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Research paper

Cost analysis of transporting forest chips and forest industry by-products with large truck-trailers in Finland

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ABSTRACT

Laws mandating the physical dimensions of freight transport vehicles were changed in Finland and the new legislation enables higher gross weights as well as larger load capacities. The aim of this study was to examine truck transportation costs associated with forest chips and forest industry by-products as a function of transportation distance and procurement volume in order to determine the most cost-effective vehicle type for each assortment and find out how much the new vehicle types can improve the efficiency of wood biomass transportation. The transported assortments were whole-tree and logging residue chips produced at roadside landings, sawdust, and bark or sawmill wood chips from forest industries and ground stumps from terminals. The transportation costs were calculated as a function of permissible payload and transportation distance from the loading point to the end-use facility on the basis of existing driving speed models, productivity parameters, GIS data and hourly cost data. The results of this paper indicate that the new measures, technology and weight limits for heavy vehicles represent a significant cost reduction and efficiency improvement potential when transporting forest chips and forest industry by-products. The 69-tonne truck-trailer was a feasible choice when the payload was not limited by the bulk weight of the forest industry by-products. With heavier forest industry by-products, such as sawmill wood chips and bark, the 76-tonne truck-trailer was the most feasible choice. The results showed clearly that the transporting costs associated with using the new type truck-trailers were lower than those for conventional 60-tonne truck-trailers in all assortments.

1. Introduction

1.1. Wood flows from forests

Truck-trailers dominate the transportation of wood supplying the forest and energy industries in Finland [26,50]. The transport is unavoidable due to the distance between the resource and the end-users and truck transportation is used since there are no alternatives for the transport wood material from forest landings [50,63]. Railway- or waterway-based transportation modes are limited to long distance transports from terminals to end-users [50,63]. Last year 75% of the industrial roundwood transported was brought to the mill directly by road [50]. Railway transportation accounted for 22% of the industrial roundwood volume, and waterway transportation (by floating and barge combined) accounted for 3% [50]. In 2014 Finnish forest industries consumed 64.5 million m^3 of roundwood [66]. Moreover, 9.2 million m^3 of sawmill wood chips and sawdust, were utilized by the pulp and paper industries in secondary wood consumption [66].

Forest chips are transported by trucks to the power and heating plants and at the present time there are only a few large CHP installations that can even use railway or waterway transportation in Finland [19,24,26,51]. A solid frame ordinary truck-trailer system is also the most commonly used vehicle for peat and forest industry by-product transport logistics [19,25,26]. Forest industry by-products, which are used as a fuel, consist of assortments such as bark, sawdust, shavings, cut off and recycled wood [19,27,67]. The raw material of forest chips consists of logging residues, tree parts, non-merchantable roundwood and stumps from timber harvesting operations and pre-commercial thinnings [19,27,67].

1.2. Production of forest chips

Comminuting is a central part of the forest energy supply chain

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and it may take place on the logging site, at the roadside landing, at a terminal, or at the plant [31,44,63]. Machines operating at terminals, roadside landings or logging sites are run using diesel engines, while grinders and chippers operating at industrial sites can be powered with electric engines [9,13]. Centralised comminution at the plant or at the terminal enables the efficient use of comminution machines. In a system where comminuting takes place at the roadside landing, it and truck transportation are linked to each other, leading to increased idling times for both the chipper and trucks [4,12,47,56,61]. Terminals operate as buffer storage facilities, enabling a secure supply of fuel chips under extraordinary conditions and also serving as a process management tool for the whole supply chain balancing the seasonal fluctuation of the plant's demand and respective variability of supply from the forests. The terminal is also a transshipment point and a compromise between comminuting at the landing and at the plant. The raw material is transported in an unprocessed or a pre-processed form to the terminal and delivered to the plant as chips [31,44,63]. Heat and combined heat and power plants (CHP) are the main consumers of forest chips. Other potential consumers are biorefineries and thermal treatment plants [33].

In the year 2014, Finnish heating and power plants consumed 18.7 million m^3 of solid wood fuels, of which 10.2 million m^3 were forest industry by-products and 7.6 million m^3 comprised forest chips [67]. A majority of the forest industry by-products were bark (7.1 m^3 million) and sawdust (2.2 m^3 million). About 49% of forest chips were made of small-diameter thinning wood produced in the tending of young stands and 36% was produced from logging residue from final fellings [67]. The share of the stump and root wood was 11%, while 6% of forest chips were produced from large non-merchantable roundwood [67]. A majority of delivered forest chips were comminuted at roadside landings [49] and the conventional supply chain consist of one mobile chipper and two or three chip trucks with trailers [4,12,56,61]. About 29% of the forest chips were produced at the terminals and 14% were comminuted at the end-use facilities [49]. Comminuting at the roadside landing is the predominant practice in the supply system for logging residue and thinning wood chips [49]. Comminuting at the terminal is the leading method for producing fuel chips from stumps or non-merchantable roundwood [49]. Comminuting in the terrain is a seldom-used harvesting method in Finland [22,49].

1.3. Transport efficiency of wood biomass

Comminuting increases the density and homogeneity of forest residues [13], which justifies its application early in the supply chain [7]. Transport efficiency is increased since each truck can carry more biomass as a result of higher solid content of volume which has a positive impact in terms of cost, CO_2 emissions, need of manpower and traffic on the roads [12,44]. Different wood biomass types have different characteristics that impact the efficiency and economics of transporting logistics [8,42,52,54,55,63]. For dry or loose material, the maximum load is limited by the volume of material, whereas the weight limits the maximum load for wet or artificially compacted chips [42,52,63].

The bulk density depends on the basic density of a wood species, particle size distribution, moisture content, as well as the loading method and applied pressure when loaded [13,35,52,54,55]. The solid volume to comminuted volume is affected by a number of factors which include the size and shape of comminuted material and the heterogeneity of the particle sizes, where larger heterogeneity will usually result in higher bulk density, as airspaces are less regular and filled by smaller particles [13,52,54,55]. In many cases forest chips and forest industry by-products are rather light and volume demanding and could benefit from larger load spaces when transported by road [28]. Utilizing modern vehicle designs, such as a moveable axle group or liftable axles or steering axles at the rear end of trailers, even a maximum dimensioned truck-trailer can be easily manoeuvred on forest roads and turnarounds [28,48].

Permissible payloads are governed by the legal gross mass and the allowable axle mass. Dimensions and weight limits for heavy vehicles were changed by the statute that came into force the 1st of October 2013 in Finland [26,28,58]. New legislation enables higher gross weights as well as 20 cm higher vehicles, meaning larger load spaces [26,28]. The changes in legislation were motivated by reductions in logistical costs and greenhouse gas emissions.

According to the new statute two new vehicle types, such as an eight-axle truck-trailer with a maximum gross weight of 68 tonnes and a nine-axle truck-trailer up to 76 tonnes are accepted [28,58]. The prerequisite is that 65% of trailer axles must have twin tyres, otherwise the maximum weights are 64 and 69 tonnes [28,58]. Current legislation on the physical dimensions of the truck-trailer combination limits total vehicle length to 25.25 m, width to 2.55 m and height to 4.4 m [26,28,58]. Maximum load spaces are for a truck about 60 m^3 and for a trailer 100 m^3 [28]. Earlier the chip truck-trailer unit consisted of a three-axle truck and four-axle trailer resulting in a 60-tonne legal gross weight [25,26]. Typical frame capacities for conventional truck-trailers range between 120 m^3 and 140 m^3 and the empty weight between 20 and 25 tonnes [25,26]. Semitrailers are not common in Finland [25] due to their lower transporting capacity, although continuous load space and high allowable axle mass represent some logistical advantages [39].

1.4. Aim and implementation of the study

Bulky wood biomass can be transported in different ways, and if the system is analysed properly, it can reduce the supply costs, and help deliver fuel or raw material at a more competitive price [12,20,21,24,26,34,37,38,42,51,52,61,64]. The aim of this study was to examine truck transportation costs of forest chips and forest industry by-products as a function of transportation distance and procurement volume in order to determine the most cost-effective vehicle type for each assortment and find out how much the new vehicle types can improve the efficiency of wood biomass transportation. The results were expressed as Euros per bulk cubic metre (€ bulk-m^{-3}).

The transported materials were whole-tree and logging residue chips produced at the roadside landings, sawdust, bark or sawmill wood chips from forest industries and ground stumps from terminals. Forest chips were transported either with a 48-tonne semitrailer, 60-tonne conventional truck-trailer or 69-tonne modern truck-trailer equipped with an Electronic Trailer Steering System (ETS). Correspondingly, forest industry by-products and ground stumps were transported with a 60-tonne conventional truck-trailer and a standard 69-tonne or 76-tonne truck-trailer. The hourly operating costs of the truck-trailers were calculated and costs were presented in Euros (€). The hourly cost of a truck-trailer was divided between driving and terminal times (loading, unloading, waiting and auxiliary time). A chipper or a wheel loader was used in the loading for transportation and transported wood biomass was unloaded after scaling to the yard of the end-use facility.

The transportation costs of forest industry by-products and ground stumps were calculated as a function of permissible payload and transportation distance from the loading point to the end-use facility on the basis of existing driving speed models, productivity parameters and hourly cost data. The transportation costs and technical harvesting potential of whole trees and logging residue chips were estimated within a 100 km radius of the power