Eur J Forest Eng 2017, 3(1): 23-34

Perceiving Major Problems in Forest Products Transportation by Trucks and Trailers: A Cross-sectional Survey

Anil Koirala[1*], Anil Raj Kizha[1], Brian E. Roth[2]

[1]University of Maine, School of Forest Resources, Orono Maine 04469, USA
[2] University of Maine, Cooperative Forestry Research Unit (CFRU), Orono Maine 04469, USA

Abstract

Hauling forest products from harvesting sites to the mills is a crucial component in forest operation which directly influence the cost of delivered products. Although past researchers have focused on various aspects of transportation including logistics modeling, productivity of trucking on various road conditions and terrain, the challenges in forest trucking are by far unnoticed. This study attempted to address some of the prominent issues on forest products trucking by using cross-sectional questionnaire survey technique. The survey was carried out in a regional council of forest engineers' workshop. With a response rate of 31.22%, the majority of respondents had more than 25 years of experience working in the forestry sector. Location and availability of markets was ranked as the major challenge faced by the industry followed by the lack of skilled truck drivers. The effective ways to reduce truck waiting times at harvesting and processing facilities along with opportunities for back-hauling of empty trucks were also analyzed. Average distance traveled by a single truck in a typical harvesting operation was found to be 98 km one-way. The findings can be utilized by the policy makers to formulate laws to support the industry and to develop management guidelines for specific trucking situations.

Keywords: Back-hauling, Forest transportation, Management guidelines, Roads, Truck drivers

1. Introduction

Transportation of timber materials from in-wood to the processing facilities is a major component of forest operations and from citizen's perspective, the most visible and appealing section of the entire forest management scheme from forest stand to the utilization of the trees (Greene et al., 2007; Murphy, 2003). It is also one of the expensive phases of timber harvesting and supply chain which accounts for about 30 to 50 percent of the total costs (El Hachemi et al., 2013; Kizha. et al., 2015; Pan et al., 2008; Shaffer and Stuart, 2005). Among various modes of secondary transportation systems prevalent in forest products industries, trucking is the most commonly used. Trucks are also a component to carry loads for some parts of the route in other transportation systems like rail and barges (Epstein et al., 2007). Different types and configurations of truck and trailers are used depending on the types of raw materials to be hauled. There are separate trucking fleets specifically designed for each product types. An example would be the use of tractor trailers for hauling long and short logs; and chip vans for hauling wood chips and hog fuel.Travel distance and speed primarily influence the operating cost of trucking. The forest products industries (FPIs) being scattered throughout the state of Maine leads to increased travel distance thereby increasing trucking cost (Lilieholm et al., 2010). Difference in bulk densities and moisture content of the woody materials can affect the payload and weight restrictions enforced by the state. Low bulk densities and high moisture content in wood decrease the density of materials thereby causes problem of overloading in the trucks, while an increase in the tare weight of truck decreases the profit of loggers and contractors (Shaffer and Stuart, 2009; Talbot and Suadicani, 2006). Similarly, road features like traffic, alignment, bends and gradients can also be influential (Koirala et al., 2016).

As forestry and related business, are among major contributors to Maine's gross domestic product (GDP) accounting of about $8–10 billion, the importance of forest products transportation cannot be undermined (MFPC, 2016, 2013; NEFA, 2013). Forest logging and operations is also one of the major sources of employment in the state and have employed over 5000 people specifically in forestry, logging, and trucking jobs (excluding industries and indirect employment) in

[*]Corresponding author: Tel: +1 2078897154 E-mail: anil.koirala@maine.edu
Received 19 May 2017; Accepted 21 June 2017

2011, out of which more than half were truck drivers (excluding self-employed operating as sole proprietors) (MFPC, 2013; NEFA, 2013). Hiring and keeping skilled and motivated young person is a serious challenge to this sector at present. There is an urgent need of attracting enthusiastic young workforce in forest transportation sector in order to secure the future of this industry. The problem also exists in general trucking sector; a study done by ATA (American Trucking Association) reflected the urgency of this matter in terms of drivers' shortage at present and future (Costello and Suarez, 2015).

Although transportation is a major determinant of the stump-to-gate production costs, studies solely related to the general problems in forest trucking are very scant. It has always been regarded as a minor portion within the study on logging firms and businesses (Egan and Taggart 2009; Leon and Benjamin, 2013). Some studies have attempted to link trucking in a bimodal transportation system to assess the cost effectiveness of transportation logistics (Abbas et al., 2013; Lautala et al., 2011). In the northeastern region of the US, several surveys on loggers have been carried out (Egan and Taggart, 2004, 2009; Greene et al., 2004; Leon and Benjamin, 2013), but survey focusing on forest trucking has not been very common. Trucking problems like shrinking labor force and markets have been noticed for many years but effective research identifying the overall problems, seeking out the solutions and integrating, are limited.

The overall goal of this study was to assess forest trucking situation in Maine. The specific objectives were to 1) understand stakeholders' perceptions towards the forest trucking conditions in Maine, 2) evaluate the potential challenges faced by the industry, and 3) analyze the specific situations responsible for these challenges. This research will shed new light on the current situation of forest trucking sector from related stakeholders' perspective, thus, is expected to assist foresters and timberland managers in developing sound transportation plans prior to harvest operations. It will also help FPIs to focus and resolve specific transportation problems to maintain and manage their large number of trucking fleets.

2. Materials and Methods

2.1. Background

Potential issues regarding the condition of forest trucking industry, in general, were initially identified through a literature study. This included over 60 scientific articles, 15 trade magazines and five government records related to the topic. The process also helped in identifying the potential stakeholders. Followed by which, personal communication was carried out with selected stakeholders comprising of timberland owners and managers, foresters, personnel from trucking companies, and loggers.

2.2. Method Justification and Workshop Settings

A cross-sectional survey design method was adopted for data collection (Lavrakas, 2008). This type of survey is a widely-used in social, economic and health sectors to provide a quick picture of the effect of selected parameters and consequences in a population at a given period. In this survey design, participants identified for the study were purposely selected based on similarity in professional interests rather than random sampling technique. The major advantages of this method over other traditional questionnaire designs like mailing survey and online survey are higher response rate, lower administering cost, and shorter time frame (Labaree and Scimeca, 2017).

The survey was carried out at the New England Council of Forest Engineers (NerCOFE) conference and workshop held at University of Maine complex in Orono, Maine, United States in the fall of 2016. NerCOFE was chosen intentionally, as it is a regional organization that has representation from forest landowning and managing companies, private forest products industries, and academicians in the region. There were 300 participants in the conference with diverse forestry backgrounds. NerCOFE's participant strength outnumbers other forestry professional meetings carried out in the region.

The questionnaire survey and written consent were approved by the University of Maine, Institutional Review Board (IRB) for conducting research on human subjects prior to the study. A written informed consent form was included along with the questionnaire to ensure confidentiality. Participation in the survey was completely voluntary and participants were given the right to review our interpretation. The information which can reveal personal identities of the participants was not used in any form of publications and presentations.

2.3. Surveying and Data Analysis

Based on the literature analysis, personal communication and previous surveys done in the region, a questionnaire set was drafted which was reviewed by 10 experts in the forestry, social science and engineering fields for clarity and organization. The reviewers had experience in conducting and analyzing similar survey design. A four-page final questionnaire with 22 questions (15 core questions and 7 sub-questions) was prepared after incorporating suggestions and comments from the experts. The average time to complete the survey was designed to be 13 minutes which was tested with two individuals prior to the study. The first page of the survey was informed consent to the individuals about their voluntary participation and confidentiality. The main body of the questionnaire was divided into three sections. Basic demographic information on the respondents and their affiliations comprised the first part. The second part focused on general problems related to forest trucking

in the state of Maine. Seven different problems finalized from initial literature study and personal communications were asked to be ranked on a scale of 1 to 3, where 1 representing a major problem, 2 - problem exists and 3 - not so concerned. The questions in the third section were more detailed to specific problems such as a) turnaround time, b) mechanical/operational delays, c) the condition and traffic of paved and gravel roads in the region; and d) average trucking distance from landing to the processing facility. Open-ended blank spaces were also included after each major section in order to incorporate respondents' relevant suggestions and comments on the topics.

The survey questionnaire was included in the conference package folder for each attendee. These packages were distributed at the beginning of the workshop and a brief announcement was made regarding the survey, its purpose, and significance. Participants were requested to place completed questionnaire in the box labeled as "Survey Form Collection Box". Facilitators were assigned to the four corners of the conference hall for assistance in filling out the questionnaire during the survey session.

Descriptive statistics such as mean, median, standard deviation, along with non-parametric tests were performed in R statistical package (R Core Team, 2016). Chi-square tests of independence were performed to see the difference in opinions of respondents. The p-value of 0.05 was set as the significance level.

3. Results

After excluding 15 individuals related to the conference organizing committee and this survey research group, a total of 285 participants were provided with the questionnaires. Overall, 89 questionnaire forms were collected at the end of the conference which yielded 31.22% response rate.

3.1. Description of Respondents/Population

Out of the 16 counties in Maine, 11 counties (four from northern region and seven from southern region) were represented in this survey. Respondents were broadly classified into two groups based on the location of their primary work stations: Northern Maine comprised of four counties (Aroostook, Penobscot, Piscataquis, and Somerset) and the remaining 12 counties fell in the southern region (Figure 1). This was primarily done to understand the difference in opinion between the comparatively highly forested northern counties and the south. The highest representation was from Aroostook county (n=20), while the lowest representation of one respondent was from Hancock, Kennebec, and York counties. There were 62 respondents from northern Maine (70%) and 27 from southern Maine (30%).

The majority of the respondents (73.1%) were affiliated with the private companies including logging,

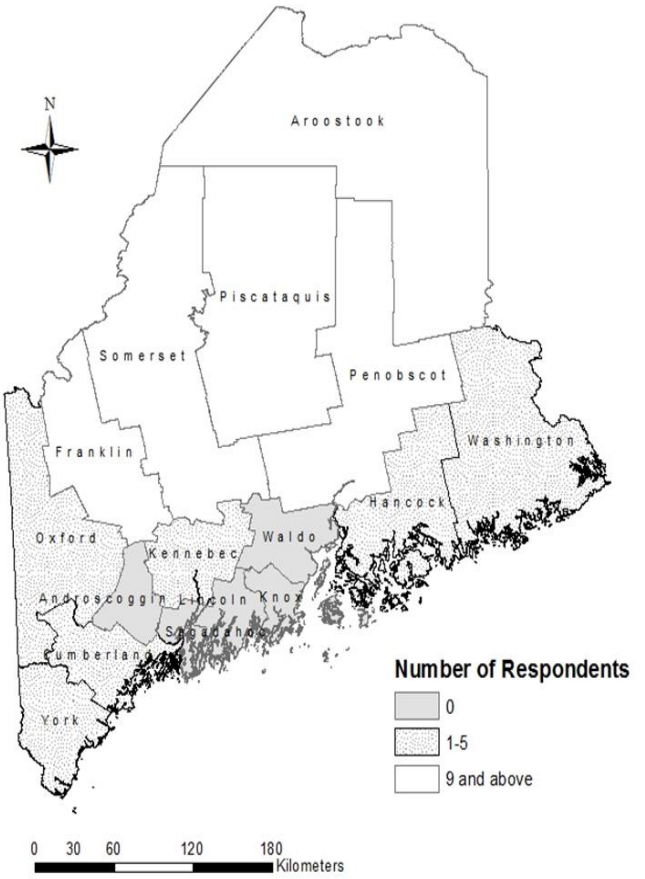

Figure 1. The countywide representation of respondents in the state of Maine

pulp and paper and trucking enterprises, which also accounted highest for both northern (69.4%) and southern region (81.5%) (Table 1). Followed by respondents from federal and state agencies (14.6%), contractors (6.7%) and other sectors including foresters and researchers (5.6%). The average experience of the respondents in forestry sector was 22 years while 31.5% of them had worked in the sector for more than 30 years. Regarding respondents' experience in handling different forest products, 40.4% of respondents had experience in dealing sawlogs followed by 31.5% for pulp/hogfuel.

3.2. Challenges Faced by the Forest Products Trucking Industry

Nearly 80% of respondents agreed that the problem existed in forest trucking industry in Maine. About 11% denied the existence of problems and the same percentage said they were not aware of the problems. These three responses were categorized into two groups: agree and disagree (combining "no" and "not aware"). The chi-square test results between these two groups showed there was no significant difference in responses of respondents based on their affiliation company, (i.e., state and federal agencies, contractors, and others) (chi-square = 0.186; p-value = 0.9798). In other words, the existence of challenges in the trucking sector was agreed all across the board which reflected the relevancy of this study.

Table 1. Summary of demographic characteristics: Number of respondents for each categories divided into northern and southern regions of Maine

Characteristics	Categories	Northern (%)	Southern (%)	Total (%)
Representation	Number of Respondents	62 (70)	27 (30)	89 (100)
Affiliation	Company (logging, trucking, and pulp & paper enterprises)	43 (69)	22 (82)	65 (73)
	State or federal agencies	10 (16)	3 (11)	13 (15)
	Contractor	5 (8)	1 (4)	6 (7)
	Others (Forester, academics and unspecified)	4 (7)	1 (4)	5 (6)
Work experience in forestry sector	Less than 10 years	14 (23)	3 (11)	17 (19)
	10 to 15 years	8 (13)	4 (15)	12 (14)
	15 to 20 years	9 (15)	2 (7)	11 (12)
	20 to 25 years	9 (15)	5 (19)	14 (16)
	25 to 30 years	4 (7)	3 (11)	7 (8)
	More than 30 years	18 (29)	10 (37)	28 (32)
	Average work experience	21 years	24 years	22 years
Major forest products dealt with	Sawlogs/Speciality	26 (42)	10 (37)	36 (40)
	Pulp/groundwood	21 (34)	7 (26)	28 (32)
	Biomass (hogfuels)	7 (11)	6 (22)	13 (15)
	Wood chips	8 (13)	4 (15)	12 (14)

Respondents were asked to rank the problems faced by forest trucking industry in Maine as to a) major, b) problem exists, and c) not concerned. Location and availability of markets was ranked to be the major problem to the forest product industries at present by about 48% of the respondents, which was followed by lack of skilled drivers and operators (about 39%); and condition of roads (about 30%) (Figure 2). Although it was not ranked as the three major problems, more than half of the respondents (56%) agreed that the cost of fuel and maintenance is one of the communal problems of this sector.

Comparing the ranking of problems based on the sub-region, respondents from northern Maine again regarded location and availability of markets to be the first major problem. However, the respondents from southern Maine ranked lack of drivers higher (52%) than the availability of markets (41%). This might be due to general presence of other industries in the southern region, which makes forest trucking jobs a low priority to the workforce. Again the recent FPI closures affected primarily the northern part of the state. Apart from these seven challenges, some of the respondents mentioned few other problems like careless drivers, high insurance cost and lack of dispatch coordination.

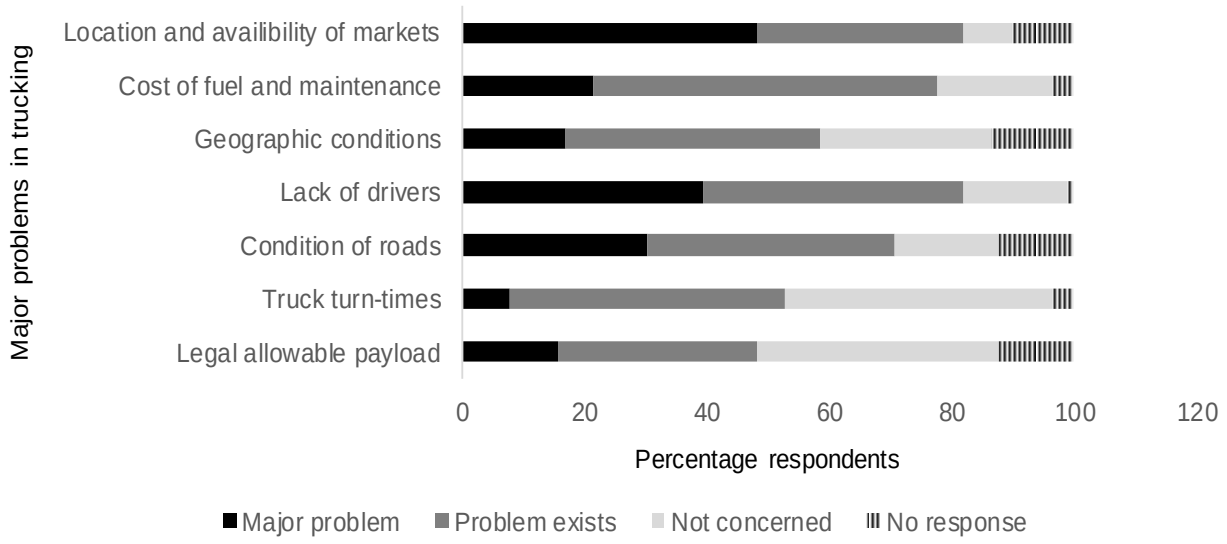

Figure 2. Respondents' ranking of the major problems faced by forest trucking industry in Maine

3.3. Truck Drivers

Driving through unpaved and rough forest roads along with operating day and night shift during harvesting season have made forest truck driving a difficult job to perform. Respondents were asked to rank the availability of skilled truck drivers in the region at present and compare it with the situations prevailing in the last five and ten years. More than half of the respondents agreed that skilled drivers and operators are harder to find at present situation compared to five or ten years back. (Figure 3).

Chi-square results showed there was no significant difference between the availability of truck drivers in these two-time periods compared to present situation (chi-square = 3.83; p-value = 0.2806). In other words, the truck drivers and other skilled labors are harder to find at present situation compared to both five and ten years back situation.

The mode of payment for trucking operations was based on the contract. About 60% of respondents said that the payment was made by the loads or tonnage, followed by 21% by the hours and 4% by distance. The rest 15% of the respondents were not aware of the mode of payment.

3.4. Space of Yarding and Truck-turnaround Times

About 60% of the respondents believed that space of landing was not a problem, whereas 31% believed that it was a problem. Chi-square results showed that there was no significant difference between the affiliation of the respondents who agreed and disagreed (chi-square = 0.560; p-value = 0.9045).

The truck turnaround times can have major impacts on the entire schedule of forest operations; for which, proper mechanisms/ strategies should be in place both at the harvesting as well as processing facilities to minimize operational delays.

Respondents were asked whether there was chances to reduce truck-turnaround delays (a) at harvesting sites and (b) at mills (processing facilities). More than 60% respondents said that processing facilities could have better chances to reduce delays than harvesting sites. However, as an open-ended question, respondents were asked to deliver their views to minimize truck turnaround times in both harvesting sites and processing facilities (Table 2). There were more suggestions for harvesting sites to reduce delays than processing facilities.

3.5. Back-hauling of the Empty Trucks

More than three-quarters of respondents believed that there were opportunities to utilize empty trucks during harvesting operation (Figure 4). Respondents were also asked whether the back-hauling would delay the forest transportation schedule of the company or not. While more than half of the respondents disagreed, a quarter of them agreed that back-hauling can delay entire forest transportation schedule.

3.6. Average Travel Distance and Condition of Forest Roads

The average one-way distance traveled by a single truck for all forest products was 98 km. While categorizing this average distance for various forest products separately, it was highest for pulpwood (109 km) and the other products (sawlogs, hog fuels, and wood chip) fell in the range of 93–95 km (Table 3).

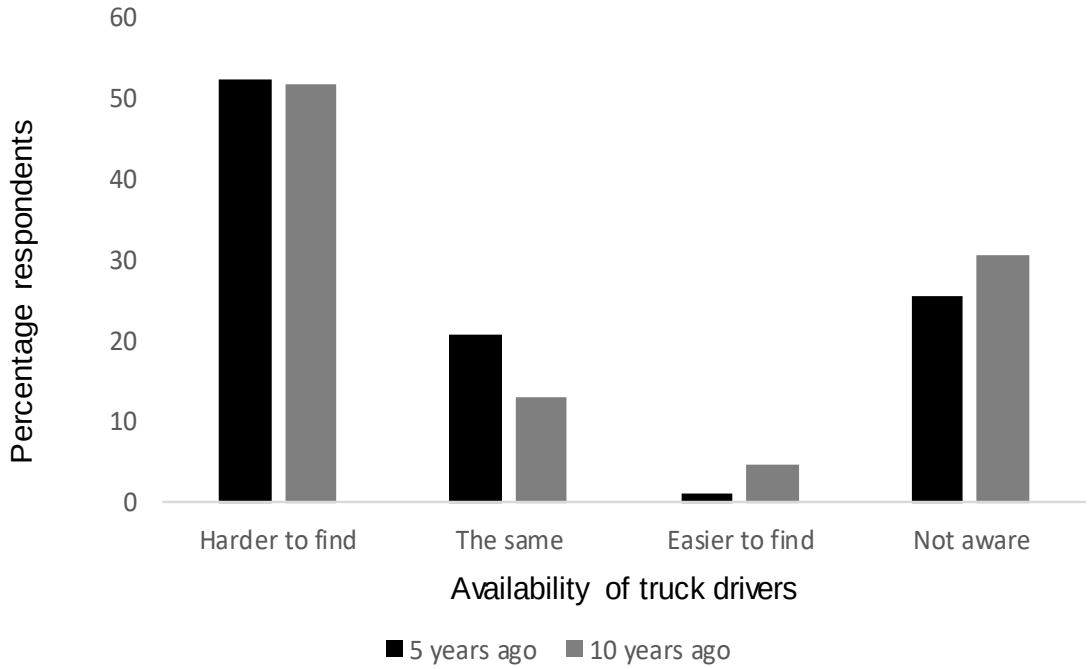

Figure 3. Views of respondents on the availability of truck drivers: present vs the past (5 and 10 years ago)

Table 2. Respondents' recommendations (direct quotations) to minimize truck turnaround times in harvesting and processing sites to minimize operational delays

Harvesting sites	**Processing facilities**
Adequate turnaround close to log landing.	*Text messaging wait time and website with up to date information on unloading equipment, crane, dumpers, trucks and chip vans.*
Wider roads at yards to accommodate traveling and traffic passage.	*Longer hours open during busier times.*
Decoupling services.	*Additional cranes to unload during busier times.*
Utilizing more center mount trucks for saw log transportation.	*Scheduling focused on light traffic times of the day.*
Utilizing smaller log trucks.	
Having crane operator or contractor be in charge of the operation at the landing, not the driver.	
Utilizing satellite yards to accumulate more "loaded miles". *More reliable equipment. Sand steep sections of road in winter. Plan roads ahead so not trucking on "fresh" roads.*	
Skilled crane operators.	
Pave more roads and landings. *More cut-to-length operation.* *Increasing two shift trucks/team hauling the loads.*	

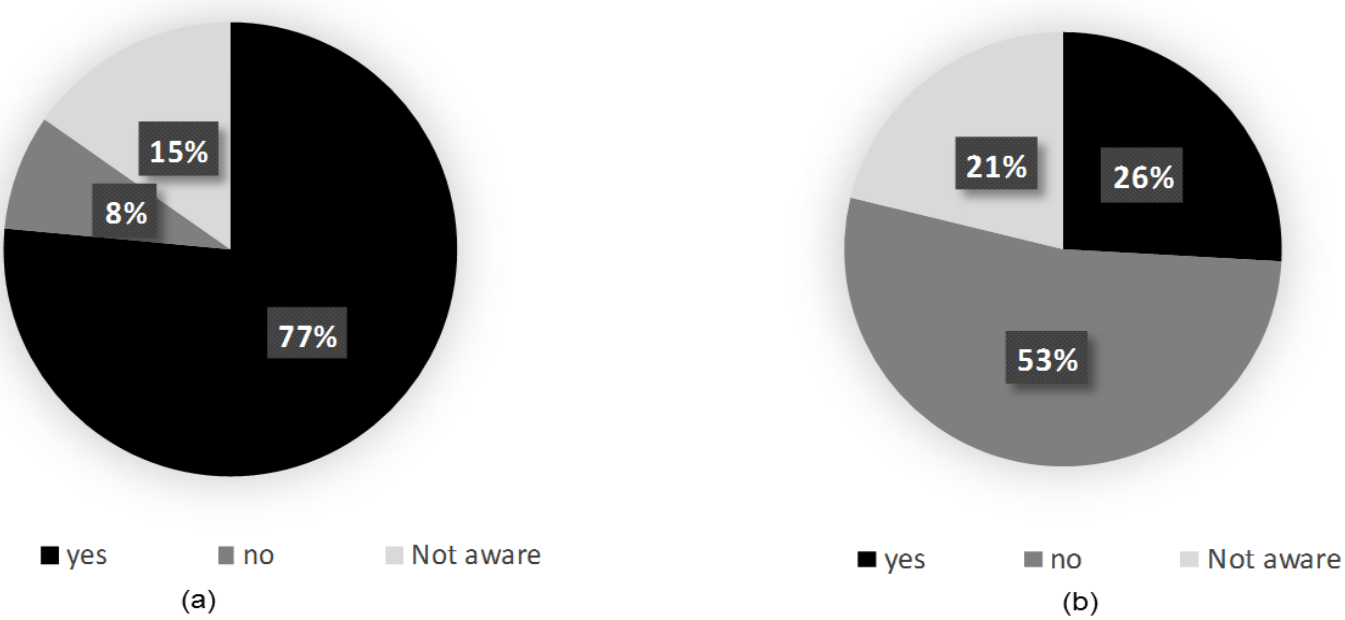

Figure 4. Respondents' views on (a) whether there were opportunities for back-hauling in Maine or not and (b) whether back-hauling could delay entire forest operations' schedule or not

Table 3. Average distance (in km) traveled by a single truck to deliver different types of forest products from Maine's woodlands to the mills according to the responses of participants

Forest products	Maximum	Minimum	Mean
Sawlogs	322	4	95
Pulpwood	322	4	109
Hog fuels	200	19	94
Woodchips	240	4	93

Respondents were asked to compare the roads in the present situation to that of ten years back. Regarding the quality of paved roads, about 35% believed that the condition is same whereas 33% believed it is worse than before. Similarly, nearly 40% believed that the traffic in paved roads is currently worse than before (Figure 5).

4. Discussion

This survey presents a general outlook of the forest trucking sector for the state of Maine; with emphasis given to the problems faced in the region. Results of this study were based on the survey carried out in a specific event and need not necessarily represent the views of whole forestry and logging sector of Maine. However, the respondent represented the major forest product companies of the region and was working for more than 25 years in their respective fields. Thus, the respondent's group can be regarded as a sample population for the region. The cross-sectional survey method adopted for this study can be considered as a novel approach for in forest operations and transportation. This technique was expected to yield higher response rate. However, the response rate of 31% was comparatively lower than similar survey techniques in other fields (medical & public health), usually higher than 50% (Ahmer et al., 2008; Akram et al., 2015; Niedhammer et al., 2007). The reason behind might be due to the general mindset of forest operation people not to reveal confidential business information that can potentially effect the competition (Irland, 2011). However, the response rate was higher than traditional mailing surveys among the loggers and forest-related companies (Abbas et al., 2014; Abbas and Clatterbuck, 2015; Leon and Benjamin, 2013). The limited number of questions (22) could have also favored the high response rate.

4.1. Respondents' Demographics

Average work experience of the respondents was 22 years, with more than 30% of them having work experience of more than 30 years in the forestry sector. This finding is somewhat consistent with the result from the previous survey in the region which showed 53% of the business owner had worked more than 30 years in logging industry (Leon and Benjamin, 2013). The highly-experienced respondent group of this survey can serve as an important aspect for validating the findings.

The majority of the respondents (>73%) were working for private companies including different logging and trucking enterprises. This is not unusual as private forestry enterprises like logging, pulp and paper and others are the major job provider within the forestry sector for the state of Maine (USDOL, 2016). Additionally, Maine has about 95% of its forest under private ownership including big landowning companies (Jin and Sader, 2006). The results also showed a higher percentage of respondents associated with the works related to sawlogs and pulpwood. This finding can be related to the fact that the forest products industries in Maine are historically based on harvesting trees for sawlogs and pulpwood (for pulp and paper) which accounted for more than 75% of the total harvest in the state in 2015 (MFS, 2015).

4.2. Major Problems and Potential Solutions in the Forest Trucking Industry

Four out of five respondents agreed on the existence of challenges to better forest trucking operations in Maine. The solution to the seven problems presented in this study was based on literature analysis and personal communication.

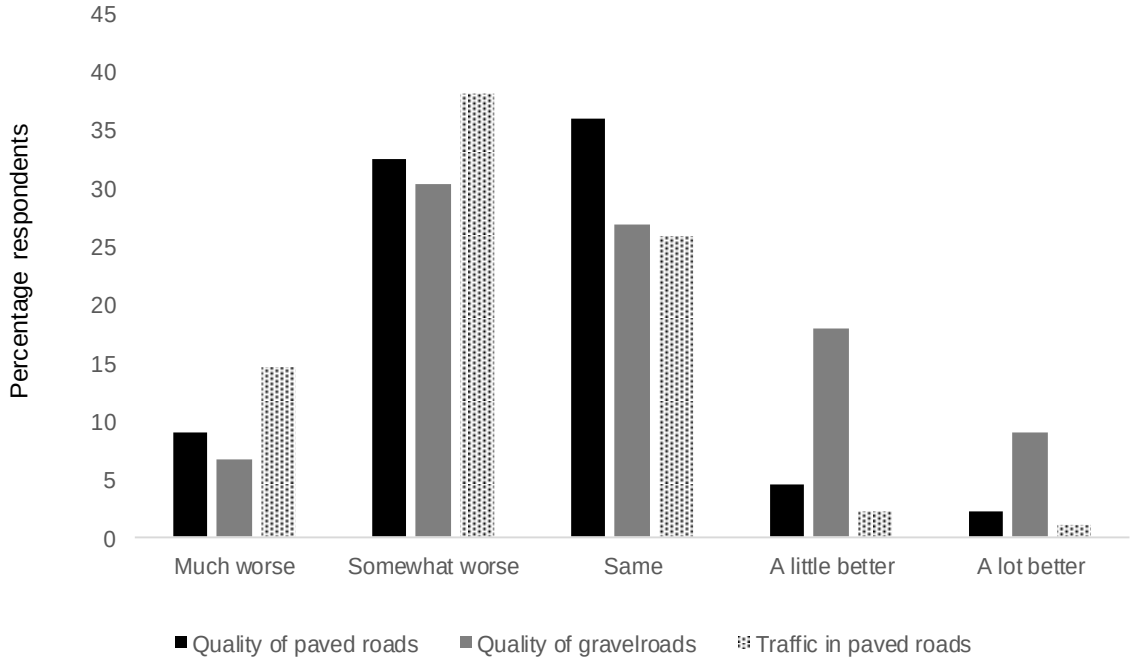

Figure 5. Respondents' views on the condition of roads in Maine at present compared to the past situation (10 years back)

4.2.1. Location and Availability of Markets

The majority of the respondents (approximately 48%) in this survey ranked the market conditions as the major problem for the forest products trucking sector. A nationwide study reported that the average hauling distance for softwood sawlogs and pulpwood was highest in the Northern states of US, which increased the price of the product substantially compared to other regions (Libbey, 2000). The location of the end-use facility is a direct determinant of the transportation cost. The FPIs being highly scattered in Maine resulted in the long-distance truck travel. With closures of six pulp and paper mills in the past five years, Maine has experienced severe pressure on its softwood pulp utilization and marketing, as well as trucking enterprise (Ohm, 2016).

There is no direct solution to this problem, however, some of the measures to cope up would be government intervention and subsidies to rejuvenate the closed mills. Recently, the state of Maine has been provided with federal government subsidies to redevelop the vacant mills and communities they were in (Sambides Jr., 2017).

4.2.2. Lack of Skilled Drivers

Lack of skilled drivers was ranked as the second major problem by 39% of the respondents. However, the respondents from the southern region ranked this first (52%). Survey results also showed skilled drivers and operators are harder to find at present in Maine than last five and ten years' situation. The problem of labor force shortage is not only limited to forest transportation sector; there has been a trend of shrinking labor force in every employment sector in Maine from last 20 years (MDOL, 2013).

A recent survey among trucking companies reported the major challenge faced by the industry was to find, retain and develop a skilled workforce; predicting the shortage would be critical in the coming years (HireRight, 2015). The American Trucking Association (ATA) estimated overall current truck driver (including forest transportation) shortage is more than 35,000 individuals and 240,000 additional truck drivers will be needed by 2023 (Costello and Suarez, 2015). The trucking industry is heavily dependent on drivers of age 45 years and older, and a report showed that the median truck driver age was 46.5 versus 42.4 for the overall U.S. workforce in 2013 (Short, 2014). These indicate the size of the core working age population (21 to 50) in forest transportation sector is shrinking. Some reason could be due to the lack of interest, extended time away from family during timber harvesting seasons, short and fixed season of operations with higher driving costs, and decreasing scope of the mills and companies resulting in falling of pay and benefits of truck drivers.

One major solution that can retain and attract skilled drivers would be the pay increment. Upgrading the equipment, bonus program, and performance based reward program can also be beneficial for the retention. Independent contract schemes along with ownership sharing mechanism are in use in Finnish forest products industry as a solution to the problem (Palander et al., 2012).

4.2.3. Road Conditions, Geography and Climate

Geographic and climatic conditions are very crucial factors to consider for the operation and maintenance of roads. According to the respondents, the quality of the northeastern gravel and paved roads is not better at present in comparison to the last 10 years. Experiencing wide variations in different road types and standards has always been a challenge to forest trucking. On one hand, the trucks are meant to travel the lowest possible standard forest roads successfully, while, they must also be able to operate on the high standard public highways. So, the selection of proper trucks with suitable specifications for both situations could often be challenging.

Forest transportation is different than other transportation sectors as it requires construction and maintenance of vast in-wood road networks and designation of loading and landing sites within the harvest unit and occasionally on secondary loading sites (Bont et al., 2012). Planning of convenient and cost-effective route that would connect every landing within one harvest operation season are often desirable in forest road design. Some solutions like upgrading forest roads (primary and secondary hauling lines) and enhancement in landing space can help in improving the overall truck's performances, thereby lowering supply chain costs (Cavalli and Grigolato, 2010).

Geographical condition of the harvesting and loading sites directly affects the cost of road construction and selection of appropriate truck and trailer types. Rough terrain and narrow road conditions lead to increased time for maneuvering and high waiting times for passing trucks (Kizha. et al., 2016). Additionally, steep terrain can pose a serious safety risk for truck operations.

The climate, in general, determines the season of timber harvesting and transportation. Forest operations are usually conducted in certain permissible windows of a year and vary regionally (Kizha and Han, 2016). Timber harvesting operations are preferred in winters for temperate regions having high snowfall in order to avoid soil displacement (Abbas et al., 2011). However, winter operations also pose a series of other challenges such as the winter road construction and maintenance including snow removal and use of anti-slip measures (Malinen et al., 2014). Severe weather conditions including poor visibility, a big snowstorm, and heavy rainfall can easily disrupt on-going operations any time. In other regions receiving relatively high rainfall, such as Northern Pacific Coast, harvesting operations are typically carried during summer. Forest roads are also closed during rainy season.

4.2.4. Fuel efficiency, Design and Maintenance of Trucks and Trailers

More than 55% of respondents believed fuel efficiency to be a common problem. Fuel consumption is positively related to the overall transportation costs, which further depends on travel time. There are also environmental as well as public concern associated with trucks performance and fuel utilization as 22% of global CO_2 emission is caused by road freight (McKinnon and Piecyk, 2009). This is of special concern to the forest products trucking as most log trucks are older than common long haulage trucks. Conventionally, most of the log trucks were first used (when new) in non-forestry purpose and were later modified into log trucks after certain years of operations (Dowling, 2010; Gallagher et al., 2005; Tufts et al., 2005a). However, new trucks are also operating in substantial quantities.

Design, size, weight and technologies along with environmental restrictions to operate are regulated by federal and state laws. Therefore the appropriate choice of engine size, correct axle ratio and desirable maximum speed of the vehicle based on legal regulations and guidelines are desirable for enhancing fuel efficiency (Lautala et al., 2015). On road operations, such as driving in the lower level of *rpm* (revolution per minute) also improves fuel efficiency (Tufts et al., 2005b). Fuel consumption is usually maximum during acceleration; therefore, it is recommended to avoid transportation routes with frequent stops, traffic lights, multiple turnings, and fluctuating gradients. Utilizing trucking simulator can help to determine the best combination of these components (Barrett, 2001). Regarding the design of trucks and trailers, different axle combinations can be used for specific situations such as- large single trailer combination for flat terrains whereas double small trailers for steep terrain with sharp bends and curves (Han et al., 2010; Zamora-Cristales and Sessions, 2015).

4.2.5. Legal Allowable Payload and Restrictions

There are state and federal regulations that restrict trucks to carry loads higher than allowable range of weights, which is also known as legal allowable payload. The survey results showed that about 40% of the respondents were not so concerned about this problem. This finding can be justifiable if we compare the legal allowable payload of Maine with other states (especially southern US). The New England Transportation Consortium (NETC) involving Maine, New Hampshire, Massachusetts, Vermont, and Rhode Island, developed a common set of standards for the movement of oversize/overweight combination vehicles. The NETC permits ~ 49,000 kg weight limit for five-axle and ~54,450 kg for six or more axle truck tractor-trailer combination vehicle (BMV Maine, 2012). In southern states, the legal weight limit ranges from 36,000 to 41,000 kg with 10% of tolerance (Tufts et al., 2005a). Therefore, the legal allowable payload is regarded a major problem in the southern US compared to the northeast.

The empty weight of the trucks without any loads is tare weight of the trucks, which is combined with the load to make a total truckload. So, it is desirable to minimize the tare weight of the trucks to the lowest possible level, by removing not so important equipment that has been attached to the trucks or trailers (Shaffer and Stuart, 2005). It is usually hard to maintain the maximum load with low bulk density forest products such as comminuted wood biomass (Schroeder et al., 2007). The bulk densities can be increased by compaction of the products while the allowable load can be met by selecting different arrangements of trucks and trailers combination (Shaffer and Stuart, 2005).

4.2.6. Truck turn-times, Back-hauling and Average Hauling Distance

Truck turnaround time is an average time taken by the truck from entering harvesting sites or processing facilities (mills, industries, depots, etc.) till leaving the place. A study showed that the idle time for trucks were 32% and 27% at harvesting and processing sites, respectively and explained the major reason being waiting for loading at harvest sites and unloading at the later (Dowling, 2010). Delays in harvesting sites could be due to a lack of space at the landings (yards), which often influences the time required for loading trucks (Kizha. et al., 2016). In a typical situation, if a loader is busy when a truck arrives at the location, the truck has to wait until the loader becomes available, leading to increased time and cost (El Hachemi et al., 2013).

A major recommendation to reduce truck turn-around time was proper scheduling and coordination of both harvesting operation and trucking. Respondents' suggestions included wider and adequately spaced paved roads at the landing for ease of traveling and traffic passage, thereby minimizing turn-around time and waiting. However, the landing space is a comparatively lesser problem for trucking in Maine than Pacific coast due to the comparatively flatter terrain in the region. Hence, 60% of response that 'landing space was not the problem' can be justifiable.

The use of more self-loading trucks for sawlog transportation was another suggestion. The self-loading mechanism in this type of trucks could minimize machine cost and dependency on labor. However, it increases loading time and cost and decreases payload. Another interesting suggestion from respondents to decrease turnaround time in harvesting sites was to execute more cut-to-length (CTL) operations than other harvesting methods like whole-tree and tree length methods. However, the recommendation could not be further probed into.

Back-hauling of empty trucks is considered important in forest operations as turnover will increase without extra expenditure. Nevertheless, back-hauling is a challenging task as different types of trucks and trailers are specialized for particular types of tasks, along with the coordination of the process (Carlsson and Rönnqvist, 2007; Epstein et al., 2007). The majority of respondents considered back-hauling as a feasible option. However, on the ground, only major vertically integrated companies (owning timberland, railway system and mills) have practiced this in Maine. Majority of respondents also believed that back-hauling would not affect forest operation schedule. In a typical long haul of forest products, trucks only transport a single load and return empty. Here, economic returns from back-haul overshadow the forest operation schedule. However, some respondents still believed it could delay the forest operation schedule. This response can be justifiable if the destinations of the back-hauled products are different or further than the initial harvesting sites.

The average distance traveled by a single truck to deliver products at the destination can be crucial for considering it for back-hauling. The reported average distance traveled was 98 km in Maine, which was similar to other regions (Abbas et al., 2014; G.C. and Potter-Witter, 2011). The minimum distance reported by the survey for the products (sawlogs, pulpwood, and woodchips) was 3.5 km each, which is very unrealistic in a real-life scenario. The possible explanation would be that the particular survey question was not clear. Previous surveys had shown that the minimum distance traveled for sawlogs was 40–48 km (Holzleitner et al., 2013).

5. Conclusion

This study helped in understanding key challenges faced by forest trucking industry in Maine. The closings of mills in Maine which led to the scattering of markets has created substantial problems for forest trucking enterprises. The lack of skilled manpower in the trucking business can negatively affect the entire forest harvesting sector in coming future. Technical aspects like roads, the average distance traveled and, the cost of fuel and maintenance are also in concern for trucking sector.

The present situation of trucking sector in the state need to be further examined and potential suggestions should be recommended, which will help in developing better and safer operating environment for forest trucking businesses. In conclusion, trucking is a critical component of the forest products industry for the state of Maine. The results are expected to help trucking companies, logging firms, industries and forestry professionals for better planning of forest transportation.

Acknowledgments

This project was supported by funding from Cooperative Forestry Research Unit, University of Maine and Maine Agriculture and Forest Experiment Station: Award Number DE-EE0006297. We would like to express our gratitude to Cynthia Paschal of School of Forest Resources, University of Maine and Ray Berthion, Chairman, New England Council on Forest Engineering for giving us chance to conduct the survey. Our appreciation goes to all those anonymous participants of the survey and others who helped in shaping the questionnaire.

References

Abbas, D., Clatterbuck, W., 2015. A Survey analysis of harvesting logistics in Tennessee. *Eur. J. For. Eng.* 1(2):84–92.

Abbas, D., Current, D., Ryans, M., Taff, S., Hoganson, H., Brooks, K.N., 2011. Harvesting forest biomass for energy – An alternative to conventional fuel treatments: Trials in the Superior National Forest, USA. *Biomass Bioenergy* 35:4557–4564. doi:10.1016/j.biombioe.2011.06.030

Abbas, D., Handler, R., Dykstra, D., Hartsough, B., Lautala, P., 2013. Cost Analysis of Forest Biomass Supply Chain Logistics. *J. For.* 111:271–281. doi:10.5849/jof.12-054

Abbas, D., Handler, R., Hartsough, B., Dykstra, D., Lautala, P., Hembroff, L., 2014. A survey analysis of forest harvesting and transportation operations in Michigan. *Croat. J. For. Eng.* 35:179–192.

Ahmer, S., Yousafzai, A.W., Bhutto, N., Alam, S., Sarangzai, A.K., Iqbal, A., 2008. Bullying of Medical Students in Pakistan: A Cross-Sectional Questionnaire Survey. PLoS ONE 3(12):e3889. doi:10.1371/journal.pone.0003889

Akram, A., Khan, H.A.A., Qadir, A., Sabir, A.M., 2015. A Cross-Sectional Survey of Knowledge, Attitude and Practices Related to Cutaneous Leishmaniasis and Sand Flies in Punjab, Pakistan. PloS One 10(6): e0130929.doi:https://doi.org/10.1371/journal.pone.0130929

Barrett, S.M., 2001. A computer simulation model for predicting the impacts of log truck turn-time on timber harvesting system productivity (MS Thesis). Virginia Polytechnic Institute and State University.

BMV Maine, 2012. State of Maine Commercial Vehicle Laws & Regulations.

Bont, L.G., Heinimann, H.R., Church, R.L., 2015. Concurrent optimization of harvesting and road network layouts under steep terrain. *Ann. Oper. Res.* 232(1):41-64. doi:10.1007/s10479-012-1273-4

Carlsson, D., Rönnqvist, M., 2007. Backhauling in forest transportation - models, methods and practical usage. *Can. J. For. Res.* 37(12):2612-2623. doi:10.1139/X07-106

Cavalli, R., Grigolato, S., 2010. Influence of characteristics and extension of a forest road network on the supply cost of forest woodchips. *J. For. Res.* 15(3):202–209. doi:10.1007/s10310-009-0170-4

Costello, B., Suarez, R., 2015. Truck Driver Shortage Analysis. American Trucking Association (ATA).

Dowling, T.N., 2010. An Analysis of Log Truck Turn Times at Harvest Sites and Mill Facilities (MS Thesis). Virginia Polytechnic Institute and State University.

Egan, A., Taggart, D., 2009. Public perceptions of the logging profession in Maine and implications for logger recruitment. *North. J. Appl. For.* 26(3):93-98.

Egan, A., Taggart, D., 2004. Who will log in Maine's north woods? A cross-cultural study of occupational choice and prestige. *North. J. Appl. For.* 21(4): 200-208.

El Hachemi, N., Gendreau, M., Rousseau, L.-M., 2013. A heuristic to solve the synchronized log-truck scheduling problem. *Comput. Oper. Res.* 40(3):666-673. doi:10.1016/j.cor.2011.02.002

Epstein, R., Rönnqvist, M., Weintraub, A., 2007. Forest transportation, in: Handbook of Operations Research in Natural Resources. Springer, pp. 391–403.

Gallagher, T., McDonald, T., Smidt, M., Tufts, R., 2005. Increasing Truck Payloads and Performance. Wood Supply Res. Inst. Technical Release.

G.C., S., Potter-Witter, K., 2011. An examination of Michigan's logging sector in emerging bioenergy market. *For. Prod. J.* 61:459–465.

Greene, W.D., Baker, S.A., Lowrimore, T., 2007. Analysis of Log Hauling Vehicle Accidents in the State of Georgia, USA, 1988–2004. *Int. J. For. Eng*. 18:52–57.

Greene, W.D., Mayo, J.H., deHoop, C.F., Egan, A.F., 2004. Causes and costs of unused logging production capacity in the southern United States and Maine. *For. Prod. J.* 54:29–37.

Han, H.-S., Halbrook, J., Pan, F., Salazar, L., 2010. Economic evaluation of a roll-off trucking system removing forest biomass resulting from shaded fuelbreak treatments. Biomass Bioenergy 34, 1006–1016. doi:10.1016/j.biombioe.2010.02.009

HireRight, 2015. HireRight 2015 Transportation Spotlight. HireRight Inc.

Holzleitner, F., Kanzian, C., Höller, N., 2013. Monitoring the chipping and transportation of wood fuels with a fleet management system. *Silva Fenn.* 47(1) article id 899, 11p.

Irland, L.C., 2011. Assessment of Conditions of Competition and Ratemaking In the Maine Logging and Log Trucking Industry (Report to the Office of the Maine Attorney General). The Irland Group, Maine, United States.

Jin, S., Sader, S.A., 2006. Effects of forest ownership and change on forest harvest rates, types and trends in northern Maine. *For. Ecol. Manag.* 228:177–186. doi:10.1016/j.foreco.2006.03.009

Kizha., A.R., Han, H., Anderson, N., 2016. Machine Activities and Interaction at the Landing in a Cable Yarding Operation., in: Proceeding of 70th International Convention, Forest Products Society. Presented at the Forest Products Society. 70th International Convention, Portland OR.

Kizha, A.R., Han, H.-S., 2016. Processing and sorting forest residues: Cost, productivity and managerial impacts. *Biomass Bioenergy* 93:97–106. doi:10.1016/j.biombioe.2016.06.021

Kizha., A.R., Han, H.-S., Montgomery, T., Hohl, A., 2015. Biomass power plant feedstock procurement: Modeling transportation cost zones and the potential for competition. *Calif. Agric.* 69:184–190. doi:10.3733/ca.v069n03p184

Koirala, A., Kizha, A.R., Roth, B., 2016. Forest trucking industry in Maine: A review on challenges and resolutions, in: Proceeding of 39th Annual Meeting of the Council on Forest Engineering. Presented at the 39th Annual Meeting of the Council on Forest Engineering and Demo International & Conference, Vancouver, Canada.

Labaree, R.V., Scimeca, R., 2017. Research Guides: Organizing Your Social Sciences Research Paper: Types of Research Designs [WWW Document]. Univ. South. Calif. Libr. URL http://libguides.usc.edu/writingguide/researchdesigns (accessed 4.7.17).

Lautala, P.T., Handler, R.M., Hicks, J.W., 2011. Spatially-Based Model to Determine Price-Optimal Log Transportation by Trucks and Rail in the Upper Mid-West--Development and Initial Outcomes. Presented at the Transportation Research Board 90th Annual Meeting, Transportation Research Board, Washington DC.

Lautala, P.T., Hilliard, M.R., Webb, E., Busch, I., Richard Hess, J., Roni, M.S., Hilbert, J., Handler, R.M., Bittencourt, R., Valente, A., Laitinen, T., 2015. Opportunities and Challenges in the Design and Analysis of Biomass Supply Chains. *Environ. Manage.* 56:1397–1415. doi:10.1007/s00267-015-0565-2

Lavrakas, P.J. (Ed.), 2008. Cross-Sectional Survey Design, in: Encyclopedia of Survey Research Methods. Sage Publications Inc., Thousand Oaks, CA, pp. 173–174.

Leon, B.H., Benjamin, J.G., 2013. A survey of business attributes, harvest capacity and equipment infrastucture of logging businesses in the northern forest. North. For. Logging Ind. Assess. Univ. Maine Orono.

Libbey, S.S., 2000. An assessment of regional variation in the factors affecting the milldelivered price of softwood sawlogs and pulpwood in nine states (MS Thesis). School of Forest Resources, University of Maine, Orono.

Lilieholm, R.J., Lammert, P.R., Lord, G.R., Trosper, S.N., 2010. 2010 Directory of Maine's Primary Wood Processors (Directory). Centre for Research on Sustainable Forests - University of Maine, Maine, United States.

Malinen, J., Nousiainen, V., Palojarvi, K., Palander, T., 2014. Prospects and Challenges of Timber Trucking in a Changing Operational Environment in Finland. *Croat. J. For. Eng.* 35:91–100.

McKinnon, A.C., Piecyk, M.I., 2009. Measurement of CO2 emissions from road freight transport: A review of UK experience. *Energy Policy* 37:3733–3742. doi:10.1016/j.enpol.2009.07.007

MDOL, C., 2013. The Maine labor force - Aging and slowly growing. Maine Department of Labor, Center for Workforce Research and Information.

MFPC, 2016. Maine's forest economy. Maine Forest Products Council.

MFPC, 2013. Maine's forest economy. Maine Forest Products Council.

MFS, 2015. 2015 Wood Processor Report. Maine Forest Service, Maine United States.

Murphy, G., 2003. Reducing Trucks on the Road through Optimal Route Scheduling and Shared Log Transport Services. *South. J. Appl. For.* 27(3):198-205.

NEFA, 2013. The Economic Importance of Maine's Forest-based Economy 2013. North East State Foresters Association.

Niedhammer, I., David, S., Degioanni, S., 143 Occupational Physicians, 2007. Economic activities and occupations at high risk for workplace bullying: results from a large-scale cross-sectional survey in the general working population in France. *Int. Arch. Occup. Environ. Health* 80:346–353. doi:10.1007/s00420-006-0139-y

Ohm, R., 2016. Shutdown of Madison mill is state's fifth in two years. Portland Press Her.

Palander, T., Vainikka, M., Yletyinen, A., 2012. Potential Mechanisms for Co-operation between Transportation Entrepreneurs and Customers: A Case Study of Regional Entrepreneurship in Finland. *Croat. J. For. Eng.* 33(1): 89-103.

Pan, F., Han, H.-S., Johnson, L.R., Elliot, W.J., 2008. Production and cost of harvesting, processing, and transporting small-diameter (≤ 5 inches) trees for energy. *For. Prod. J.* 58(5):47-53.

R Core Team, 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Sambides Jr., N., 2017. Researchers, $1M in grants to help Maine recover from 'natural disaster' of mill closures. Bang. Dly. News.

Schroeder, R., Jackson, B., Ashton, S., 2007. Biomass Transportation and Delivery, in: Sustainable Forestry for Bioenergy and Bio-Based Products Trainers Curriculum Notebook. Southern Forest Research Partnership, Inc. Athens, GA, pp. 145–148.

Shaffer, R.M., Stuart, W.B., 2005. A checklist for efficient log trucking. Va. Coop. Ext. 420-094.

Short, J., 2014. Analysis of Truck Driver Age Demographics Across Two Decades. American Transportation Research Institute (ATRI).

Talbot, B., Suadicani, K., 2006. Road transport of forest chips: containers vs. bulk trailers. *For. Stud. Metsanduslikud Uurim* 45:11–22.

Tufts, R., Gallagher, T., McDonald, T., Smidt, M., 2005a. Let's Talk Trucking: Trucks and Trailers In Use In South. Wood Supply Res. Inst. Technical Paper.

Tufts, R., Gallagher, T., McDonald, T., Smidt, M., 2005b. Let's Talk Trucking: Truck Performance and Fuel Consumption. Wood Supply Res. Inst. Technical Paper.

USDOL, 2016. Occupational employment and wages: May 2015. United States Department of Labor, Bureau of Labor Statistics.

Zamora-Cristales, R., Sessions, J., 2015. Are double trailers cost effective for transporting forest biomass on steep terrain? *Calif. Agric.* 69:177–183. doi:10.3733/ca.v069n03p177