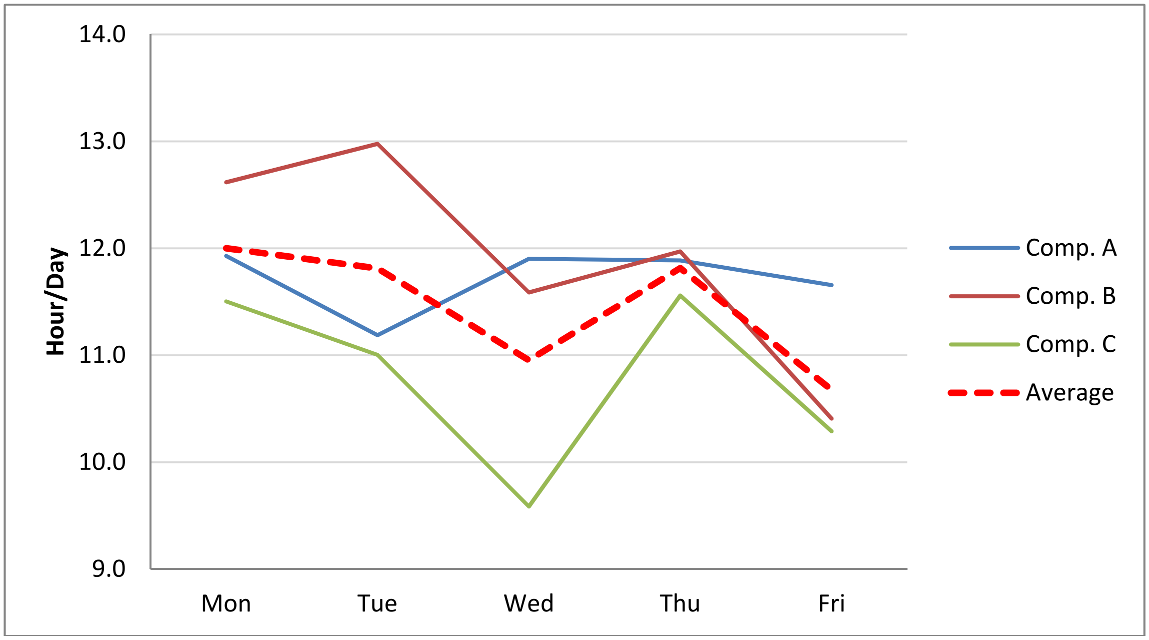


Figure 25: Average Operating Hours by Company - Round II

5.3.2 Review of Truck Performance

Figure 26 presents the average hours spent for different movement categories by each truck. Overall, all trucks spent slightly more hours moving than being stopped. The results are consistent with the results from the previous round.

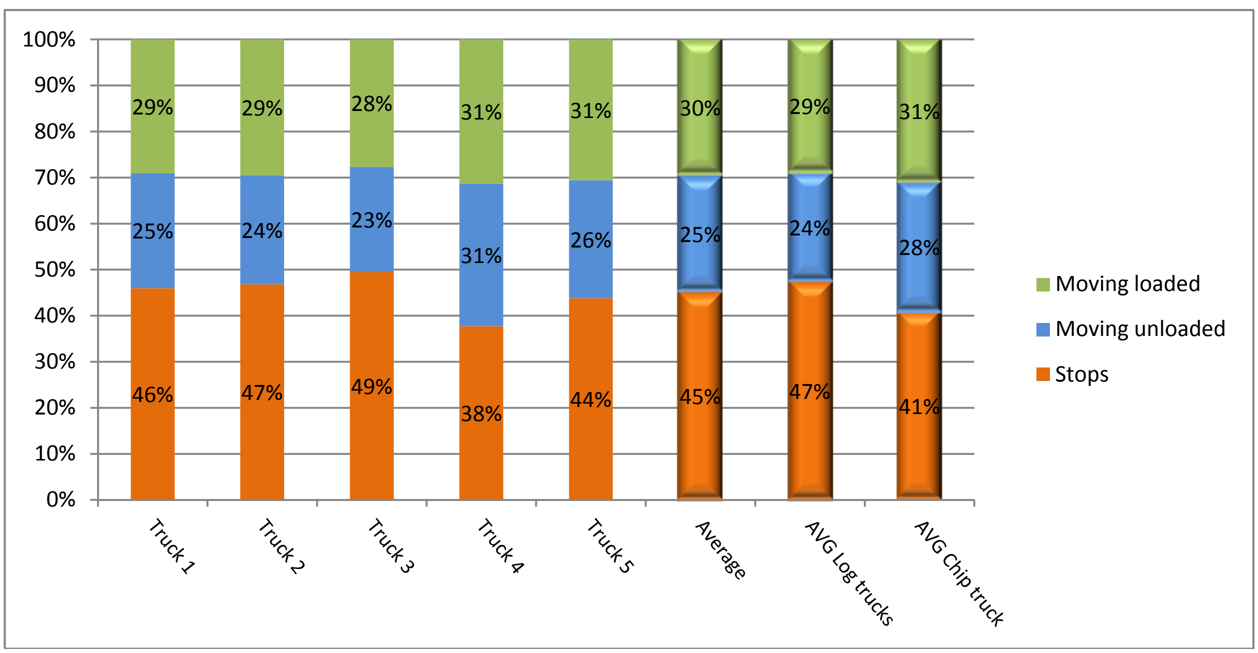


Figure 26: Share of Operating Times for Each Truck per Day - Round II

Figure 27 represents a summary of average daily operating hours for each company. The second round revealed more variation between companies than the first round which may be partially due to smaller sampling size (five versus eight). The difference in stop times between company B and C is significant. Both chip trucks in the second round, which typically had shorter stop times, were operated by company C. Also, Company C used pre-loaded trailers in some situations which were ready to be picked up by trucks as they arrived at the site. This process reduced the average stop times when compared to the practices of other companies.

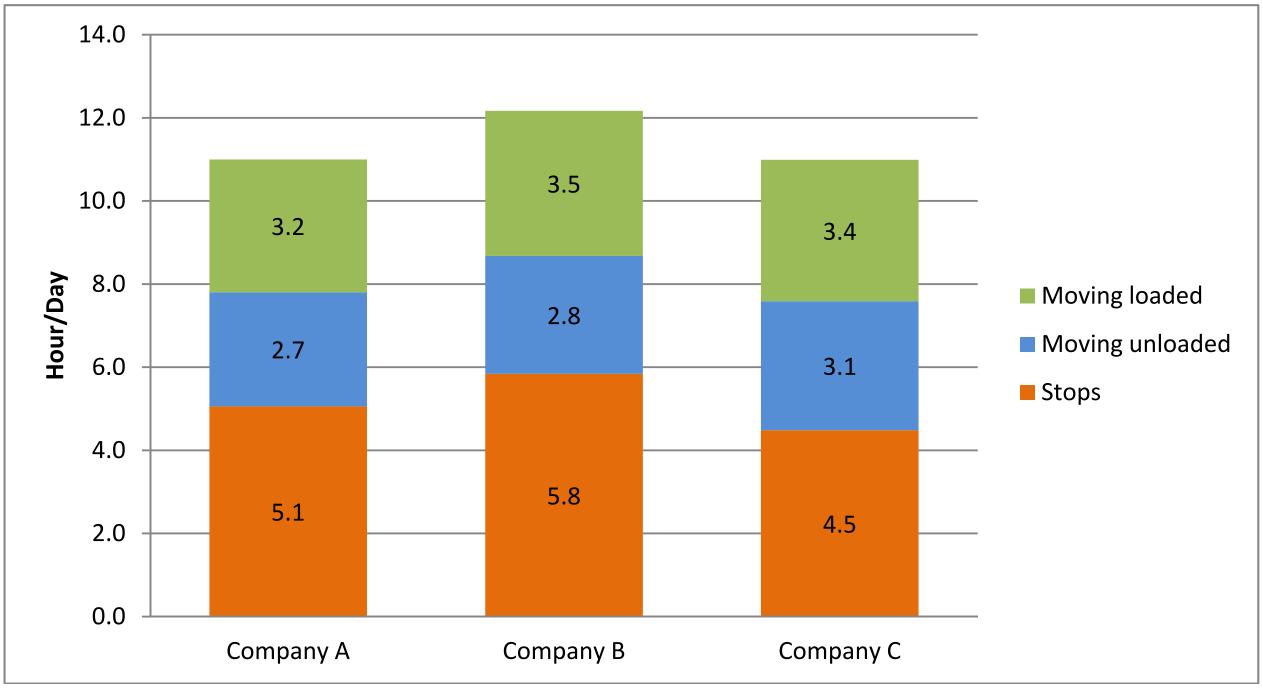


Figure 27: Average Daily Operating Hours of Truck Companies - Round II

5.3.3 Stop Time Analysis

The stops on the second round were divided into seven different categories similar to the first round except the idling stops that were changed to the "other stops" in second round.

Another change from first round of data collection is that the drivers were asked in the first round to use the log sheet to mark down the start and end time of the loading process. In the second round, all intermediate stops between the start and end were considered part of the loading process unless the driver mentioned otherwise in the log sheet. Therefore, small technical tasks that were part of the loading or unloading process were included in the overall loading/unloading times.

Similar to the first round, loading represents the largest share of the total stop times, ranging from 45% to 57% of the total stop time. The increase in loading times from the previous round can be explained by the improved log sheet that identified all stops and activities in the forest as part of a single loading process. Unloading represented the second largest share, from 16% to 27%. Technical stops represented the third largest group with the share ranging from 10% to 18%. One of the reasons for increased share of technical stops was that trucks usually had to chain and unchain the tires in the forest due to winter conditions during data collection. During the first round of data this was unnecessary. The distribution between stop time categories for each individual truck is presented in figure 28 and in figure 29.

Share of Stop Times							
	Administrative	**Technical**	**Gas**	**Other**	**Loading**	**Unloading**	**Unknown**
Truck 1 **(log)**	2%	18%	6%	0%	51%	20%	3%
Truck 2 **(log)**	2%	10%	4%	3%	48%	21%	11%
Truck 3 **(log)**	4%	11%	3%	1%	45%	27%	9%
Truck 4 **(chip)**	8%	12%	2%	1%	57%	16%	4%
Truck 5 **(chip)**	3%	13%	6%	7%	47%	16%	8%
Average	**4%**	**13%**	**4%**	**2%**	**50%**	**20%**	**7%**
AVG Log trucks	2%	13%	4%	1%	48%	23%	8%
AVG Chip trucks	6%	12%	4%	4%	52%	16%	6%

Figure 28: Share of Stop Times for Each Truck - Round II

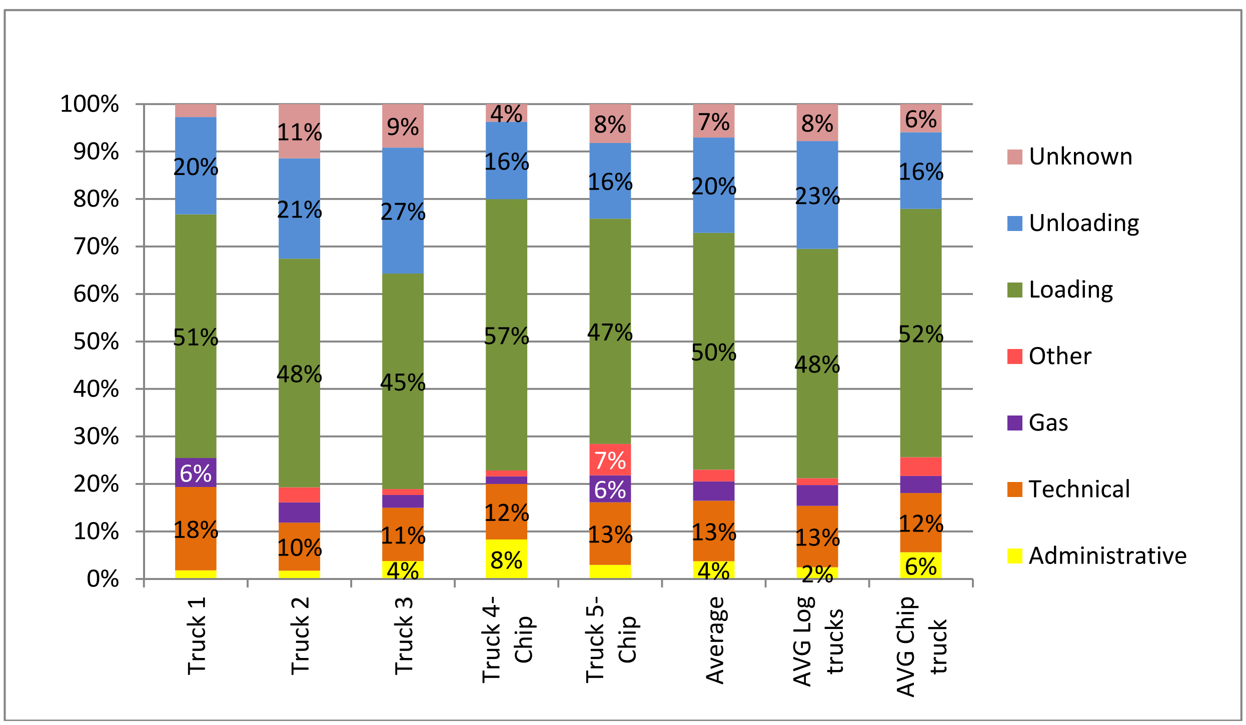


Figure 29: Share of Stop Times - Round II

According to figures 28 and 29 the share of unloading stops for chip trucks (no. 4 and no. 5) were less than log trucks, while their share of loading and administrative stops were a bit more than log trucks. However, by comparing the average stop minutes per day for each truck, (figures 30 and 31), it demonstrates that except administrative stops, the duration of other major stop categories (including loading, unloading and technical stops) for chip trucks are relatively shorter than log trucks, especially for loading and unloading. Also, trucks 2 and 3, which had the highest unloading times, were also the ones that had the most unloading sites outside mills, where unloading often requires the use of self-loaders. They were also handling significant amounts of saw logs versus pulp wood, which requires a more detailed process during unloading.

Average Stop Times per Day (min)							
	Administrative	**Technical**	**Gas**	**Other**	**Loading**	**Unloading**	**Unknown**
Truck 1 (log)	5	53	19	0	156	62	8
Truck 2 (log)	6	34	15	11	164	72	39
Truck 3 (log)	14	41	10	5	165	96	33
Truck 4 (chip)	21	29	4	3	144	41	9
Truck 5 (chip)	8	38	16	19	135	45	23
Average	**11**	**39**	**13**	**7**	**153**	**63**	**23**
AVG Log trucks	8	43	14	5	162	77	27
AVG Chip trucks	15	34	10	11	140	43	16

Figure 30: Average Stop Time per Day by Truck in Minutes - Round II

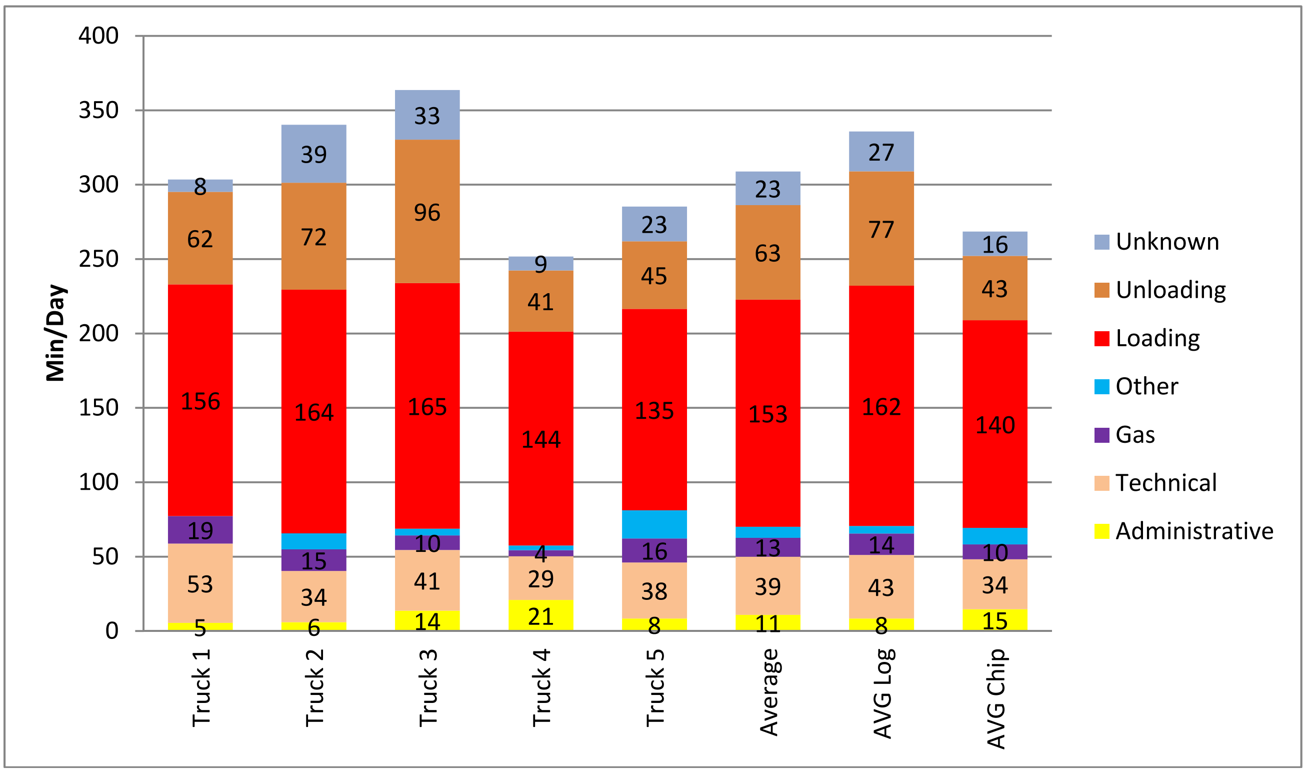


Figure 31: Average Stop Time per Day by Truck in Minutes - Round II

On typical days, the trucks had two loading and unloading processes. The total number of deliveries and average loading times were captured using the GPS data and load tickets, (figure 32). The unloading site impacted the duration of the unloading process. Trucks 2 and 3 which worked for Company B had the longest daily unloading times, but they also had the most unloading activities outside the mills, (figure 33). Based on the second round data, unloading at rail sidings or other sites is 50-70% more time consuming than unloading at mills, (figures 33 & 34). However, the data set is small and there is variation in unloading times between the trucks. Unloading at mills is more efficient because of the heavy equipment used to unload a truck quickly, while using self-loaders on the trucks takes more time. On the other hand, the unloading process at mills often requires waiting, thus negating some of the benefits. It is notable that the chip trucks, (trucks no. 4 and no. 5) had shorter overall unloading times at mills than any of the log trucks. The short unloading times of trucks 4 and 5 at mills is due to using truck-tippers for chip trucks, which is faster than using cranes commonly used for unloading log trucks. (See Appendix for photos.)

	Total Number of Deliveries			
	Unl.Mill	Unl.Rail	Unl.Other	Per Day
Truck 1 (log)	30	4	2	1.6
Truck 2 (log)	31	0	11	2.0
Truck 3 (log)	6	0	20	1.6
Truck 4 (chip)	31	1	2	2.1
Truck 5 (chip)	30	0	0	1.8
Total	**128**	**5**	**35**	**1.8**
AVG Log	67	4	33	1.7
AVG Chip	61	1	2	1.9

	Average Unloading Times (min)		
	Unl. Mill	Unl.Rail	Unl.Other
Truck 1 (log)	39	52	29
Truck 2 (log)	36		36
Truck 3 (log)	48		63
Truck 4 (chip)	17	15	50
Truck 5 (chip)	26		
Average	**30**	**45**	**52**
AVG Log	38	52	52
AVG Chip	22	15	50

Figure 32: Total Number of Deliveries and Average Unloading Time - Round II

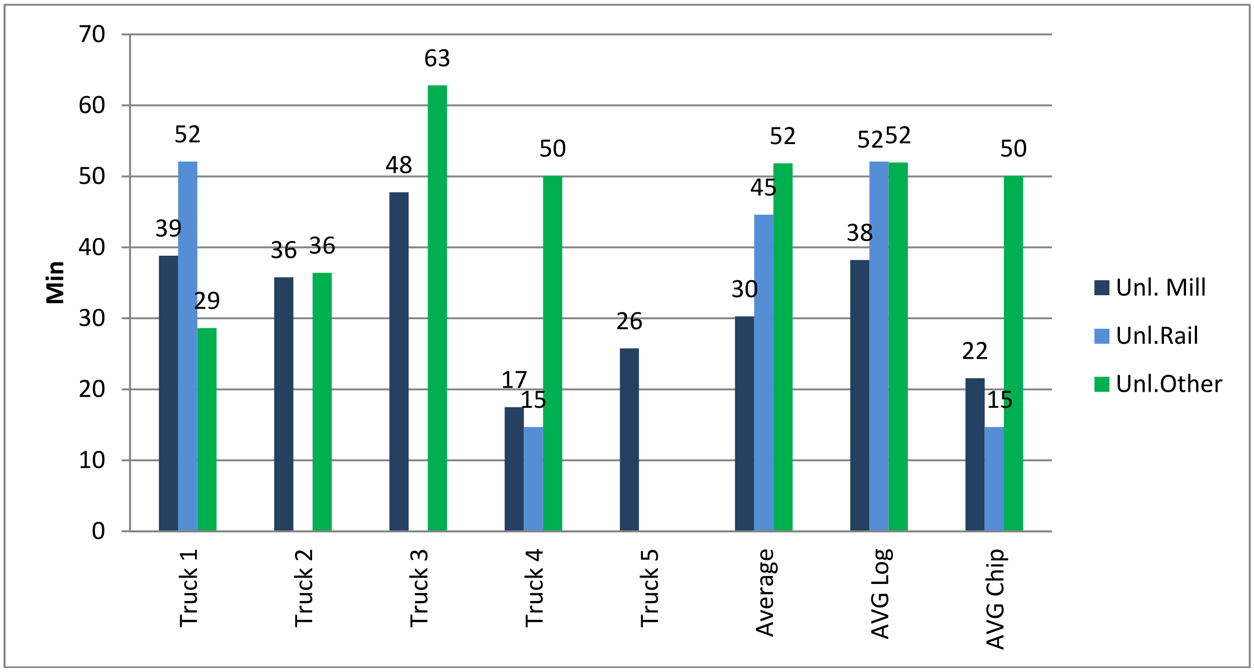


Figure 33: Average Times for Unloading by Site

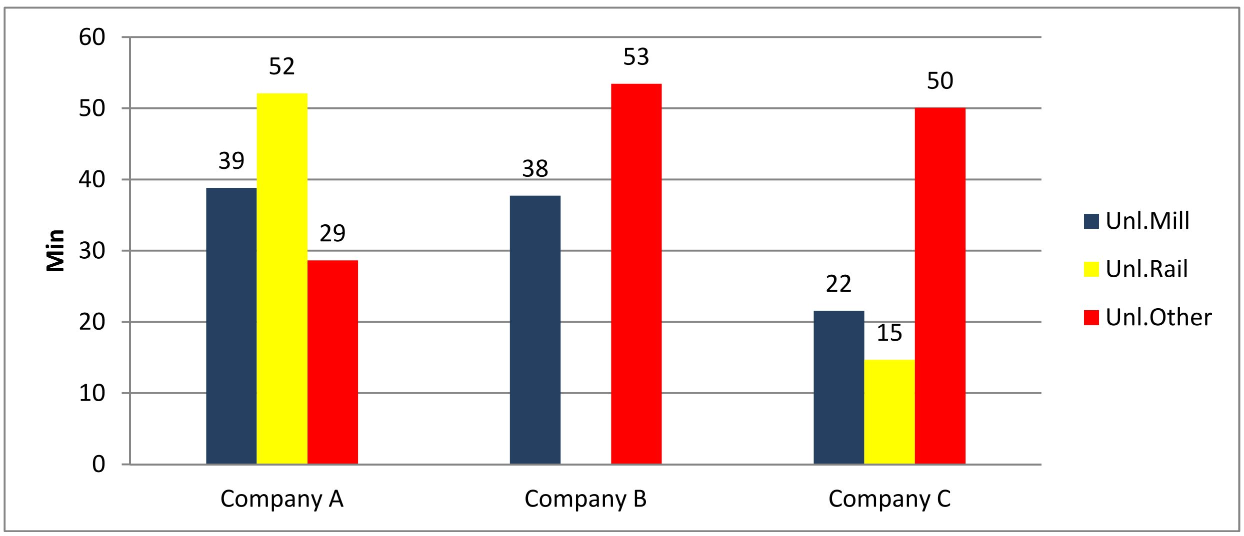


Figure 34: Average Times for Unloading by Company - Round II

The total number and duration of "unknown stops" decreased significantly from the first round. This was credited to the improved driver daily activity sheet that provided more accurate information about the stops and clarified the instructions for loading processes. The secondary explanation might be that on the second round the drivers had more experience in filling out the daily activity sheets correctly. Compared to the first round, the average unknown stops of less than 10 minutes decreased by 25 percent and unknown stops between 10 and 30 minutes decreased over 30 percent. The changes in longer unknown stops were even more notable. The average of unknown stops between 30 and 60 minutes decreased 75 percent and stops more than 60 minutes went down over 60 percent, (figures 35 and 36).

Similar to the first round, the biggest category of unknown stops included stops less than 10 minutes, (figure 36). These short stops may have been too insignificant for the drivers to mark down in the daily activity sheet, resulting in unknown status. Drivers may also have forgotten to mark down some stops. On average, the trucks had seven hours of unknown stops over the four weeks of data collection. This equals to an average of approximately 23 minutes of daily unknown stops (3% of the average total operational time) per truck.

Classification of Unknown Stops (hours)					
Truck # (Type)	T<10 min	10<T<30	30<T<60	60<T	Total
Truck1 (log)	2.1	0.5	0.6	0.0	3.2
Truck2 (log)	6.8	4.4	1.2	1.1	13.6
Truck3 (log)	3.9	3.4	0.6	1.0	8.9
Truck4 (chip)	1.8	0.7	0.0	0.0	2.5
Truck5 (chip)	2.8	2.8	0.0	1.0	6.6
Average	**3.5**	**2.3**	**0.5**	**0.6**	**7.0**
AVG Log Trucks	4.3	2.8	0.8	0.7	8.6
AVG Chip Trucks	2.3	1.7	0.0	0.5	4.6

Figure 35: Classifications of Stop Times - Round II

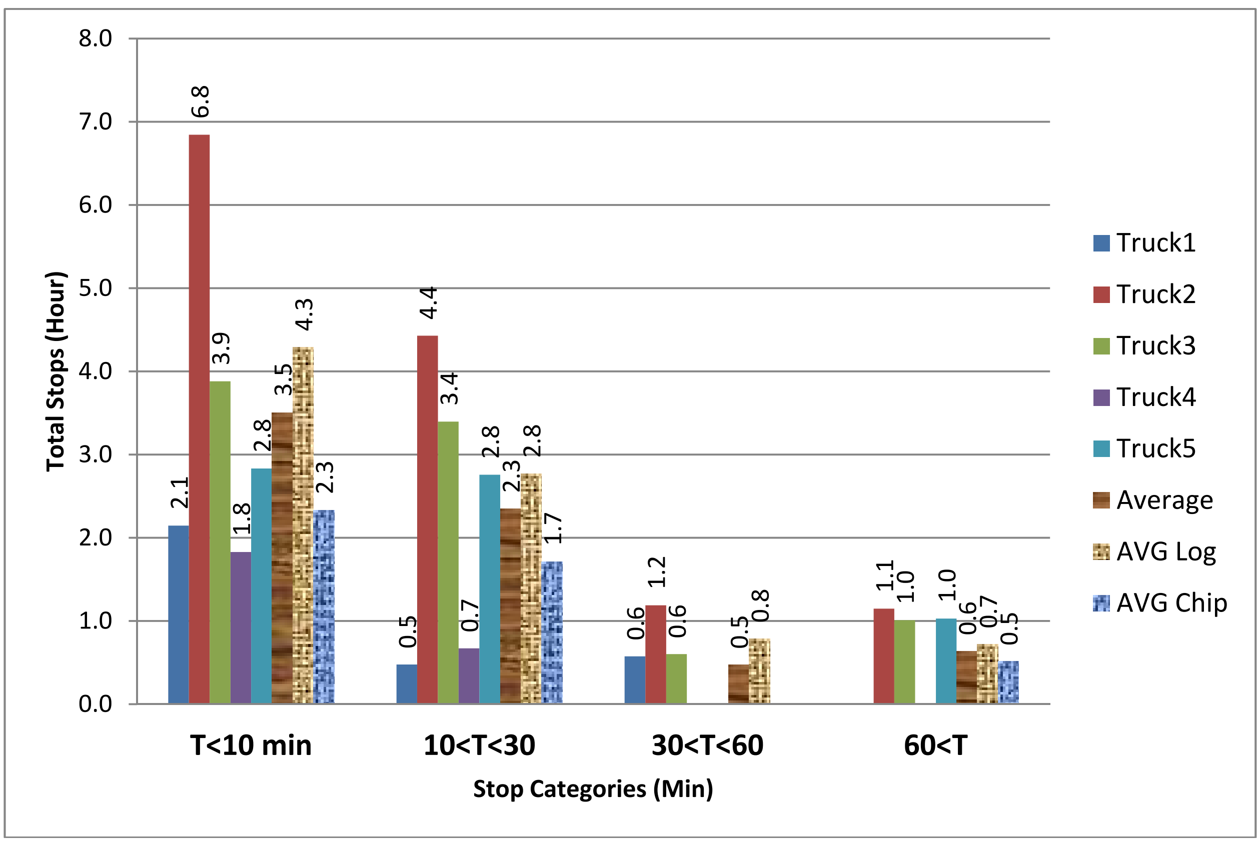


Figure 36: Total Unknown Stop Hours per Truck - Round II

5.3.4 Idling and Fuel Consumption

During the first round of data collection, it was recognized that drivers rarely turn the engine off during operating hours. Some of the stops, especially loadings and unloading for log trucks require idling to power self-loaders. However, unloading at mills for chip trucks and stops for "administrative" or "other" purposes (for both log and chip trucks), usually do not require idling unless the truck's equipment is used for unloading. Some of the technical and unknown stops may require idling, but the analysis in this report assumes the engine could be turned off during these stops as well. The team was requested to investigate the fuel consumption during the potentially unnecessary idling periods.

The Study's fuel consumption estimates derived during idling, employed operational assumptions, national averages for fuel cost, and consumption rates of idling trucks collected from literature. It is acknowledged that technical specifications of truck engines may make idling preferable in some cases, so the outcomes of this specific investigation should not be taken as a recommendation to shut down the trucks, but rather to identify and quantify opportunities for operational savings.

The Environmental Protection Agency (EPA) has completed several research efforts investigating new technologies to reduce the idling time. One of these technologies is Truck Stop Electrification with a cost in the range of $1,500 to $7,000. This technology involves modifications to the truck and to the truck stop parking space to provide electrical power, heat and air conditioning, (EPA, 2011). It is unlikely that there is sufficient truck volume to implement this technology in the study area, but the fuel savings for turning off the engine can be used for estimation purposes.

One location where trucks might be able to reduce idling may be at mill locations where there was a sufficient wait time to justify the expenditure. Many drivers arrive at mill locations in advance of the mill opening in order to get a head start on the working day. Mill locations would have easy access to electrical power. Mill owners would have to be compensated for electrical usage and maintenance of the units. However, the mill owners would have environmental benefits in the reduction of truck emissions in their mill area. In the interest of determining the cost of the idling the team reviewed relevant literature and has developed estimates of the cost of idling, in terms of fuel consumption.

The American Transportation Research Institute (ATRI) prepared a study "*Idle Reduction Technology: Fleet Preferences Survey*" for New York State Energy Research and Development Authority in 2006, (Tunell, 2006). Over 55,000 trucks around the United States participated in the study. According to the study the average cost of idling in 2005 was $3.00/hour, average fuel price being $2.40/gallon. Based on these numbers, the average fuel consumption rate for idling becomes 1.25 gallons/hour. While it is recognized that trucks used in the ATRI study probably had significantly smaller engines than Michigan log trucks, this rate was used by the research team as a conservative estimate for the fuel consumption. Another research conducted by Transportation Technology R&D Center of Department of Energy (DOE) and University of Chicago, estimated 1 gallon/hour as basic fuel consumption rate of truck during idling time, in addition to the 0.2 gallons/hour as auxiliary uses including cooling/heating systems, (Stodolsky, 2000).

According to Energy Information Administration – EIA the average retail diesel price in the Midwest during data collection in February, 2011 was $3.533 per gallon. Figure 37 shows the estimated fuel consumption and cost due to what the research team identified as idling time with the potential for optimization. These were times during the second round when the trucks were waiting, with engines idling, to commence an operation.

Monthly and annual rates were based on the average daily fuel price for 21 operating days in a month and 12 operating months in a year.

	Fuel Consumption (gal)			Cost		
	Daily	Monthly	Annually	Daily	Monthly	Annually
Truck 1 (log)	1.8	37	450	$6.30	$132	$1,588
Truck 2 (log)	2.2	46	549	$7.70	$162	$1,939
Truck 3 (log)	2.1	45	536	$7.52	$158	$1,895
Truck 4 (chip)	2.1	44	529	$7.41	$156	$1,868
Truck 5 (chip)	3.1	66	787	$11.04	$232	$2,782
Average	**2.3**	**48**	**570**	**$7.99**	**$168**	**$2,014**
AVG Log Trucks	2.0	43	512	$7	$151	$1,807
AVG Chip Trucks	2.6	55	658	$9	$194	$2,325

Figure 37: Fuel Consumption and Cost of Truck Idling - Round II

According to Figure 37, the total expected fuel savings for fuel consumption through idling time for chip trucks was estimated to be higher than for log trucks, as all unloading at mills was considered unnecessary for chip trucks, while required for log trucks.

Cost of idling is very sensitive to the per gallon retail price of diesel fuel. Figure 38 shows the effect of diesel fuel price on the average annual cost of idling calculated from all five trucks with an inflationary increase in fuel prices up to $6.00 per gallon. The data suggests that each dollar increase in fuel price adds almost $600 in idling costs annually.

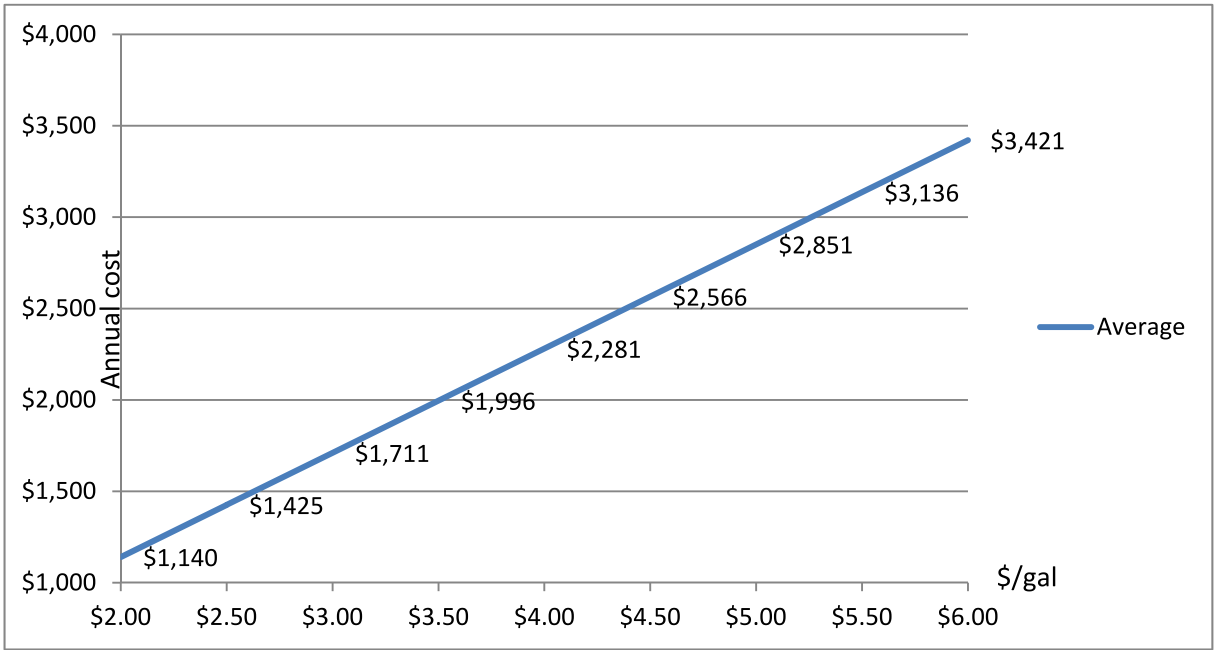


Figure 38: The Effect of Diesel Fuel Price and Average Annual Idle Cost - Round II

The investigation revealed that on a theoretical level, there seem to be opportunities for economic gains by shutting down engines when they are not needed for an operation. The research team realized that theoretical concepts may not stand up to the realities of the workplace and sought advice from industry as to the operating conditions. Industry advisors had mixed reviews about the ability and / or value in shutting down diesel engines because of the remote locations most log and chip trucks operate in. If the truck does not restart, remote location servicing can be expensive in time lost as well as service costs. Additionally if the truck is operating in subzero conditions there may be risk to the truck driver if it occurs in the backwoods on a private logging road where cell phones do not operate**.**

While it is probable that operational modifications to reduce idling are not acceptable at this time, the potential high returns would certainly warrant additional analysis of the topic, or consideration of new truck stop technology implementation. The reality is that due to the nature of this trade most idling costs will not be able to be addressed with current technology. The cost of idling needs to be integrated into the truck pricing calculation. Driver time spent moving vs. waiting should be part of management/driver decisions to improve driver productivity. This study identifies that improving driver productivity has a secondary benefit when fuel savings are considered.

5.3.5 Additional Truck Movement Analysis

The collected GPS data (.kml format) was converted to an ArcMap format (.mxd) for additional truck movement analysis. Figure 39 depicts all movements and stops of truck 1 during second round of data collection. Individual GIS maps of the other trucks are presented in the Appendix.

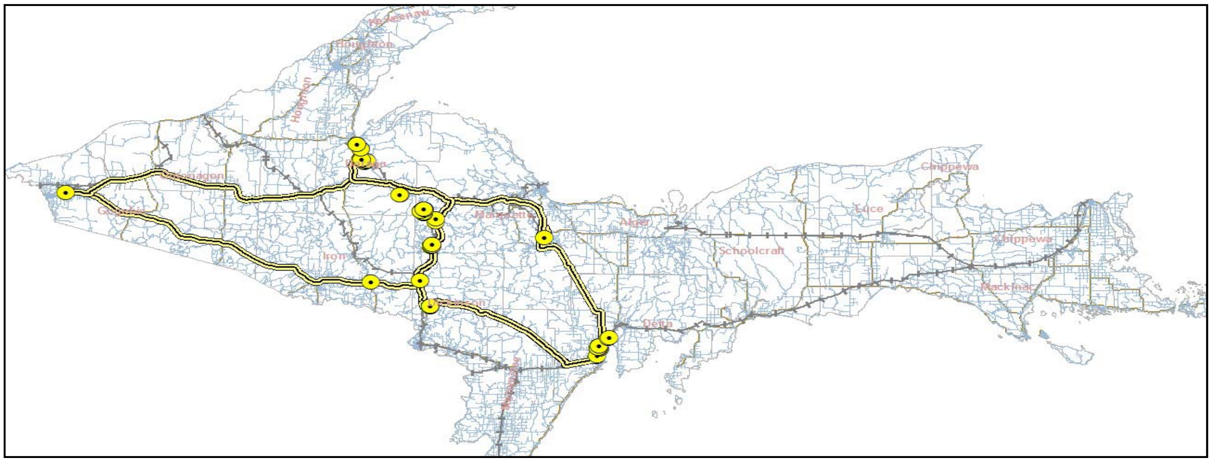


Figure 39: All Movements and Stops of Truck 1 - Round II

Figure 40 shows the routes of all five trucks in Round II. Primary roads to New Page and Verso Mills including US 2, US 141, US 41, M 28, & M 69 were used by most trucks.

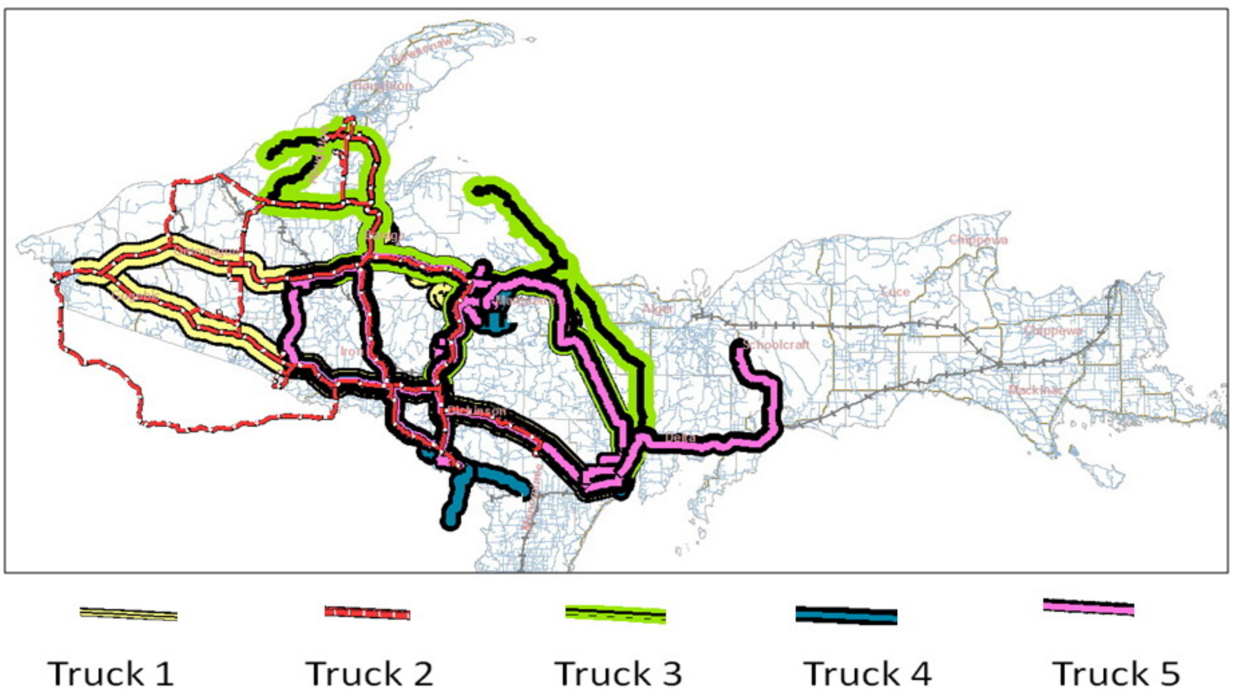


Figure 40: Combined Truck Movements - Round II

The roads have been classified to three different classes including state-major roads, minor roads (minor county roads) and woods access - private roads (logging roads), as described in figure 41. Figure 42 shows the distribution of truck movements between road categories, based on the mileage. Approximately 80% of all truck mileage was on state and major (principal) roads, (figure 42). Truck 3 had significantly less movement on state and major roads, as it usually transports logs from harvesting sites to log yards, instead of mill locations with unloading capabilities. It should be noted that the distributions between road classes are approximations made by the research team based on route records.

Road Category	Subcategories based on GIS database (MI)
State-Trunkline	Rural Interstate, Rural Other Principal Arterial, Rural Other Freeway, Rural Minor Arterial, Rural, Major Collector, Urban Interstate, Urban Other Freeway, Urban Other Principal Arterial, Urban Minor Arterial
Minor-Others	Minor County Roads, County Local
Woods Access, Private	Private Roads, Unknown Roads, Uncoded Roads

Figure 41: Road Classification Categories – Round II

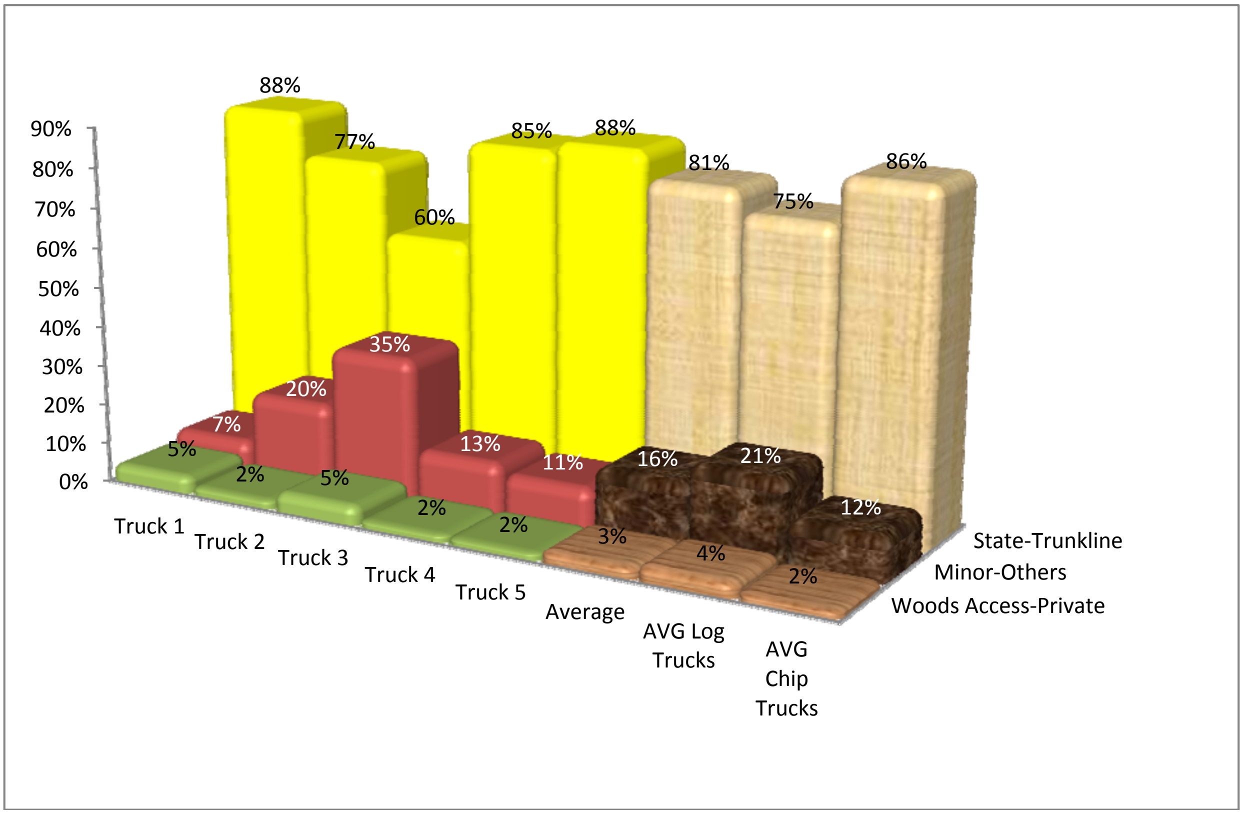


Figure 42: Percentage of Mileage by Road Type - Round II

The team was also asked to analyze the distribution of loaded and unloaded miles. Based on collected data, loaded and unloaded miles represent an almost equal share of total mileage (figure 43).

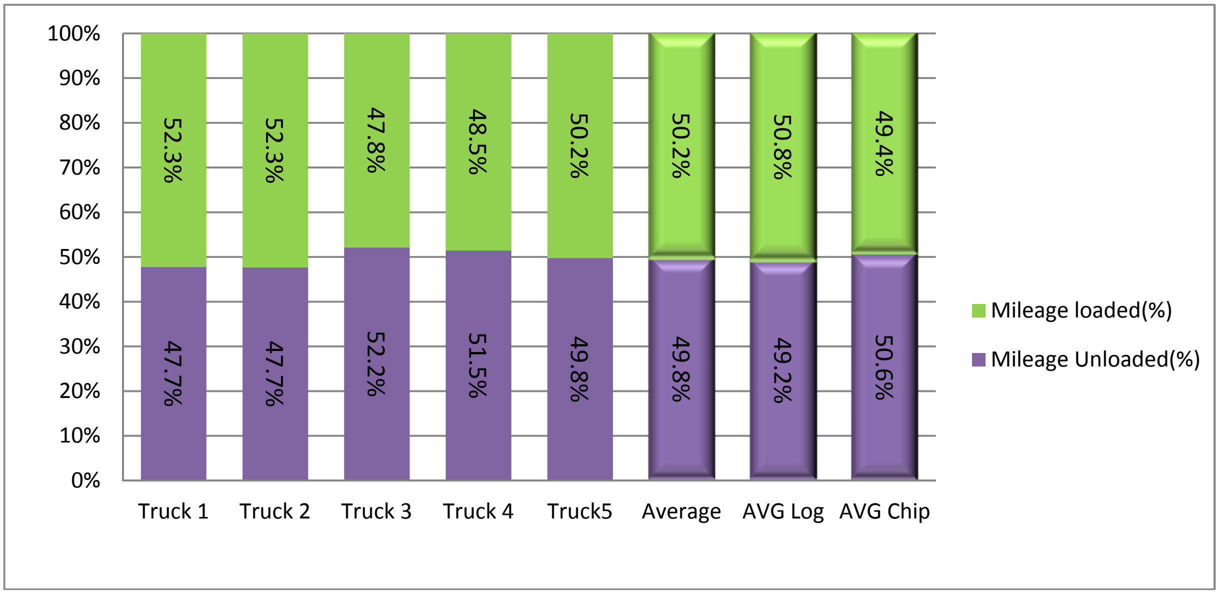


Figure 43: Truck Mileage Loaded vs. Empty - Round II

Figure 44 reviews the number of miles operated daily by participant trucks. Chip trucks moved about 40 miles per day more than log trucks (295 versus 256), although the average operational hours of chip trucks were approximately one hour shorter than log trucks. This suggests better performance and productivity of chip trucks in comparison to the log trucks. On average, the trucks stopped every 31 to 35 miles, respectively for log and chip trucks.

One of the findings of this study was that the average round trip distance from point of origin to point of delivery for both log and chip trucks was approximately 150 miles. Industry representatives believe that most wood products are gathered from within a 100 mile radius of a mill. The average 75 mile trip point of origin to point of delivery distance reflected in the study's data appears to confirm that belief.

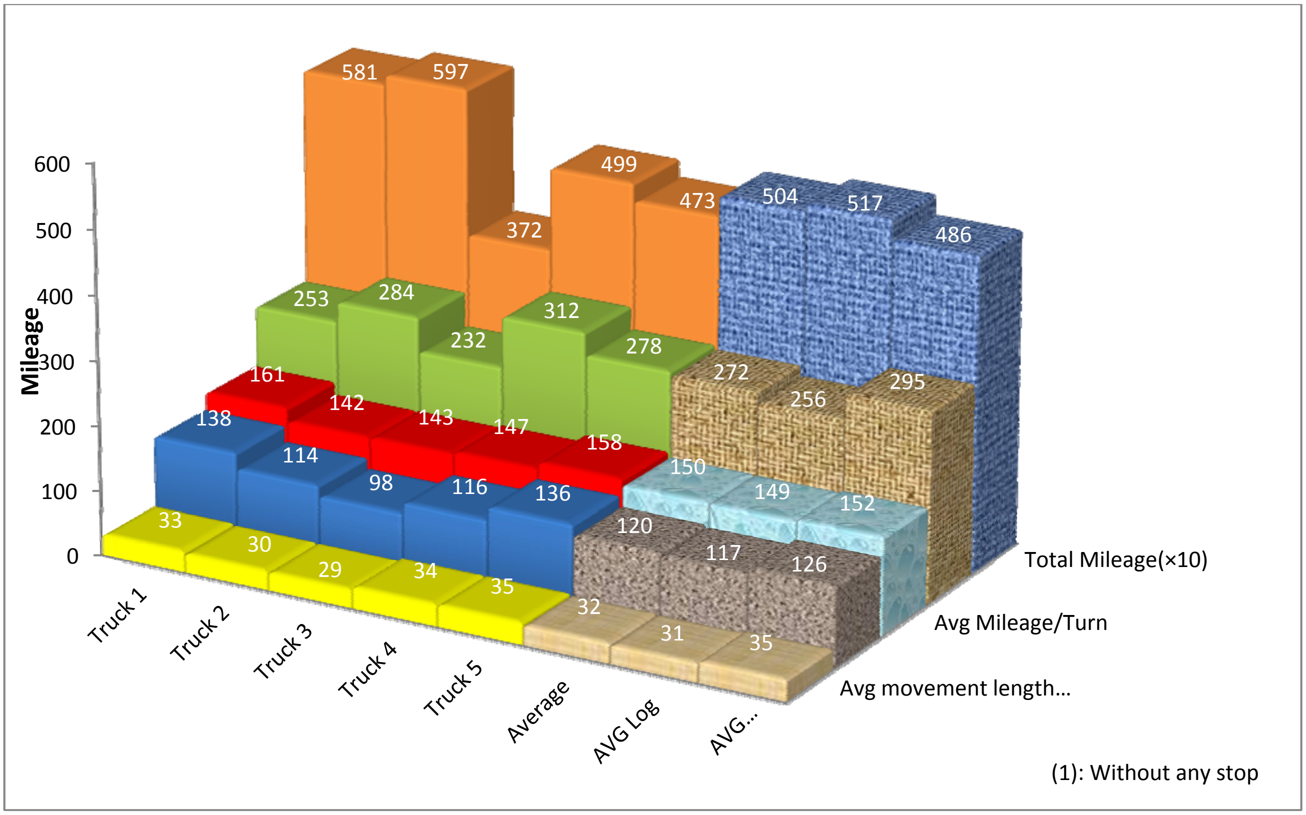


Figure 44: Truck Mileage - Round II

5.3.6 Productivity of Trucks Based on Load Ticket Records

In addition to the GPS data and drivers activity sheets, load tickets from one of the chip trucks, (truck no. 5), were used to analyze the truck productivity during the second round of data collection. Load tickets of two other trucks were also collected, but they were lacking sufficient detail to reliably conduct the analysis, as data was incomplete, or the load measures were vague and unclear. Load tickets provide information on date, ticket number, unloading location, job number, species, and tonnage. Figure 45 presents the productivity of truck 5 based on the comparison between actual ton-mileage (net tons multiplied by respective loaded mileage) and ton-mileage capacity for the same movement (45 tons assumed load capacity of chip truck, multiplied by loaded mileage). Based on the analysis, truck 5 utilized approximately 81% of its maximum total carrying capacity on ton-mileage basis.

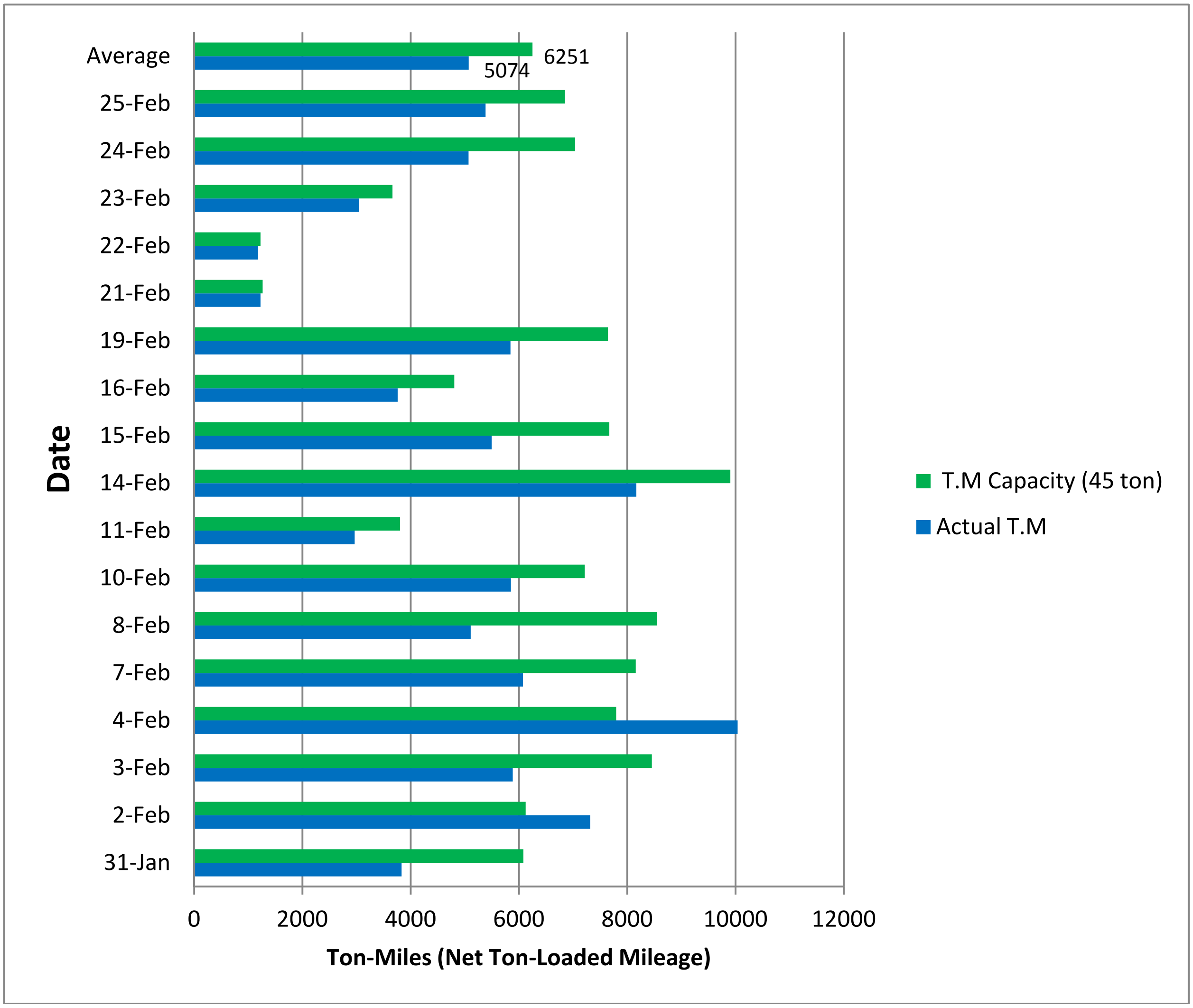


Figure 45: Productivity of Truck 5 Based on Ton Miles - Round II

5.3.7 Loading and Unloading Locations Analysis

By reviewing loading and unloading locations, the research team could compare different truck routes and review the proximity of loading/unloading locations. Figure 46 presents all loading/unloading locations used by trucks in the second round of data locations. In this figure, “L” and “U” represent “Loading” and “Unloading” locations for each truck, respectively. The individual loading and unloading locations for each truck are presented in the Appendix. As presented in figure 46, some unloading locations (mostly mills), have been used by more than two participating trucks, but the majority of the loading locations were unique for each truck.

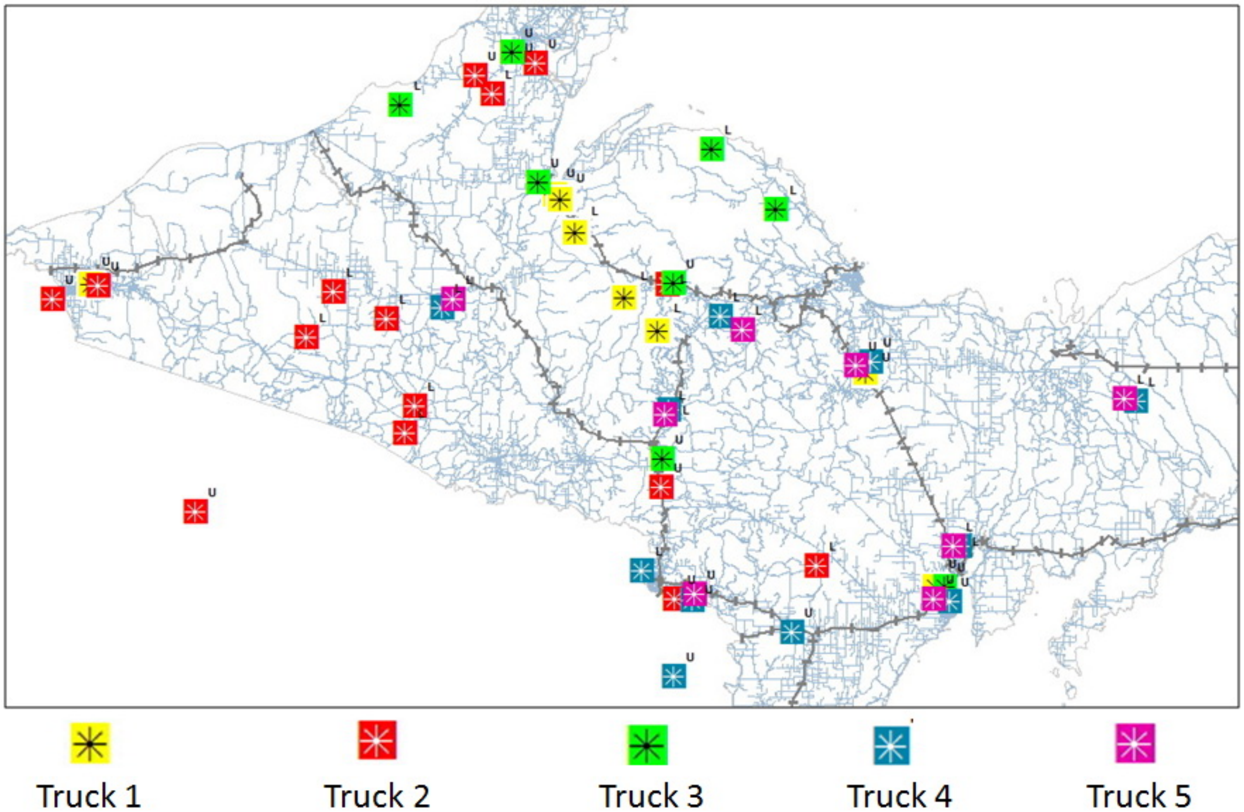


Figure 46: Loading and Unloading Locations for All Trucks - Round II

Figure 47 shows number of alternative loading locations for each individual log truck that is close to the unloading spots (within a 30 mile radius) of other trucks. In a collaborative environment, this information can be used by the companies to identify potential movements that minimize the amount of unloaded miles between loadings. Since trucks 4 and 5 were chip trucks from company C, they have been removed from the table, as these truck types are not interchangeable for the different products.

Truck	# of unloading locations	# of potential loading locations within 30 miles			
		Truck 1	Truck 2	Truck 3	Total
Truck 1	5		3	3	**6**
Truck 2	8	2		1	**3**
Truck 3	5	3	3		**6**

Figure 47: Alternative Loading Locations within 30 Miles of Unloading Sites - Round II

The table (figure 47) reveals that on a theoretical level, every truck in the study had alternative loading locations close to their unloading spots, although the limited number of trucks in the study didn't allow the research team to broadly investigate this issue. Based on an analysis of the data displayed in figure 47, trucks 1 and 3 (companies A and B) would have the highest potential for backhaul opportunities, if the possibility to share loading locations would be available. Such arrangements could increase the percentage of loaded miles and time of operation in loaded (revenue) conditions, but would also require close coordination and might cause other operational complications that are beyond the scope of this project.

5.3.8 Analytical Review on Mills - Trucks Interactions

Mills are the most frequent unloading location for most trucks. Truck 3 had a significant portion of deliveries outside the mill (most moves between harvesting locations and log yard facilities), but the rest of the trucks entered mills frequently (on average, 87% of the time). Figure 48 represents the unloading times and average deliveries of each truck to the mills. In the table below, unloading time at mills refers to the unloading activity only, excluding waiting times at the mill entrance, administrative activities, and trucks weighing on the scale. The data collected indicates that average unloading time in the mills for chip trucks is almost 50% less than the unloading of log trucks, (figure 48). Approximately 95% of all unloading of chip trucks occurred at mills, compared to 64% by log trucks.

Truck # (type)	# of Unl at Mill	# of Unl at Mill/day	Avg. Unl time at Mill (Min)	Total # of unloading	% of Unl at mill/total
Truck 1 (log)	30	1.3	39	36	83
Truck 2 (log)	31	1.5	36	42	74
Truck 3 (log)	6	0.4	48	26	23
Truck 4 (chip)	31	1.9	17	34	91
Truck 5 (chip)	30	1.8	26	30	100
Average	25.6	1.4	30	30	85
AVG Log Trucks	22.3	1.1	41	35	64
AVG Chip Trucks	30.5	1.9	22	32	95

Figure 48: Unloading Performance at Mills - Round II

Twelve different mills were used by the trucks during round II. Some of the mills were saw mills (Channing, Baraga, Hermansville, and Atlantic Mine) that cut wood. Some mills were stopped at only once or twice (mostly saw mills) and others (pulp mills) more frequently. Figure 48 lists the number of unloading that each truck performed in visiting mills during round II. This figure represents all possible stops during round II and the total number of stops for unloading that each truck performed. Chip trucks 4 and 5 were more limited in the potential locations that they could stop at for unloading as the mill had to have chip unloading capability.

It should be noted that for trucks 4 and 5 (chip trucks), some of the mills may not have demand, nor appropriate unloading facilities, for chips.

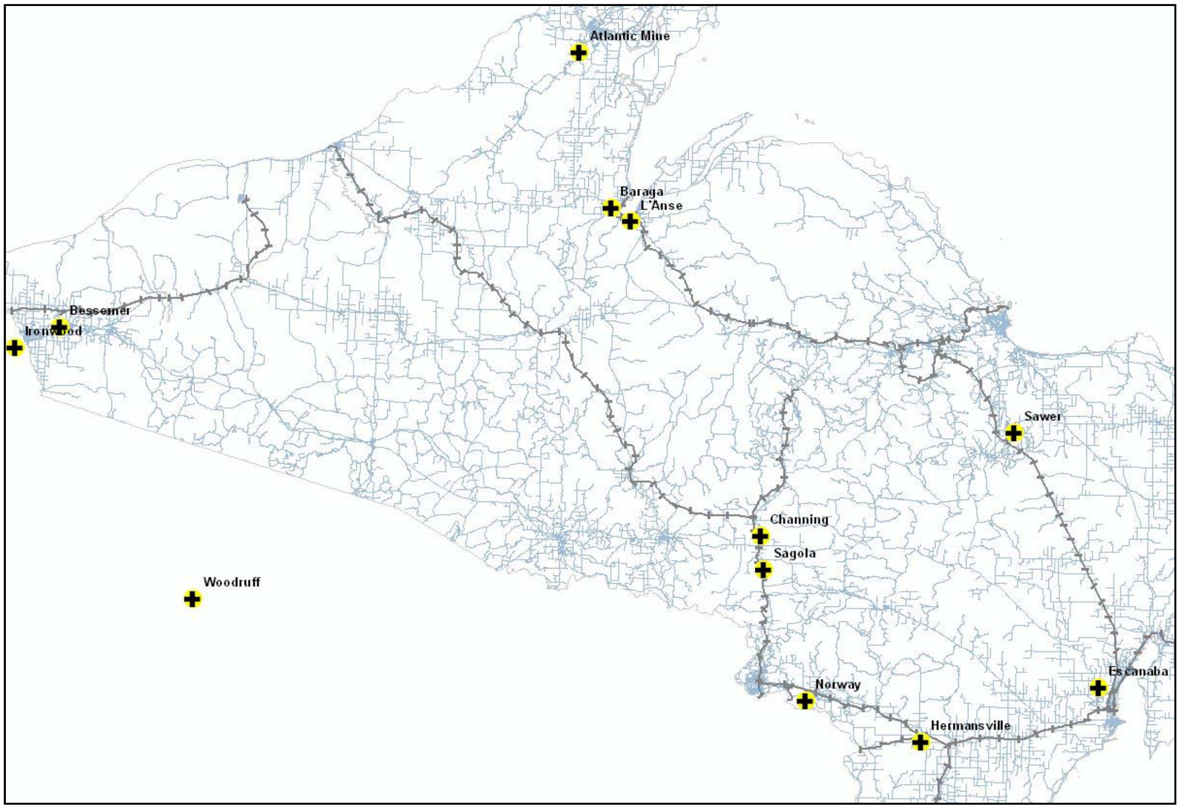


Figure 49: Mill Destinations - Round II

Figure 49 compares the distance of available mills from loading locations used by the trucks. Figure 50 compares the actual destinations of trucks with mills that would have been available within the 50 mile radius from the loading locations.

Truck	# of loading locations	Potential mills within 50 mi of loading locations	Actual mill destinations	
			Within 50 mi	Out of 50 mi
Truck 1	3	Norway, Sagola, Channing, Sawyer, Baraga, L'Anse, Atlantic Mine	Sawyer, L'Anse	Escanaba, Bessemer
Truck 2	8	All mills	Ironwood, Bessemer, Norway, Atlantic Mine, Woodruff, Sagola	
Truck 3	3	Sawyer, Channing, Sagola, Baraga, L'Anse, Atlantic Mine	Channing, Baraga, Atlantic Mine	Escanaba
Truck 4	6	Norway, Sagola, Sawyer, L'Anse, Escanaba	Norway, Sawyer, Escanaba, Hermansville	
Truck 5	5	Norway, Sagola, Sawyer, L'Anse, Escanaba	Norway, Sawyer, Escanaba,	

Figure 50: Mill Proximity to Loading Locations - Round II

The table in figure 50 reveals that even though there are many mills located in close proximity of the loading and log yard facilities, some of the loaded and unloaded movements were over 50 miles in length, especially movements to the mill at Escanaba. It should be mentioned that saw mills (Channing, Baraga, Hermansville, and Atlantic Mine) have not been considered as alternatives for chip trucks, since they don't have demand for chip and residue material. The ability of trucks to make their next load after unloading from a site within 50 miles of the mill could reduce the unloaded miles, but in reality the selection of a mill by any given truck is mostly an interaction between the demand of log/chip species (ordered by the mills), and location of supply in the harvesting sites. Therefore, recommendations made purely on a distance factor would have little relevance to the daily operations and supply chain management.

5.3.9 Unloading at the Mills

After the loading process, the unloading at mills has been recognized as one of the most time-consuming processes for trucks. Review of the total unloading time (including waiting) at respective mills is shown in figures 51 and 52. Figure 51 shows the average total time (waiting and unloading) spent in each mill, divided between different periods of day. Total amount of deliveries by participating trucks in any given mill is also presented.

	Time	3-6 am	6-9 am	9-12 pm	12-3 pm	3-7 pm	Total
Norway	Ave. Time (Min)			32.15	29.22	26.67	29.32
	# of truck entries			5	9	5	19
Escanaba	Ave. Time (Min)		30.19	21.76	30.04	31.24	29.86
	# of truck entries		15	6	19	29	69
Sawyer	Ave. Time (Min)	22		31.8	40.9	30.07	30.71
	# of truck entries	1		1	1	4	7
Channing (saw mill)	Ave. Time (Min)			41.4		45.75	44.3
	# of truck entries			1		2	3
L'Anse	Ave. Time (Min)			45.85	53.1		48.27
	# of truck entries			2	1		3
Bessemer	Ave. Time (Min)			48.4		38.9	41.28
	# of truck entries			1		3	4
Ironwood	Ave. Time (Min)				39.5	38.25	38.36
	# of truck entries				1	10	11
Sagola	Ave. Time (Min)			26.9	37.9		32.4
	# of truck entries			1	1		2
Woodruff	Ave. Time (Min)					44.2	44.2
	# of truck entries					1	1
Atlantic Mine (saw mill)	Ave. Time (Min)			44.88	29.68	32.2	36.26
	# of truck entries			4	4	2	10
Baraga (saw mill)	Ave. Time (Min)					58.4	58.4
	# of truck entries					1	1
Hermansville (saw mill)	Ave. Time (Min)			38.2			38.2
	# of truck entries			1			1

Figure 51: Average Time Spent At Mill and Truck Volumes - Round II

Figure 52 represents the summary of average unloading time (in minutes) at each mill in addition to the total number of unloading (or entrance of trucks) in the respective mills. According to the data compiled in figure 52, Escanaba and Norway mills had the most efficient performance by the least unloading time and most entrances of trucks (both chip and log trucks). Also, Sawyer, Sagola, Atlantic Mine, and Ironwood are other mills with acceptable records in terms of unloading time and number of truck entrances. Figure 52 data also indicates that saw mills had a relatively longer unloading time in comparison to the other mills, although the limited number of truck visits to them reduces the statistical reliability of these findings.

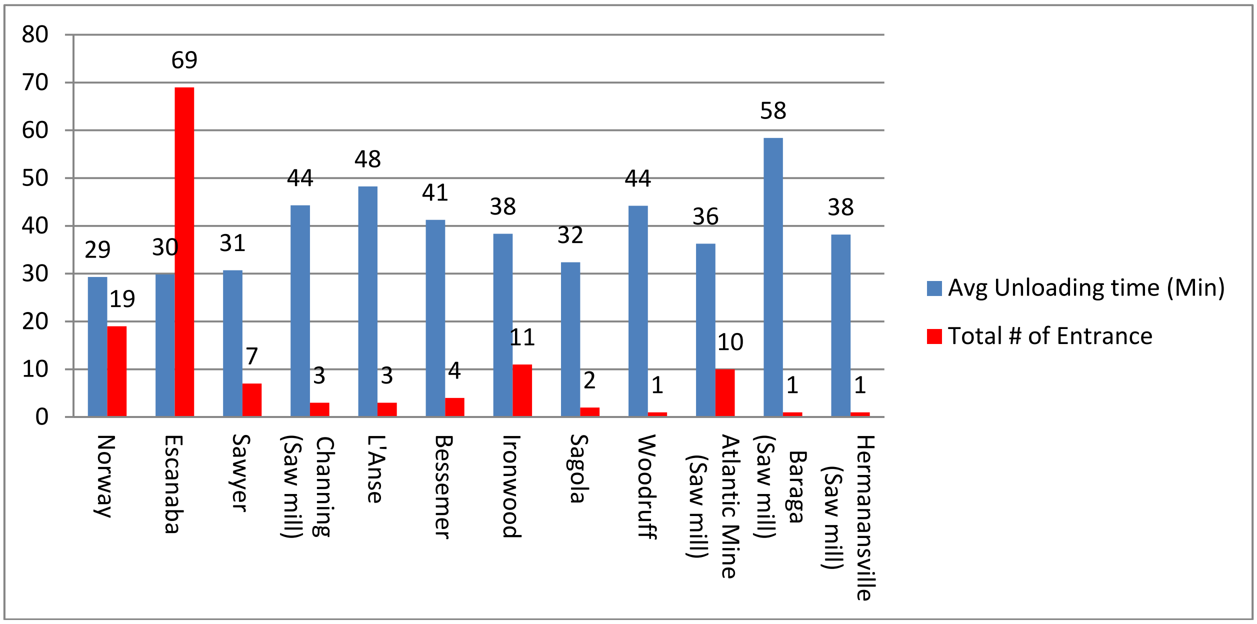


Figure 52: Summary of Mill Performance - Round II

Figure 52 presents the number of times trucks visited each mill and the average time spent for all activities in the mill (including administrative activities, wait time, unloading, and other stops within mill area). For example during the multi week data gathering period in round II trucks entered the Norway mill 19 times and for each entrance spent an average of 29 minutes at the mill.

Since the time of day can affect the truck-mill performance, stops have been divided into five different three-hour time periods from 3:00 a.m. until 7:00 p.m. Trucks 1, 4, and 5 mostly delivered to the mill at Escanaba in the afternoon rather than morning. Based on data, chip trucks (trucks no. 4 and 5) had shorter total waiting and unloading time (13.7 - 29.4 minutes in Escanaba and 22 - 26.4 minutes at Norway mill) than log trucks. Total process time at the major mills (Escanaba and Norway) for log trucks ranged between 34.1 - 48 minutes through both morning and afternoon hours without any particular distribution pattern.

Based on figures 53 and 54, mills located at Norway, Escanaba, Sawyer, and Sagola had the shortest times for total unloading process (about 30 minutes), in comparison to the other mills. Since the research team didn't investigate the operations in the mills, it has refrained from speculating the reasons for differences. A more thorough data collection effort would be required to accurately analyze the unloading performance of each mill.

		Norway		Escanaba		Sawyer		Channing (saw mill)		L'Anse		Bessemer	
	Time	Ave. Time	#	Ave. Time	#	Ave. Time	#	Ave. Time	#	Ave. Time	#	Ave. Time	#
Truck 1 (log)	6-9 am			40.48	10								
	9-12 pm							41.4	1	45.85	2	48.4	1
	12-3 pm			39.64	7	40.9	1			53.1	1		
	3-7 pm			44.82	6			45.6	1				
Truck 2 (log)	9-12 pm	48.05	2										
	12-3 pm	40.1	5										
	3-7 pm	34.1	1									38.9	3
Truck 3 (log)	6-9 am			36.3	1								
	9-12 pm												
	12-3 pm			41.7	1								
	3-7 pm							45.9	1				
Truck 4 (chip)	3-6 am					22	1						
	6-9 am			16.1	3								
	9-12 pm	22	2	18.05	2	31.8	1						
	12-3 pm	23.85	2	13.75	5								
	3-7 pm	23	3	19.53	8	32.03	3						
Truck 5 (chip)	6-9 am			27.9	1								
	9-12 pm	26.4	1	25.47	4								
	12-3 pm	23.7	2	25.07	6								
	3-7 pm	22.9	1	29.38	15	28.1	1						

Figure 53: Summary of Average Truck Unloading Times (minutes) at Mills - Round II

		Ironwood		Sagola		Woodruff		Atlantic Mine (saw mill)		Baraga (saw mill)		Hermansville (saw mill)	
	Time	Ave. Time	#	Ave. Time	#	Ave. Time	#	Ave. Time	#	Ave. Time	#	Ave. Time	#
Truck 2 (log)	9-12 pm			26.9	1			26.7					
	12-3 pm	39.5	1	37.9	1			29.675	4				
	3-7 pm	38.25	10			44.2	1	32.2	2				
Truck 3 (log)	9-12 pm							63.05	2				
	3-7 pm									58.4	1		
Truck 4 (log)	9-12 pm											38.2	1

Figure 54: Mill Unloading Time by Log Truck at Mills (minutes) - Round II

Conclusions

This research effort investigated log and chip truck performance within the Upper Peninsula of Michigan by using passive GPS recorders and driver annotated daily log sheets. The combination of applying driver activity logs and an easy-use passive GPS tracking device helped the research team accurately evaluate the types and purposes of truck delays. The GPS devices provided a low cost alternative for data collection and performed well over the research period.

The outcomes were consistent during both rounds of data collection and demonstrated significant similarities between log truck and chip truck operation. For instance, the daily hours of operations and the distribution between stops, loaded and unloaded movements were almost the same. The outcomes also validated several issues that have been anecdotally discussed by forest products companies, such as the fact that significant time is spent loading wood at the harvesting sites and unloading wood at the mills. Both of these activities are optimized by others leaving the trucking community with extended waiting times.

The research team found that stop time for loading and unloading, for both log and chip trucks averages 40-50% during a daily operation. If truck companies or drivers can reduce the duration of stop times, there may be the opportunity to improve the truck running time which means more productivity, more daily miles and more revenue. One potential alternative to reduce the loading time could be use of pre-loaded trailers for chips, or staged cut logs piled at the roadside for log trucks. The unloading time may be reduced by applying modern cranes and machines at the mills, power plants, or at rail sidings. Extended wait times at the mills might be reduced if appointments were used to facilitate truck flows. Unloading times for chip trucks were significantly shorter than log trucks, due to modern innovations such as truck tippers. Modernized unloading equipment and heavy cranes might also improve the log truck unloading times. A more detailed evaluation of truck wait times at mills should also be investigated, as the small sample size of this research reduced its usability for such analysis.

Reduced idling provides the greatest potential for immediate cost savings for both log and chip truck operators. Simply turning off the engine, or using new technologies to reduce the idling time would reduce the fuel consumption and lead to significant annual savings, especially considering the price of fuel. The analysis showed that each dollar increase in fuel price adds $600 - $700 in idling costs annually. While it is not certain that operational modifications to reduce idling are acceptable for all truck companies, the high returns would certainly warrant additional analysis. A detailed idling fuel consumption test of Michigan log trucks would especially help to accurately define the actual fuel burn rate during idle operation.

The limited number of log/chip trucks didn't allow the research team to focus on optimization through shared loading locations between different log transport companies. Pooled dispatching or other methods to coordinate transportation between multiple loggers and land owners have potential to reduce total transportation miles, especially empty mileage generated by the “one truck to one land owner” model used to serve many logging sites across the Upper Peninsula of Michigan. With the GPS devices used in the research, it would be realistic to conduct another study with a larger truck sample to identify potential optimization opportunities.

The economic considerations are some of the best motivators for log companies and shippers to improve their productivity. Future projects should focus more on the economic aspects of the business by reviewing the productivity of trucks (such as $/loaded ton-mileage) as well as conducting feasibility studies and cost-revenue analysis for different transportation alternatives. If rate and cost information was readily available, an economic analysis of truck productivity and transportation costs would provide a useful insight on how to organize the work interfaces between independent parties.

Increasing productivity is dependent on the cooperation of truck drivers, especially independent owner-operators. During interviews (appendix 1.4 and 3.11) the drivers listed what they believed to be basic barriers to increased productivity that were not under their control. These factors, such as weather, may not be under any person’s control but several others including heavy truck traffic at mills and a lack of dispatching in case of difficulties can be addressed. The drivers indicated during interviews that there would be a resistance to systems that reduced their gross revenue as most of them operated with a marginal return on investment. They expressed interest in programs that would be mutually beneficial in reducing the costs and increasing revenue for all participants in the wood products supply chain.

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Appendix

Appendix 1 - Pilot Study

1.1 Pilot Study - Sample Driver Daily Activity Sheet

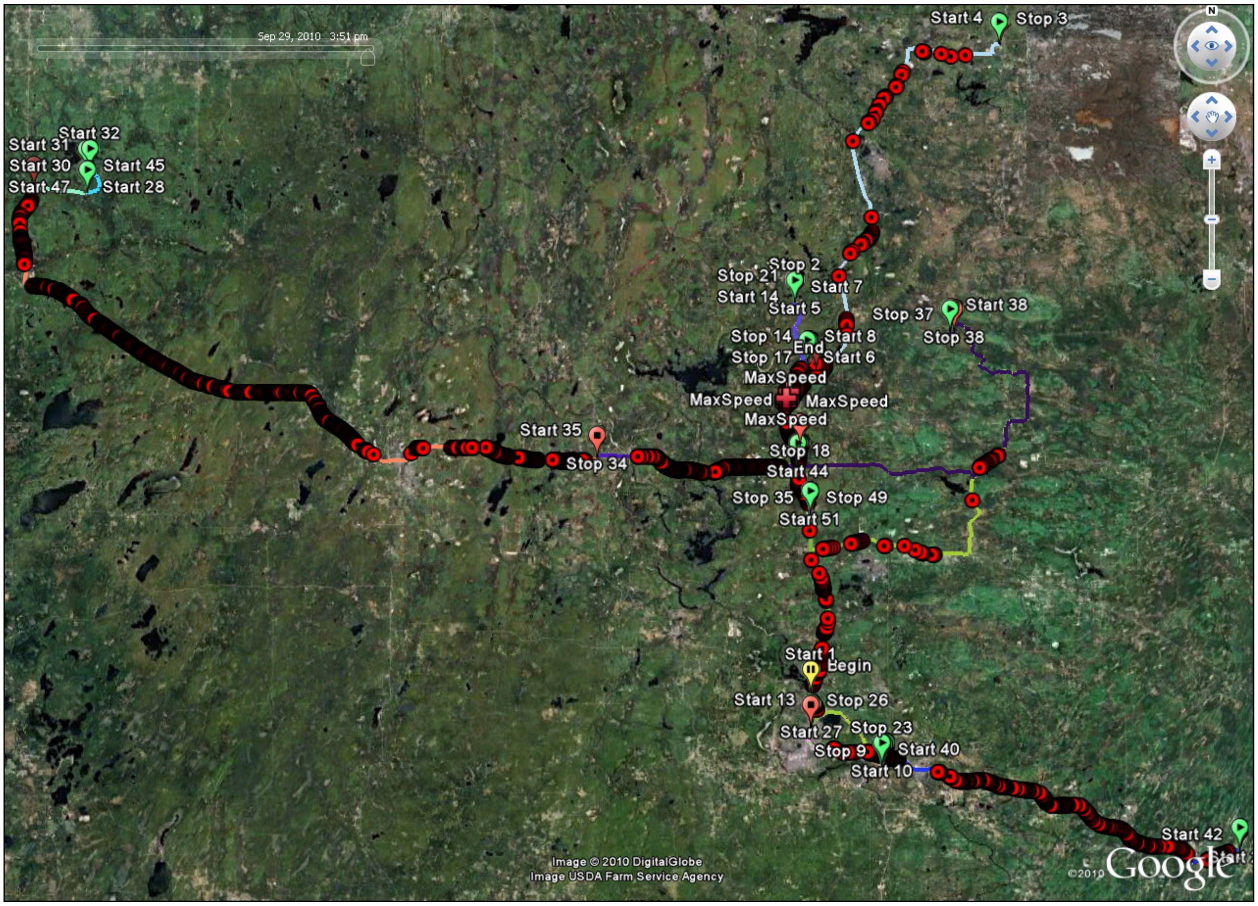
Action Codes:

~~1: Start to move,~~ 2: Stop for loading, 3: Stop for unloading, 4: Stop for something else,

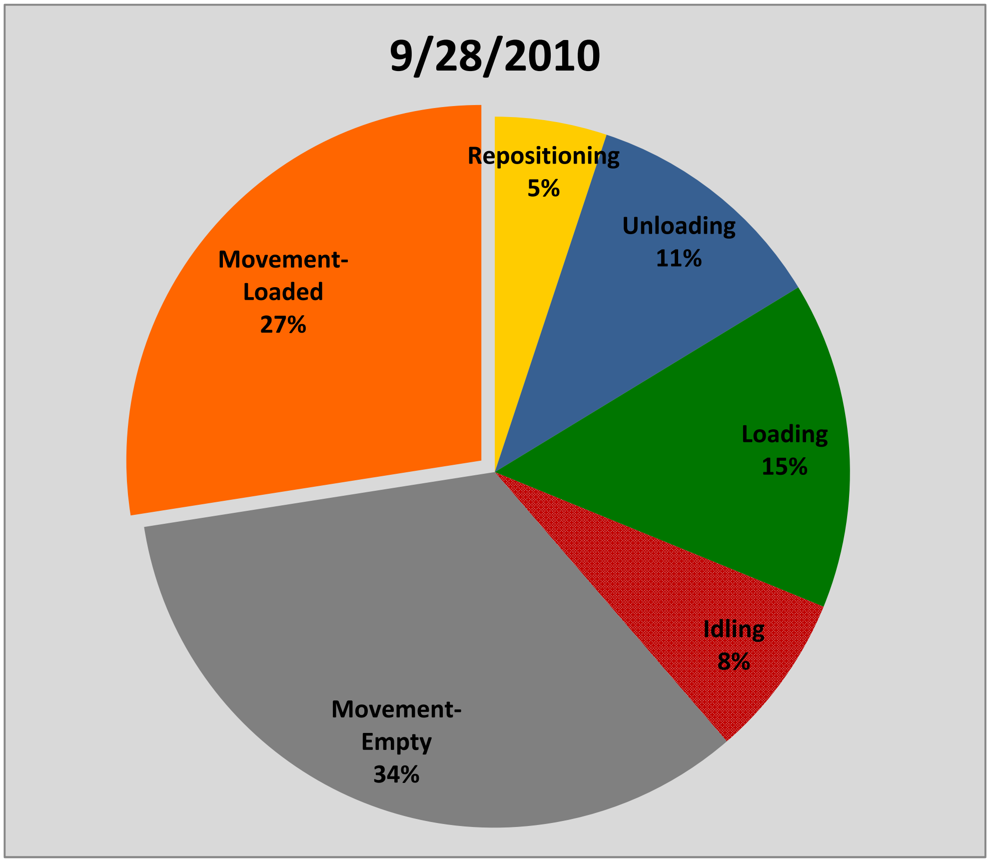
Date 9-28	Fuel consumption: 160

Time, (hh:mm)	Action code	Description (If 2 or 3, please insert the net tonnage; If 4, stop for something else, please describe the reason)	Engine off (✓)
2.40	1		
2.54	4	Coffie	
3.27	1		
3.52	4	meeting a truck	
3.55	1		
3.58	4	on Hook PuP	
5.26	1		
5 55	2		
6-15	1		
6-39	3	Hock UP Trailer	
7-15	1		
7 35	2		
8-06	1		
8 40	4		
8 47	1		
10-30	3		
11-07	1		
11-14	4	TALK wilt Boss	
11-30	1		
12:45	2		
14:00	1		
15:10	3		
15 20	1		
16	4	Home	✓
		123 gal Faul	
		332 miles	

1.2 Snapshot of Trucking Pilot Study (Google Earth Map)



1.3 Summary of Pilot Study Operational Activities



1.4 Pilot Truck Driver(s) Interview / Notes Summary

- His trucks engine is on all the time even during the stops. Most of the log truck drivers do the same
- There is no stop for lunch.
- Between 10-13 hours daily work
- In average he rides about 300 miles per day
- The fuel consumption is calculated only once per day by checking the truck tank at the start and end of the day
- All the loadings are performed by self-loading hook of his truck, but self-unloading is done only in half of the times.
- His truck model is Kenworth-1995 with empty weight about 59,000 pounds and full gross weight of 175,000 pounds including 2 trailers.
- The power of truck is 550 hp.
- The loading time takes about 30 min for one trailer and 50 min for both trailers,
- The unloading time takes about 20 min in addition to the 5-10 min as cleaning time of the bottom of the trailers.
- Each skidder' price is about $300,000 and by working with one of the skidders, it can provide woods and material for 2-3 trucks per day.
- One skidder can averagely provide 50-60 cords per day and sometimes it can produce logs and wood up to 120 cords/day,
- The main customers of wood log in UP are fire wood and paper industries
- The waiting time at mills for truck weighting is about 30 minutes on average, but rest of the times there is no scale or weighting machine.

Appendix 2 - First Round of Data Collection

2.1 Sample Daily Activity Sheet Provided to Truck Drivers - Round I

MichiganTech

IMPROVING LOG TRANSPORTATION WITH DATA BASED MONITORING AND ANALYSIS IN NORTHERN WISCONSIN AND UPPER PENINSULA OF MICHIGAN

UNIVERSITY of WISCONSIN Superior — Wisconsin's Leading Public Liberal Arts College

(Please mention each stop which is more than 5 minutes)

Truck Driver name:	**Date:**	**Fuel consumption during a day:**
Terry Jackson	10/10/2010	70 gal

Time *(hh:mm)*	Stop for loading (✓)	Stop for unloading (✓)	Detach pup (✓)	Hook up pup (✓)	Stop for gas/diesel (✓)	Coffee break (✓)	Stop for something else *(Please explain briefly)*	Engine off (✓)
3:20	✓							
3:55					✓			
4:45		✓						
6:15			✓					
7:00						✓		✓
8:40	✓							
10:40							Talking to customer	
12:30		✓						
1:15 pm		✓						
1:50 pm				✓				
2:45 pm							Home	✓

2.2 Sample of a Daily Activity Sheet Filled by One Driver of Round 1

MichiganTech

IMPROVING LOG TRANSPORTATION WITH DATA BASED MONITORING AND ANALYSIS IN NORTHERN WISCONSIN AND UPPER PENINSULA OF MICHIGAN

UNIVERSITY of WISCONSIN Superior
Wisconsin's Leading Public Liberal Arts College

(Please mention each stop which is more than 5 minutes)

Truck Driver name:	Date:	Fuel consumption during a day:
Meyer	10-25 10	

Time *(hh:mm)*	Stop for loading (✓)	Stop for unloading (✓)	Detach pup (✓)	Hook up pup (✓)	Stop for gas/diesel (✓)	Coffee break (✓)	Stop for something else *(Please explain briefly)*	Engine off (✓)
8:55							✓ put in log stakes	
9:30							✓ Leave shop	
10:30	✓							
10:45	✓							
10:52	✓							
11:07	✓							
11:25	✓							
11:48							✓ STOP AND WAIT FOR	
							Skidder to push up mud Hill	
11 50							✓ Stop to hookup	
12:00	✓						to Skidder (Beach sand)	
12:10	✓							
1211	✓							
1220	✓							
1225	✓							
1241							✓ Check chains	
1:30							✓ Chains	
2:05								✓

2.3 GPS Device (Trine XL) Instructions Provided to Companies

Instructions for using GPS units and steps of implementation

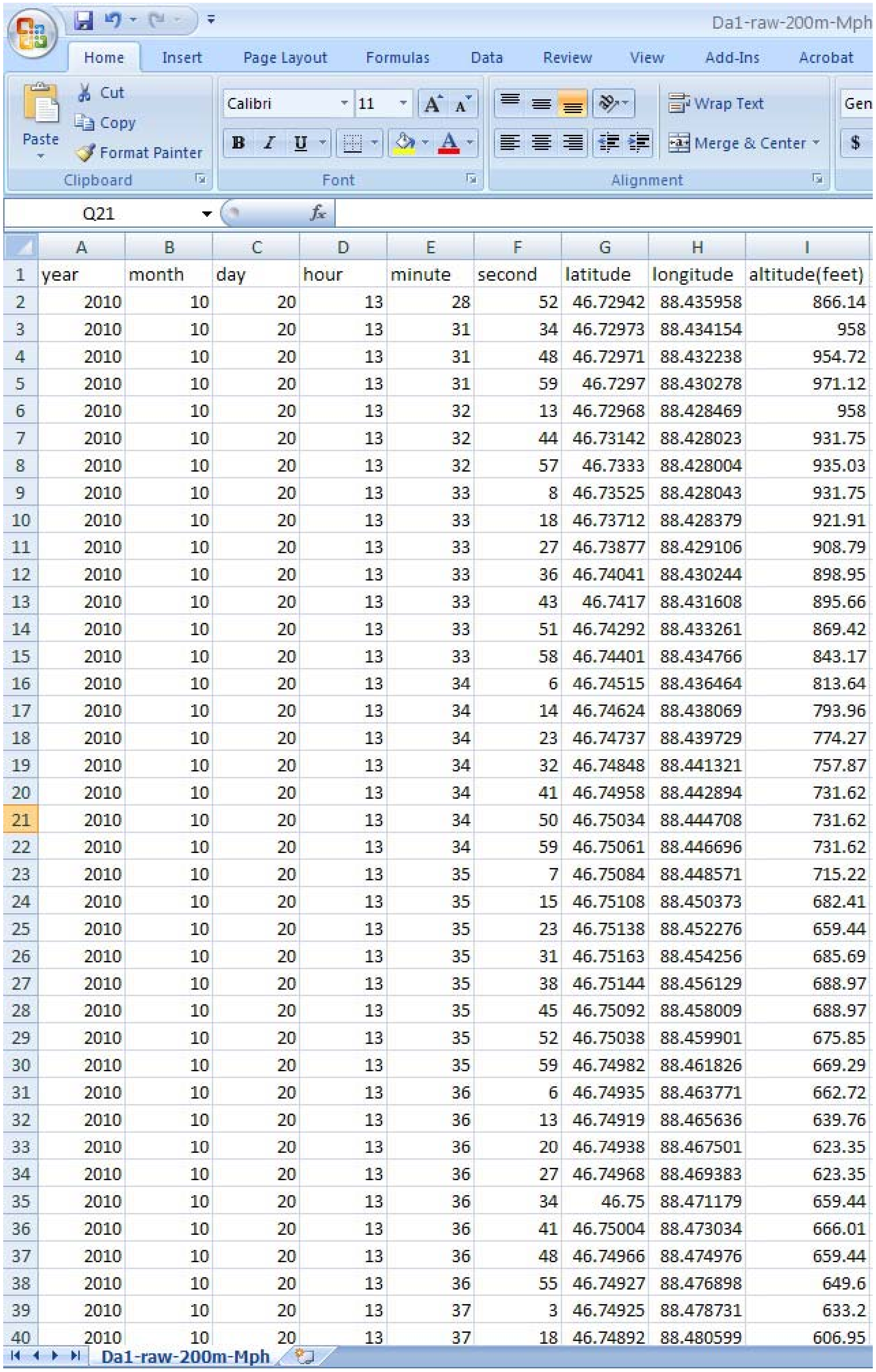
1. When receiving the units from Michigan Tech take one unit with a charger to each truck. Take the data sheets to each truck as well.
2. Attach the unit to the charger with a charging cable
3. Attach the charger to the cigarette lighter

4. Turn the GPS unit on by sliding a little button on the side of the unit
5. Attach the unit firmly under the windshield with Velcro fastener but do not attach it near the heating system
6. Every few hours check that the green light in the unit is on/flashing and the charger is fully attached to the cigarette lighter
7. Do not detach the unit from the cigarette lighter
8. Do not detach any parts of the GPS unit
9. Do not turn the unit off once it has been turned on
10. Fill the data sheet according to the instructions provided to collect information from the trips

IF YOU HAVE ANY PROBLEMS OR QUESTIONS, PLEASE CALL HAMED AT

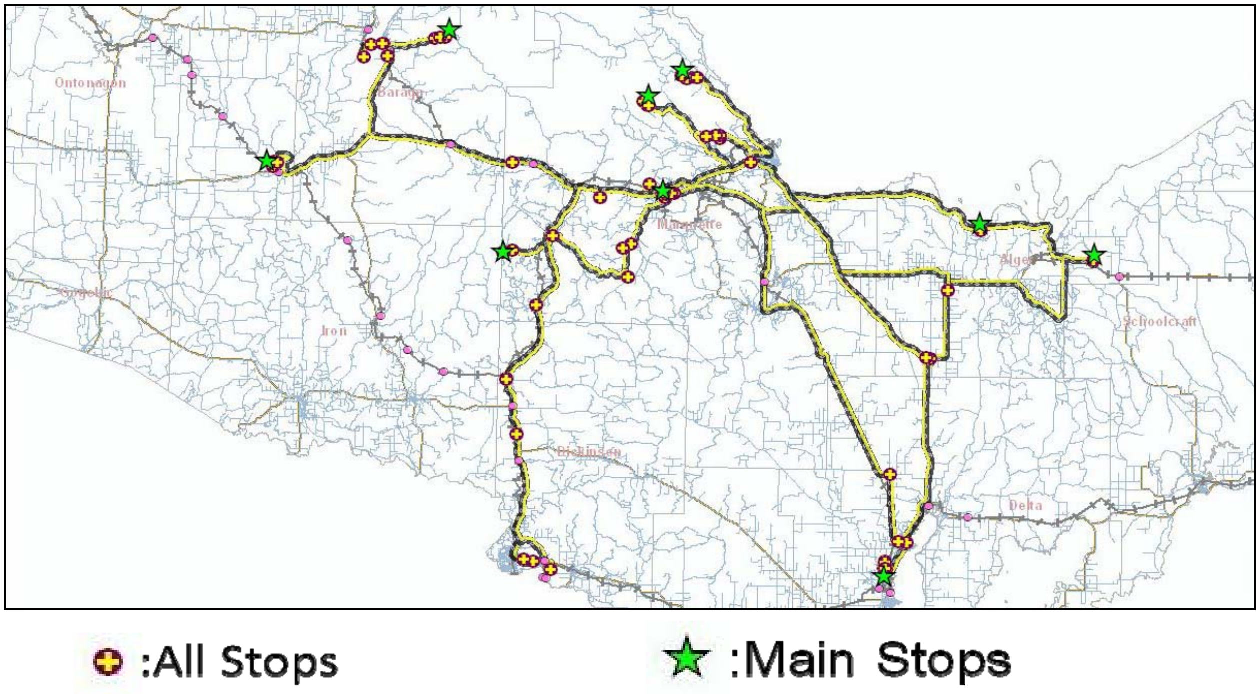
THANK YOU FOR PARTICIPATING IN THE PROJECT. WE REALLY APPRECIATE IT!

2.4 Snapshot of Raw Data Obtained from GPS Units

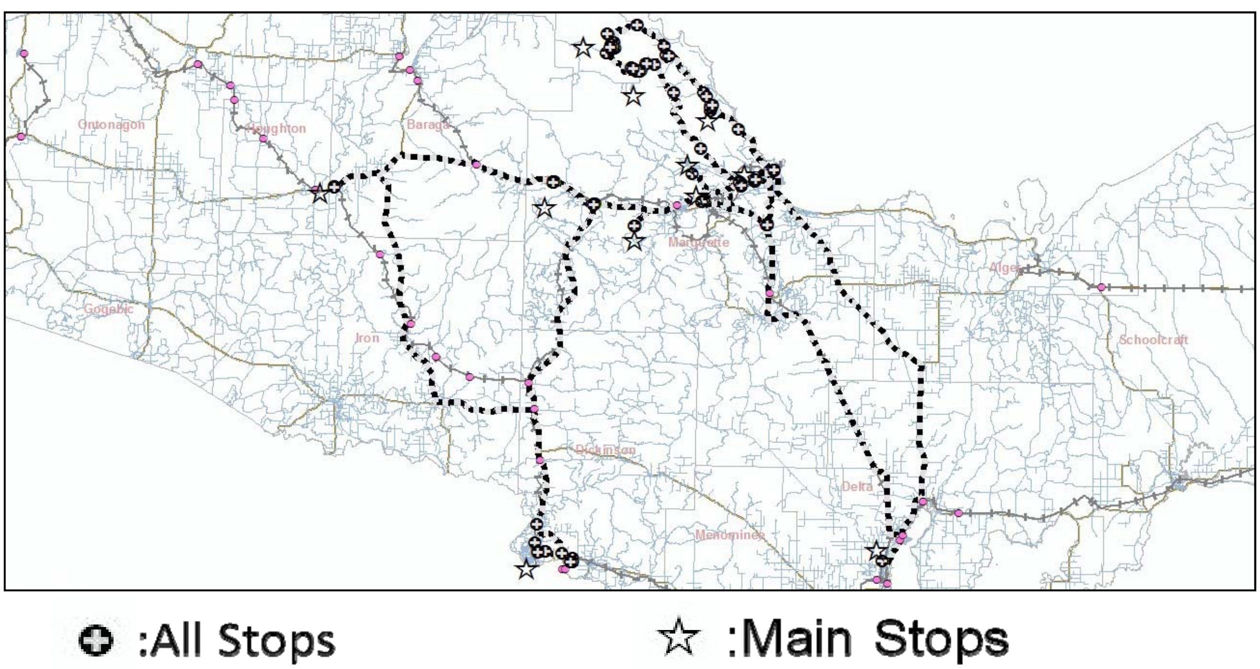


	A	B	C	D	E	F	G	H	I
1	year	month	day	hour	minute	second	latitude	longitude	altitude(feet)
2	2010	10	20	13	28	52	46.72942	88.435958	866.14
3	2010	10	20	13	31	34	46.72973	88.434154	958
4	2010	10	20	13	31	48	46.72971	88.432238	954.72
5	2010	10	20	13	31	59	46.7297	88.430278	971.12
6	2010	10	20	13	32	13	46.72968	88.428469	958
7	2010	10	20	13	32	44	46.73142	88.428023	931.75
8	2010	10	20	13	32	57	46.7333	88.428004	935.03
9	2010	10	20	13	33	8	46.73525	88.428043	931.75
10	2010	10	20	13	33	18	46.73712	88.428379	921.91
11	2010	10	20	13	33	27	46.73877	88.429106	908.79
12	2010	10	20	13	33	36	46.74041	88.430244	898.95
13	2010	10	20	13	33	43	46.7417	88.431608	895.66
14	2010	10	20	13	33	51	46.74292	88.433261	869.42
15	2010	10	20	13	33	58	46.74401	88.434766	843.17
16	2010	10	20	13	34	6	46.74515	88.436464	813.64
17	2010	10	20	13	34	14	46.74624	88.438069	793.96
18	2010	10	20	13	34	23	46.74737	88.439729	774.27
19	2010	10	20	13	34	32	46.74848	88.441321	757.87
20	2010	10	20	13	34	41	46.74958	88.442894	731.62
21	2010	10	20	13	34	50	46.75034	88.444708	731.62
22	2010	10	20	13	34	59	46.75061	88.446696	731.62
23	2010	10	20	13	35	7	46.75084	88.448571	715.22
24	2010	10	20	13	35	15	46.75108	88.450373	682.41
25	2010	10	20	13	35	23	46.75138	88.452276	659.44
26	2010	10	20	13	35	31	46.75163	88.454256	685.69
27	2010	10	20	13	35	38	46.75144	88.456129	688.97
28	2010	10	20	13	35	45	46.75092	88.458009	688.97
29	2010	10	20	13	35	52	46.75038	88.459901	675.85
30	2010	10	20	13	35	59	46.74982	88.461826	669.29
31	2010	10	20	13	36	6	46.74935	88.463771	662.72
32	2010	10	20	13	36	13	46.74919	88.465636	639.76
33	2010	10	20	13	36	20	46.74938	88.467501	623.35
34	2010	10	20	13	36	27	46.74968	88.469383	623.35
35	2010	10	20	13	36	34	46.75	88.471179	659.44
36	2010	10	20	13	36	41	46.75004	88.473034	666.01
37	2010	10	20	13	36	48	46.74966	88.474976	659.44
38	2010	10	20	13	36	55	46.74927	88.476898	649.6
39	2010	10	20	13	37	3	46.74925	88.478731	633.2
40	2010	10	20	13	37	18	46.74892	88.480599	606.95

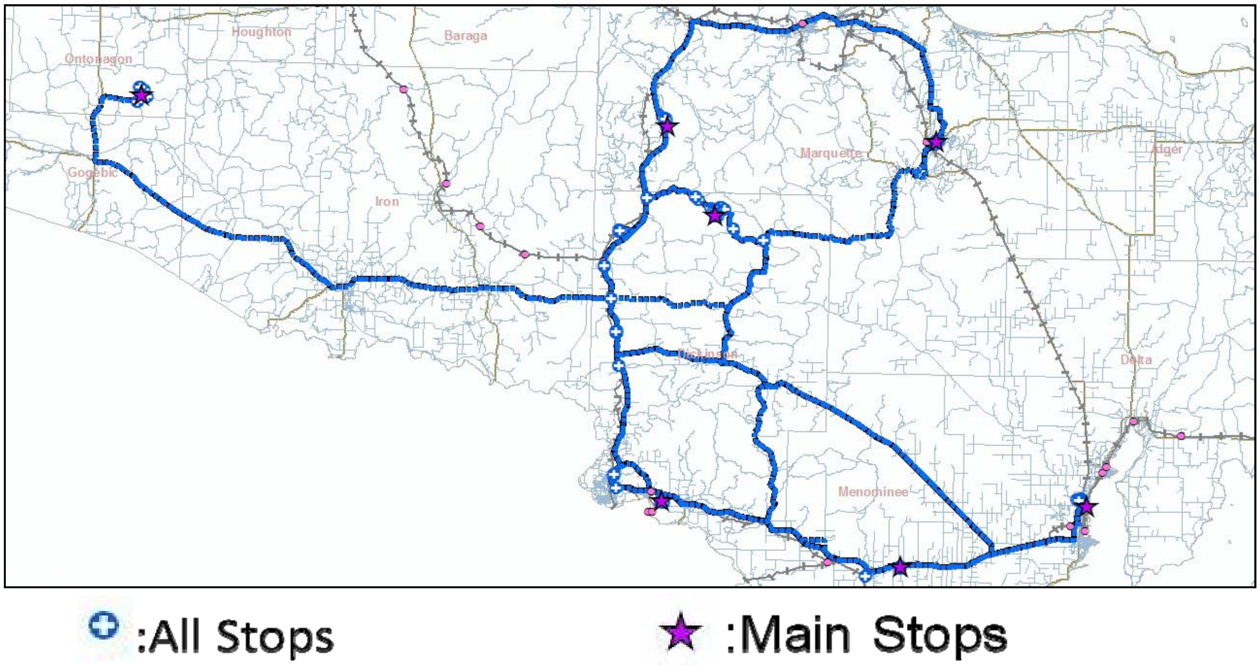
2.5 GIS Map Showing All Movements and Stops of Truck 1 (Company A)



2.6 GIS Map Showing All Movements and Stops of Truck 5 (Company B)



2.7 GIS Map Showing All Movements and Stops of Truck 8 (Company C)



Appendix 3 - Second Round of Data Collection

3.1 Sample Daily Activity Sheet Provided to Drivers - Round II

MichiganTech

IMPROVING LOG TRANSPORTATION WITH DATA BASED MONITORING AND ANALYSIS IN NORTHERN WISCONSIN AND UPPER PENINSULA OF MICHIGAN

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(Please mention each stop which is more than 5 minutes)

GPS unit number:	Date:	Fuel consumption:
TR1	1/17/2011	85 gal (provide only on days when truck refueled)

Stop time *(hh:mm)*	Loading site Arrive (✓)	Depart (✓)	Unloading Mill (✓)	Rail (✓)	Other (✓)	Paper work & waiting (✓)	Technical issue (✓)	Fuel (✓)	Stop for something else *(Please explain briefly)*	Engine off (✓)
4:45	✓									
5:50		✓								
7:10						✓				
7:25			✓							
7:45						✓				
8:15									Coffee break	✓
9:00	✓									
10:20		✓								
10:50							✓			✓
11:30						✓				
11:50				✓						
12:20pm						✓				
1:00 pm								✓		✓

3.2 Sample of a Daily Activity Sheet Filled Out by One Driver - Round II

MichiganTech

IMPROVING LOG TRANSPORTATION WITH DATA BASED MONITORING AND ANALYSIS IN NORTHERN WISCONSIN AND UPPER PENINSULA OF MICHIGAN

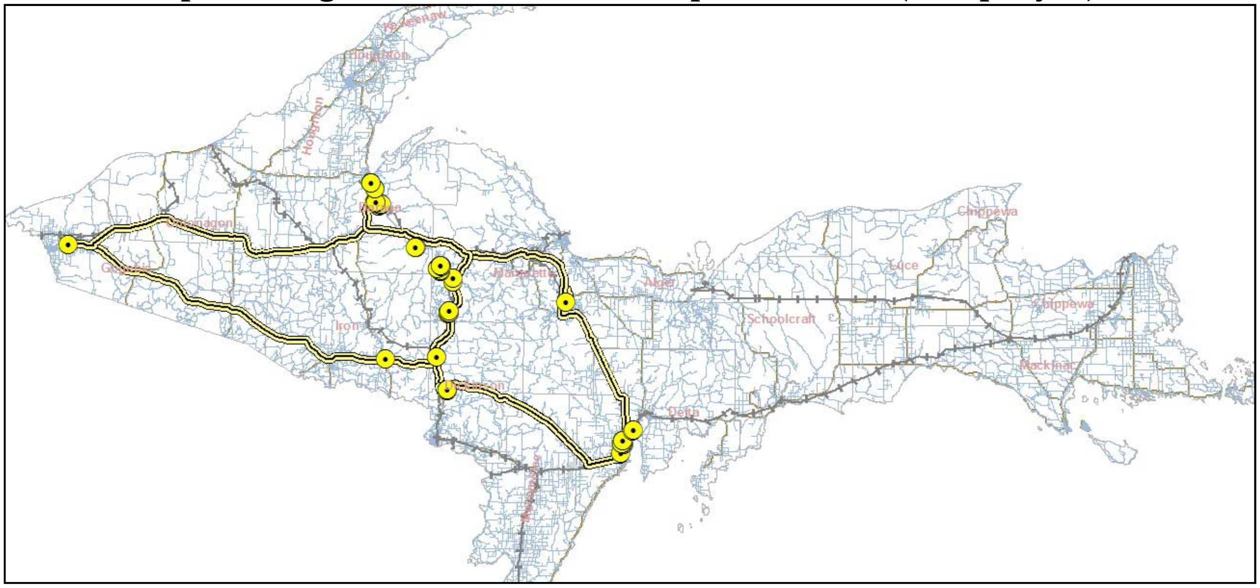
UNIVERSITY of WISCONSIN Superior

(Please mention each stop which is more than 5 minutes)

GPS unit number:	Date: 2/24/11	Fuel consumption (please mark gallons at each fueling):

Stop time *(hh:mm)*	Loading site Arrive (✓)	Loading site Depart (✓)	Unloading Mill (✓)	Unloading Rail (✓)	Unloading Other (✓)	Paper work & waiting (✓)	Technical issue (✓)	Fuel (✓)	Stop for something else *(Please explain briefly)*	Engine off (✓)
6:50								✓		
9:30	✓									
10:30		✓								
11:15			✓							
12:00	✓									
1:00		✓								
1:45			✓							
2:45	✓						✓		wait for a truck to move out	
4:00		✓								
6:39					✓					
7:30										✓

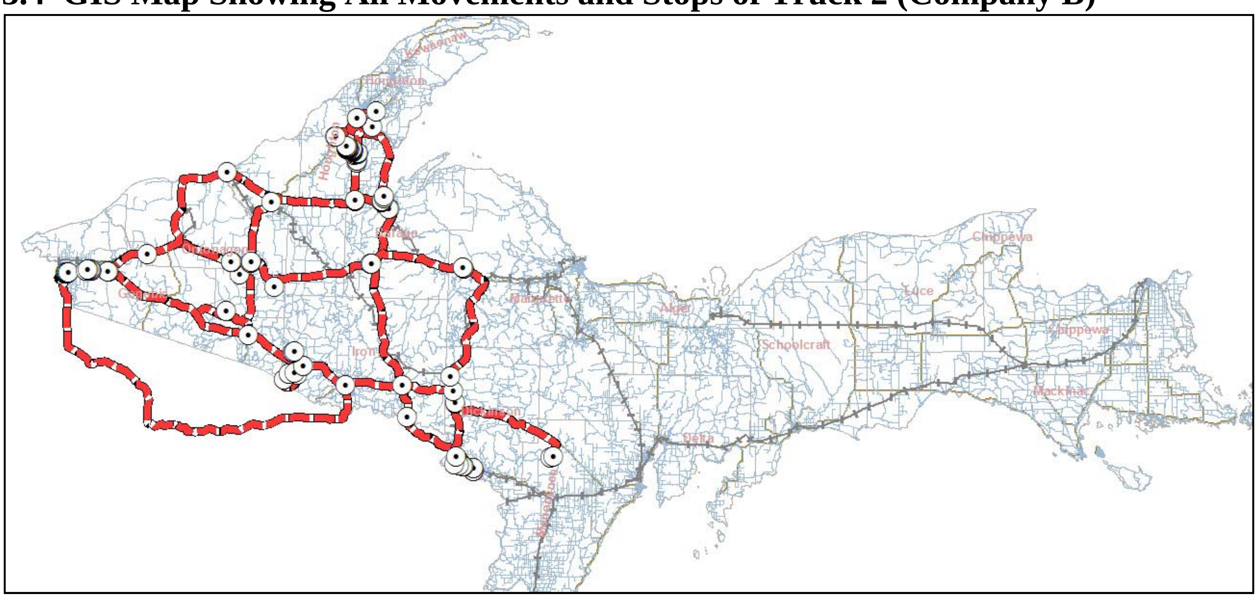
3.3 GIS Map Showing All Movements and Stops of Truck 1 (Company A)



Truck 1 - Company A

(Total Mileage: 5812.8 mi;   Average Mileage/day : 252.7 mi)

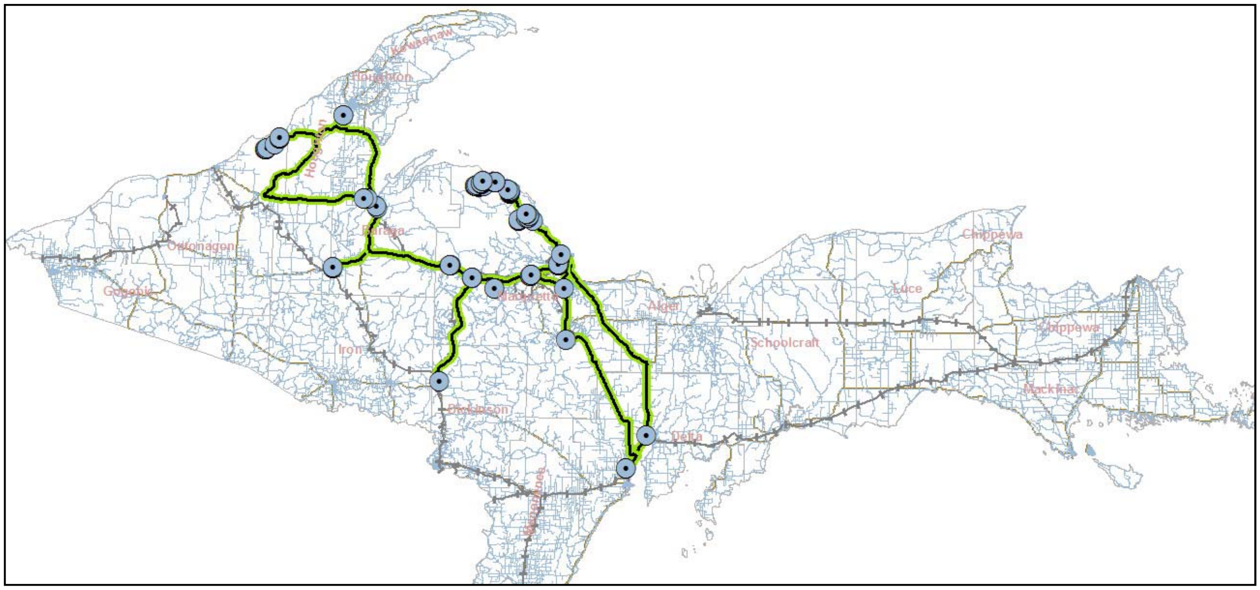
3.4 GIS Map Showing All Movements and Stops of Truck 2 (Company B)



Truck 2 - Company B

(Total Mileage: 5969.2 mi;   Average Mileage/day : 284.2 mi)

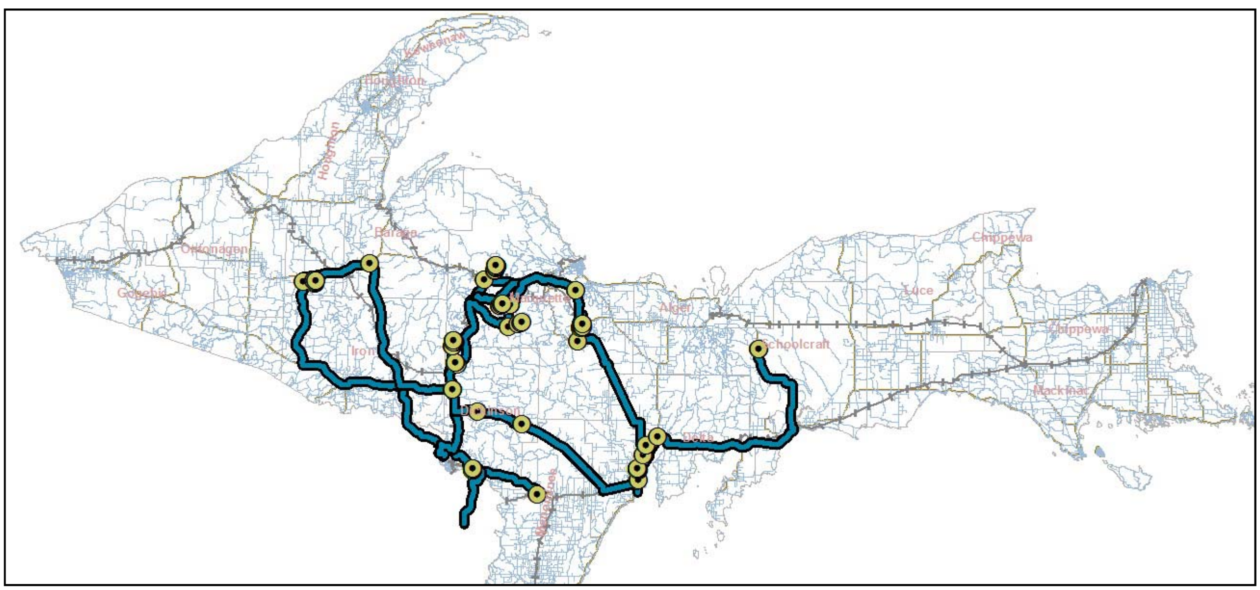
3.5 GIS Map Showing All Movements and Stops of Truck 3 (Company B)



Truck 3 - Company B

(Total Mileage: 3715.1mi; Average Mileage/day : 232.2 mi)

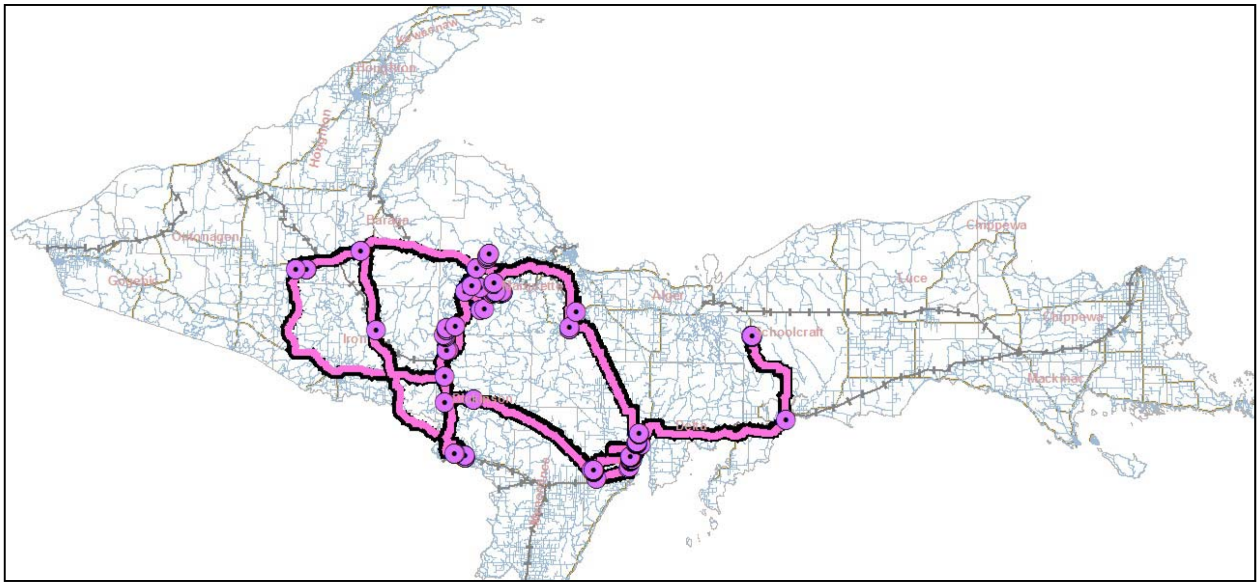
3.6 GIS Map Showing All Movements and Stops of Truck 4 (Company C)



Truck 4 - Company C (Chip Truck)

(Total Mileage: 4990.3mi; Average Mileage/day: 311.9 mi)

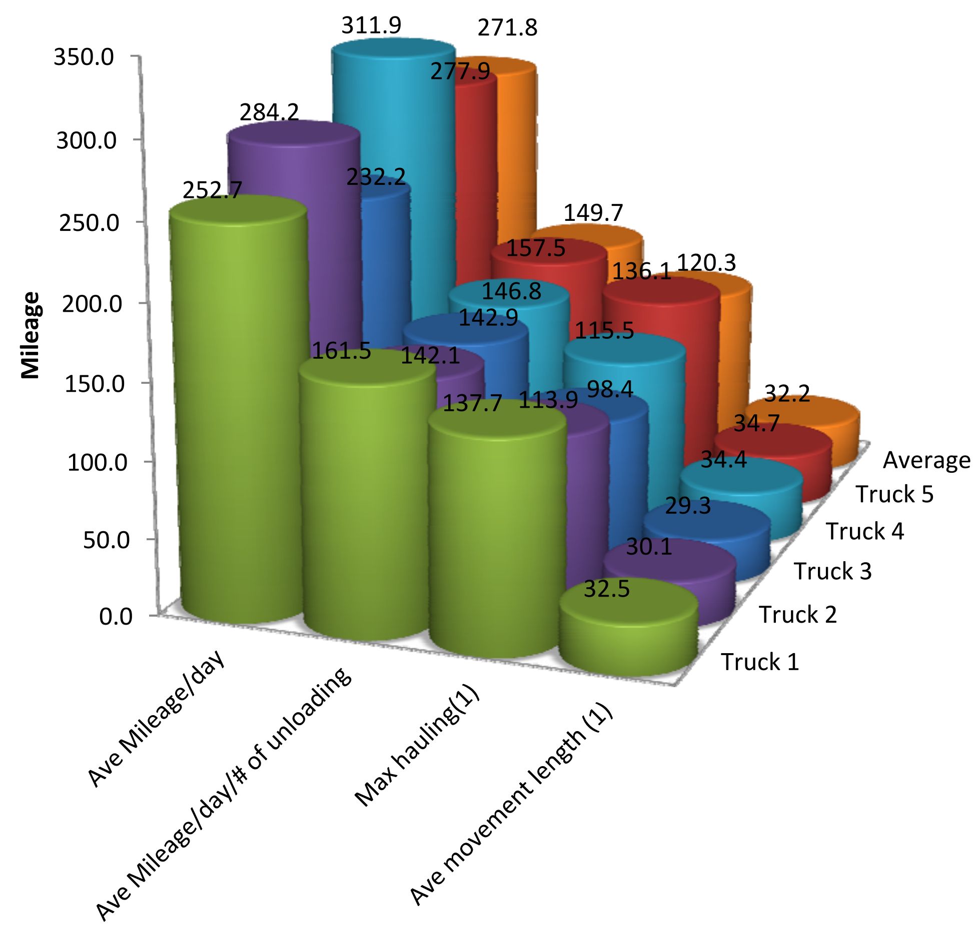
3.7 GIS Map Showing All Movements and Stops of Truck 5 (Company C)



Truck 5 - Company C

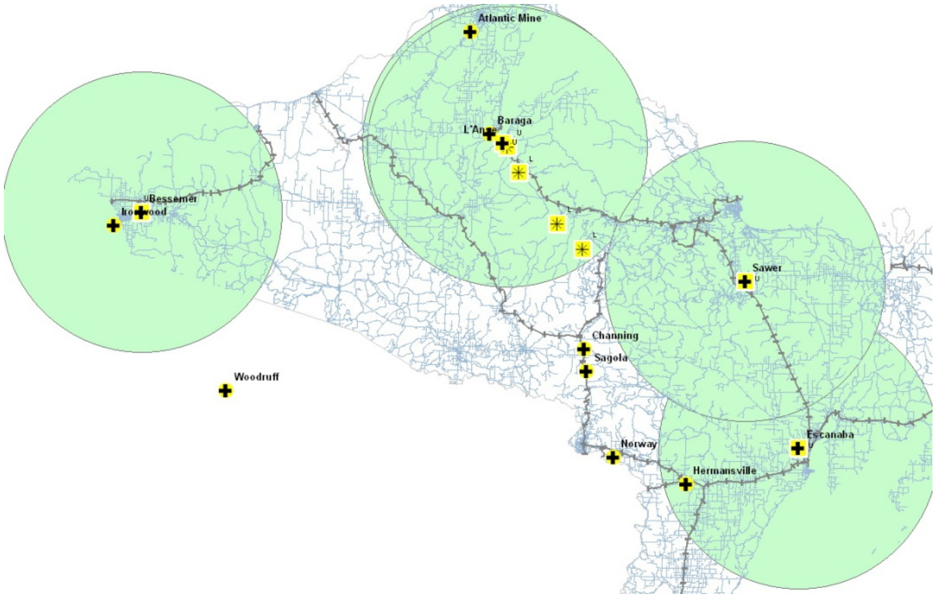
(Total Mileage: 4725.1mi;   Average Mileage/day: 277.9 mi)

3.8 Comparison of Mileage Records between all Trucks in Round II



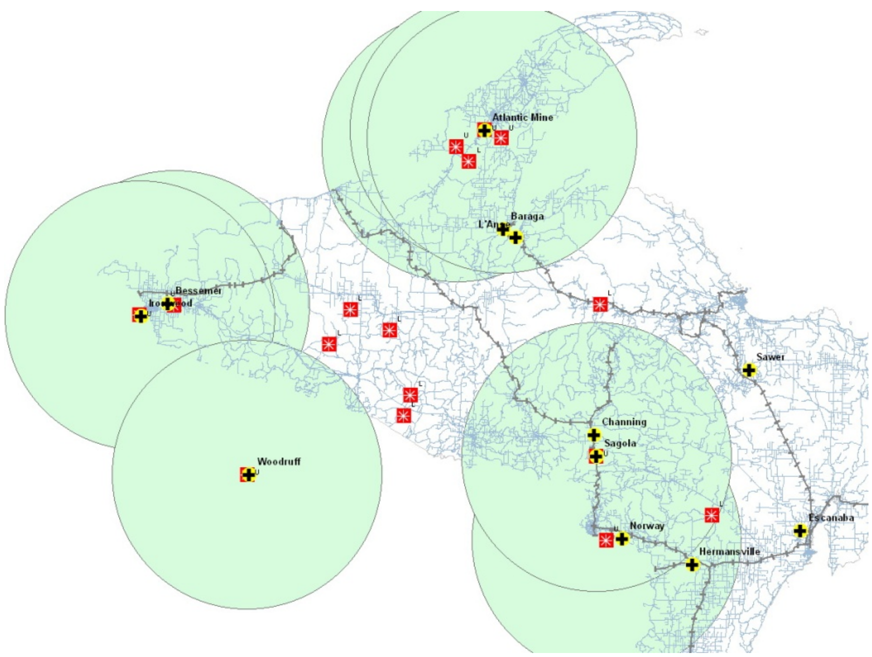
(1) : Individual Movement without any stop

3.9 Distribution Map of Mills Served Round II Data Collection Truck 1 (Company A)



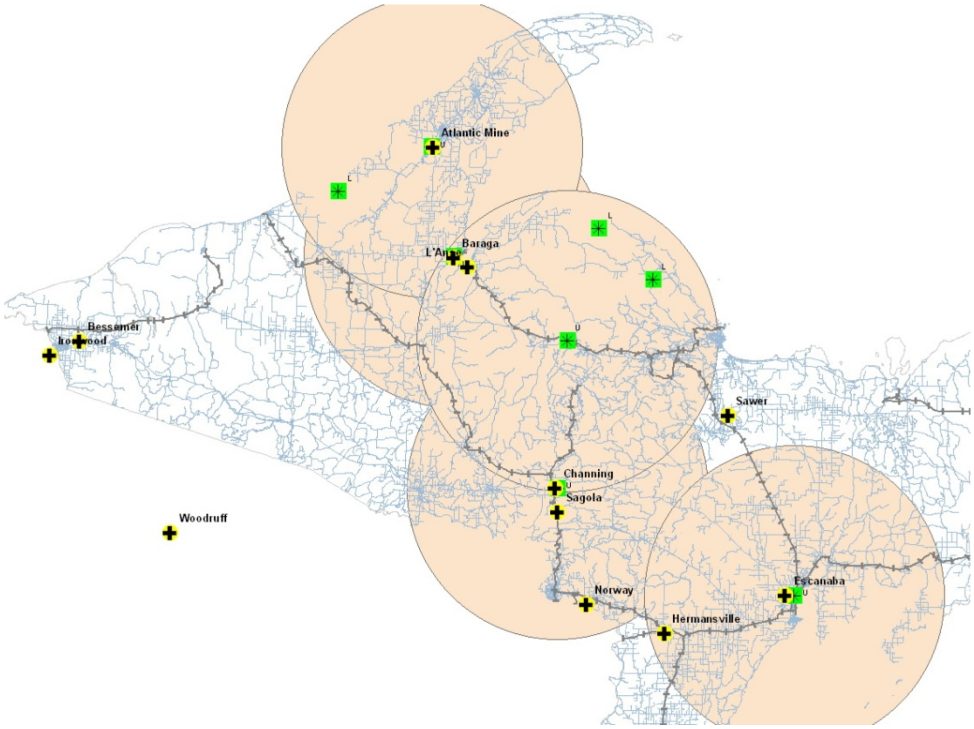
(Unloading locations of Truck 1 have been marked by 30 mi radius buffers)

Truck 2 (Company B)



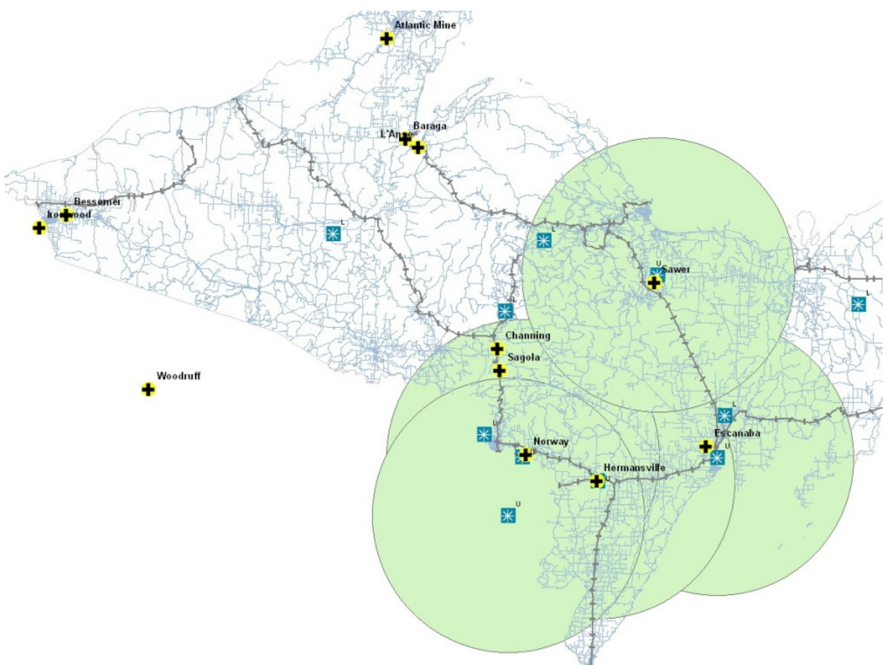
(Unloading locations of Truck 2 have been marked by 30 mi radius buffers)

Truck 3 (Company B)



(Unloading locations of Truck 3 have been marked by 30 mi radius buffers)

Truck 4 (Company C)



(Unloading locations of Truck 4 have been marked by 30 mi radius buffers)

3.10 Partial Sample of Load Ticket of Truck 5

Date	Ticket	Mill	Job	Job #	Specie	Load
1/31/11	50750	NewP	G&G	B-06	Bandit	28.37
2/1/11	230397	Verso	G&G	B-06	Bandit	30.30
2/1/11	51023	NewP	G&G	B-06	Bandit	29.15
2/2/11	230541	Verso	G&G	B-06	Bandit	26.64
2/2/11	51273	NewP	G&G	B-06	Bandit	27.14
2/3/11	230728	Verso	G&G	B-06	Bandit	24.90
2/3/11	51524	NewP	Black River	G-02	Bandit	37.91
2/4/11	51611	NewP	Black River	G-02	Bandit	38.88
2/4/11	51679	NewP	Black River	G-02	Grinder	42.05
2/4/11	51720	NewP	Black River	G-02	Bandit	35.21
2/7/11	231428	Verso	G&G	B-06	Bandit	27.13
2/7/11	52019	NewP	Black River	G-02	Grinder	40.53
2/8/11	231700	Verso	G&G	B-06	Bandit	25.70
2/8/11	232108	Verso	G&G	B-06	Bandit	28.06
2/9/11	232231	Verso	G&G	B-06	Bandit	28.19
2/10/11	52694	NewP	Black River	G-02	Grinder	40.10
2/10/11	52769	NewP	Garrett	B-07	Bandit	32.35
2/11/11	52967	NewP	Black River	G-02	Grinder	35.07
2/14/11	53185	NewP	Black River	G-02	Bandit	38.04
2/14/11	53311	NewP	Black River	G-02	Grinder	35.67
2/15/11	53427	NewP	Black River	G-02	Bandit	32.46
2/15/11	53554	NewP	Black River	G-02	Bandit	32.02
2/16/11	53822	NewP	Black River	G-02	Bandit	35.21
2/19/11	54288	NewP	Black River	G-02	Grinder	37.45
2/19/11	54338	NewP	Black River	G-02	Bandit	31.20
2/21/11	54454	NewP	Golf Course	B-08	Bandit	43.67
2/21/11	54505	NewP	Golf Course	B-08	Bandit	48.67
2/21/11	54549	NewP	Golf Course	B-08	Bandit	38.80
2/22/11	54688	NewP	Golf Course	B-08	Bandit	41.64
2/22/11	54718	NewP	Golf Course	B-08	Bandit	41.62
2/22/11	54790	NewP	Golf Course	B-08	Bandit	46.71

3.11 Summary of Interviews with Truck Drivers – Round II

Truck Driver #3 (Log Truck)

- Doesn't have power saw, loading process takes longer due to need to sort logs by length.
- Operates the truck between harvesting and logs yard usually every day.
- Typically never does any paperwork in the log yards.
- The daily schedule is defined by the dispatcher.
- The truck driver only gets paid hourly.
- Pup trailers are never detached.
- Sometimes another guy with a moving crane helps him to unload logs inside the log yards. Assisted unloading takes about half-time compared to his self-unloading times.
- Fuels truck every 2-3 days at a public gas station, no fuel purchase program.
- Driver doesn't own the truck and never takes truck home. Driver picks up the truck at the log yard and drives to the site located about 70 miles far away from log yard.
- Daily work is determined the day of the job due to weather and cutting schedule.
- Signs and symbols are painted on the logs to show the type of the logs and loading, unloading and destination of the logs for driver identification.
- Truck engine is never turned-off during the day, only turned off during night hours.
- Trucks idle between 10-30 minutes each morning to warm up, actual time depends on the weather conditions and temperature.
- There is a scale in the log yard that is used for heavy loads.
- Truck weight(lbs.): 83,000 (full), 43,000 (empty)
- Trailer weight(lbs.): 74,000 (full), 17,000 (empty)

Truck Driver #4 (Chip Truck)

- Trips are usually less than 100 miles.
- The forest roads near loading sites can be sometimes difficult to drive.
- If the weather conditions are bad there is usually another vehicle at site to assist.
- It can be hard to move on forest roads during or after a heavy snow fall.
- The basic unloading process for chip trucks consists of following steps: arriving at the mill, wait for scale, scale load, actual unloading (tipping), scale empty truck, leaving the mill. In addition to actual operations there is a lot of required movement inside the mill between the operations. Tipping takes the longest time. Waiting times vary a lot.
- Log trucks may have several small unloading sites for one truck load. Chip trucks, on the other hand, are always completely unloaded at one site, usually at a mill.
- This driver did not consider hooking up a loaded pup as a loading process because he did not actually load the trailer himself.
- Chip trucks are usually loaded using a grinder but this time the driver had to use a front end loader which ended up being quite tricky and time consuming. The loader could not properly reach over the high trailer which is why they had to build a temporary “dirt ramp” out of wood chips to be able to do the job.
- According to the driver loading a trailer using a grinder usually takes about 40 minutes. Using a front end loader and the self made “dirt ramp” it took 2.5 hours to load the two trailers. However, loading a trailer using a front end loader without having to create a self made ramp is considerably faster than even the grinder.
- According to the driver loading a trailer takes about 20 minutes using a front end loader in good conditions.
- Some of basic problem which hamper the logging process are, according to the driver:
    - waiting times
    - breakdowns
    - heavy truck traffic at mills
    - poor quality forest roads and
    - dispatching system in case of sudden difficulties

3.12 Round II - Truck Activity Photos

3.12.1 Chip truck during unloading activity at mill (Photo by J. Vartiainen, Feb. 11)

3.12.2 Inside of a chip truck prior to loading (Photo by J. Vartiainen, Feb. 11)

3.12.3 Loading the chip truck by using a front-end loader. A temporary chip pile beside the truck is used to help the loader reach over the truck lip (Photo by J. Vartiainen, Feb. 11)

3.12.4 Log truck loading trailer (Photo by H. Pouryousef, Feb. 11)

3.12.5 Log piles in one of the mid-size mills in UP (Photo by H. Pouryousef, Feb. 11)

CFIRE

University of Wisconsin-Madison
Department of Civil and Environmental Engineering
1410 Engineering Drive, Room 270
Madison, WI 53706
Phone: 608-263-3175
Fax: 608-263-2512
cfire.wistrans.org