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Forest Products Trucking Industry in Maine: Opportunities and Challenges

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FOREST PRODUCTS TRUCKING INDUSTRY IN MAINE:

OPPORTUNITIES AND CHALLENGES

By

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A THESIS

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An Abstract of the Thesis Presented
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Forest transportation from in-woods to the final point of utilization is one of the major components in forest harvesting operations in terms of economics, public visibility and safety. In many cases, the price of delivered wood products depends on the transportation distance. Transportation is also crucial in terms of ensuring the supply of demanded products on time.

Globally, road transportation being the most predominant medium for forest products transportation, majority of research are focused on this subject. These scientific researches are of diverse nature; with main emphasis on improving the supply chain issues and minimizing cost of transportation, including road construction and maintenance. However, the scientific research focusing on overall challenges faced by forest transportation sector and their potential resolutions is scant.

The aim of this study was to document and evaluate the problems associated with the forest tucking sector of Maine. The next objective was to validate potential solutions, obtained through literature, with the stakeholders in the state. The third objective was to

develop a management guideline. The first step was an extensive scientific literature search related to secondary forest products transportation. A total of 131 scientific articles published from year 2000 to 2015 were collected and categorized into six different research themes. This helped in better understanding of the current trends and advances in the field. Supply chain issues and roads were the most studied research themes in this field; while trucking efficiency and safety bottomed the list.

Followed by which, a cross sectional survey was carried out in a conference setting to document and rank the major challenges to the forest trucking sector in the state. The specific reasons behind the prevalence of those challenges were also discussed. The survey yielded 31.22% response rate and the major challenge for the state was regarded as availability of market and lack of skilled manpower. These challenges were also compared with the situation of other regions in the nation and world through literature and trade magazine analysis.

For developing a management guideline with validated resolutions for the trucking related problems, a qualitative case study method with semi-structured interviews was implemented. The primary intention was to understand the perspectives of stakeholders on field level solutions. The stakeholders included forest managers, personnel from professional forestry societies, and trucking & logging contractors. Thirteen interviews were conducted, with each being audio recorded and later transcribed verbatim. The presented results included various solutions for specific problems related to trucking in Maine from stakeholders' perspective. The key findings of this process also serve as a management guideline for forest trucking industry of Maine.

This study is expected to support the understanding of challenges in general and fill the gap of knowledge regarding trucking in Maine. Land owning and managing, trucking, and logging companies would be able to use the results from this study to prepare trucking plans to support logistics based on given circumstances. These findings can be used as a baseline figure for future studies involving supply chain analysis for the logging industry.

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LIST OF ABBREVIATIONS

BSC – Biomass Supply Chains

CHP – Combined Heat and Power

CJFE – Croatian Journal of Forest Engineering

CTL – Cut-to-length

EU – European Union

GIS- Geographic Information System/ Studies

GT – Green Ton

IJFE – International Journal of Forest Engineering

Km – Kilometer

L – Liter

m – Meter

MPa – Mega Pascals

MW – Mega Watts

ODT – Oven Dry Ton

PMH – Productive Machine Hour

Tg yr^{-1} – Tera-gram per year

TWh – TeraWatt Hour(s)

WPS – Wood Procurement System

WT- Whole-tree

US/ USA- United States of America

CHAPTER 1:

INTRODUCTION

1.1. Background and Problem Statement

The whole forestry business is a collaborative effort of different stakeholders starting from tree plantation to the final utilization of wood based products. Within this process, transporting the wood from landing sites to the processing facility, also known as secondary forest products transportation, plays an important role in fixing the price of delivered wood products. It is also considered as one of the most expensive phases in the entire forest operations (Kizha. et al., 2015; McDonald et al., 2001; Pan et al., 2008).

Secondary transportation can be broadly classified into three: 1) Road transportation system (will be referred to as trucking hereafter) with trucks and trailer configurations; 2) Railway system; and 3) Water transportation system with barge and log drives (Epstein et al., 2007; Pentek and Poršinsky, 2012). With well-connected road networks in the US, trucking has become the most common form of timber transportation system at present time (Dowling, 2010). The system also has significant impact on the overall economic performance of the entire forestry sector and ensures continuous supply of wood products in demand.

Large log trucks and chip vans used in this system can haul up to 200,000 kilograms of wood products on private forest roads. On public roads and highways, they have to be under legal weight restrictions in order to operate (Gallagher et al., 2005; Sosa et al., 2015). There are also certain other issues on truck design, dimension, and axle numbers for operations in public roads. All these restrictions are based on states and policies vary between them. Apart from legal issues, there are various technical, managerial, socio-economical, seasonal, and geographical challenges associated with forest products transportation.

Past research had addressed various aspects of wood supply chains including cost, roads and networks, trucking characteristics, efficiency and safety, different modes of transportation, and logistics and optimizations. Regional information on the operation of trucking systems in forestry is equally important, as trucking conditions changes between region. There is also a need of compiling and classifying the published literature related to the supply chain and transportation of forest products. This would allow stakeholders to review and adopt suitable options for specific challenges prevalent in the region.

A nationwide study reported the average hauling distance for certain forest products, such as softwood sawlogs and pulpwood, was highest in the northern states of the US, which increased the price of products substantially compared to other regions (Libbey 2000). In Maine, the forest products industries being scattered throughout the state leads to long distance travel to reach the final point of utilization (Lilieholm et al. 2010). With the closure of five pulp mill in the past two years, the problem has been further aggravated. Therefore, having information on the challenges faced by the forest products transportation at a regional scale by incorporating related stakeholders' views and suggestions would help in better managing the entire timber harvesting operation thereby reducing the cost of the delivered products.

1.2. Organization of Thesis

There are three full length manuscripts in this thesis which are intended to be published in scientific journals. Therefore, certain statements may be repeated in different chapters. The first and current chapter is an introduction which includes the background information and problem statement of the thesis. The second chapter focuses on collection and classification of scientific articles on forest products secondary transportation published from year 2000 to 2015. The article has been submitted to peer-reviewed journal "Renewable and Sustainable Energy Reviews" for publication.

The third chapter is a study based on a cross sectional survey carried out in a regional conference of forest engineers to document and rank the challenges faced by forest trucking industry of Maine. The article has been published in "European Journal of Forest Engineering" on June 30th, 2017.

The fourth chapter has utilized a qualitative case study approach to comprehend the resolutions that can be adopted for the state of Maine to solve the challenges in forest trucking industry. This chapter has been submitted to peer-reviewed journal "PLoS One".

The fifth chapter has provided the overall conclusions of entire thesis. The applicability of the research findings for the state of Maine and directions for future research has also been discussed.

CHAPTER 2:

ANNOTATED BIBLIOGRPHY OF THE GLOBAL LITERATURE ON TRANSPORTATION OF RAW FOREST PRODUCTS (2000 – 2015)

2.1. Introduction

Transportation in forest operations can be broadly divided into two phases: the first phase involves with moving wood out from tree stump to the landing sites, referred to as primary transportation. The next phase called secondary transportation, is hauling the processed forest products (sawlog, pulpwood, or energy wood biomass) from the landing to processing facilities (Pentek and Poršinsky, 2012). Secondary transportation is considered to be one of the most expensive elements in the harvesting operation, generally accounting for 30–50% of the total cost (El Hachemi et al., 2013; Kizha. et al., 2015; Koirala et al., 2016). Therefore, a small improvement on this aspect can allows the forest product companies to reduce significant cost.

Now-a-days secondary transportation is predominantly done by roads. Various factors influence the cost of secondary transportation including - but not limited to - road network & conditions, operating cost of the truck, and hauling distance. Research generally focus on the transportation problem addressing one or some of these factors, but rarely all at the same time. It cannot be expected that one research can even look into all these factors because addressing each topic requires expertise in different domains. Nonetheless, having all informational aspects on transportation integrated will be of great value to stakeholders. This collection of scientific literature will pioneer studies addressing several relevant topics in forest products secondary transportation. It will provide an overview of the current state of the art, and help in identifying knowledge gaps that require attention. To this end, the objective of this article is to list the major findings and assesses the chronological development of forest products secondary transportation research in the past 15 years.

2.2. Materials and Methods

2.2.1. Literature Collection

The literature was searched using major online databases and library catalogs: CrossRef, Scopus, Google Scholar, and Web of Science. The initial search started in November 2016 with three keywords: “forest transportation”, “forest trucking”, and “wood supply chain”, which yielded 71 scientific articles. After careful analysis of those articles, a second search was carried out during January 2017 adding four more keywords, “forest optimization”, “biomass’, “sawlogs” and “forest roads”. Additionally, the reference section of the previously selected articles was also utilized for more specific search. A total of 169 scientific articles related to forest products secondary transportation were collected from this process. The four major journals with higher publication frequency of related articles were selected and every issue of those journals from year 2000 to 2015 were accrued through University of Maine, Folger Library Access for the faculty and students, from January to April 2016. A total of 369 volumes and issues of four journals were assessed in order to include all information related to forest products transportation. Finally, after careful analysis of titles, abstract, and objectives, a total of 131 articles were considered relevant for this review. The article search was limited to English-written scientific articles.

2.2.2. Literature Categorization and Presentation

Based on the scope and objectives of articles, six major research themes emerged: (I) cost, (II) roads and route planning, (III) trucking characteristics, (IV) efficiency and safety, (V) other modes of transportation, and (VI) supply chain and optimizations. The categorization was primarily done to facilitate compilation and reporting. However, some of the themes were closely related, for e.g. theme II- roads and route planning and VI - supply chain and optimizations. Apart from this several articles dealt with more than one theme. The articles were compiled based on the primary objective of the research. Additionally, for minimizing ambiguity, no articles in one theme have been repeated in another.

Theme I (cost) primarily dealt with articles focusing on financial aspects of trucking operations. The theme also included articles related to detailed time studies; strategies to minimize the overall transportation costs; assessing the impacts of transportation distance on final cost of delivered forest products; and evaluating the performance of transportation cost estimating software and models. Theme II (roads and route planning), focused on every aspect of forest roads including engineering, planning, design, construction, maintenance, spatial modeling, and computer software. Theme III (Trucking characteristics) was specific for road transportation. Some of the topics were: truck size & configuration, speed on various road conditions, weight limits, payload enhancement measures, trucking performance, and features of trailers. Theme IV (efficiency and safety) dealt with fuel efficiency, log trucks accident analysis, social surveys with related stakeholders, and evaluation of fuel consumption capacity. Other studies included effects of forest road erosion to supply chain potential. Theme V (other modes of transportation) focused on articles dealing with railways and water transportation. Theme VI (supply chain and optimizations) incorporated articles primarily modelling supply chain in different regions, using geospatial and linear programming approach. It also included articles related to strategic and tactical planning, optimization of supply chain, decision support tools for wood procurement and management, and simulation of logistics models. The information of articles in each theme were summarized in a tabular format with table headings: authors – countries/regions – types of products – objectives – major findings and/or suggestions.

2.3. Results

Out of total 131 articles used in this study, 127 were published in peer-reviewed scientific journals, three in conference proceedings and one was a cooperative extension article. With more than 22% publications, *Biomass and Bioenergy* published the highest number of articles related to the field followed by *Croatian Journal of Forest Engineering* and *International Journal of Forest Engineering* (Table 2.1).

Table 2.1: Peer-reviewed journals with number of published articles.

Journal	Number of Publication
Biomass and Bioenergy	29
Croatian Journal of Forest Engineering	26
International Journal of Forest Engineering	25
Renewable and Sustainable Energy Reviews	10
European Journal of Operational Research	3
Forest Policy and Economics	3
Transportation Research: Part A	2
European Journal of Forest Research	2
Canadian Journal of Forest Research	2
Journal of Cleaner Production	2
Western Journal of Applied Forestry	2
European Journal of Forest Engineering	2
Others (23 journals with single publication each) *	23
Total	**131**

*publication details can be accessed from the reference

On a regional basis, about 56% of the research articles were published by authors with primary workstation in Europe and 33% were related to the North America (Table 2.2). However, the US had the highest number of publication country basis.

Table 2.2: Geographic distribution of selected articles. Articles are categorized based on the area of the study. First author's primary address was used for articles without clear indication of study area.

Region	**Number of articles**
Europe	73
North America	43
Asia	8
Australia & New Zealand	3
Africa	2
South America	2

For the given period, highest number of articles were published in the year 2013 (16 articles) followed by 2005 (15) (Figure 1). On average, eight articles related to forest products transportation and supply chain were published per year from 2000 to 2015. Nearly 33% of the reviews were related to supply chain logistics and optimization (Figure 2.2).

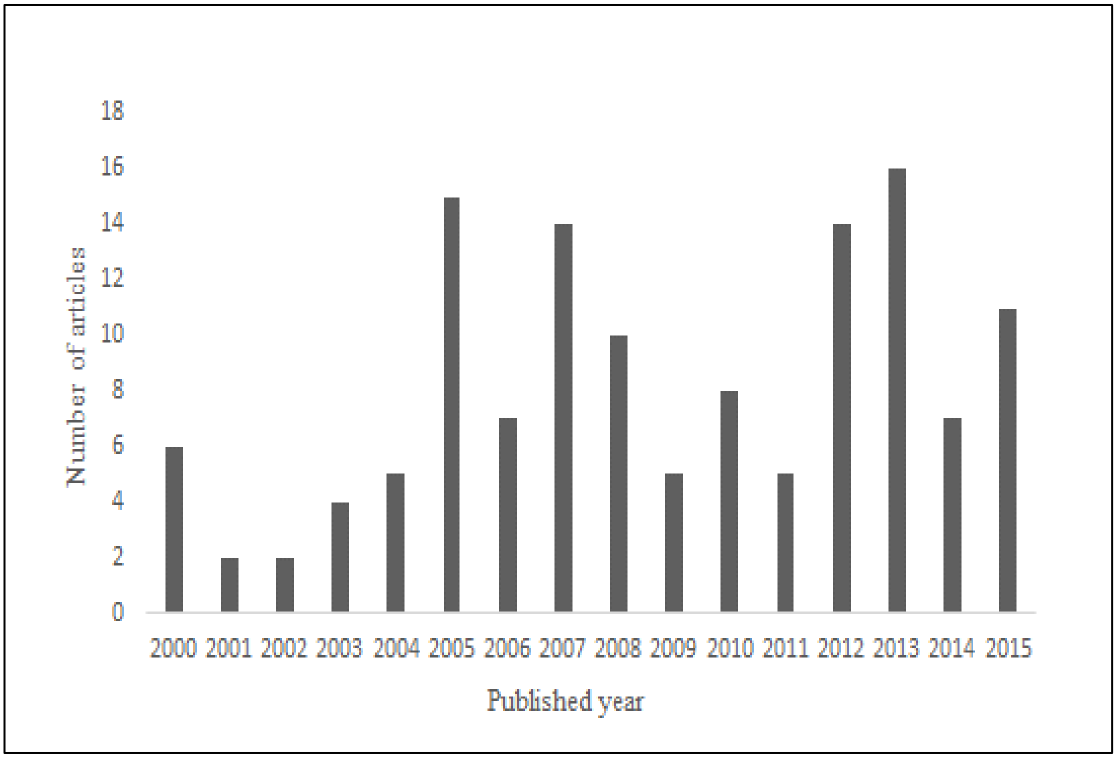

Figure 2.1: Publication frequency of the articles per year.

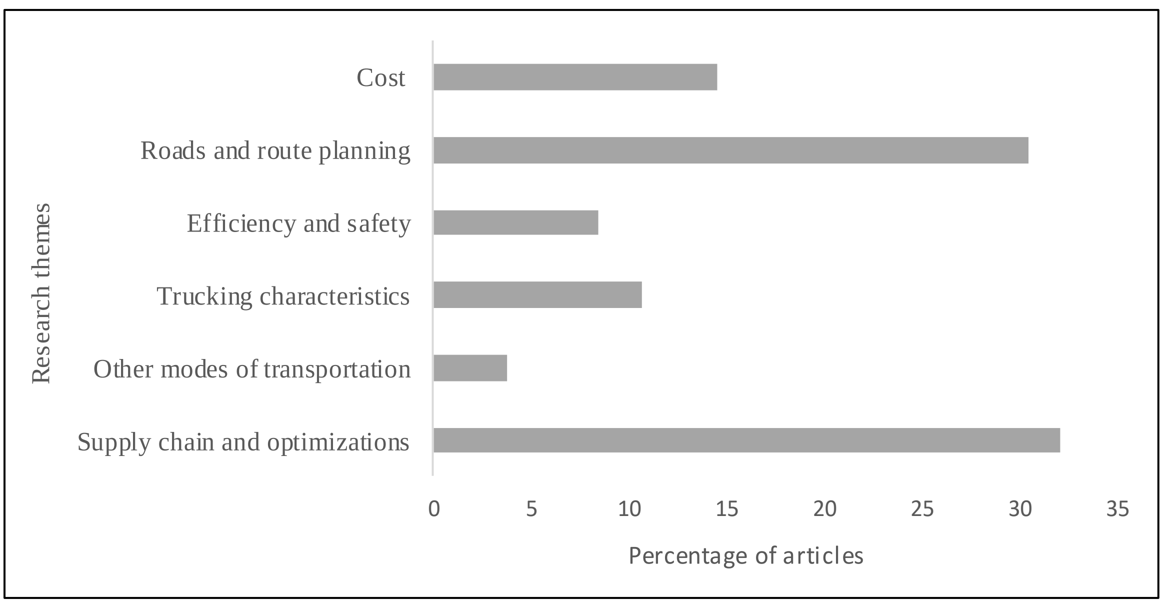

Figure 2.2: Distribution of articles according to research themes.

2.3.1. Theme I - Cost

There were altogether 19 articles in this category that accounted for about 15% of total articles reviewed. An average of 1.2 articles were published each year for this category. Majority of the articles (more than 80%) were based on comminuted forest products mainly wood chips and logging and industrial residues for bioenergy and biofuel development (Table 2.3). Regarding the country specific metadata, the highest number of publications (6 articles) were based in the USA followed by Sweden, Finland and Austria.

Mainly the section covered various aspects of expenditures, including different techniques to minimize overall costs of forest products transportation. Few articles also discussed the impacts of forest industries to the local economies, which were further associated to the transportation distance and cost. Some of the articles reported the performance of transportation cost estimating software and models.

Table 2.3: Published scientific articles' metadata under theme I – cost. The cost values mentioned reflects the actual value presented in the article. In author section only the last name provided by reference manager is presented. Objectives and findings mainly related to forest products transportation are presented while others are eliminated.

Author(s)	**Country**	**Wood products***	**Research objective(s)**	**Major finding(s) and/or suggestions**
(Acuna et al., 2012)	Australia	3	Illustrated the advantages of optimizing trucking efficiency and cost	Model resulted in savings of 52 and 29% of the total cost in truck payload and chipper utilization, respectively.
(Aksoy et al., 2011)	USA	4,5	Assessed economic impacts of four different types of bio-refinery	Average transportation distance was 52 km to the bio-refinery plants. Longer distance for paper sludge. Out of different biorefinery technologies studied simultaneous saccharification and fermentation (SSF) and direct spouted bed (DSB) gasification process were only economically feasible to carry out.
(Frisk et al., 2010)	Sweden	1,2,3	Used cost allocation method for allocating transportation costs among forest companies	Better planning within each company could save about 5% and collaboration could increase this saving to a total of 14% on transportation cost.
(Graham et al., 2000)	USA	3,4	Estimated potential energy feedstock transportation costs in eleven US states	Transportation cost was lowest in Iowa, North Dakota and South Dakota and highest for South Carolina, Missouri, Georgia and Alabama.
(Grebner et al., 2005)	USA	1,2,3	Excel based program 'Routechaser' to assess the impacts of different variables on transportation cost	This tool was useful for establishing contract rates from timber harvest units to markets.
(Johansson et al., 2006)	Sweden	4	Analyzed cost of transporting logging residues	Dry energy woods bundles were cheaper to transport than fuel chips. Volume was the limiting factor when transporting dry material. Transportation cost decreased until the moisture content reached the critical levels: below 41% for chips in road transport bins and below 45% for bundles on timber truck.
(Jones et al., 2013)	USA	4	Analyzed financial feasibility of delivering biomass resulting from changes in diesel and delivered biomass prices	For lowest delivered biomass price (\$32 ODT^{-1}) and diesel price (\$0.05 L^{-1}), 28% of the potential volume was financially feasible; while only 6% was available with highest diesel price (\$1.32 L^{-1}).

Table 2.3 continued

(Junginger et al., 2005)	Sweden	4	Quantified cost reduction of primary forest fuel production and supply chain	Major cost reductions were achieved in forwarding and chipping, largely due to learning-by-doing, improved equipment and changes in organization
(Kizha. et al., 2015)	USA	4,5	Identified potential biomass feedstock available regionally based on transportation cost	Area within \$20 ODT^{-1} transportation cost zone had the highest potential supply of woody biomass for the region. In-wood operational cost was also included to estimate the resource availability.
(Kurka et al., 2012)	UK	3	Allocated biomass feedstock supply to bioenergy plants and estimated transportation costs	Ten bioenergy plants could produce 49 MW electrical, and 129 MW of thermal output. Based on this suitability of plant locations the transportation cost was calculated at ~\$23 million/year.
(Möller and Nielsen, 2007)	Denmark	3	Estimated transportation costs	Large energy plants with optimal road connections had higher costs of fuel supply
(Paolotti et al., 2015)	Italy	6	Compared and evaluated economic feasibility of various transportation modes	Road and water transport cost ranged between \$19–120 ton^{-1} and \$73–88 ton^{-1}, respectively.
(Ranta and Rinne, 2006)	Finland	4	Profitability and possible measures for improving forest residue transportation	Most cost-efficient way to transport raw material was in the form of bundles and most expensive was as loose residues. The difference between options increased with increase in distance.
(Rauch and Gronalt, 2011)	Austria	4	Impacts of rising energy costs and transportation mode mix on forest residue procurement costs.	With an increment of 20% in energy costs resulted in a procurement cost increase of 7%. One way to decrease procurement costs would be to reduce the share of empty trips with truck and trailer. Reducing this share by 10% decreased the average procurement costs by up to 20%.
(Rauch et al., 2010)	Austria	4	Cost gap between co-operative and non-co-operative BSC (biomass Supply Chain)	Co-operation between power plants lowered forest fuel transportation costs by 23% on average and reduced average transportation distances by 26%.
(Spinelli et al., 2009)	Italy and USA	1,2	Modelled transportation cost for short rotation plantations	Simulation showed Whole tree (WT) system allows cheaper harvesting and transport than Cut-to-length (CTL) system for a range of conditions. The delivered cost for pulp chips from WT was ~\$21 GT^{-1} while it was \$27–30 GT^{-1} for CTL.

Table 2.3 continued

(Tahvanainen and Anttila, 2011)	Finland	3	Estimated costs of forest chips procurement for long-distance transport	For distances shorter than 60 km, trucking of loose residues and end-facility comminution was most cost-competitive. Over longer distances, roadside chipping with chip truck transportation was most cost-efficient option. For transportation distance range 135–165 km, rail transportation offered the lowest costs.
(Yemshanov et al., 2014)	Canada	4	Potential amount and financial costs of forest residue biomass supply	Annual supply of harvestable residual biomass was about ~19.2–23.3 Tg/yr and 16.5–20.0 Tg/yr. Decreasing residue extraction costs by 35% increased the residues available by ~5.5 to 5.7 times at \$45 ODT^{-1} supply price and ~1.5 to 1.6 times at \$60 ODT^{-1} supply price.
(Yoshioka et al., 2006)	Japan	4	Examined the cost feasibility of transporting systems for logging residues	Compared European countries and Japan and showed the need of a low-cost harvesting, transporting, and chipping techniques for energy utilization in Japan.

*Type of wood products: Sawlogs (1), Pulpwood (2), Wood chips (3), Logging residue (4), Sawmill residue (5), and wood pellets (6).

2.3.2. Theme II – Roads and Route Planning

A total of 40 articles (about 31%) were categorized under this theme; an average of 2.5 articles were published per year. Similar to the Theme I, the highest number of publications were from the USA (12 articles) followed by Turkey, Croatia, Slovenia, Sweden, Iran, and Japan (Table 2.4). 3.3 Articles related to GIS modeling and linear & mixed integer programming to solve forest roads planning problems were included in this theme instead of Theme VI (Supply chain and optimization). Similarly, for articles analyzing the cost related to certain aspects of forest road (for e.g., constructions) were included in Theme II instead of Theme I (cost).

In this theme, most of the studies were focused on construction and maintenance of forest roads. Computer-aided technologies in road designing was also presented in some studies. Other studies categorized in the section were aimed at minimizing costs of road construction.

Table 2.4: Published scientific articles' metadata under theme II – roads and route planning. The recommendation/ findings are specific to the research/ region and conditions described in the article.

Authors	**Countries**	**Objective(s)***	**Major findings and/or suggestions**
(Abeli et al., 2000)	Tanzania	Addressed issues of road alignment and grades on a secondary access gravel forest road maintenance costs	Road alignment and gradient were found to influence the rate of soil loss. For minimal maintenance costs, grades less than 6% and radii above 100m were ideal.
(Akay and Sessions, 2005)	Turkey	Determined route from two demonstration routes (A and B) with lowest total construction, maintenance, and transportation costs	Unit costs for A and B were $46/m and $28/m, respectively. Construction cost (for A: $9,107 and for B: $5,754) was the largest component, followed by maintenance (A: $2,918; and B: $1,112) and transportation costs (A: $941; and B: $929).
(Akay et al., 2005)	Turkey	Reviewed the evolution of software to design forest roads	Development of modern heuristics techniques such as *Tabu Search, Threshold Accepting, Simulated Annealing, Genetic Algorithm*, and their hybridization with traditional solution techniques into meta-heuristic algorithms can offer opportunities for future research.
(Aruga et al., 2006)	USA	Optimized road alignments using the Dijkstra shortest path method and cubic spline function	Reported initial effort to use the spline function in optimal road design. The solutions using a spline function was 10% poorer than the solution without a spline function. Additional investigation could improve solution quality using the Dijkstra method and cubic splines.
(Beck and Sessions, 2013)	USA	Determined access of woods chip trailers in forest roads using Ant Colony optimization and Breakeven analysis	Being able to modify the forest transportation network to accommodate larger trucks access could greatly reduce hauling costs. Decisions for isolated biomass operations depended on road modification cost, transport volume, and transport costs on forest and highway roads.
(Beck et al., 2015)	USA	Examined use of intensity values and return densities to identify and extract roads using Aerial LiDAR	Road extraction process resulted in 80% true positives, 34% false positives, 20% false negatives, and 38% true negatives in identifying forest roads. The average absolute value difference in the road width between the two data sets were 1.1 m, while the cut/fill slope differences were minimal (> 4%) and the difference in road cross slope was 2%.
(Boston et al., 2008)	USA	Discussed the potential economic gain in construction of surface layer of roads by improving subgrade strength	Study showed that a 34% saving in road aggregates cost may be possible with improvement in road subgrades.

Table 2.4 continued

(Contreras et al., 2008)	USA	Compared ant colony optimization (ACO) meta-heuristic and mixed-integer programming (MIP) to solve forest transportation planning problems	ACO solutions were equal to or slightly worse than the MIP solution. However, ACO algorithm took only a fraction of the computation time compared to MIP.
(Contreras et al., 2012)	USA	Improve accuracy in earthwork volume estimation for roads using high-resolution digital elevation model	Cross-section spacing increased the accuracy of earthwork volume, whereas decreased the lack of the ability to capture terrain variations. The short cross-section spacing should be applied to improve accuracy in earthwork volume estimation when roads are planned and located on hilly and rugged terrain.
(Demir, 2007)	Turkey	Analyzed forest road network system	Need for total forest roads in Turkey was ~201,000 km, of which 66.25% was constructed in 2005. It was projected that the construction of the planned forest roads and the completion of road structures will take around 20 years.
(Devlin et al., 2008)	Ireland	Designation of articulated haulage routes from a central depot to various destinations in terms of road class, distance, speed and travel time	Shortest path determined by Network Analyst Tool (NAT) did not replicate the actual GPS routes. However, when NAT was manipulated based on road classes, the GPS routes were over 90% similar. This might allow GIS alone to be used in the network analysis of timber truck routing from forest harvesting site to sawmill and incorporate the use of GPS for other features like real-time tracking and monitoring of timber movement.
(Ghaffarian and Sobhani, 2007)	Iran	Determined the best forest road network that minimized total cost of road maintenance	Shortest path algorithm showed road segments that could be used and segments could be eliminated from existing road network to achieve minimal cost of road transportation and skidding.
(Ghajar et al., 2012)	Iran	Presented Rock Share Estimation procedure to estimate the cost of forest road construction	This approach was useful to show the variability of rock proportion and model excavation costs.
(Greulich, 2003) (review paper)	USA	Evolution of transportation network in forest harvesting	Theoretical basis for transportation networks in forest harvesting can be found in the research of early European academics. From twentieth century, this theory continued its development in America. The last fifty years have seen swift development in Europe and America, with increasing contributions from Asia.

Table 2.4 continued

(Gumus, 2015)	Turkey	Evaluated the future use of forest road networks of a specific site in accordance to sustainable forestry practices	All forest roads in the study area were classified into four quality classes (Class I: very good; Class II: good; Class III: bad; Class IV: very bad) for the future use. After evaluation, it was found that 51% of the road was classified as Class II, while 31% and 18% were classified as Class I and III, respectively. The results suggested that the forest road network of the area was sufficient in general regarding with the sustainable forestry goals.
(Gumus et al., 2008)	Turkey	Develop road network planning method for timber harvesting with minimal impact on surrounding environment	Forest road density value was determined as 23 m ha^{-1}: the opening-up rate of the area was increased to 78% and the opening-up rate of the existing stand value was increased to 94%. The method was expected to have minimal negative impact on the existing forest environment.
(Hernández-Díaz et al., 2015)	Mexico	Assessed impacts of forest roads on soil during timber harvesting	Run-off in the rainy season decreased the ground level by between 38 and 58 mm along the truck ruts, and the soil loss was different in each type of road. The findings have helped in proposing the elimination of some tertiary roads, to reduce the total road density. The study estimated that soil loss would be reduced by 20% with the proposed changes to the road network.
(Košir and Krč, 2000)	Slovenia	Show the existing condition of forest road design and construction in Slovenia and adopt multi-criteria decision model to build new forest roads	Results showed that the terrain was suitable for the design and construction of forest roads and skidding tracts. The model can be considered for future forest road construction.
(Krč and Beguš, 2013)	Slovenia	Developed a model that can identify inaccessible forests and helped in future forest roads planning.	There was still 210,385 ha of inaccessible forests. The construction of 758 km of new roads was planned at the national level.
(Lugo and Gucinski, 2000)	USA	Proposed a unified approach to the management and analysis of the function forest roads on rural landscape	The study proposed that roads be analyzed as ecosystems using environmental gradient analysis to distinguish between road segments in different sectors of the landscape or across latitudes and elevation.
(Murphy and Stander, 2007)	USA	Developed a two-step robust optimization model to tackle the real-world forestry transportation problem.	The results showed that the deterministic solution was unstable and dependent on some degree of uncertainty, that the robust solution was dependent on the robust performance measure selected.

Table 2.4 continued

(Najafi and Richards, 2013)	Iran and Canada	Mixed integer programming model to design an access system consisting of roads and spurs to minimize costs of road construction	The model performance was explored on mountainous region, where a persistent access network for partial harvesting was required. High quality solutions were achieved in reasonable computational time.
(Najafi et al., 2008)	Iran	Assess and plan alternative forest roads and skidding network	The network was accepted in which the environmental impacts were decreased, along with minimized cost of roads network and skidding.
(Nevečerel et al., 2007)	Croatia	Categorize forest roads based on traffic load and distance	Determination of forest roads by GPS and snap-back method presented a very fast and sufficiently accurate technique. The average relative openness of given management unit for road construction showed 72% of open area (14% of roads and 58% of skid roads) and 28% of closed canopy area.
(Olsson, 2005)	Sweden	Mixed integer model (decision support system) for strategic planning of road investments for large areas	The study concluded that the type of objective function to be used depends on the situation and the entire network of roads must be optimized simultaneously, to avoid sub-optimizations. Although the forest area included 440 roads, it will be possible to obtain the global optimal solutions from the optimization within a few minutes using commercial software.
(Olsson, 2007)	Sweden	Two-stage stochastic model to optimize the upgrading of a forest road network	The model was rather insensitive to uncertainty in critical period length, such as the length of spring thaw, at least when applied to the medium-sized problem presented in the study.
(Olsson and Lohmander, 2005)	Sweden	Optimize sawlog transport and road investments on gravel road	With a simple heuristic method 'near to optimal' solutions were obtained in reasonable time.
(Pellegrini et al., 2013)	Italy	Decision support system to rank maintenance priorities of forest road network based on actual conditions and needs	The results showed that the integrated use of GIS and AHP (Analytic Hierarchy Process) analysis represents a valuable tool to rate the importance of the forest road network for the management of a mountain territory and to define priorities among maintenance operations of the road network.
(Pentek et al., 2005)	Croatia	Analyzed existing forest road network using GIS	The analysis helped the forest managers to allocate resources efficiently to specific forest areas. The model was sensitive to the situation on the ground and yet easily implemented.

Table 2.4 continued

(Pentek et al., 2007)	Croatia	Analyze the situation of forest roads; recognized and defined problems that were detected	An average of 272 and 319 km of lower and upper forest road layers were constructed annually at an average cost of 118,134 and 135,020 Croatian Kuna km^{-1}, respectively.
(Pentek et al., 2008)	Croatia	Prepare the registry of secondary forest roads	Terrain measurement of the secondary forest roads by a GPS receiver, with the use of snap-back method of surveying, represented a sufficiently quick and exact method for establishment of the secondary forest traffic infrastructure registry.
(Péterfalvi et al., 2015)	Hungary	Evaluated the effect of lime-stabilized subgrade on the performance of forest road pavement	The bearing capacity of the lime stabilization was 500 MPa. For long term performance, 25–35 cm of lime stabilization under the pavements was considered good. Also, 35 cm thick layer of the stabilized soil was good to bear traffic.
(Potočnik et al., 2005b)	Japan	Maintenance of forest road network in the natural forest management	The main roads are maintained every year. The management roads are maintained every 10 years, coinciding with rotation year of selection cutting.
(Potočnik et al., 2005a)	Slovenia	Analyze traffic load on forest roads due to forest operations	The cumulative traffic load and hauled forest products quantity were highest at the cross-section of forest roads and public roads while it was lowest at the farthest point from public road.
(Robek and Klun, 2007)	Slovenia	Described trends in forest traffic way construction	The study showed forest road network in Slovenia was not considered optimal. It was getting increasingly worn out, and the new transportation technologies demand certain adaptations to be made in the existing technical elements.
(Saito et al., 2013)	Japan	Examined a model which can automatically designed forest roads on shallow landslides area using LiDAR data	The model was developed with LiDAR based Digital Terrain Model (DTM) and shallow landslide risk map using cubic spline interpolation and dynamic programming. The program could minimize the earthwork costs while avoiding shallow landslide risk areas.
(Sessions et al., 2006)	USA	Determined optimal policies for managing aggregate resources on temporary forest roads	A mathematical model was suggested to determine optimal policies to manage high quality durable rock aggregates resources

Table 2.4 continued

(Stückelberger et al., 2006)	Switzerland	Estimated the life-cycle costs of forest roads	When location-specific slope gradients were considered, costs were reduced by about 17% from those calculated via currently available engineering practices. However, when both slope gradient and geotechnical formations were included, those costs were decreased by about 20%. Besides that, the length of the road network was increased by about 4% and 10% respectively, compared with current practices.
(Tan, 2000)	Australia	Optimized internal forest road location	Programming procedure integrated with spatial database and transportation network models, were used to assist foresters in determining the optimum location for a forest road.
(Trzcinski and Kaczmarzyk, 2006)	Poland	Estimated the carrying capacity of forest roads with slag and gravel pavements	Carrying capacity of slag and gravel pavements defined according to the mean module (Me) was insufficient. The largest mean deformation module (123 MPa) was detained for gravel pavement. Only two-ply gravel pavements (about 25 cm thick) had the mean carrying capacity complying with the requirements of low traffic intensity.

*****All roads described in the article refers to forest roads unless specified.

2.3.3. Theme III – Trucking Characteristics

This theme comprised of 14 articles which was about 11% of total included articles (Table 2.5). About 60% of the studies were related to the transportation of sawlogs and pulpwood while rest were focused on comminuted biomass and energy woods. A total of five studies were carried out in the USA followed by four in Finland.

The articles were mainly related to the characteristics and nature of trucking like weight limits, speed, and features of trailers. Some other noticeable studies in this section were: the use of GPS tracking system in trucks to evaluate trucking performance, options for backhauling empty trucks and solution for truck scheduling problems in forest operations.

Table 2.5: Published scientific articles' metadata under theme III – trucking characteristics. The recommendation/ findings are specific to the research/ region and conditions described in the article.

Authors	Countries	Type of products*	Objectives	Major finding(s) and/or suggestions
(Antoniade et al., 2012)	Romania	1	Estimate maximum loading heights for vehicles used in timber transportation	The maximum truck load height for average conditions varied the main characteristics of the loading-unloading equipment, as well as the maximum allowable loads per axles.
(Devlin and McDonnell, 2009)	Ireland	1	Evaluated the performance of real-time GPS asset tracking systems for timber hauling trucks	The horizontal root mean square (HRMS) accuracy values were 2.55–2.47 m for public roads, while for forest road the values were 27–41 m.
(Han and Murphy, 2012)	USA	3	Modelled woody biomass truck scheduling problem	An optimization model was developed for transporting four types of woody biomass. For an actual 50-load order size, the truck scheduling model produced significant improvements in solution values within 18 seconds. The average reductions in transportation cost and total travel time were 18 and 15%, respectively.
(Han et al., 2010)	USA	4	Evaluate the economic feasibility of removing hand-piled slash using a roll off trucking system in mountainous terrains	The overall cost to collect and haul hand-piled slash was $34 ODT^{-1}. Roll-off trucking system was found to be better for short hauling distances since trucking costs significantly increased with small increases in hauling distance due to slow traveling speeds and hauling of lower slash weight. Financial analysis showed that contractors can gain high return on their invested capital after accounting for inflation and income taxes, but limited work opportunities were a concern for them.
(Laitila and Väätäinen, 2012)	Finland	2	Evaluated the competitiveness of various supply systems of small-diameter wood	Harvesting of multi-stem delimbed shortwood was a good way to simplify operations and to reduce transportation and chipping costs. For whole-tree bundling, reduction in transportation did not counterbalance the high felling and compaction costs, and the bundling system was least competitive alternative.
(Malinen et al., 2014)	Finland	1,2	Surveyed challenges related to timber trucking in a changing operational environment	Half of respondents thought that the profitability of timber trucking had decreased greatly (23%) or to some extent (24%). Results showed most influential infrastructure factor affecting timber trucking was winter maintenance, including removing snow and ice and anti-slip measures.

Table 2.5 continued

(McDonald et al., 2013)	USA	1,2	Characterized the baseline loaded-distance driven efficiency of an existing pooled log-transport system operating in Alabama, USA	Data on distance driven and loads delivered from five loggers to nine consuming mills were collected from a log-trucking firm. Routes were assigned by a supervisory person and were not optimized. On average, over the week of testing, the schedule achieved a loaded-distance driven proportion of 57%. A route-optimization system was used to assign delivery schedules, and it achieved a loaded-distance driven proportion of 66%, significantly higher than the human-assigned routes ($p < 0.02$) and potentially saving the firm up to 24,000 km per year.
(Nurminen and Heinonen, 2007)	Finland	1	Introduced a statistical procedure for examining the variation in time consumption during the timber trucking phases	As transportation includes several phases with multiple factors affecting the work performance, a significant variation in the total transportation time was observed. This makes planning and cost accounting more difficult. The models developed in this study were a promising initial tool to support route planning and optimization, and cost and profitability calculations.
(Palander et al., 2004)	Finland	3	Introduced a support method for modeling backhauling of energy wood trucking	This method could minimize empty-route driving. However, further development of the empty-route minimization method was recommended before using it in combination with the optimization of backhauling.
(Picchi and Eliasson, 2015)	Sweden	3	Evaluated the use and performance of container handling chipper trucks (CCT)	The average productivity varied between 9.3 and 13.5 ODT PMH^{-1} depending on choice of grapple. A standard residue grapple was considered better for CCT. About 17% of the work time consisted of delays. With wise planning and adjusting the number of container trucks used, total waiting costs can be reduced.
(Roscher et al., 2004)	Sweden	1,2,3	Examined transport patterns of trucks with (first group) or without the support (second group) using mobile data systems (MDS)	The daily number of separate forest destinations was 4.1 for trucks with MDS and 3.7 for those without, while separate mill destinations visited was 2.7 and 2.2 respectively. The size of the total annual operating area was 29,050 km^2 for those with MDS and 18,656 km^2 for those without, while the main operating area constituted 35% and 28% of the total annual operating areas for trucks with and without MDS, respectively.
(Shaffer and Stuart, 2005)	USA	1,2,3	Developed a checklist for efficient log trucking	A guideline for efficient timber trucking for the state of Virginia.

Table 2.5 continued

(Spinelli et al., 2015)	Europe	2	Tested a chipper truck performance in different geographic conditions	Productivity varied between 13 and 19 tons of green chips per scheduled hour, inclusive of all delays. Fuel consumption ranged from 1.8 to 2.8 liter of diesel per ton of green chips. Machine utilization ranged from 68 to 89%.
(Thompson et al., 2012)	USA	2	Evaluated the transportation of woody biomass	The larger trailers contained 19% more volume than traditional one, however, only increased 10% payload. If used exclusively, larger trailers can reduce 6 loads to transport all chips from the site.

*Types wood products: Sawlogs (1); Pulpwood (2); Wood chips (3); and Logging residue (4).

2.3.4. Theme IV – Efficiency and Safety

There were 11 articles in this category which was 8% of total articles reviewed (Table 2.6). An average of less than 1 article was published per year from 2000 to 2015.

This theme mainly included studies attempting to assess and enhance the efficiency of forest products transportation. The articles were of diverse nature ranging from surveys with loggers to the analysis of log hauling accidents. The evaluation of fuel consumption capacity and effects of forest road erosion to supply chain potential were also presented.

Table 2.6: Published scientific articles' metadata under theme IV – efficiency and safety. The recommendation/ findings are specific to the research/ region and conditions described in the article.

Authors	Countries	Objectives	Major finding(s) and/or suggestions
(Abbas et al., 2014)	USA	Surveyed existing forest-based production capacity and its potential to supply the startup of large scale forest-based industries	The response rate was 28%. The study provided technical forest products operations information and methods for assessing the capacity of logging firms and markets looking to expand their businesses
(Arce et al., 2002)	Brazil	Solved forest-level bucking optimization problem considering customer's demand and transportation costs by a system.	The system was used to evaluate three scenarios: an observed medium-term forest harvesting scenario, with 32 stands harvested for one month, a simulated demand-oriented scenario and a simulated supply-oriented one.
(Greene et al., 2007)	USA	Analyzed log hauling vehicle accidents in Georgia, USA	Accidents per million tons of wood consumed had increased steadily from 11 in 1991 to 19 in 2003.
(Hall et al., 2001)	New Zealand	Identified promising delivery systems of logging residues to an energy plant and evaluate the associated costs	The cheapest system identified ranged from NZ$22 - 37 ODT^{-1} for residues from the landing and NZ$29 – 42 per ODT for those collected from the cutover.
(Hedlinger et al., 2005)	Sweden	Examined the service divergence potential of round wood transport	This study was based on interviews from 20 transport service providers and buyers. The results presented three main themes: transport service goals, decisions and decision support processes. The rankings and correlations were used to suggest a customer service matrix for round wood transport
(Holzleitner et al., 2011)	Austria	Analyzed time and fuel consumption in road transport for round wood	The transport distance from the forest to sawmill averaged 51 km. The average share on forest roads within a route to the sawmill was 14% with an average speed of 14 km per hour. Transport costs from the forest site to the sawmill with a truck and trailer were € 11 m^{-3} solid timber based on an average load size of 25 m^3. On an average 0.77 L/km of diesel was consumed during a round trip.

Table 2.6 continued

(Jerbi et al., 2012)	Canada	Evaluated supply chain management policies in the forest products industry using simulation based framework	The framework was based on two phases. The tactical phase was supported by software called LogiLab. It facilitated to model the supply chain and determine the aggregate production-transportation plan. From this plan, production & products flow policies were extracted. In the second phase, the user evaluated this policy at the operational/execution level on combination with execution policies, using a discrete events simulation supported by Simio software.
(Klvač et al., 2013)	Czech Republic	Evaluated fuel consumption by timber trucks	Obsolete and inadequate truck-and-trailer units were continuously replaced with new units, resulting in a considerable reduction in fuel consumption per unit of production (0.5 L m^{-3}).
(Rackley and Chung, 2008)	USA	Analyzed the effects of forest road erosion and incorporated it on transportation planning	The results indicated that incorporating environmental impacts into transportation planning can generate alternative road networks that reduce a large amount of estimated sediment delivery at an expense of a relatively small increase in transportation costs.
(Ranta and Korpinen, 2011)	Finland	Maximized the forest fuel supply availability to power plants	The total availability to the selected CHP (combined heat and power) plant population was 7 TWh at a maximum transportation distance of 100 km. Share came from logging residues (3.3 TWh), stumps (1.8 TWh), and small diameter energy wood (1.9 TWh). The highest plant-specific availability reached the level of 1.7 - 1.8 TWh, but the overlapping procurement areas reduced the availability for most plants to a level less than 1 TWh.
(Sikanen et al., 2005)	Finland	Investigated an internet-based, general-purpose logistics control system, using mobile terminals in forest fuel chipping and transportation	The management tool, Arbonaut Fleet Manager TM, was tailored for forest fuel supply chain management and trailed for three months. It was found that use of mobile handsets with GPS and map display assisted in finding exact location of in-wood storage piles.

2.3.5. Theme V – Other Modes of Transportation

Only five articles comprised this category, which was the least of all categories (Table 2.7). This group assorted articles with modes of transportation other than trucking. However, studies related to intermodal and other secondary intermediate transportation involving trucks were also presented in the findings. The major focus of articles was on the role of rail or water transportation in wood products supply chain.

Table 2.7: Published scientific articles' metadata under theme V – other modes of transportation. The recommendation/ findings are specific to the research/ region and conditions described in the article.

Authors	Countries	Type of products*	Objectives	Major finding(s) and/or suggestions
(Ackerman and Pulkki, 2003)	South Africa	2	Analyzed economic impact of secondary intermediate transportation (SIT) of pulpwood	South African(SA) forest industry's average annual transportation cost penalty, by maintaining SIT, was SA$4.32 million or $0.82 m^{-3}. This showed the need of maintaining good quality forest roads and eliminating the SIT system in future.
(Asikainen, 2001)	Finland	1	Simulated barge transportation of wood from forests on island	A new push barge system suitable for transport of wood from islands was compared to the current powered barge system. A three barges' setting system gave the lowest harvesting costs when the transport distance exceeded 100 km. At shorter transport distances, the current system was most competitive. Direct loading of barges by forwarders was cheaper than the use of a separate loader. Direct loading, however, requires new driving ramps and is not applicable everywhere.
(Flodén and Williamsson, 2016)	Sweden	3	Evaluated the business models for sustainable biofuel transport using intermodal transport	Four typical business models were dealt: Regional/National Biofuel Company, Local Biofuel Company, Heating Plant Own Account, and Wood Processing Industry. Cooperation and vertical integration among the stakeholders were important to reach the large transport volumes required for intermodal transport. Key issues to increase the intermodal potential were: increased vertical integration and cooperation, sharing of transport resources and infrastructure, joint purchases, outsourcing to expert actors, building trust and open communication, and not underestimating the complexity of intermodal transport.
(Gonzales et al., 2013)	USA	3	Analyzed the impact of rail, truck and barge transportation on costs	For shipments from mid-west to the southeast USA, barge transportation was the least expensive mode. After barge, unit trains were the least expensive for distances longer than 160 km. For shipments from the mid-west to the west USA, unit trains were the least expensive mode for distance over 340 km. For shorter distances, trucking was the least expensive transportation mode.

Table 2.7 continued

(Lautala et al., 2012)	USA	3	Analyzed the role of railroads in multimodal transportation in Michigan, USA	Some of the greatest challenges for use of rail in log/biomass transportation included the short length of trip; numerous originating locations with limited shipping volumes; difficulty to reach destination without rail to rail interchanges; and the potential lack of rail access to destination. Rail offers potential savings in transportation rates, but one of the challenges when analyzing the cost of multimodal log/biomass transportation was that the rates should be typically estimated case-by-case for each origin-destination pair.

*Types of wood products: Sawlogs (1); Pulpwood (2); Biomass (3).

2.3.6. Theme VI – Supply Chain and Optimizations

The supply chain logistics and optimization was the most studied topic related to forest products transportation in given timeline There were altogether 42 articles in this theme with an average frequency of 2.6 articles per year (Table 2.8). More than 70% of the studies were based on biomass, energy woods and logging residues. Highest number of studies were carried out in Canada and US with 8 articles each, which was followed by Sweden with 6 articles and Finland and Greece with 5 articles each.

The findings included articles focused on different models and systems of supply chain of wood-based products It ranged from mathematical modeling to integration of tasks for better supply chain planning.

Table 2.8: Published scientific articles' metadata under theme VI – supply chain and optimization. The recommendation/ findings are specific to the research/ region and conditions described in the article.

Authors	**Countries**	**Types of products***	**Objectives**	**Major finding(s) and/or suggestions**
(Akhtari et al., 2014)	Canada	3	Literature review on economic assessment of district energy systems using forest biomass feedstock	Bulk density showed the highest impact for the transportation cost and choice of biomass type. Transportation cost contributed 50% of total delivered costs.
(Arabatzis et al., 2013)	Greece	3, 5	Examined the uncertainty of demand in Biomass Supply Chain (BSC)	The generated model can be used to minimize total cost of operation including fuel wood transportation.
(Asikainen, 2004)	Finland	1, 2, 3, 5	Analyzed the effects of integration of work tasks and supply chains in wood harvesting	At the operational level, integration enabled in improving cooperation between the sawlog and biomass logging crews and fleet.
(Aydinel et al., 2008)	Canada	1, 2, 3	Analyzed different options for a wood manufacturing company for transportation of different forest products to different customers	Models were run with real order files and the test results indicated the potentials for significant cost savings over the company's current practices. The company further customized the models, integrated them into their IT system and implemented them successfully.
(Beaudoin et al., 2007)	Canada	1, 2, 3	Developed a detailed tactical model to support centralized annual planning by an integrated forest company that may own several mills, and allowed for wood exchanges between companies	A hypothetical test case showed that it was possible to manage the wood flow from stump to end market in such a way as to extract higher value from the logs processed in the mills. It also showed that the proposed planning process achieved an average profitability increase of 9% compared to an approach based on a deterministic model using average parameter value.
(Cambero and Sowlati, 2014)	Canada	3	Reviewed studies focusing on the economic, social and environmental aspects of forest BSC	Most of the problems studied used mixed integer programming models. The main objectives of the reviewed articles were to minimize biomass supply chain cost and to some extent maximize profit.
(Carlsson and Rönnqvist, 2005)	Sweden	1, 2, 3	Developed a supply chain management model	Five projects to improve supply chain were described. The models provided better decision support. The major benefit included objective based discussions and decision ''over the borders'' between stakeholders.

Table 2.8 continued

(Díaz-Yáñez et al., 2013)	Europe	3	Reviewed the current procurement methods for wood chips	The main source of wood chips in EU was logging residue which in future could be replaced by stumps and round wood. With the development of novel technology, countries could improve the efficiency of the supply.
(Dumanli et al., 2007)	Turkey	5	Investigated logical aspects of forest BSC	Results showed that Turkey has good rail and road infrastructures to transport and utilize its available biomass resources in coming future.
(Eriksson et al., 2014)	Sweden	3, 5	Evaluated various systems for stump transport and comminution with focus in cutting unnecessary costs	Simulation model showed large variations in system performance and costs. Costs of the best and worst alternatives differed by a factor of two, irrespective of transportation distance. The most cost-effective option proved to be crushing stumps into the ground and using a self-loading truck for fuel wood transport.
(Forsberg, 2000)	Sweden	5	Analyzed bioenergy transport chains using life cycle inventory methods	Emissions from long range transportation (1,200 km) performed with ships, was of minor importance compared to emissions from local bioenergy systems in a local market. The results indicated that biomass for energy can be transported from Scandinavia to Holland without losing its environmental benefits.
(Frayret et al., 2007)	Canada	1, 2, 3	Agent-based supply chain planning	Developed a software aimed at designing distributed advanced planning and scheduling tools for the forest products industry. The platform followed the double objective of providing the industry with advanced planning tools, as well as with a means of studying the dynamics and performance of such tools working together.
(Freppaz et al., 2004)	Italy	3	Assessed the possibility of biomass exploitation for both thermal and electric energy production	The available biomass present on the territory was divided into parcels (of different areas) that corresponded to the areas that were characterized by a predominant biomass type. This structure allowed determining the parcels to be harvested, thereby ensuring that such harvest was sustainable for the ecosystem, as well as correctly evaluating the costs of harvest operation.
(Frombo et al., 2009)	Italy	3	Strategic planning level of woody biomass logistics	A user-friendly interface was created to link different modules and to allow the user selecting the biomass sources, inserting the plant, choosing the technology, modifying parameters, and viewing results. The GIS-based Environmental Decision Support System (EDSS) when applied generated an optimal solution in terms of plant technology, capacity and harvesting.

Table 2.8 continued

(Gautam et al., 2013)	Canada	1, 2, 3	Analyzed literature to identify opportunities to improve the agility of wood procurement systems (WPS)	Aspects of the practices embodied in agility capabilities have already been proposed in the WPS literature but without explicit reference to agility. However, opportunities to further improve the agility of WPSs were also identified. It was suggested that future research should focus on determining optimal levels of investments in agility in order to maximize supply-chain profits.
(Gerasimov et al., 2008)	Russia	4	Developed a GIS-based decision support program for planning and analyzing short-wood transport (SWT) for a logging company	Testing of the program and comparison of alternative delivery plans showed that the efficiency of SWT can be increased by 40%
(Gold and Seuring, 2011)	German y	3, 5	Synthesized the information from scientific literatures that covers issues of bioenergy production and BSC	Most of the articles were from Biomass and Bioenergy journal, whereas the year with most publications was 2007. The primary focus was on system design for bioenergy production.
(Gronalt and Rauch, 2007)	Austria	5	Designed a regional forest fuel supply network	Designing supply network could be used for several planning tasks. The calculation of available regional forest fuel potential (RFFP) was a good indicator to estimate whether planned plants can be served within the region or not. Also, average transport distance could be assumed. Transport and chipping costs can be minimized by knowing RFFP, regional supply, and demand balance.
(Gunnarsson et al., 2004)	Sweden	5	Mathematical model to analyze BSC	The model developed described the supply chain problem considered. The heuristic approach and CPLEX software provided comparable solutions, but the heuristic was about two times faster. The quality of the solutions found by both methods was very high, the objective function values were within 0.5% of the optimal value.
(Haartveit and Fjeld, 2003)	Norway and Sweden	1, 2, 3, 4	Wood Games (WG) to study how supply chain performance is affected by supply chain configuration	Results from pilot experiments indicated that performance and predictability of the system were negatively affected by increasing the complexity of the supply chain. The level of demand distortion varied considerably between different games. Distorted demand signals might complicate the planning and execution of upstream operations.

Table 2.8 continued

(Kanzian et al., 2013)	Austria	5	Designed forest energy supply network using multi-objective optimization	To minimize CO_2 emissions, 30% of the woody biomass should be delivered chipped from the terminals, 50% chipped directly from forest, and the rest should be transported in solid form from forest to plant. This resulted in CO_2 emissions of 24.3 kg ton^{-1} and a profit of € 3 ton^{-1}. CO_2 emissions only increased by 4.5% when the weight was changed to maximize profit. However, the profit increased from € 3 - 7 ton^{-1} while average transport distance increased from 46 - 48 km.
(Kühmaier and Stampfer, 2012)	Austria	5	Developed decision support tool for energy wood supply management	The tool considered several criteria like energy efficiency, nutrient balance, stability, supply guarantee, employment rate, working safety, vitality of remaining stand and soil. Users could specify site, stand, environment data and technology parameters, to set their individual preferences for balance between the criteria.
(Kudakasseril Kurian et al., 2013)	Canada	3	Reviewed the alternate logistical practices for important lingo-cellulosic biomass feedstock	Results showed that it was not economical to increase transportation distance of biomass for its value addition. Involvement of locals in biomass collection, handling and transportation in cooperative manner could help to systemize the process.
(Lautala et al., 2015)	USA	3	Analyzed opportunities and challenges in the design and analysis of BSC	Some of the most prevalent challenges, included availability and quality of data to analyze the various components of the supply chain; lack of a common framework for sustainability indicators; and deficiency in integrated analysis when developing the supply chains.
(Miao et al., 2012)	USA	3	Literature review on systematic analysis, innovative design of a feedstock transportation, and supply chain	Different modes of transportation, including roads, railways, waterways, pipelines, and combinations of these, were extensively studied. The design of efficient and reliable transportation systems should consider harvesting sites, storage, bio-refinery sites, transportation mode availability, equipment and facility configurations, regulation, policy and environmental impact analysis.
(Nivala et al., 2015)	Finland	5	Evaluated long-distance transportation and intermodal handling of energy wood for its journey from forests to a power plant	Train-based chains proved to be cost-competitive with the traditional truck chain utilized in very limited areas around the terminals. The costs of the supply chains based on use of high capacity transport (HCT) vehicles of 68 and 76 ton were always lower than the costs associated with the train-based chains.

Table 2.8 continued

(Rantala et al., 2003)	Finland	6	Effect of management strategies for seedling production and transportation planning on the total costs of long-distance transportation for a tree nursery company	Cost-effectiveness was improved by centralized transportation strategy than decentralized transportation strategy. Values varied from 13 to 37%, depending on the number of nurseries and the degree of specialization of production among them.
(Rauch and Gronalt, 2010)	Austria	5	Suggested choice of spatial arrangement of terminal facility in forest fuel supply network	A simulation of a transportation cost increase showed that the optimal network design was stable within an increase of 20 to 50% and between 70 to 110%. Moreover, the number of terminals decreased as the domestic forest timber utilization rate increased. The cooperation from CHP operators with a forest-based industry partner as a terminal provider was one of main management implications of the study.
(Ravula et al., 2008)	USA	3	Simulated cotton logistics as a model for a forest biomass transportation system	The utilization factor for the transportation system was increased to 99%. Transportation managers should have knowledge about the location of all modules and have the ability to post trucks to any location to achieve this increment.
(Rentizelas et al., 2009)	Greece	3	Compared three biomass storage techniques, in terms of total system cost and analyzed multi-BSC	Even with some issues like increased health and safety risks the lowest cost storage method was the most efficient solution while the multi-biomass supply chain approach was more advantageous when combined with relatively expensive storage methods.
(Selkimäki et al., 2010)	Finland and Sweden	3	Analyzed present and future trends of wood pellets supply chain	Most of the pellet plants were near to the raw material supply points thus transportation cost was lower. Trucks were the primary means of transportation. New trucks with integrated weighing scale were in use, which allowed accurate delivery and billing.
(Shabani et al., 2013)	Canada	3	Reviewed studies on deterministic and stochastic mathematical models to optimize forest BSC	Optimization models were used to provide optimal solutions for network design, logistic options, supply area and other economic objectives.
(Sharma et al., 2013)	USA	3	Reviewed BSC design and modelling	Approximately 41% of the work related to mathematical modelling of BSC was published in 2011. Common network design for most of the models had biomass supply site, collection sites and processing sites.

Table 2.8 continued

(Stone et al., 2011)	USA	3	Evaluated BSC and harvesting innovation activities among logging contractors	A high degree of collaboration between land owners, logging contractors, and biomass consuming facilities is required for innovation processes. It also showed that the innovation process of logging firms was not sufficiently studied during that time.
(Troncoso and Garrido, 2005)	Chile	1,2,3	Proposed a mathematical model for the integrated problem of production and logistics in the forest industry	The optimal solution was found with affordable computation effort, considering the strategic scope of the problem. Also, due to the type of modeling, less than 1% of the total of decision variables corresponded to integer variables (binary). The model can be subdivided to sub-problems that allowed obtaining the optimal solution relatively fast for real application instances.
(Uusitalo, 2005)	Finland	1	Laid down a general framework for CTL (cut-to-length) method-based wood procurement management and highlighted the most important research and development objectives for the region.	Tree bucking control and wood transportation problems should not be considered as separate tasks, but instead be optimized together. If considered separate, the gains achieved through better product characteristics are lost due to increasing transportation costs.
(Valenzuela et al., 2005)	USA	1,2,3	Proposed a computer meta-heuristic model for scheduling several silvicultural projects simultaneously.	A small size problem with five worksites, solutions could be obtained in less than four minutes using the model. Larger problem with twenty worksites took 30 minutes.
(Van Belle et al., 2003)	Belgium	5	Presented methods used to establish a forest fuel supply chain for coal-fired power plants considering wood resources, potential suppliers, financial, economic and environmental constraints.	Optimal strategy should include three levels: one base level made up of large-scale loggers harvesting softwood from final harvest; one top level made up of medium-scale loggers mainly harvesting hardwoods; and a reserve level made up of small-scale loggers and tree farmers.
(van Dyken et al., 2010)	Norway	3	Developed a linear mixed-integer models for biomass supply chains	Linear models for general biomass supply chains was developed. Due to assumptions and simplifications made in the models as well as the fact that the biomass module was embedded in the already existing eTransport framework, there were some model limitations.

Table 2.8 continued

(Windisch et al., 2013)	Germany	1, 5	Applied business process modeling and engineering approaches to an integrated industrial sawlog and biomass supply chain in Germany	The redesign of the current business process provided a cost-saving potential of 20 – 39% (the then German Franc 2.64–5.25 per m^3). The study demonstrated that simple and low-cost measures can improve business processes in forest supply chains and achieve considerable cost savings.
(Wolfsmayr and Rauch, 2014)	Austria	5	Investigated the key issues on the transportation of primary forest fuel to heat and/or power plants	Key challenges were: transportation modes, terminal types, and BSC management. For longer transportation distances, rail or waterway was preferred because of lower transportation costs per volume transported and lower CO_2 emissions.
(Zhang et al., 2012)	USA	3	Developed simulation model for BSC	The model proved to be important for BSC management including transportation logistics and other factors.

*Wood products: Sawlogs &timber (1); Pulpwood (2); Biomass (3); Short woods (4); Bioenergy & forest fuels (5); Seedlings (6).

2.4. Discussion

The collection and categorization of scientific literatures on secondary forest products transportation found that more than half of the studies addressed transportation of woody biomass from forest, and industrial residues for bioenergy generation. Generally, woody biomass generated from forest operations and forest products industries are regarded as low value products compared to the primary forest products such as sawlogs and pulpwood. This raises a question as to why the frequency of the scientific studies was higher for biomass transportation. Woody biomass constitutes forest residues with low bulk density that are not economically feasible to transport in the raw form. In regions without demand for biomass, forest residues are generally left at the harvesting sites (Kizha and Han, 2016).

On a regional basis, higher number of studies were published from Europe followed by North America and Asia. This high number of articles from Europe can be attributed to the policies favoring biomass utilization. While transportation cost is considered to be one of the major limiting factors for biomass utilization, the feasibility also depends heavily on favorable policies. Country wise, USA had the highest number of publications which could be due to large area of managed timberland, and the developed economy which sustains on high level of research.

Biomass and Bioenergy journal published highest number of articles on the subject. This is related to the higher number of studies focusing on the transportation of forest residues. Forest products transportation is an important component of forest engineering, thus there were significant number of articles in journals like *Croatian Journal of Forest Engineering* and *International Journal of Forest Engineering*.

Two of the most studied research topics on forest products transportation were supply chain models and forest roads. Many site and region-specific optimization and supply chain models have been tested and presented which increased the number of publications. Similarly, forest roads are crucial for hauling wood materials from harvesting sites to the markets. Construction and maintenance of roads requires huge amount of investment. In this study, there were only 14 articles directly related to trucking characteristics, however, most of the other articles (dealt in the study) also discussed about trucking in many different ways.

Overall, the results indicated that there was a need for more research on increasing efficiency of transportation system, specifically trucking. Except for one study done in Finland, there were no research focusing on the overall challenges facing the forest trucking industry as a whole (Malinen et al., 2014). The cost of transportation is also another major topic that needs to be addressed in the future.

2.5. Conclusion

Regardless of categorization into different research themes, the main aim of all the collected articles in this study was to minimize the cost of transportation. The goal of this paper was to provide exclusive bibliographic information on research focusing on secondary forest products transportation. Major details of each article including authors' information, research location, forest products, main objectives and main findings related to transportation were presented in tabular format. This study will therefore be helpful for faculties, students and research scientists from the field of forest engineering to get background knowledge of previous studies on forest transportation. It will provide insight on the specifics that are lacking in this sector and show the way ahead for future research and innovation. This paper is completely based on literature collection and assortment and thus should not be regarded as critical literature synthesis paper.

CHAPTER 3:

PERCEIVING MAJOR PROBLEMS IN FOREST PRODUCTS TRANSPORTATION BY TRUCKS AND TRAILERS

3.1. 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. 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, 2005; 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 undermine (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 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, 2009, 2004; 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.

3.2. Materials and Methods

3.2.1. Background Study

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.

3.2.2. Selection and Justification of Method

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 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.

3.2.3. Questionnaire Design, Distribution, and Collection

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 (Appendix A) 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 (Appendix B). 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.

3.2.4. Data Analysis

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.

3.3. 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% of response rate.

3.3.1. Description of Respondents

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 3.1). 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 (70%) respondents from northern Maine and 27 (30%) from southern Maine.

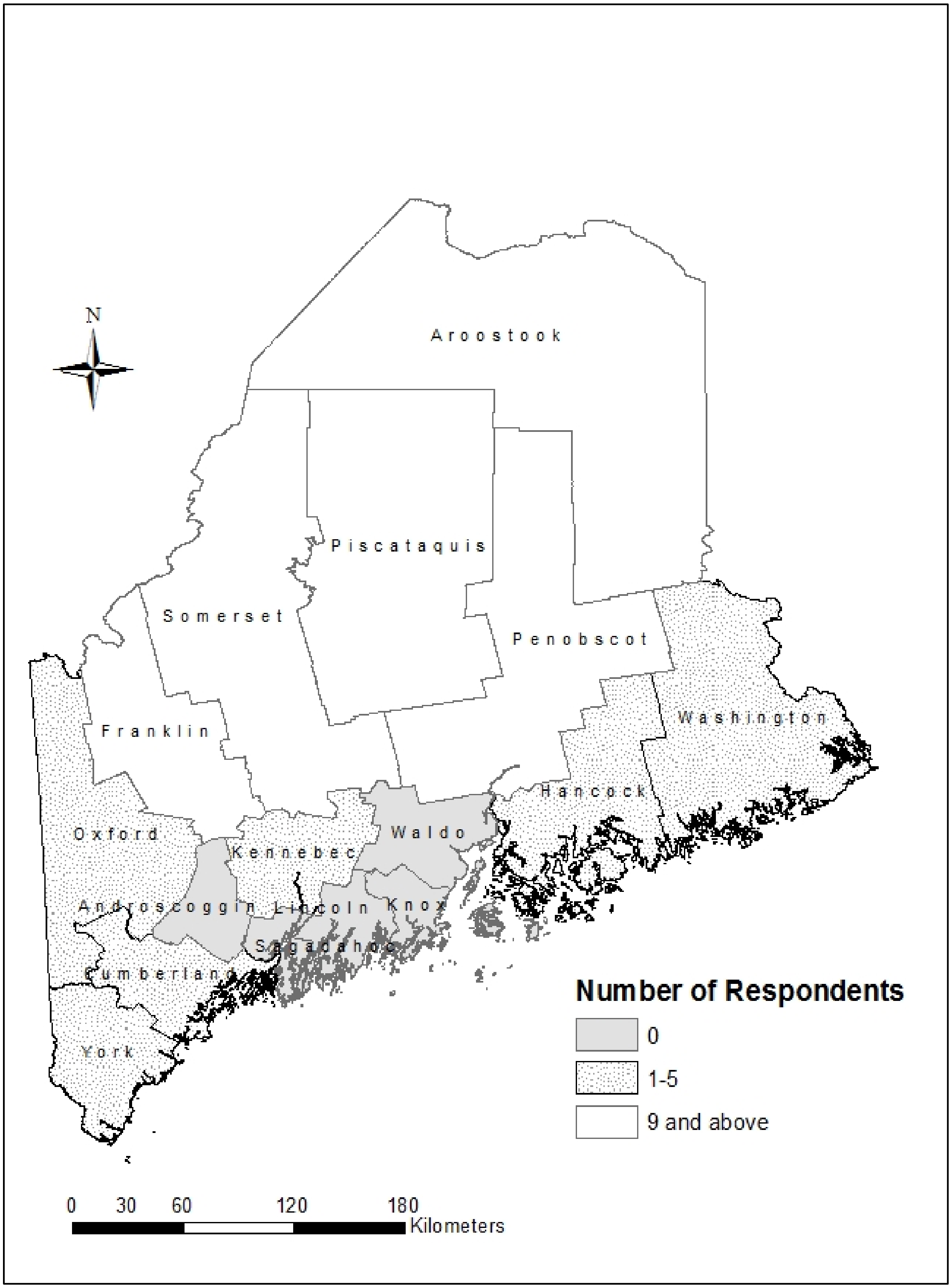

Figure 3.1: Map of Maine showing countywide representation of respondents.

The majority of the respondents (73.1%) were affiliated with the private companies including logging, pulp and paper and trucking enterprises, which also accounted highest for both northern (69.4%) and southern region (81.5%) (Table 3.1). Followed by which came 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/hogfuels.

Table 3.1: Summary of demographic characteristics of respondents. Number of respondents for each categories divided into northern and southern regions of Maine.

Characteristics	**Categories**	**Northern Maine (%)**	**Southern Maine (%)**	**Total (%)**
Representation	Number of Respondents	62 (70)	27 (30)	89 (100)
Affiliation	Company (logging, trucking, and pulp & paper enterprises)	43 (69.4)	22 (81.5)	65 (73.1)
	State or federal agencies	10 (16.1)	3 (11.1)	13 (14.6)
	Contractor	5 (8)	1 (3.7)	6 (6.7)
	Others (Forester, academics and unspecified)	4 (6.5)	1 (3.7)	5 (5.6)
Work experience in forestry sector	Less than 10 years	14 (22.6)	3 (11.1)	17 (19.1)
	10 to 15 years	8 (12.9)	4 (14.8)	12 (13.5)
	15 to 20 years	9 (14.5)	2 (7.4)	11 (12.3)
	20 to 25 years	9 (14.5)	5 (18.6)	14 (15.7)
	25 to 30 years	4 (6.5)	3 (11.1)	7 (7.9)
	More than 30 years	18 (29)	10 (37)	28 (31.5)
	Average work experience	21 years	24 years	22 years
Major forest products dealt with	Sawlogs/Speciality	26 (41.9)	10 (37)	36 (40.4)
	Pulp/groundwood	21 (33.9)	7 (25.9)	28 (31.5)
	Biomass (hogfuels)	7 (11.3)	6 (22.2)	13 (14.6)
	Wood chips	8 (12.9)	4 (14.9)	12 13.5)

3.3.2. Major Challenges

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.

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 3.2). 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.

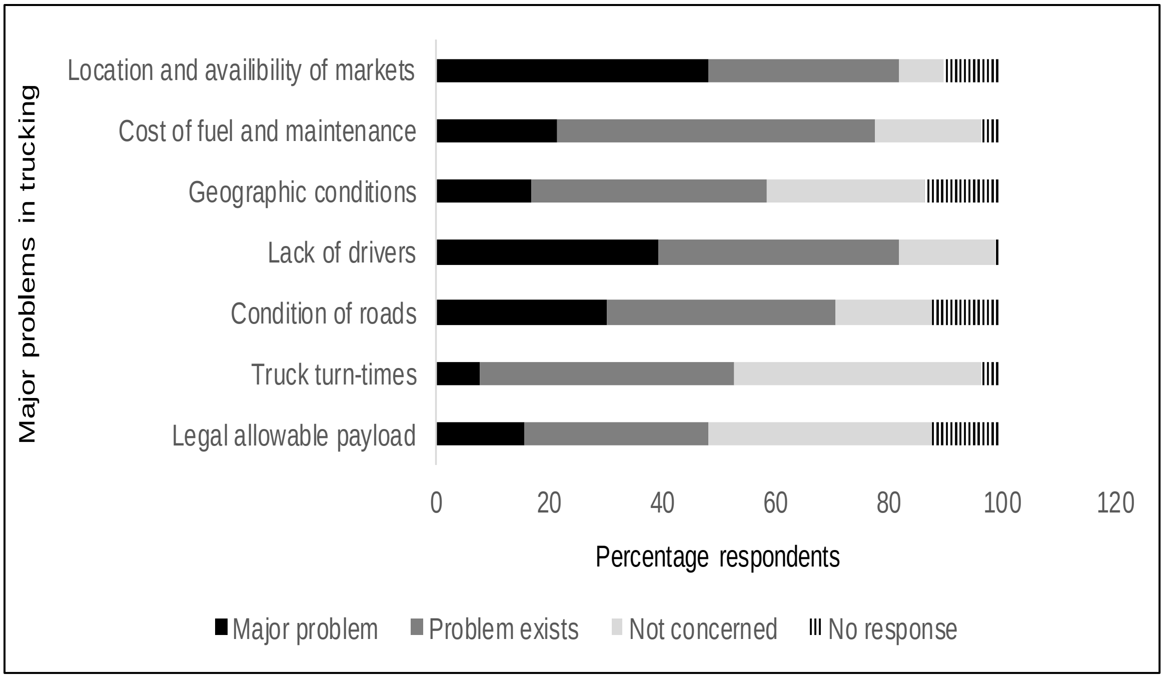

Figure 3.2: Ranking of the major problems faced by forest trucking industry.

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.

3.3.2.1. 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 3.3).

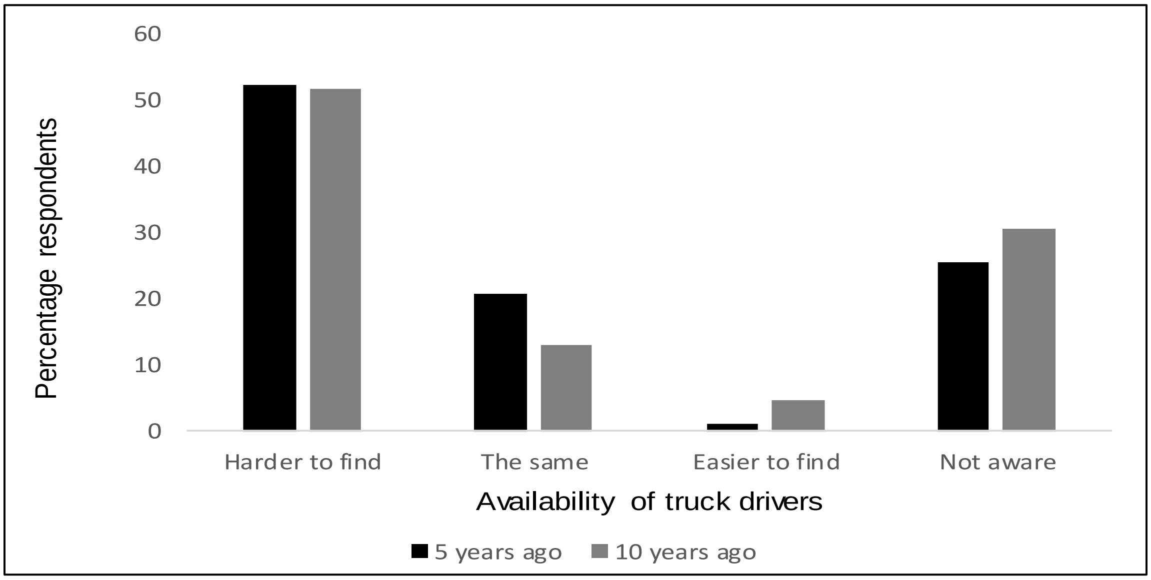

Figure 3.3: Respondents' views on the availability of truck drivers. The present situation of truck drivers was compared to the past situations (5 and 10 years ago).

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.

3.3.2.2. Space of Landing and Truck-turnaround

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. We asked respondents whether there were 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 3.2). There were more suggestions for harvesting sites to reduce delays than processing facilities.

Table 3.2: Respondents' recommendations to minimize truck turnaround times. Direct quatations of respondents are presented for harvesting sites and processing facilities separately.

Harvesting sites	Processing facilities
"Adequate turnaround close to landing sites."	*"Text messaging wait time and website with up to date information on unloading equipment, crane, dumpers."*
"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."	
More reliable equipment. Sand steep sections of road in winter. Plan roads ahead so not trucking on "fresh" roads.	
Utilizing satellite yards to accumulate more "loaded miles".	
"Skilled crane operators. "	
"Pave more roads and landings."	
"Increasing two shift trucks/team hauling the loads."	
"More cut-to-length operation."	

3.3.2.3. Back-hauling

More than three-quarters of respondents believed that there were opportunities to utilize empty trucks during harvesting operation (Figure 2.4). 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.

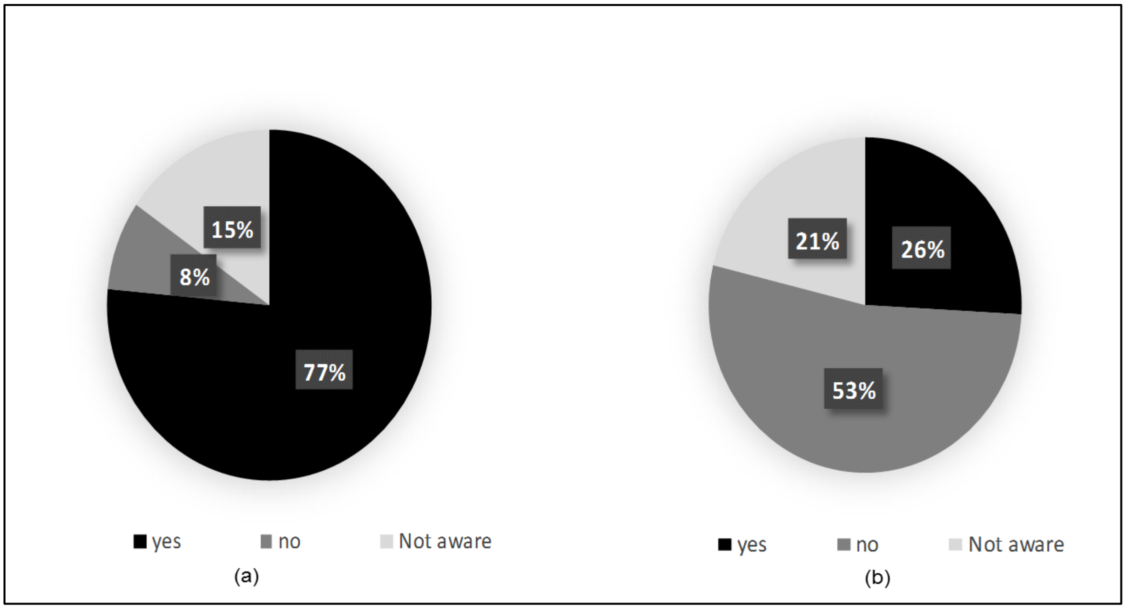

Figure 3.4: Respondents' views on back-hauling of empty trucks in Maine. (a) If there were opportunities for back-hauling in Maine or not and (b) if back-hauling could delay entire forest operations' schedule or not.

3.3.2.4. Average Travel Distance and Road Conditions

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 3.3).

Table 3.3: Average distance (in km) traveled by a single truck one-way.

Forest products	Maximum	Minimum	Mean
Sawlogs	322	3.5	95
Pulpwood	322	3.5	109
Hog fuels	200	19	94
Woodchips	240	3.5	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 3.5).

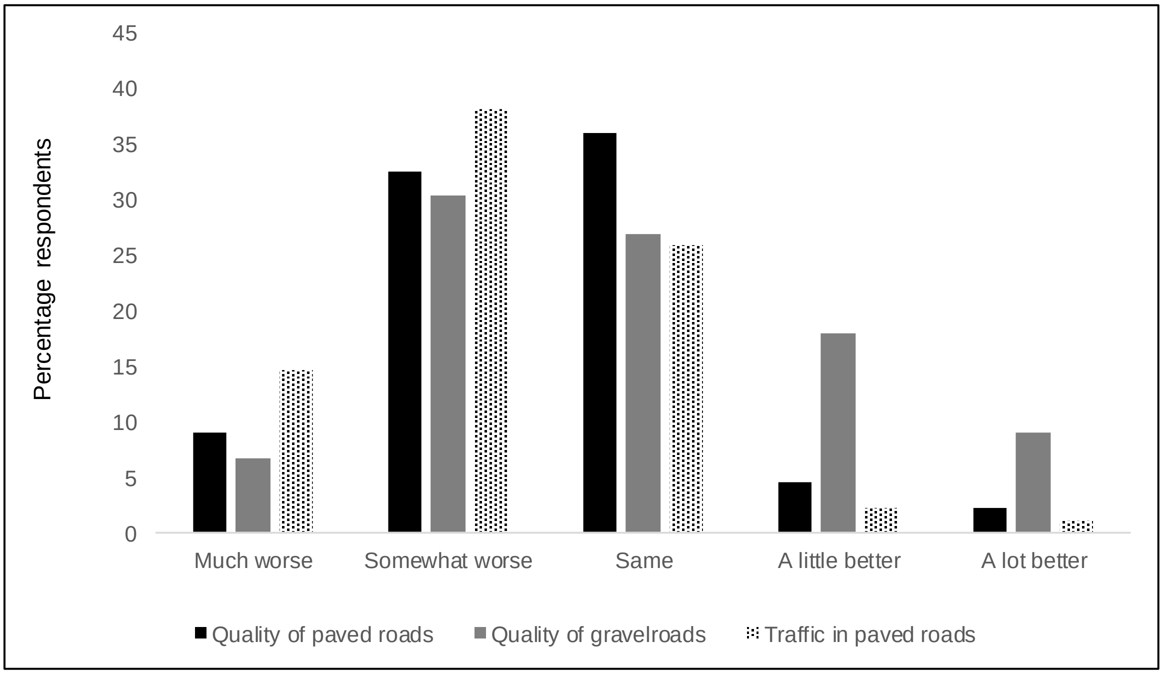

Figure 3.5: Respondents' views on condition of roads in New England region. The present condition was compared with the past (10 years back) road condition.

3.4. 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 affect 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.

3.4.1. 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 who owns majority the woodland in the northern region (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).

3.4.2. Major Problems and Potential Resolutions

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.

3.4.2.1. Location and Availability of Markets

The majority of the respondents 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).

3.4.2.2. 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).

3.4.2.3. 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.

3.4.2.4. Fuel Efficiency, Design, and Maintenance

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; 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. 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).

3.4.2.5. Legal Allowable Payload

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.

3.4.2.6. Truck-turnaround and Back-hauling

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 is 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.

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 to perform 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 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 not being clear. Previous surveys had shown that the minimum distance traveled for sawlogs was 40–48 km (Holzleitner et al., 2013).

3.5. 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 as well. The lack of skilled manpower in the trucking business can negatively affect 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.

CHAPTER 4:

IMPROVING MAINE'S FOREST PRODUCTS TRUCKING ENTERPRISES: A QUALITATIVE STUDY APPROACH

4.1. Introduction

The flow of forest products from harvesting sites to the processing facilities is a combined effort of different stakeholders. The supply chain of the forest products generally starts with foresters laying out harvest plan for forest landowners i.e., small woodlot owners, industrial land owners, and public lands. Logging operators with direction of foresters and logging contractors take responsibilities of felling trees and piling the wood at the log landing. With guidance from procurement manager and trucking contractor, the products are hauled from landing to facilities (usually primary forest products industries or bioenergy plants). The trucking (also referred to as secondary transportation) part in this process is considered essential because of its functionality of moving products from one place to another. It is also one of the expensive phases and can be crucial in fixing prices of delivered forest products (Koirala et al., 2016; Kizha. et al., 2015; Pan et al., 2008). Despite the prevalence of railroad transportation, trucking is the most common way to deliver wood products (Sosa et al., 2015). Its popularity can be associated with well-developed road networks, limited access of railway lines for many areas in US, and embargo in using water and rivers for timber hauling in the US and other parts of the world (Dowling, 2010; MFPC, 2013). However, there are various challenges associated with forest products trucking that need to be addressed for its efficient operations. These challenges can be specific to the region thereby require local level understanding of constraints and potential mitigation strategies including policy development. Hence, strategic suggestions from closely related stakeholders and experts in the field are important.

Concerns regarding higher cost associated with forest products transportation has led to several studies in forest operations including analysis of wood products hauling costs (Acuna et al., 2012; Grebner et al., 2005; Möller and Nielsen, 2007; Yoshioka et al., 2006); increasing efficiency in transportation (Greene et al., 2007; Holzleitner et al., 2011; Sikanen et al., 2005); and survey analysis of logging and transportation sector (Abbas et al., 2014; Egan and Taggart, 2009, 2004; Leon and Benjamin, 2013; Malinen et al., 2014). Similarly, there has also been research utilizing qualitative methods such as semi-structured interviews, to comprehend views and opinions of experts (Fielding et al., 2012; Silver et al., 2015). To this end, such qualitative research approach has not been utilized to get in-depth information on forest products transportation. The purpose of this research was to a) gain an in-depth understanding of stakeholders' perceptions of the problems related to trucking, and b) identify possible measures to resolve them. Understanding related stakeholders' attitudes towards applicability of particular solutions in the state of Maine could help the industry and policymakers implement them.

4.2. Methodology

A qualitative research approach was selected to allow in-depth understanding of a problem within a concrete setting (Creswell, 2012; Stake, 1995) and learn the interpretation of verbal experiences from stakeholders (Denzin and Lincoln, 2008).

4.2.1. Philosophical Foundation

The methodology was based on the constructivist paradigm and used a single case study design to explain related stakeholders' perception and experiences. The epistemological approach of constructivism proclaims that different individuals describe the same problem in multiple ways (Crotty, 1998). Constructivism is based on the fact that truth is dependent on the perception. Another important assumption is that problems are solved by the interaction between researcher and respondents, hence, open-ended questions like interviews and discussion were used (Guba and Lincoln, 1994). These questions generally begin with how and why, rather than what and when, with the intention of getting comprehensive insights on the subject (Seidman, 2006).

4.2.2. Case-study Design

Case-study is a research design that allow researchers to explore problem, process, situation, or even individual, and group of people (Creswell, 2012; Stake, 1995). A common way to conduct a case study research is to collect comprehensive information on the case by utilizing and triangulating across different data collection techniques such as interview, document review, direct observations, and archival records (Leedy and Ormrod, 2014; Yin, 2013). The case includes bounded time, context, region and activity. The state of Maine was the area of study while year of 2016 was the timeframe for this study. The activity was local level measures adopted in different parts of Maine to mitigate forest trucking related problems, hence, the study was intrinsic case study. The solutions were first developed from previous survey, personal communication, and literature analysis (Koirala et al., 2016) and validated through the interview process.

4.2.3. Participant Selection Strategy

The stakeholders were divided into four categories based on their job profile: a) Foresters, b) Truck owners/ logging contractors (from here on referred to as contractors), c) Representatives from forestry professional societies, and d) Procurement managers. The categories were selected for providing appropriate and relevant responses to address the objectives from different perspectives.

The Forest Resource Association (FRA) of Maine, a group of more than 500 organizations and businesses related to the forest products industry, was consulted first for participant recruitment. A public announcement for interested individuals to participate in the study was made at a FRA forum in Brewer, Maine. The process did not yield sufficient responses; hence the combination of criterion and snowball sampling techniques was used to select participants (Gummesson, 2000). The selection criteria were that the participants should have more than 15 years of experience in forest products handling & transportation, and should have a primary workstation within the state.

4.2.4. Ethics Statement

Approval was obtained from the Institutional Review Board (IRB), University of Maine, Orono for conducting research on human subjects prior to the interviews on January 4th, 2017. A written informed consent form was given to the participants prior to the interviews which ensured confidentiality and voluntary participation.

4.2.5. Data Collection and Analysis

The primary data collection method was semi-structured face-to-face interview. This method had advantage over other qualitative techniques like focus group discussion; because interview allowed more anonymity and safer environment to talk on dedicated issues than the later. Additionally, participants could have more time to express their feelings and discuss the subject matters in detail. Interviews could also be helpful for triangulation of information gained from supplementary sources, which ensured credibility in the study results (Stake, 1995).

The interview protocol consisted of 13 major open-ended questions; each question included additional four probing questions (on average), totaling to about 50 questions per interview. The interview protocol along with consent form were emailed to the participants three weeks prior to the interviews, to facilitate reviewing the questions and to decide a response. The questions were mainly organized into four thematic sections: a) outlook on forest trucking sector; b) major challenges faced; c) potential measures; and d) applicability of those measures in Maine. To obtain regional based information, the respondents were further categorized based on regions: Northern, Central, and South-Coastal regions.

Thirteen semi-structured interviews with open-ended questions were conducted from February to May 2017. Interviews were continued until new interviewee did not provide any additional information on the subject, i.e. up till saturation point was reached (Corbin and Strauss, 2007; Miles and Huberman, 1994). There are no rigid rules on the number of interview participants in this type of studies. However, the number of interviews in this study (13 interviews) was consistent with other studies which utilized similar research approach (Guest, 2006).

With an average of 51 minutes, the total duration of the interviews ranged from 33 to 71 minutes. Due to the general interests on particular topics, most interviews lasted longer than slated time frame. Three interviews lasted less than 40 minutes which was affected by various factors including participants' reluctance to answer certain questions, irrelevancy of certain topics to the participants, and participants' schedules.

The whole content of the interview was audio recorded. The recorded audio files were transcribed verbatim and uploaded into NVivo 11 (NVivo qualitative data analysis Software, 2014). The transcripts were meticulously read several times followed by highlighting important phrases/ dialogues. These were then abstracted into concepts to fit previously identified four themes in interview protocol. During data analysis, thematic coding was used to compare specific issues. The codes were generated by iterative process that involved reviewing data multiple times. This process also helped in determining the point of saturation for each question.

4.3. Results and Discussion

4.3.1. Participants Description

Among 13 interview participants, four were based in Northern, three in Central, and three from South regions of the state. Based on the job profile majority were foresters (Table 4.1). Due to challenging work hours truck drivers could not be interviewed. The average work experience of the participants in the field was 25 years, with an age ranging from 36 to 74 years. All of them were male-Caucasian.

Table 4.1: Description of the participants interviewed for the study.

Stakeholder categories	**Number of participants (by sub regions of Maine)**	**Experience***
Foresters (company based and consultant)	5 (Central = 3, North =1, South = 1)	30
Truck owners / Logging contractors	2 (All regions** = 2)	28
Professional society representative	2 (South = 1, All regions = 1)	25
Procurement managers	4 (North = 3, South = 1)	19

* Average work experience in forestry or their job profile (in years).
** Participants having primary work station in more than one sub-region, or working in forestry sector for the whole state.

4.3.2. Forestry Related Responsibilities and Services

The services provided by the companies or organizations that respondents were affiliated with were of diverse nature from land managing to wood processing. Nearly all of them were involved in multiple forestry related tasks. One of the participants stated:

> *"We have forest operations of every nature. We do harvesting, trucking, chipping, loading, slashing, merchandising, building forest roads, developing forest management plans, managing our own lands, and other people's lands. We have three equipment shops; one for forest harvesting machines and two for trucks and trailers."*

One procurement managers described his duties as: "*overseeing entire harvesting operations, dealing with logging/trucking contractors, along with inspecting and regulating dispatch of trucks and chip vans."* There was also a procurement manager just to oversee transportation related works and their duties were, *"…to look after road maintenance for the company, and transportation of all raw materials to the mills."*

Primary duties of company foresters interviewed, were managing woodlots, preparing management plans, hiring and managing temporary workers, and dealing with contractors & truck drivers. Independent consultant foresters generally worked for various landowners at any provided time.

The participants were from varying company size, in terms of number of employees, ranging from small companies (<5 employees) to large (>50 employees). Basic benefits to the workers (including truck drivers) included health insurance, paid leaves, and subsidies for buying wood products. One procurement manager quoted:

> *"We have health and many benefits like other businesses, but the additional one is the career we really enjoy and passionate about. I think there are other disciplines with higher pay. But this profession provides flexibility of schedule and time. I'm not in a cubicle daily and I'm doing something different."*

Other participants who hired trucking service, were unaware of the exact benefits package offered:

> *".... I've not known exact details, but there should be enough to make a person sit on that giant and drive on rough terrain, all day."*

4.3.3. Trucking in Maine

All participants regarded trucking as an essential component, as more than 90% of the wood hauled in the state was done by road. Railway systems were also in use in northern and western parts of the state, however, trucks were still used for certain portion of that journey. Most of the timberland owners and management companies did not own trucks but hired trucking service. The participants seemed aware of the role of trucking in determining the end price of the delivered forest products. They were also concerned about the loss incurred due to inefficient trucking. One procurement managers stated:

> *".. as far as the role of trucking: it's a key to the business. When you look into harvesting and trucking of wood to our mill, it's probably one of the biggest costs both for distance and other factors like payload. It's the cost that continues to go up every year because it's something that you **cannot** increase productivity like in the harvesting operations. You can only put so much wood on the truck and you can only drive so far safely and efficiently."*

Several factors affected the cost of trucking including fuel price, maintenance cost, trucking distance, and payload. Contractors were always trying to make their operations efficient enough to avoid extra expenditures: "…*it's everything for us. We have more trucks than truck drivers. We have to keep an eye on every detail to make profits. All of them operates year around and are maintained timely. We are service provider so no compromise at all."*

Both above statements, although of different nature, allude to the issues faced day to day forest trucking enterprises. As a different perspective, one participant from the professional society stated:

> *"… most of the logging contractors, probably 75 percent, have a truck or two. This provides them with more stability in their services. Owning and operating trucks makes them more flexible and competitive"*

There were mixed responses regarding the outlook on trucking business for the region, and was articulated in terms of challenges and opportunities in the field. In general, the participants considered trucking as a challenging business but expected that it will go further with new horizon of market opportunities (Table 4.2).

Table 4.2: Participants' attitudes on outlook of Maine's forest trucking business.

Stakeholder Responsibility	**Attitude**	**Outlook on the trucking business ***
Forester	Positive and negative	*"... from the forestry perspective, there is good and bad news. The good news is that in recent years, the weight limit has been raised on the interstate system making a very big difference for trucking. Using interstate, lowers travel time. The other is related to the drastic drop in oil price over recent years. The bad news is that we are having hard time finding drivers. .... So, I would say that the profit margins are very tight, and the business is not booming."*
Trucks owner	Positive	"*The business is not booming but it's strong. Trucking capacity seems to be in demand and there's NOT an oversupply of trucks and trailers for the work that's available. On the average, trucks are in demand and will be in future."*
Professional society representative	Negative	*"...trucking business is getting to be a like getting into the forestry equipment business; more expensive than it used to be. Probably much more difficult for the owner operator to get started."*
Procurement manger	Positive and negative	*".. the forest trucking market is growing in the sense that forest products are hauled to greater distances. But this does not mean it's very profitable, because mostly in long distances, there's not a lot of margin. If the trucking cost doesn't work out then we're not going to be able to operate."*
Forester	Positive	"*...trucking business for the northern climate, can be a profitable business. The key is moving more volume of wood, as the pay is based on ton. There is also room for new business to enter in the market. But primary concern is about the aging workforce."*

* Quotes from the interview participants

In a different context, participants except truck owners and contractors mentioned that for forest products companies, it might be better to contract trucking portion of forest operations than owning and operating entire trucking fleets. One of the procurement manager mentioned, *"We had a fleet of trucks that we managed in the past but it's to our benefit that we hire contractors. They can run a business better than we do. There are certain things that contractors are more efficient than company managed fleet."* One another forester agreed, *"This section is difficult to handle if you are dealing with many other things."*

4.3.4. Challenges to Trucking

All participants agreed that there were numerous challenges to efficient trucking operations in Maine. Majority regarded lack of skilled drivers as the most prominent challenge at present time (Table 4.3). This challenge was not only getting severe due to the aging workforce, but also the difficulty to keep truck drivers in this profession for longer period. Even with enough experience and physical abilities many drivers did not pass the mandatory drug tests for operation, which also contributed to the cause. For international shipping, age factor was also an issue, as drivers below 21 years were restricted to cross Canadian borders. Because of these legal complications participants mainly from northern region (two from Central) ranked border crossing requirement as the main challenge. A forester stated:

> *"A lot of our wood goes across border into Canada. So, there are new restrictions on border crossing, their weight restrictions are different than ours (two tiers systems in US). Contract rates needs to be adjusted accordingly."*

All respondents agreed that the recent closures of pulp mills in central and southern parts of the state was a key challenge. The impact of which was reflected as the increased hauling distance and cost of forest products in the state. However, the effects of the closing appeared to be less severe in the northern parts compared to other regions. One respondents from northern Maine explained, "*It does have effects, but not much than the adjoining regions. It affected us in a way that wood started moving in different direction and started* *infringing on the markets that we always relied on."* For small landowners, the impacts were of another nature, a forester working for small landowner stated, *"…it has affected some of our capability to market low value products like everybody else. We have very little market cloud because we're small. So, this probably affects us more than big land owners. We don't have negotiating powers like landowners who produces 250,000 cords a year does. Last year we cut 3200 cords."*

Despite having affected by the closing of mills, participants were optimistic about the future of forestry business in Maine. They agreed that certain products like hardwood pulps and biomass which were not in demand previously were in high demand at present situation due to mill closures.

Another challenge was regarding the conditions of public and forest roads. Especially participants from northern Maine were disgruntled by the condition of public roads in the region. Some of them also compared the bad conditioned roads with good Canadian roads across the border.

Other challenges mentioned were related to back-hauling, payload, high equipment owning & insurance cost, timber harvesting season, safety, and turnaround times (Table 4.3). Some of these were common to all forest operations, in general. Results also showed that specific challenge can be of less importance for one stakeholder group while being major concern for another. For example, all foresters were convinced that the legal allowable payload for the public highways in the state was sufficient, while the contractors and procurement managers wanted weight limit should be increased.

Table 4.3: Participants' views on challenges to the forest trucking sector.

Stakeholders' responsibility	Main challenges	Participants' direct quotes
Forester	Drivers, roads, and safety	*"Finding good drivers is the main thing. We hear that all the time from our contractors. The other thing is the worse roads. I am very much concerned about the safety of drivers as well as public."*
Procurement manager	Supply chain issues and contractors' nature	*"There is a supply chain issue. Majority of logging contractors own everything, logging equipment and trucks, and they employ drivers and operators. This is somehow inefficient. They want to do that because they want their wood to reach the market first."*
Forester	Contractors' nature	*"Trucks are passing each other with same products and same origin and destination, it seems there is a competition between contractors."*
Professional society representative	Drivers and insurance cost	*"Many of these contractors could not find drivers because of the drug tests; most of them failed the test. The insurance cost goes really high if you don't have good drivers."*
Truck owner/ Logging contractor	Aging workforce and back-hauling	*"There are two major challenges. The drivers hauling wood out of the forest requires a special skill, which many do not have. The ones we had are also retiring. The other challenge is too much percentage of empty drive miles, that makes the transportation costs very high."*
Truck owner/ Logging contractor	Market condition and state policies	*"Closing of mills has affected our business tremendously. We lost literally a third of our business over sales in about a twelve-month period of time, which is very painful, very hard to adjust and we haven't fully adjusted yet. The other thing is the state's regulations; some of them are terrible and not business friendly."*
Procurement manager	Roads	*"Public roads in this region (northern Maine) are terrible. I mean it was really bad this time of year as the frost comes out but they don't get a lot better anymore in the summer and fall winter. Terrible terrible!!"*
Professional society representative	Transportation distance	*"…. increased hauling distance is the main issue at present"*

Manpower shortage and present forest products markets condition of the state were the major challenges to the sector according to the participants. The drivers' shortage was also a prominent challenge for other trucking businesses as well; a report prepared by ATA (American Trucking Association) pointed out that the US trucking sector was short of 35,000 truck drivers in 2015 (Costello and Suarez, 2015). The challenging forest products market condition of Maine, by large, was the result of five pulp and paper mills closure within the last two years (Ohm, 2016). It resulted in harvesting and marketing of new forest products which were not considered valuable before. There is a need of research on the diffusion of new forest products and services to achieve global sustainability goals from forestry sector (Hetemäki and Hurmekoski, 2016).

4.3.5. Potential Solutions for Maine

The interview questions were designed to group potential solutions based on the problem type. Several options emerged, while asked about mitigating some specific challenges such as shortage of skilled truck drivers and current market conditions. Participants also put forward solutions which could turn these challenges to opportunities for future. One respondent appeared very optimistic, *"I agree there are problems now, but we will get through this. Maine is very resilient state, we have dealt with lot of issues in the past, take spruce-budworm outbreak."* The same individual responded for the shrinking market condition, *"It requires new investments and business models to start up. It will take time but it will eventually. New markets are opening for new products because our market is changing."* The group representing contractors provided suggestion for improved market situation: *"Maine has a forest-based economy; we need to become a business-friendly* *state. Policies should be in favor of startup forestry businesses. There are examples that you have to wait for two to three years only to get an agreement from the state."* According to them, adjustment in the state level policies can have greater impact on new businesses. They were also in the favor for providing subsidies to new products for struggling businesses. From foresters' perspective, introduction of new technologies in the business could help revamp the shrinking market. However, they were not certain that condition would be similar to that of the last decade. One forester mentioned, *"We have been rescued by technologies in past. We started off cutting the trees with an average diameter of 12 inches* and soon we ran out of that tree diameter class. Then technology comes in, where we started chipping, and had mills that took smaller sized logs. So, our technology has changed over the years and I expect it will again."* Like other stakeholder groups, procurement managers also believed that the present market condition could be better. Their suggestion was to utilize new products as much as possible: *"Currently it appears that there is extra fiber in the Maine wood market, I think this will help us being a good spot to build new facilities. A company in Skowhegan, Maine has decided to put almost two hundred million dollars in new products. So, something is telling those guys that this is a good place to invest."* Another procurement manager provided an opposite view towards the market condition. He believed that the market will stabilize first before getting better; and the businesses with efficient operations will stay while others might shut down. He added, *"The only solution I see is that companies should be more efficient and start harvesting and selling varieties of products. For trucking, we should figure out how to manage empty miles."*

For tackling the problem of manpower shortage, most of the participants suggested good benefits and proper training to drivers. Participants were also asked to validate solutions that had been adopted in other parts of the world. For instance; as a motivation to stay in the job, drivers were given certain portion of truck shares to create the feeling of ownership (Palander et al., 2012). The participants were not aware of this kind of practice in Maine. Contractors disagreed with this as a proper solution to keep drivers in the job, while all the other stakeholder groups believed it as a novel approach. However, a large portion (actual data unknown due to anti-trust policy of the state) of trucking fleets in Maine are owner-operators (Irland, 2011). Truck owners mainly focused on better benefits for drivers: *".... because we offer good benefits, and have a good reputation, we have steady employment. Many logging and trucking companies don't have that."*

To attract younger generation to the sector, some participants suggested logging and trucking companies focus on extension activities to showcase the novelty in equipment and technologies being used, *"Trucking is becoming* ***increasingly comfortable*** *compared to past. Now all trucks are equipped with climate control cabs and drivers do make fairly good money based on their education."* According to a forester, the state government entities can be key players for promoting employment in trucking, *"... the forest service and department of transportation can promote trucking as a highly skilled profession like others, through different publication series and extension."*

Some foresters suggested truck owners to pay their drivers in hour-based payment system instead of load-based system. Another forester argued on work related pressure to drivers, pointing out the need for providing independency to drivers on time scheduling and work issues. The problem can be related to another problem about supply chain issue and contractor's nature. In order to manage issues related to dispatching, procurement managers suggested that the trucking and the actual harvesting process should be separated (decoupled). In their view, at present there is a trust issue between different contractors working in same area. Separating harvesting and trucking will insure efficiency and stability in the market. This can be helpful in minimizing competition between contractors and easing up the pressure on drivers and supply chain.

Regarding the issues related to roads, participants from northern Maine proposed an increment on state spending on maintenance of public roads. While participants from southern Maine were more worried about public outcry and aesthetic issues created by large log hauling trucks. Some companies have started using crushed rocks on the last hundred feet of the forest roads leading to public highways to eliminate depositing muds and clays from trucks tires on the later. The problem of ruts and depreciation of roads also seemed to be associated with legal allowable payload. There were contradictory views on legal allowable payload on the pubic highways of Maine. Mainly trucking contractors and procurement managers were positive on increasing payload on public highways, as it could increase trucking efficiency including fuel consumption. One of the trucking contractor stated, *"There could be certain situations where you could have increased weight limits for certain types of trucks on certain roads and that could help the industry. I think that's something nice to keep on the table but could be hard to do politically."* As an opposing view, one forester argued, *"I agree the work they did to get interstate payload raise from 80,000 pounds to 110,000 pounds is important. But for safety we must remember that my wife and daughter drives on that road. Big companies might have different views because if they can haul more amount of woods with same amount of fuel then it can be profitable* *for them. But they also want to be safe. So, I think increasing the payload is not an option."* In a different context, one participant also pointed out the benefit of having east-west highway in the state, especially for better forest products' transportation and minimizing extra cost associated with long hauls. The route I-95 is the only interstate highway (running from north to the south) connecting Maine with other states. The east-west project is a long debated topic in Maine's infrastructure development history, but the project has been rejected till present time due to its expected effects on Maine's wilderness and recreation (Miller, 2014).

Apart from the challenges mentioned above there were other issues related to truck-turnaround times, back-hauling opportunities, and climatic adjustments. Most of the participants agreed that waiting time is a problem in mill yards. Some suggestions were to increasing coordination between drivers, managing concentration yards, and using self-loading trucks to mitigate this issue. However, they also agreed that the self-loading trucks could be a bad option in terms of extra loader (dead weight) being carried. Some of them also pointed out the $20-million investment proposed by a forest product industry in southern Maine, to help minimize turnaround time in their mill yard.

Although participants regarded back-hauling as a challenging job to perform, they still believed it can be carried out with some adjustments. Interestingly, the increased hauling distance incurred by the recent closing of mills seemed to be an opportunity for trucking contractors to back-haul different products. Some of the important suggestions to increase chances of back-hauling were: building more concentration yards; adopting proper networking strategy between mills within and outside the state; using self-loading trucks for short hauls; and making trucks and trailers as dynamic as possible to transport different types of products.

Similarly, the participants also regarded seasonal adjustment in harvesting and trucking as an important issue for transportation. They seemed very concerned about transportation of wood in muddy as well as winter season. During heavy winter season, log trucks in Maine use chains on their tires while driving through forest roads. Except for ploughing snows and clearing public highways, no new anti-slip innovations were used in Maine to mitigate this seasonal barrier.

Based on the strategies suggested and accepted by participants, a summary table was prepared, which is expected to serve as a basic guideline (managerial perspective) for trucking companies and related stakeholders (Table 4.4).

Table 4.4: Summary and highlights of the potential mitigation measures. The measures are represented as views and suggestions of participants. The stakeholder groups favoring those strategies are also included.

Challenges	**Views and suggestions**	**Favoring stakeholder group(s)**
Present market conditions	New technologies, new investments, and marketing new products	All
	Opportunities to negotiate with new markets which was not accessible before	All
	Favorable policies for startup businesses and subsidies in certain products	Trucking contractors and procurement managers
	Attracting new investors; showing the potentiality of the state in terms of forest products	All
Manpower shortage	Good benefits, proper training, more vocational schools.	All
	More extension activities; showing young generation the modern technologies currently used in forest trucking	All

Table 4.4 continued

Manpower shortage	US forest service and DOT as lead organizations to attract youths	Forester and professional society
	Change in payment methods to truck drivers from load based to hour based	Forester
	Ownership sharing mechanism to drivers (giving certain percentage of truck shares)	Forester and procurement manager
	Flexible time schedule and independency to drivers	Forester and professional society
	Developing a well maintained and disciplined trucking fleets	Professional society and forester
Roads and payload	More federal and state budget for maintenance of public roads	Procurement managers and foresters from North
	Avoiding public roads (not interstate highway) as much as possible due to aesthetic issues	Forester and professional society representative from South
	East to west interstate highway in Maine	Professional society representative
	Different measures to clean truck tires before entering public roads	Professional society representative and Foresters from south
	Straight forest roads as much as possible	All
	Minimize repeated maintenance of private forest roads by constructing them properly at the beginning	Trucking contractors and foresters
	Increasing legal allowable payload in interstate highways for certain situations	Trucking contractors and procurement managers
	Not increasing legal allowable payload in interstate highways to insure public safety and minimize impacts on the roads	Foresters and professional society
	Light trailers to increase capacity of trucks	Trucking contractors
Turnaround time	More unloading cranes at the mill; example: overhead cranes used by big mills	Trucking contractor and procurement managers
	Adding some self-loading trucks in the fleets	All
	More concentrated landing sites	Trucking contractor and forester
	Pavements in wood landing sites	Forester
	Proper coordination in dispatching between different mills in same area	Procurement manager

Table 4.4 continued

Back-hauling of empty trucks	Long distance hauling of the forest products; an opportunity to back-haul	All
	More concentrated landing sites	All
	Proper networking between mills from different regions.	All
	Dynamic trucking configurations to accommodate various products	All
Seasonal and topographic barriers	Using trucks for other works during mud season when timber harvesting stops	Forester
	Learning road building knowledge from other US states, mainly for steep terrain	Forester
	Use of stud tires during snow season	All
	Learning new innovations from other countries for winter transportation	Trucking contractors and procurement managers
Fuel efficiency	Using air deflectors in the trucks	Procurement manager
	Increasing payload	Trucking contractors
Contractors	Separating harvesting and trucking parts, i.e. using two different contractors for each work	Forester and procurement manager
	Proper dispatching strategy to minimize competition between contractors	Forester and procurement manager

4.4. Conclusions

Based on the qualitative case study, this research has provided comprehensive views of different stakeholders towards forest trucking business in Maine and associated challenges. It has also validated mitigation measures that can be adopted for sound forest trucking operations in context of a forest-based economy such as Maine. As the views and suggestions are explicitly based on the situation of Maine, the results of this study cannot be generalized for broader perspective like other quantitative studies. However, these findings can have significant effects for new studies attempting to tackle these issues. The resolutions identified can be validated for other regions with the help of stakeholders operating in those regions. The study is first of its kind for forest products transportation sector and can serve as a basic guideline to test technological feasibility behind the suggested resolutions.

Overall, due to recent changes in forest products market condition of the state and shortage of skilled labor force, the trucking enterprise is a challenging business to operate. In general, disintegration of trucking business from harvesting operations was regarded productive for the long run. The local field level suggestions for mitigation of major challenges seemed crucial in trucking sector. The region-specific suggestions can also help forest products companies and trucking enterprises to focus more on that resolutions. A constant collaboration among forest products companies, contractors, and foresters is important to resolve supply chain issues like trucks dispatching, turnaround times, and backhauling. Nonetheless, coordination with public and policy level personnel for issues related to public road conditions and safety is vital for better trucking business.

CHAPTER 5:

CONCLUSIONS

The aim of this study was to document challenges associated with secondary forest products transportation, and provide potential field level resolutions to resolve those challenges by utilizing related stakeholders' views and suggestions. The state of Maine has the highest percentage of forest cover in the US and forestry related business and services are one of the vital components of state's economy. Transportation plays an important role to maintain sustainability in the supply chain of wood products in the state. The process of transportation including construction and maintenance of forest roads and owning and operating large log trucks and chip vans is the largest cost component of forest operation. Therefore, it is important to have information on the current challenges faced by this sector and ways to mitigate them.

The second chapter of this thesis presented the overall trend of scientific studies in secondary forest products transportation around the world. The collection and classification of more than hundreds of scientific articles, was first of its kind specifically focusing on forest product secondary transportation. More than half (56%) of the collected articles were based on research conducted in European countries, while about 33% were based on North America. Supply chain and optimization was the most studied research theme followed by roads and route planning. This chapter can serve as a guideline for academics and new researchers in forest products transportation. Forest based industries and trucking companies can also use the findings to review and update advances in the field.

The third chapter focused on the challenges faced by forest trucking industry of Maine and analyzed specific situations responsible for those challenges through literature analysis. The cross-sectional survey technique was used for the ranking of major challenges prevalent in the region. The survey was conducted in a regional conference of forest engineers and yielded more than 30% response rate. All participants agreed that there were some major problems in the sector which needed to be addressed separately. Location and availability of market was regarded the most prominent challenge in the sector followed by lack of skilled manpower and road conditions. Other issues which were discussed and analyzed included truck waiting, payload, and backhauling. The findings also pointed out the need of further examining the actual situation of trucking sector in the state through face-to-face conversation with related stakeholder. The suggestions and recommendation from field level personnel will help in resolving the challenges mentioned earlier with local techniques.

The fourth chapter utilized qualitative research method to comprehend the trucking situation at the field level and validate potential resolutions specifically for the state of Maine. The innovative and explorative nature of study was the main reason behind selecting qualitative approach with semi-structured interviews. Participants were mainly concerned about issues like truck driver shortage, road condition, and current forest products market situation. Technical issues related to payload, turnaround time and backhauling was also regarded important. Suggestions like providing good training, increasing benefits to drivers and conducting extension and outreach activities were put forward to deal with manpower issue. Other resolutions suggested were, proper coordination between all related stakeholders. On the same problem, different stakeholders had varying opinions. These localized natures of suggestion from the stakeholders can be used by policymakers to specifically address and review those options. This study was specifically focused on the trucking situation of Maine; hence, the results can be utilized as a management guideline by all related stakeholders of the state to resolve issues related to forest trucking.

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APPENDIX A:

SURVEY QUESTIONNAIRE

Survey on Challenges Faced by the Forest Trucking Industry

"Your information is very valuable"

As a part of identifying the major challenges faced in the forest trucking industry within the Northeastern region, we would like to acquire your thoughts and opinions to shape up possible solutions. This survey is expected to take only take 4-5 minutes to complete. We will not report individual responses, but rather, will only release summarized data (individual responses will be kept **strictly confidential)**.

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1) How many years have you been associated with the forest industry?

2) a. Please describe your firm/ business:

Independent contractor ☐ Company ☐ State or Federal agencies ☐

Others (please specify):

b. Please state the County and State of your firm/ primary work:

3) What are the major forest products your business produces and/or transports? *Please check all that apply*.

Sawlogs/Specialty ☐ Pulp/groundwood ☐ Biomass (hogfuels) ☐ Chips (paper) ☐

Others (please specify):

4) Do you think there are problems in the forest trucking industry?

Yes ☐ No ☐ I am not aware ☐

5) What are the main problems faced by forest trucking industry according to your perspective?

(*Please check (√) only one column for each problem mentioned below*)

	Major problem	***Problem exists***	***Not so concerned***
a) Legal allowable payload			
b) Truck turn-times at harvesting and processing facilities			
c) Condition of roads			
d) Lack of skilled drivers and operators			
e) Difficult Geographic Conditions			
f) Cost of fuel and maintenance			
g) Location/availability of markets			

Others:

6) How available are skilled truck drivers today as compared to

5 years ago: Harder to find ☐ The same ☐ Easier to find ☐ Don't know ☐

10 years ago: Harder to find ☐ The same ☐ Easier to find ☐ Don't know ☐

Comments:

7) How are the drivers (or trucking company) usually paid? *(Check one).*

By the hour ☐ By the load ☐ I am not aware ☐

By the mile ☐ By the day ☐
By the ton ☐ Other ☐

Please identify if others:

8) Is the amount of space at the woods yards an issue?

Yes ☐ No ☐ I am not aware ☐

9) Are there opportunities to reduce the truck turnaround times at:
Harvesting sites?

Yes ☐ No ☐ I am not aware ☐

Processing facilities?

Yes ☐ No ☐ I am not aware ☐

10) What would you recommend as possible ways to reduce the truck turn times?

Harvesting sites:

Processing facilities:

11) Are there opportunities to utilize empty trucks for back-hauling?

Yes ☐ No ☐ I am not aware ☐

12) Will back-hauling delay the entire forest product transportation schedule?

Yes ☐ No ☐ I am not aware ☐

13) What is the average distance travelled from the landing to final processing facility by product

	Sawlogs	*Pulp/groundwood*	*Chips*	*Biomass*
Miles (one-way)				

14) What are the average number of trips for a single truck/driver by:

	Sawlogs	*Pulp/groundwood*	*Chips*	*Biomass*
Day				
Harvest operation				

15) How would you compare the roads in the northeast today as compared to 10 years ago?

	Much worse	*Somewhat worse*	*Same*	*A little better*	*A lot better*
Quality of PAVED roads					
Quality of GRAVEL roads					
Traffic in PAVED roads					

Thank you for completing our survey!

We appreciate your effort and time to participate in our survey. We truly value the information you have provided. Your responses will be vital in shaping potential solutions for addressing the challenges faced by the trucking industry.

We value & welcome your input. Please contact us to discuss this research effort:

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APPENDIX B:

SURVEY CONSENT FORM

INFORMED CONSENT FORM

You are invited to participate in a research project being conducted by Anil Koirala, a *graduate student* in the School of Forest Resources at the University of Maine. The purpose of the research is to analyze challenges faced by forest trucking industry in Maine and develop a management guideline suggesting resolutions. The study is guided and sponsored by Dr. Anil Raj Kizha, assistant professor of forest operations in school of forest resources, University of Maine. You can remove this page from survey and keep it for your information.

What Will You Be Asked to Do?

You are requested to complete an attached survey based on forest trucking industry in Maine, which will take no more than 5 minutes to complete.

Risks

Except for your time and inconvenience, there are no risks to you from participating in this study.

Benefits

(1) The research participants from forestry sector in Maine can use the final product of the study, a management guideline, to plan forest transportation effectively prior to the harvesting season.

(2) The management guideline will be uploaded on the Center for Research and Sustainable Forests (CRSF), SFR, UMaine. Respondents will be able to access this guideline through CRSF website http://crsf.umaine.edu/publications-resources/. This information is clearly stated in survey forms.

(3) The study will analyze overall challenges to forest trucking industry in Maine and suggest potential resolutions for specific situations. Hence, the management guideline will be an important tool for landowners, trucking companies, truck drivers and foresters for better planning and execution.

Confidentiality

The survey will be completely anonymous. Data will be kept in the investigator’s locked office and on a password-protected computer. The paper survey data and digital data will be stored for 3 years and will be destroyed in 2019.

Voluntary

Participation is voluntary. If you choose not to take part in this study, you may stop at any time. You may skip any questions you do not wish to answer.

Contact Information

If you have any questions about this study, please contact at:

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If you have any questions about your rights as a research participant, please contact Gayle Jones, Assistant to the University of Maine's Protection of Human Subjects Review Board, at 581-1498 (or e-mail gayle.jones@umit.maine.edu).

APPENDIX C:

INTERVIEW PROTOCOL

I would like to start our interview by asking you about your background, profession and experience.

1. Could you tell me about your profession or business?
   a. How many years of experience do you have in this field?
   b. What specific services do you or your business offer?

2. How many people are employed in your business?
   a. How many are temporary seasonal workers?
   b. Can you please explain some basic benefits to the workers (like insurance and holidays)?

3. What is the role of forest products transportation in your profession or business?
   a. How many log trucks and chip vans are in your business?
   b. Are these operated seasonal or year-round?

4. What is your outlook for the trucking business in New England?
   a. Is the business booming? Is it profitable?
   b. Is there any room for increasing profitability?

Now, I would like to shift our focus on forest trucking operations in Maine.

5. Do you think there are challenges to the efficient forest trucking operations in Maine?
   a. What are some of the important challenges?
   b. Please rank these challenges from most important to least important if possible?

6. Why you have sorted it as a major challenge?
   a. Do you have your own experience regarding that?
   b. Do you think, other business owner or interviewee will think same about this challenge (as major one)?

Now, I would like to get your opinion on possible solutions to these challenges that can be adopted for the state of Maine.

7. What are your thoughts about the forest products market conditions in Maine?
   a. How far would trucking companies of Maine be prepared to truck the products to new markets (maybe distance in miles or other states or international)?
   b. How has the closing of mills affected your business?
   c. How confident are you that there is a solution to this market situation?

8. What is your view towards availability of skilled manpower in the trucking industry, mainly truck drivers?
   a. Is this a severe problem?

b. Are drivers leaving this profession for others or are they leaving Maine for other jobs?
c. What can be done to solve this problem?
d. How concerned are you about the aging workforce in this profession?
e. What are your ideas for attracting a young workforce towards this profession?

9. Let us talk about forest roads (its construction and maintenance), can you please briefly describe about the road condition of the state, from the forest trucking point of view?
   a. Are there problems in truck routing and selecting the easiest roads or paths for supply chain?
   b. Is there a better mechanism for funding private forest road maintenance in the state?
   c. In other states, different mathematical models have been used for better supply chain planning, do you think that approaches have been applied to our state?
   d. If yes, is it successful?
   e. Can you suggest some points for better transportation planning and minimizing extra cost in road construction and maintenance?

10. I want to focus our talk towards payload, do you have idea about the legal allowable payload in our state? Do you think it is enough?
    a. Is it an issue in Maine?
    b. Can something be done to maximize the payload of the trucks?
    c. Are these techniques in use in Maine? Are they successful?

11. What is your view towards truck turnaround times? Is there a problem regarding increased turnaround time in Maine?
    a. Where do you think the truck turnaround bottlenecks are: harvesting sites or processing facilities?
    b. Are there any ways to minimize the turnaround time at these sites? (perspective of Maine)
    c. What is your view towards self-loading trucks? Is it helpful for minimizing downtime?

12. What do you think about back-hauling of the empty trucks?
    a. Would you consider backhauling log trucks and chip vans in Maine?
    b. Does the long-distance hauling of forest products in Maine affect the chances to backhaul? What is your viewpoint about this?
    c. Can you suggest ideas that can be adopted to back-haul empty trucks and vans in Maine?

13. What do you think about geographical and seasonal challenges to the forest products transportation in Maine?
    a. What are some anti-slip innovations adopted in Maine for roads?
    b. Are there different truck and trailer combinations for different geographic conditions (steep terrain and flat lands) in Maine?

14. What configurations of tractors, trucks, trailers and chip vans are in use in our state?
    a. Do you think it is possible to enhance the fuel efficiency of the trucks?
    b. Does design of the truck play a role in enhancing the efficiency?
    c. Some people from southern states has suggested about using trucking simulators to find out proper tractor trailer combinations, do you have any idea about that and do you know about their uses in Maine?
    d. Can you please tell us about rpm (revolution per minute)? Is operating in lower rpm for trucks helpful for fuel efficiency?

Thank you very much for your time and effort. We appreciate your participation.

APPENDIX D:

INTERVIEW CONSENT FORM

INFORMED CONSENT FORM
Personal semi-structured interview

You are invited to participate in a research project being conducted by Anil Koirala, a *graduate student*, and Dr. Anil Raj Kizha, a faculty member, in the School of Forest Resources at the University of Maine. The purpose of the research is to analyze challenges faced by forest trucking industry in Maine and develop a management guideline suggesting resolutions. For this, we would like to have your views on potential measures that can be used to mitigate challenges faced by forest trucking industry in Maine. You must be at least 21 years of age to participate in this study.

What Will You Be Asked to Do?

The interview will take approximately one hour. With your permission, I will record the session. Examples of potential interview questions include:

15. What are your thoughts about the forest products market conditions in Maine?
16. What is your view towards availability of skilled manpower in the trucking industry, mainly truck drivers?
17. Does the long-distance hauling of forest products in Maine affect the chances to backhaul? What is your viewpoint about this?

Risks

Except for your time and inconvenience, there are no risks to you from participating in this study.

Benefits

(1) The research participants from forestry sector in Maine can use the final product of the study, a management guideline, to plan forest transportation effectively prior to the harvesting season.

(2) The management guideline will be uploaded on the Center for Research and Sustainable Forests (CRSF), SFR, UMaine. Respondents will be able to access this guideline through CRSF website http://crsf.umaine.edu/publications-resources/. This information is clearly stated in survey forms.

(3) The study will analyze overall challenges to forest trucking industry in Maine and suggest potential resolutions for specific situations. Hence, the management guideline will be an important tool for landowners, trucking companies, truck drivers and foresters for better planning and execution.

Confidentiality

Data will be kept in the investigator's locked office. Your name or other identifying information will not be reported in any forms of publications. A special code number will be used to protect your identity. The paper key linking your name to the data will be kept in a locked office and destroyed after data analysis is complete. Data analysis will be completed in 2018 and then the keys will be destroyed in the same year. Audio recordings will be deleted in three years in 2020 and transcripts will be deleted after five years in 2022.

Voluntary

Participation is voluntary. If you choose not to take part in this study, you may stop at any time. You may skip any section of interview you do not wish to answer.

Contact Information

If you have any questions about this study, please contact at:

Anil Koirala
Graduate Research Assistant
School of Forest Resources
5755 Nutting Hall
University of Maine
Orono, ME 04469-5755, Room 231
Phone: (207) 889-7154
Email: anil.koirala@maine.edu

Anil Raj Kizha
Assistant Professor of Forest Operations
School of Forest Resources
5755 Nutting Hall
University of Maine
Orono, ME 04469-5755, Room 217
Phone: (207) 581-2851
Email: anil.kizha@maine.edu

If you have any questions about your rights as a research participant, please contact Gayle Jones, Assistant to the University of Maine's Protection of Human Subjects Review Board, at 581-1498 (or e-mail gayle.jones@umit.maine.edu).

APPENDIX E:

IRB APPROVAL

APPLICATION FOR APPROVAL OF RESEARCH WITH HUMAN SUBJECTS

Protection of Human Subjects Review Board, 418 Corbett Hall, 581-1498

(Type inside gray areas)
PRINCIPAL INVESTIGATOR: Anil Koirala
EMAIL: anil.koirala@maine.edu TELEPHONE: (207) 581-2851
CO-INVESTIGATOR(S):
FACULTY SPONSOR (Required if PI is a student): Anil Raj Kizha
TITLE OF PROJECT: Forest Trucking Industry in Maine: Opportunities and Challenges

START DATE: 08/19/2016 PI DEPARTMENT: School of Forest Resources
MAILING ADDRESS: 5755 Nutting Hall, Orono, 04469, Maine
FUNDING AGENCY (if any): MAFES and CFRU
STATUS OF PI:
FACULTY/STAFF/GRADUATE/UNDERGRADUATE GRADUATE

1. If PI is a student, is this research to be performed:

- ☐ **for an honors thesis/senior thesis/capstone?**
- ☒ **for a master's thesis?**
- ☐ **for a doctoral dissertation?**
- ☐ **for a course project?**
- ☐ **other (specify)**

2. Does this application modify a previously approved project? N (Y/N). If yes, please give assigned number (if known) of previously approved project:

3. Is an expedited review requested? Y (Y/N).

Submitting the application indicates the principal investigator's agreement to abide by the responsibilities outlined in Section I.E. of the Policies and Procedures for the Protection of Human Subjects.

Faculty Sponsors are responsible for oversight of research conducted by their students. The Faculty Sponsor ensures that he/she has read the application and that the conduct of such research will be in accordance with the University of Maine's Policies and Procedures for the Protection of Human Subjects of Research. REMINDER: if the principal investigator is an undergraduate student, the Faculty Sponsor MUST submit the application to the IRB.

Email complete application to Gayle Jones (gayle.jones@umit.maine.edu)

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FOR IRB USE ONLY **Application # 2016-08-01** **Date received 08/04/2016** **Review (F/E): E** **Expedited Category:**

ACTION TAKEN:

X Judged Exempt; category 2 on 8/5/2016 Modifications required? Y Accepted (date) 8/17/2016

☐ **Approved as submitted. Date of next review: by Degree of Risk:**

☐ **Approved pending modifications. Date of next review: by Degree of Risk:**
Modifications accepted (date):

☐ **Not approved (see attached statement)**

☐ **Judged not research with human subjects**

FINAL APPROVAL TO BEGIN **08/17/2016**
Date

04/2016

BIOGRAPHY OF THE AUTHOR

Anil Koirala was born in Sarlahi, Nepal on September 7, 1989. He grew up in the city of Hetauda, Nepal, which is also famous for its green and clean environment. In 2009, Anil joined Institute of Forestry, Tribhuvan University, Hetauda, Nepal to get his 2 years-intermediate degree in forestry. Anil finished his intermediate degree in 2011 with highest student honor. In the same year, he got enrolled in the same university to pursue his BS in forestry. During his time there, Anil completed a research project to create a local volume table of Teak tree species. He was awarded with a prestigious Erasmus Mundus scholarship to pursue his final semester of BS study in University of Göttingen, Germany. Anil completed his BS studies in summer of 2015 with highest student honor from the university.

In spring of 2016, Anil was accepted to the University of Maine as a Graduate Assistant in the School of Forest Resources. During his time at University of Maine, Anil has submitted four scientific articles including his undergraduate research work in different journals. Three of them are already accepted and ready to be published.

Anil is a candidate for Master of Science degree in Forest Resources from the University of Maine in August 2017.