ANALYZING LOG AND CHIP TRUCK PERFORMANCE IN THE UPPER PENINSULA OF MICHIGAN WITH GPS TRACKING DEVICES

University of Wisconsin-Superior
Paper No. 02-22:1

National Center for Freight & Infrastructure Research & Education
College of Engineering
Department of Civil and Environmental Engineering
University of Wisconsin, Madison

Authors: Pasi Lautala, Ph.D.; Hamed Pouryousef; Richard Stewart, Ph.D.; Libby Ogard; and Janne Vartiainen
Michigan Tech. University, Houghton MI; University of Wisconsin-Superior, Superior, WI.

Principal Investigator: Richard Stewart, Ph.D.
Chair, Department of Business and Economics, University of Wisconsin-Superior

Analyzing Log and Chip Truck Performances in the Upper Peninsula of Michigan with GPS Tracking Devices

Pasi Lautala. Ph.D., PE
Research Assistant Professor, Civil and Environmental Engineering, Director, Rail Transportation Program, Michigan Tech Transportation Institute,
318 Dillman, Dept. of Civil and Env. Engineering, Michigan Tech. University,
1400 Townsend Dr, Houghton, MI 49931, Tel: 906-487-3547, ptlautal@mtu.edu

Hamed Pouryousef
PhD Candidate, Civil and Environmental Engineering, 824 Dow Michigan Tech. University, 1400 Townsend DR, Houghton, MI 49931, Tel: 906-231-2320, hpouryou@mtu.edu

Richard Stewart, Ph.D, CTL
Director, Transportation and Logistics Research Center) Professor,
Department of Business and Economics, Erlanson Hall 5, University of Wisconsin-Superior,
Superior, WI 54880, Tel: 715-394-8547, rstewart@uwsuper.edu

Libby Ogard
President, Prime Focus LLC, MBA, DBE/WBE
918 Fox River Drive, De Pere, WI 54115
Tel: 920-217-7222, ogard@comcast.net

Janne Vartiainen
Undergraduate Research Assistant, Rail Transportation Program, Michigan Tech. University, 1400 Townsend DR, Houghton, MI 49931, Tel: 906-370-3287, jvartiai@mtu.edu

*** Corresponding Author**

Submitted for Presentation at the 2012 Annual Meeting of the Transportation Research Board
July 31, 2011

Total words = 4,737 + 250*11 (8 Figures + 3 Tables) = 7,487

ABSTRACT

Minimizing transportation costs is essential in the forest products industry, as the relatively low value and high weight of the products causes transportation to account for exceptionally high portion of the overall cost. The Midwest forest products industry competes in a global market, and the region's value proposition is highly dependent on affordable and efficient transportation system. Understanding of system efficiencies requires sufficient data, but while most individual forest products companies collect data on origins and destinations of truck trips, little is known about the actual aggregate movements along the route. One alternative to collect data on 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 is a logical alternative, but the use of such devices has been limited in the forest products industry, partially due to high cost of devices and the carrier's reluctance for centralized dispatching.

The research, sponsored by National Center for Freight & Infrastructure Research & Education (CFIRE), focused on using GPS data recorders on both log and chip trucks operating in the Upper Peninsula of Michigan (UP) and analyzed the data to validate trends and to identify potential improvements and savings. A Trine XL data collector was selected for this research effort because it is inexpensive, easy to use and provides the necessary geospatial information to perform truck movement analysis. Since this GPS system doesn't have real-time tracking capabilities, log sheets were developed for truck drivers to compliment the geospatial data. With combination of GPS data and filled out log sheets, the research team was able to make interpretations of truck movements and activities during stops or idling periods.

This paper presents a brief literature review of past truck tracking studies and alternative GPS devices available for tracking purposes. It introduces the three project steps and reviews the outcomes of the project. The research concluded that there are significant similarities between log and chip truck movements. It also validated the fact that the main hindrance for truck productivity involves numerous truck stops required either for loading or unloading, totaling almost fifty percent of the overall operational time. On the other hand, chip trucks had significantly shorter unloading times when compared to the log trucks and they recorded higher average daily mileage. The research did not identify specific inefficiencies in the actions of truck drivers, but it was recognized that trucks experience extensive idle periods during operations. The sensitivity analysis conducted to identify potential savings from reduced idling suggested that several thousand dollars in fuel savings could be realized by each individual truck annually, if idling could be reduced.

Key Words: Log Transportation, Chip Trucks, Transportation optimization, GPS tracking

1- INTRODUCTION

The increase in global competition and energy prices over the past decade has forced industries to search for potential savings in their transportation supply chains and logistics systems. In the forest products industry minimizing transportation costs is even more crucial, as the relatively low value and high weight of the products cause transportation to account for exceptionally high portion of the overall cost. The Midwest forest products industry is no exception, as it functions in an extremely competitive global market, where most products are a pure commodity with little in the way to differentiate production. Transportation costs may account for almost half of the delivered cost of feedstock (logs) to the mill gate, so the overall health and competitiveness of the industry is highly dependent on affordable and efficient transportation system. [1]

The transportation of forest products is typically provided by two alternative types of trucks, either log trucks for round wood, or chip trucks/vans for chips from round wood branches and logging residues. Historically, little has been known on the actual movements and productivity of either type of truck, as truck monitoring/data collection systems have rarely been implemented in the industry. There is anecdotal evidence to describe the inefficiencies of the system, but lack of quantitative data has been limiting the opportunities to analytically understand the inefficiencies and search for improvements to the system.

The research project made an attempt to collect quantitative data on truck movements that could be further utilized to investigate the movements and activities of both log and chip trucks and to analyze and evaluate the performance of these types of trucks in the Upper Peninsula of Michigan. The research team utilized inexpensive passive GPS recording units to collect the necessary data for analyses. Supplementary data forms were filled by truck drivers during the day to describe reasons for stops or idling. The project was conducted by a cooperative research team from Michigan Technological University, University of Wisconsin- Superior and Prime Focus LLC, with assistance from three forest products companies. The study was funded by National Center for Freight & Infrastructure Research & Education (CFIRE).

This paper reviews past experiences and studies for tracking truck movement and provides a short introduction to different GPS technologies available for tracking truck movements. It will explain the study phases and provide an introduction to collected data. Finally, the paper will review the outcomes of data collection and related analysis, concentrating on potential areas of productivity improvements identified during the study. It will also provide short conclusions and discussion of future research topics for log and chip truck transportation.

2- LITERATURE REVIEW

Scientific research on log and chip truck movements in the US and abroad is fairly limited. According to Lake State Shippers Association (LSSA), one of the key deficiencies of forest products transportation system in the mid-west is the extensive 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. [2] 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, making the transportation system somewhat fragmented. [3] 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 time inefficiencies haven't been investigated with data based approaches. [2]

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 system, user can monitor the vehicle location and its respective features in live environment, typically by logging on to a website or another digital interface like smart phones. [4] Typically, there is a monthly subscription cost for real time tracking system, in addition to the initial purchase price of the unit. Passive tracking systems are GPS units placed inside the vehicle or trailer that collect geographical information of the vehicle movements and store it to an internal memory space to be downloaded later. The passive tracking systems are usually less expensive than real time systems and rarely include monthly subscription cost.

There are various GPS models and commercial brands with different technical and operational specifications which can be used for tracking. A 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. Based on the outcomes, the company was able to address safety concerns and inefficiencies in the driver behavior[5] In another study, University of Washington 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. [6]

3- REVIEW OF AVAILABLE GPS DEVICES

As part of the study, the research team identified alternative brands and GPS devices available for truck monitoring. Table 1 presents a summary of key features of reviewed GPS devices.

TABLE 1 Comparison between different GPS technologies suitable for truck tracking

Brand Name	Passive or Real time	Data collection interval	Data categories	Report format	Communication mode
Insta mapper [7]	Real time	Min. 5 sec Capacity: up to 100k data	Coordinates, altitude, speed, direction	Google Earth (KML) Excel (CSV)	Mobile phone network
Integrate GPS Insight [8]	Real time	Few seconds	Two-way messaging Dispatching status, direction, route	GIS maps, Garmin Nuvi maps, Excel (CSV),	Cell phone or Satellite GPRS, (Garmin Nuvi GPS device is also needed)
m!Trace, m!Truck [9]	Real time	Few seconds	Two-way messaging, status of vehicle, all movements maps, speed, location, date and time	-Dedicated software, map and spreadsheet formats -MS Office	GPS, cell phone network
NetTrack [10]	Real time	Few seconds	Full movements of truck, address, latitude/longitude, speed, direction, spent time and idling time	Enterprise Google Maps, Excel, Word, and Adobe PDF	Either satellite-based or Cellular-based through some service providers like AT&T, Verizon and T-Mobile
RightWay Trine XL [11]	Passive	- Time: 1 sec - Distance: 10’ - Speed: 1 mi/h	Date, time, latitude, longitude, altitude, speed	Google Earth (KML) CSV), NMEA	GPS data via Satellite
Live Trac [12]	Real time	- 20’ or 10 sec - 90 Day Historical Playback	Alarm and messaging Location, Speed, Vehicle mileage, idling,	PDF, HTML, CSV, MS-Word,	Either Satellite GPRS or Cellular (via iPhone and Droid)

4- THE STUDY STEPS AND IMPLEMENTATION PROCESS

The current research included three major steps within one year time frame, as presented in Figure 1. The research steps included (1) selecting GPS technology and performing a pilot test, (2) first round of data collection and analysis, (3) second round of data collection, analysis and conclusions. Each round of data collection and analysis was followed by review and feedback session with participating industry companies and Professional Advisory Committee (PAC).

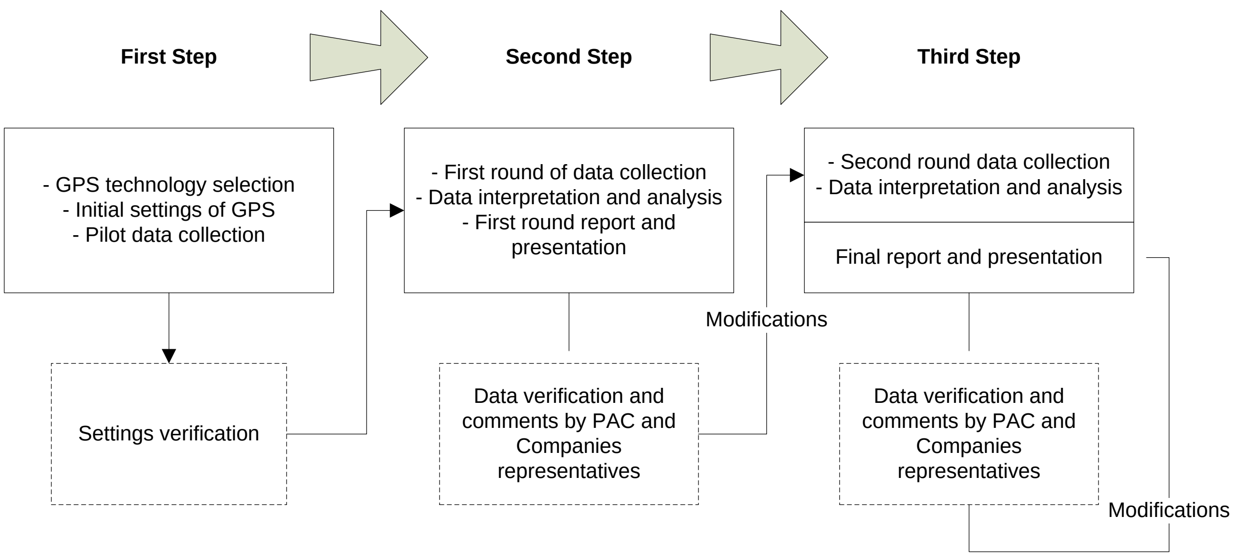


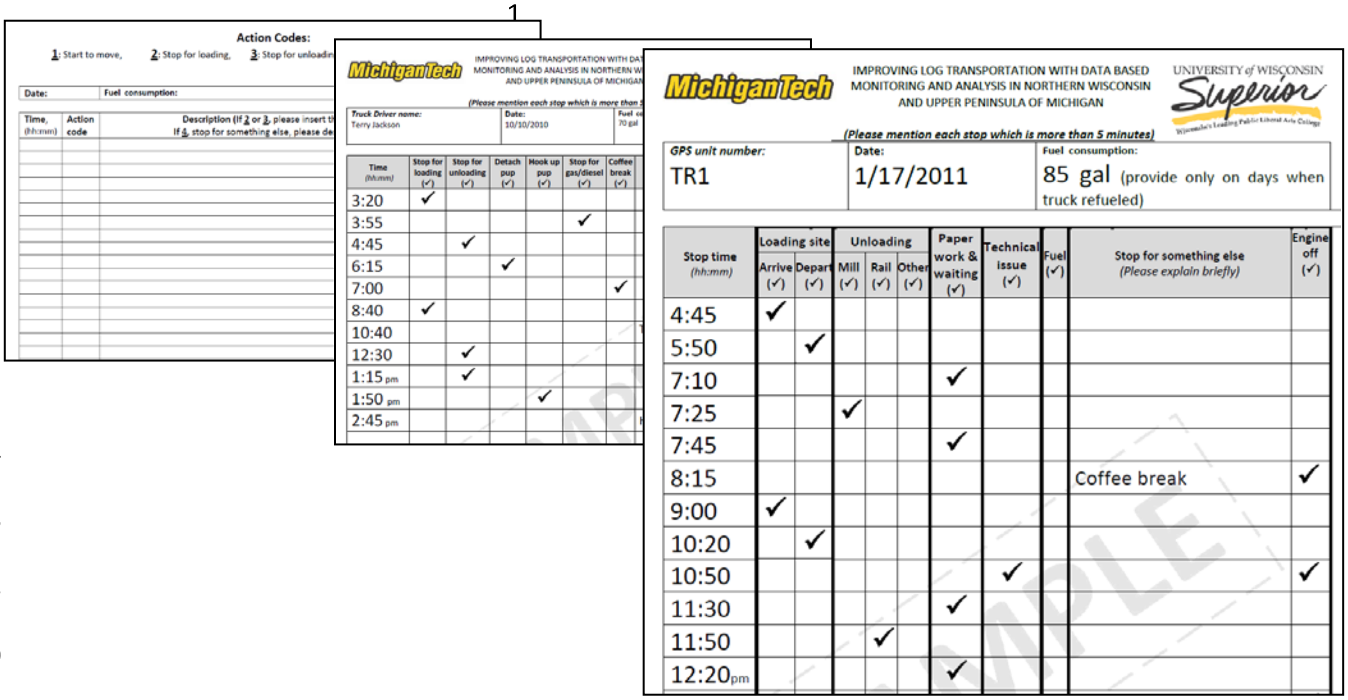
FIGURE 1 Study process

After reviewing alternative GPS technologies RightWay Trine XL GPS technology was selected for the study. The main reasons for the selection included:

- Ease of use and limited requirements for interactions between GPS device and truck drivers. Most log/chip truck drivers are not familiar with digital tools and modern GPS units, which was a concern during the study planning.
- Reliance on satellite coverage rather than cell phone network. Cell phone network coverage is limited in the study area, especially outside main highways.
- Cost. Each individual unit costs only $100, without any subscription or monthly service fee, making it affordable for both research team and participating forest products companies.

4-1- Log Sheet Design and Modifications

After a pilot study was conducted with one log truck, it was recognized that identifying reasons for different truck stops or idling periods would be difficult purely based on data received from the GPS device. A log sheet was developed to provide more information on each major stop and whether the truck was loaded or unloaded during the stop. The research team asked truck drivers to fill up the log sheet and requested their feedback on the input efficiency and ease of use. After each data collection period, the log sheet was modified based on the data analysis, company feedback and driver comments (Figure 2). The final edition of log sheet tried to minimize the time required by utilizing check mark process, but also provided more detailed information of unloading locations of trucks that were divided to mill, rail siding and other categories.



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 (✓)
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						✓				

FIGURE 2 Snapshot of designed log sheets, Left (Pilot round), Middle (1st round), and Right (2nd round)

4-2- Spreadsheet Tools and Google Earth/GIS Maps

The data parameters collected by GPS unit included Date, Time, Latitude, Longitude and Speed. GPS units were able store between 15,000 - 35,000 collected points which was sufficient to collect one month of movement data without intermediate downloads. The analysis of data required importing the raw data to spreadsheet and interpretation of data with assistance from related log sheets. To visualize the truck movements and stop locations, Google Earth was used to facilitate the interpretation and analysis. Figure 3 presents a snapshot of all movements and stops of one truck during one round (month) of data collection, after converting GPS data to a Google Earth format.

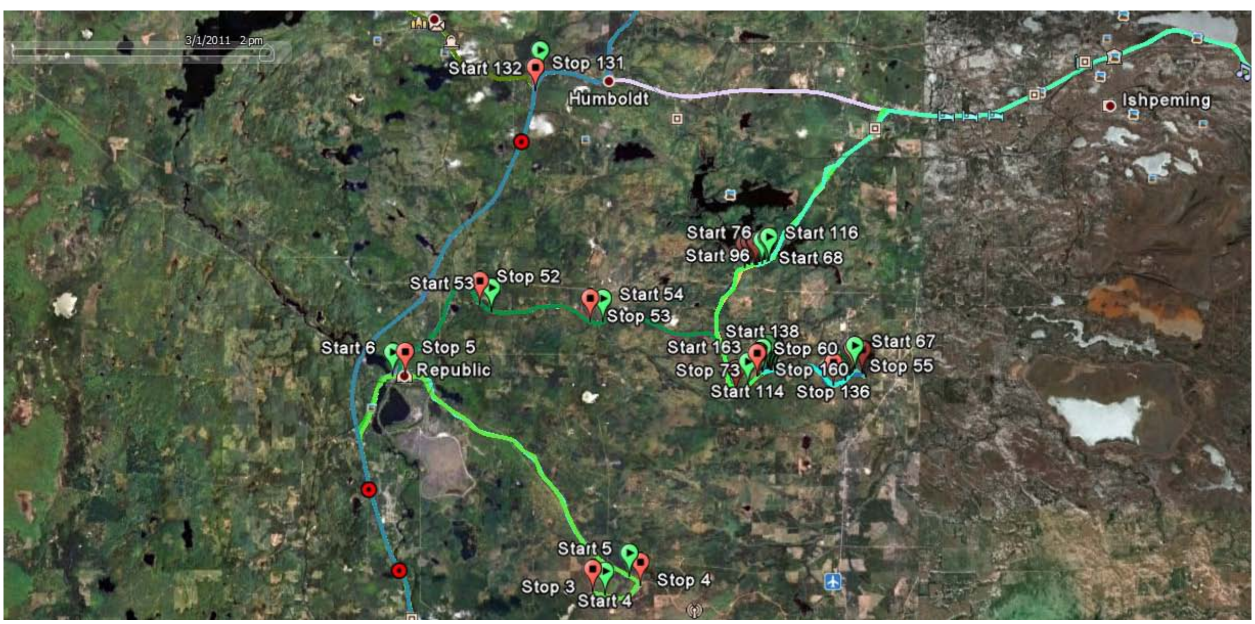


FIGURE 3 Converted GPS data on movements by one truck presented on Google Earth map

5- OUTCOMES OF DATA COLLECTION

Two rounds of data collection were conducted after the pilot run. The first round was completed to identify information and analysis that can be extracted from the data and to examine potential errors in data collection and interpretation. After the first round data was reviewed and analyzed, the second round was conducted to verify the first round outcomes and to investigate additional topics of interest identified by the participating companies, such as more detailed analysis of log/chip truck performance.

5-1- Comparison between Outcomes of First and Second Rounds

Table 2 provides a summary of data collection parameters and some key findings from Round 1 and 2. Three more trucks participated in the first round of data collection, as several truckers did not have interest to continue with experiment (no specific reason was provided by truckers to forest companies). There was also an unplanned change in data recording intervals, as the data collection interval had unintentionally changed from 200 meters (600 feet) to 600 meters (1800 feet). The effect of this to the overall outcomes was investigated by the research team and it was found to have minor effect on the overall accuracy of results. The consistency of chip and log truck performances after both rounds of data collection suggested that the study settings, processing and analysis approaches were set up correctly by the research team. Some of the key similarities between log and chip trucks included average hours of daily operations and the distribution of time trucks spent moving loaded, moving unloaded, or stopped. However, some differences were identified, especially on stopping subcategories. These differences and the comparison between log and chip trucks are discussed in the next section.

Overall, one of most important findings was the fact that 45% of the log trucks operational time is spent stopped. In addition, another 25 % is spent moving unloaded, which means that actual "revenue" activity is only 30% of the overall operational time.

TABLE 2 Comparison between major features of study through first and second rounds

Feature/ Settings		First Round	Second Round
# of participant trucks		6 log trucks, 2 chip trucks	3 log trucks, 2 chip trucks
GPS data collection interval		200 meters (600')	600 meters (1800')
Average # of operation days		16 days	18.6 days
Period of data collection		Oct. 18, 2010 – Nov. 30, 2010	Jan. 31, 2011 – Feb. 26, 2011
Average operating hours (Standard deviation of operation hours)		AVG= 11.1 h (S.D= 2.2 h)	AVG= 11.4 h (S.D= 1.3 h)
Time distribution between movement categories (average for all trucks)		Stops (45%), moving loaded (30%), moving unloaded (25%)	Stops (45%), moving loaded (30%), moving unloaded (25%)
Stopping subcategories (% of all stops)	Loading	46.1%	49.5%
	Unloading	20.1%	20.5%
	Administrative	6.1%	3.3%
	Technical	7.3%	12.9%
	Gas	2.7%	4.3%
	Unknown	15.9%	7.2%
	Others	1.8%	2.3%

Stopping subcategories were defined as follows:

- **Loading**: stops for loading activities (all steps of the process).
- **Unloading**: stops for unloading activities in the mills, rail sidings or other private locations.
- **Administrative**: paperwork, communications with customers or supervisors, and waiting times at the mills and rail sidings, excluding the main unloading actions in the mill or rail locations
- **Technical**: any technical activity, such equipment maintenance, detaching and hooking up pup, chaining tires and clearing obstacles from the road
- **Gas**: refueling the truck at gas stations.

- **Others**: stops that did not match any other category. Those stops included things such as coffee breaks and waiting for other trucks in the woods.
- **Unknown**: all the stops that were not mentioned in the log sheets but were recorded by the GPS units.

5-2- Fuel Consumption during Idling Time

One of the requested research topics during second round was investigation on fuel consumption while trucks were idling, as it was recognized that truck drivers rarely turn the engine off during operating hours. Some of the stops, especially loading and unloading of log trucks require idling to either operate the self-loaders, or to keep them out of the way of mill unloading equipment. However, stops for “administrative” or “other” purposes, usually do not require idling. Some of the technical and unknown stops may require idling, but the analysis in the report assumes the engine could be turned off during these stops.

The Environmental Protection Agency (EPA) has launched several studies about new technologies to reduce the idling time. [13] According to a study conducted by The American Transportation Research Institute the average cost of idling in 2005 was $3.00/hour, average fuel price being $2.40/gal. [14] Based on these numbers, the average fuel consumption rate for idling was calculated to be 1.25gal/h. It was recognized that trucks used in EPA study had probably smaller engines than Michigan log trucks, so the used rate was considered a conservative estimate for the fuel consumption.

According to Energy Information Administration (EIA), the average retail diesel price in Midwest during data collection in February, 2011, was $3.53 per gallon. [15] Figure 4 shows the sensitivity of fuel consumption cost per year due to “non-required idling” based on the estimated idling times and with various fuel price scenarios. Cost of idling is very sensitive to the per gallon retail price of diesel fuel. The investigation reveals that on theoretical level there seems to be opportunities for significant gains by shutting down engines when they are not needed. Increase in fuel price has a great effect on the savings.

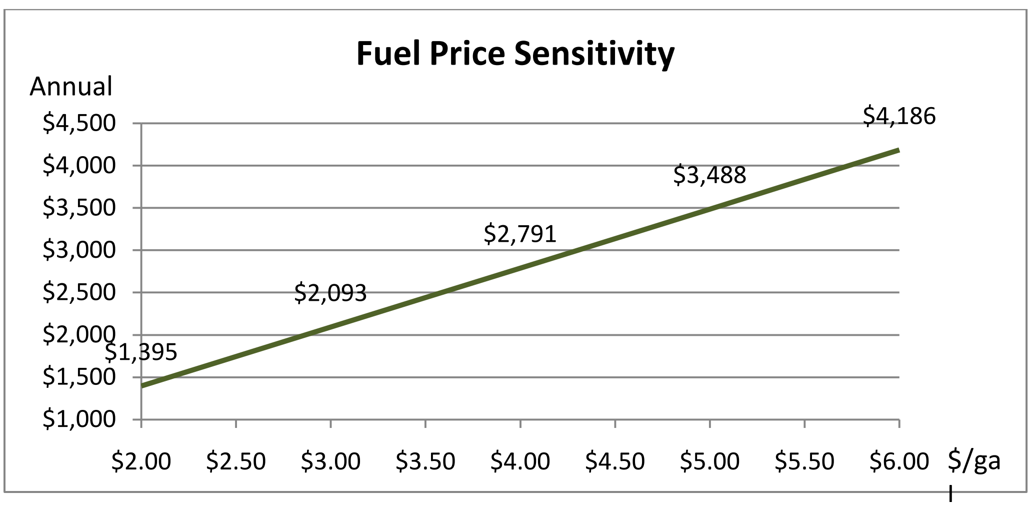


FIGURE 4 Sensitivity of annual fuel cost per truck due to the idling with various fuel prices

6- LOG TRUCK VS. CHIP TRUCK PERFORMANCE

6-1- General Review

After second round of data collection, more detailed analyses were conducted to compare log truck and chip truck performance. The second round data was used for analysis, as more detailed data was collected. Table 3 briefly compares key collected data items for both log and chip trucks.

TABLE 3 General review of collected data split between log trucks vs. chip trucks in second round

Feature	Log Truck	Chip Truck
# of participant trucks	3 log trucks	2 chip trucks
Period of data collection	Jan. 31, 2011 – Feb. 26, 2011	Jan. 31, 2011 – Feb. 25, 2011
Average # of operation days	20 days	16.5 days
Average operating hours (Standard deviation of operation hours)	AVG= 11.8 h (S.D= 1.3 h)	AVG= 10.8 h (S.D= 1.3 h)
Time distribution between movement categories (average for all trucks)	Stops (47%), moving loaded (29%), moving unloaded (24%)	Stops (41%), moving loaded (31%), moving unloaded (28%)

The variation between the average daily hours of operations was almost equal for both types of trucks, but chip trucks operated approximately one hour less per day than log trucks. The chip trucks had lower percentage of stopped time out of total operational time, which suggests better productivity than log trucks. Figure 5 represents details of stop time distribution for both log trucks and chip trucks per day. Chip trucks took shorter stops than log trucks in almost all of stop categories (especially unloading). However chip trucks spent more time, on average, for the administrative stops, probably because of longer stops for paper work due to unloading activities in the mills.

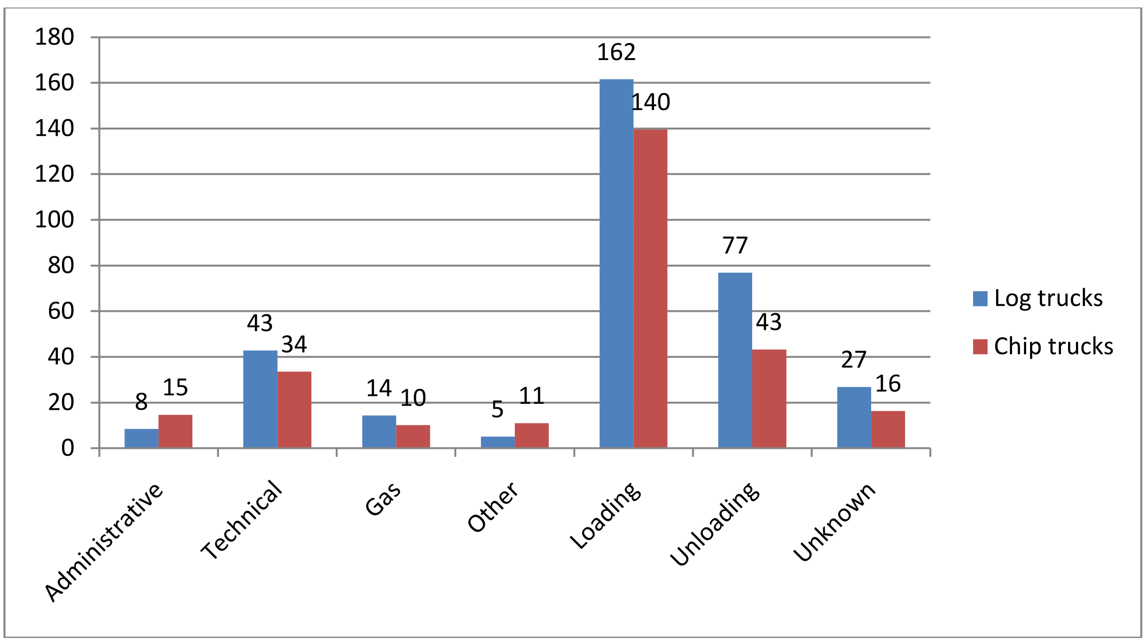


FIGURE 5 Average spent time per day (in minutes) through different categories of stops for log/chip trucks

6-2- Loading/Unloading Analysis

Figure 6 presents all of movements of all five trucks during second round of data collection.

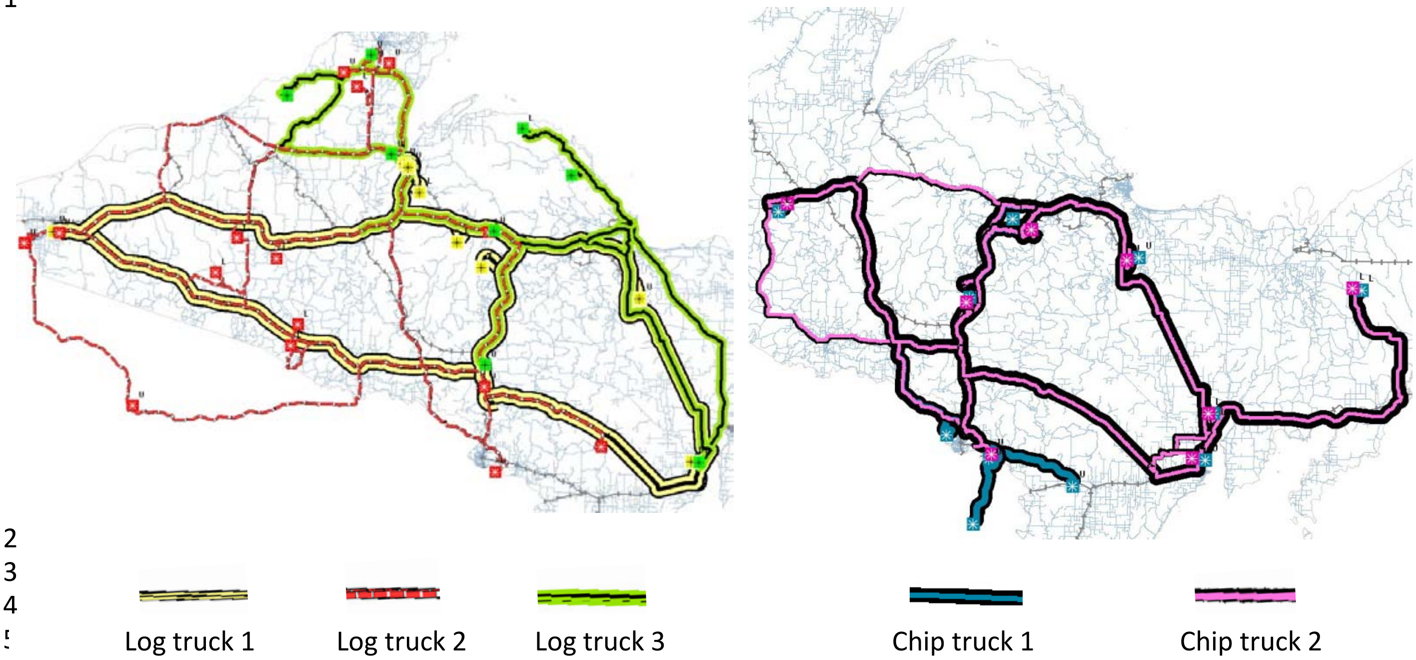


FIGURE 6 Review of all movements of Log trucks (Left) and Chip trucks (Right)-2nd round

Overall, the chip trucks moved more consistently with a homogenous pattern, in comparison to the log trucks, that operated within larger geographic area. There were also fewer loading and unloading locations dedicated for chip trucks in comparison to the log trucks. Figure 7 compares total number and average time spent (in minutes) unloading at different locations.

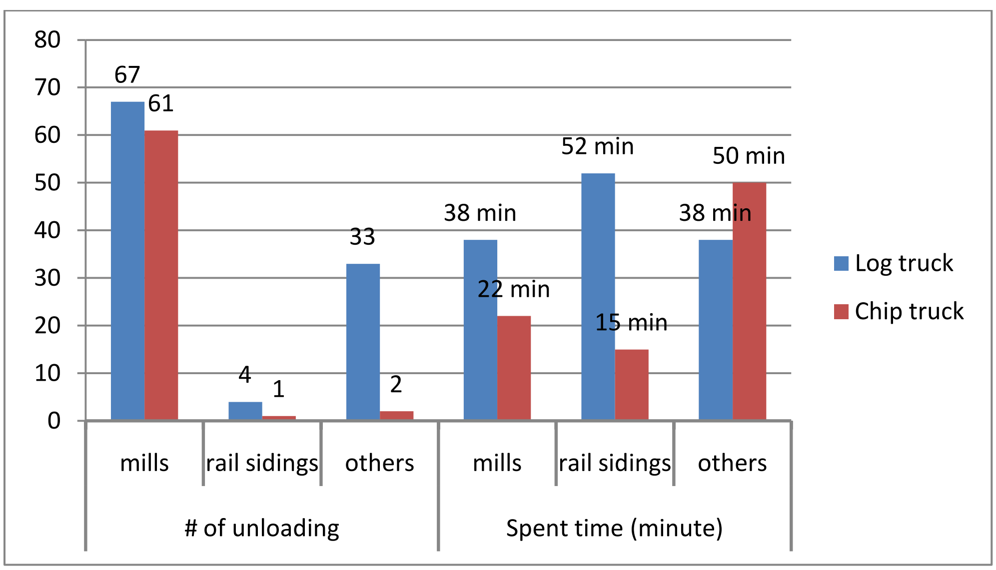


FIGURE 7 Total number of unloading activities and average time spent by log/chip trucks based on unloading location categories

Mills are the most common unloading location for chip trucks while private locations and log yards are utilized more frequently by log trucks. Neither log trucks nor chip trucks used rail sidings extensively for unloading. The research revealed that unloading time in mills is much faster for chip trucks, than log trucks. Truck-tippers are used at mills to unload chip trucks and fewer chip trucks loads are delivered to the mill. On the other hand, unloading of chip trucks outside mills, such as private landings and facilities, took longer time than log trucks, mainly due to the reason that none of participant chip trucks had walking-floors to automate the unloading process.

6-3- Mileage Analysis

Figure 8 reviews of the mileage performance between log truck and chip truck during second round of data collection. Overall, chip trucks outperformed log trucks in most categories. For instance, 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 (Table 3). This highlights the productivity and better performance of chip trucks in comparison to the log trucks. Both log trucks and chip trucks had similar maximum hauling distances without a stop, which averaged between 117-126 miles. One of the important parameters was the overall length of each delivery cycle which was approximately 150 miles for both log and chip trucks. This confirms the industry's notion that most transportation activity occurs within 100 miles from the destination. In our case, the average distance was approximately 75 miles.

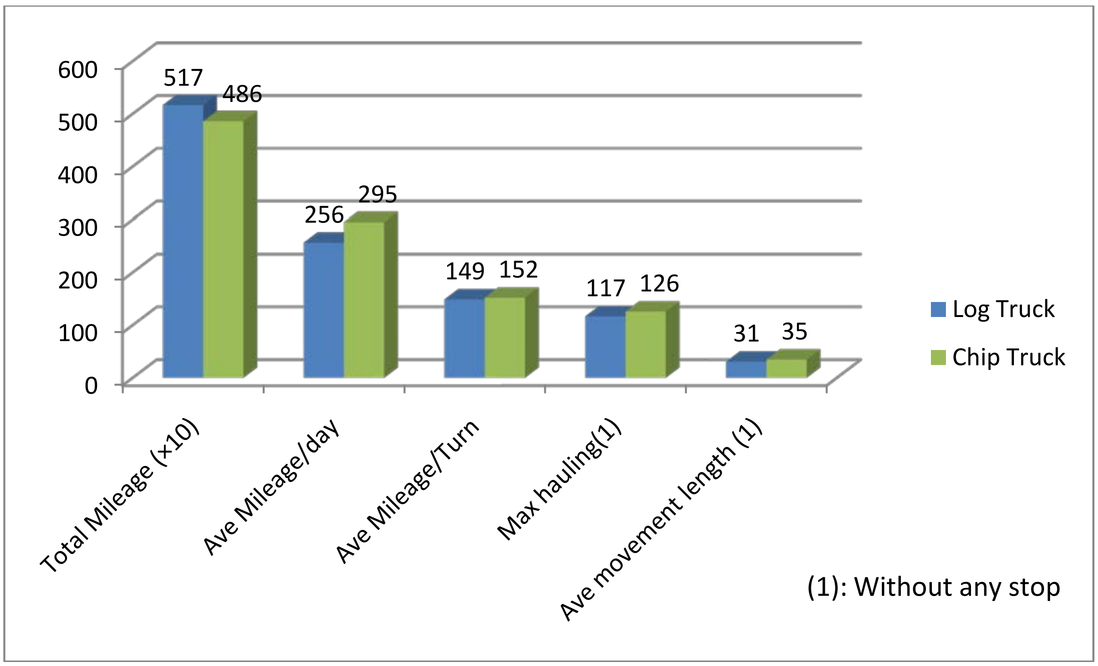


FIGURE 8 Comparison of mileage indices between log and chip trucks (y-axis is miles)

7- CONCLUSIONS AND RECOMMENDATIONS FOR NEXT STEPS

The research investigated log and chip truck performance within the Upper Peninsula of Michigan by using passive GPS recorders, complimented with daily log sheets. The combination of applying simplified log sheets and user friendly passive GPS device helped the research team accurately evaluate the types of movement and minimized other requirements, such as training drivers to work with sophisticated GPS tools. The GPS devices provided a low cost alternative for data collection and performed well over the research period.

The majority of the outcomes were consistent during both rounds, and demonstrated significant similarities between log truck and chip truck operations. For instance, the daily hours of operations and the distribution between time spent for stops, and 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 operational time is spent loading wood at the harvesting sites and for unloading wood at the mills.

Stop time is remarkable for both log and chip trucks, as trucks are only earning revenue when moving loaded. The majority of stop hours (40-50% during a daily operation) was spent either loading or unloading trucks. If truck companies or drivers can reduce the duration of stop times, they can 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 cut logs staged at the storage areas for log trucks.

The unloading time may be reduced by applying modern cranes and machines in 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 time of chip trucks was significantly shorter than log trucks, due to modern innovations such as truck tippers. Modernized unloading equipment such as heavy cranes, might also improve the log truck unloading. A more detailed evaluation of truck wait times at mills should also be investigated, especially to identify the main reasons for differences between log and chip trucks.

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 during high fuel prices. The analysis showed that each dollar increase in fuel price adds almost $700 in idling costs annually. While it is not certain that operational modifications to reduce idling are acceptable by all truck companies, the high returns would certainly warrant additional analysis in the topic, initiated by a simple idling fuel consumption test of Michigan log trucks to define the actual burn rate.

The limited number of log/chip trucks didn't allow research team to focus on pooled dispatching optimization for sharing loading locations between different logging companies. Pooled dispatching among multiple land owners can optimize total transportation miles and offers a great opportunity to improve truck productivity by reducing the empty mileage generated by the traditional “one truck to one land owner” model. With the GPS devices used in the research, it would be realistic to conduct another study with larger truck sample to identify potential optimization opportunities.

ACKNOWLEDGMENT OF SPONSERSHIP

This work was sponsored by National Center for Freight & Infrastructure Research & Education (CFIRE). The research team would also like to acknowledge the forest product companies and their respective truck drivers who participated in the research.

REFERENCES

[1] Youngs, R. L. *"Meeting the Challenge of Change"* Forest Products Journal 57(6), 2007

[2] Stewart, Richard, Cao, Mei, Lautala, Pasi, Ogard, Elizabeth, Graman, Gregory and Paterson, Kurt, *“Study of Greenhouse Gas Savings associated with Congestion Reduction using Multi-Modal Optimization of Timber Shipments in the North Central United States”*, US Department of Transportation, 2010, http://www.uwsuper.edu/tlresearchcenter/index.cfm.

[3] Green, C.A., et al., *Log Truck Study II – Final Report*, Michigan Tech Transportation Institute, Michigan Tech University, September, 2005

[4] Berney, G. *Supply Chain Basics: Tracking Trucks with GPS*, U.S. Department of Agriculture (USDA)-Agricultural Marketing Service, Jan. 2008

[5] Charest, C., Culp Lumber Company, *Inexpensive GPS Data Logger for Wood hauling Trucks*, Forest Operations Review, Summer 2009

[6] Tabat, D., McCormack, E., *Washington State Truck Freight Performance Measure Research-Interim Report*, Washington State Department of Transportation, PSRC Freight Roundtable, March 2010

[7] InstaMapper web page, www.instamapper.com/overview.html, Accessed April 2011

[8] GPS Insight web page, www.gpsinsight.com, Accessed April 2011

[9] Sycada Manage Mobility Catalog , http://www.sycada.com/img/x2/collection/DOWNLOADS/engmm_1239823457.pdf, Accessed April 2011
[10] NetTrack software webpage, http://www.trackyourtruck.com, Accessed April 2011
[11] Trine XL RightWay GPS, Trine XL User's Manual, Version 1.0, MN-USA, 2010,
[12] Live View GPS, *GPS Tracking- 2011 Product Catalog*, Valencia-CA, 2011
[13] EPA, *What You Should Know About Idling Reduction*, http://www.epa.gov/reg3artd/diesel/truck_idling_fs.pdf, Accessed July 2011
[14] Tunnell, M., Dick, V., et al, *Idle Reduction Technology: Fleet Preferences Survey*, Prepared for: New York State Energy Research and Development Authority, American Transportation Research Institute (ATRI), Alexandria, VA, 2006
[15] EIA website, *Gasoline and Diesel Fuel Update*, http://www.eia.gov/oog/info/gdu/gasdiesel.asp, Accessed April 2011