

## Article

# Total Weight and Axle Loads of Truck Units in the Transport of Timber Depending on the Timber Cargo

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**Abstract:** When transporting timber, the high variability of species, assortments and moisture content of the wood raw material does not allow the weight of the transported timber to be precisely determined. This often contributes to the excessive weight loading of the entire truck unit. The aim of the research is to present the variability of the total weight of truck units with wood cargoes (GVW—gross vehicle weight) depending on the weight of the empty unit and the transported timber load, as well as to analyze the changes in GVW, unit loads of wood and load on individual truck unit axles depending on the season. This study analyzes the total weight of truck units for 376 transports of Scots pine timber at different times of the year. The total weight of the truck units depends on the weight of an empty unit and the weight of the load. GVW was determined by using a weighbridge to weigh the vehicles and then the empty unit after unloading. The weight of the load was obtained as the difference between GVW and the tare. It was found that GVW differed significantly depending on the truck unit used, ranging from 43.60–58.80 Mg, often exceeding permissible limits for public roads. The individual axle loads for various truck units were also analyzed. The obtained results indicate that these loads are more equally distributed in the case of five-axle trucks compared to six-axle ones.

**Keywords:** timber transport; axle load; gross vehicle weight; timber load; empty vehicle weight

## 1. Introduction

Transport plays a vital role in the proper functioning of every economic system. The success of a company specializing in timber haulage depends not only on the transportation system, but also on the cooperation of all entities associated with its supply chain [1–3].

The share of costs relating to the transport of wood raw material in relation to the total costs of forestry activities is significant [4,5]. Its estimated amount is approximately 17%, and this is definitely a higher share compared to other sectors of the economy. The highest costs of transport operations are for hauling timber, accounting for 40–60% [6]. In order to increase their efficiency, companies operating in the timber haulage market try to reduce transport costs, as this is perceived as an important factor for increasing competitiveness. One of the methods of improving the efficiency of timber transport is to reduce the variability of loads and maximize the loads, in accordance with applicable public transport regulations, carried by truck units [5,7,8]. Research conducted in the USA indicates that by maintaining a uniform timber load weight, suppliers are able to achieve savings of 4–14% [9].

An important element in this respect are the legally-established limits of the permissible total weight of vehicles. In 1996, the Member States of the European Union adopted Directive 96/53/EC

specifying permissible vehicle weights of 40 Mg and 44 Mg and weights on a single-axle of 100 kN and double axle of 160 kN [10]. In individual countries, institutions responsible for public transport and public roads have the power to limit the total weight of a truck unit (gross vehicle weight) with the simultaneous possibility of limiting permissible axle weights or increasing them in relation to those specified in EU regulations, as well as indicating the roads to be used by such vehicles [5,11–16]. In Poland, the permissible vehicle weight of a truck and trailer of over four axles has been set at 40 Mg or 44 Mg for a six-axle vehicle; a truck with a 40-ft intermodal container with a maximal single axle load of 80 kN and double axle load of 160 kN and for national roads at 100 and 115 kN [17]. In Finland, 7-, 8- and 9-axle truck units are allowed, with a maximal weight of 64, 68 and 76 tonnes, respectively, and 4.4 m in height [18]. The increase of the permissible weight of truck units in Finland contributed to the reduction of CO<sub>2</sub> and NO<sub>x</sub> emissions and has resulted in economic benefits [19]. Analyses performed by Palander and Kärhä [20] on transporting timber at the increased permissible loads in Finland indicate the possibility of reducing the required number of vehicles and transport work conducted in tonne-kilometers. Estonian experiences show that increasing the weight limit from the current 44–60 Mg would reduce the share of transport costs in roundwood prices from 17.7–14.2% [8]. Vehicles traveling with a full load and with an increased weight can result in economic and environmental benefits in the long term [21,22].

In reality, however, when transporting timber, the high variability of the transported assortments made of different species and the variable moisture content of wood do not allow a precise determination to be made of the weight of the transported raw wood material [23–26]. These differences very often influence the excessive weight of the truck unit [27–30]. McDonnell et al. [31] specify that 58–80% of the vehicles exceeded the permissible truck unit weight, and Devlin [32] shows that the gross vehicle weight (GVW) was exceeded by 60% of the vehicles, of which 20% exceeded the permissible load capacity specified by the vehicle manufacturer. Research conducted in the USA also showed significant overloading of vehicles with wood; as much as 88% of the vehicles had a gross vehicle weight of more than 44 Mg [9].

The volume of the timber harvest in Polish forests has been systematically growing in recent years. In 2015, 40,247 million m<sup>3</sup> were harvested [33]. The units of the State Forests National Forest Holding plan to harvest over 42 million m<sup>3</sup> of timber in 2018. This wood raw material is delivered to several thousand recipients. This presents a major transport challenge, both in terms of logging operations and its transport. In most cases, approximately 90% of the transport is conducted by vehicles using high-tonnage five- or six-axle truck units [25].

The transportation of wood raw material is one of the key operations in forest management, representing a large share of total costs, and has significant potential for optimization [34–36]. A good diagnosis of the configuration of timber truck units, their own weight and their potential timber cargoes, given the large variation in cargo weight, can contribute to improving the efficiency of forest transport [5,9].

Determining the actual weights of transported timber loads and attempting to link them to GVW and individual axle loads will allow the overloading of vehicles and exceeded individual axle weights to be avoided by providing appropriate information to transport companies. The aim of the research is to present the variability of the total weight of truck units (GVW) with wood cargoes depending on the weight of the empty unit and the transported timber load, as well as to analyze the changes in GVW, unit loads of wood and load on individual truck unit axles depending on the season.

## 2. Materials and Methods

In order to conduct the research and perform the relevant analyses, deliveries were studied to one of the largest wood buyers in Poland, a sawmill supplied with large-sized timber, both long logs and shortwood. The transport was conducted by external companies commissioned by the sawmill. Data for 2016 were collected in four periods: January, at the end of March/beginning of April, July–August and October–November.

The gross weight of the truck unit (GVW) expressed in Mg is understood as the actual weight of the vehicle and trailer or truck unit and semi-trailer with all the equipment, the driver and timber load. GVW was determined based on weighing the entire truck unit on a weighbridge at the sawmill at the moment the wood raw material was delivered, and then after unloading, the empty unit was re-weighed. The actual weight of each load was obtained from the difference of GVW and the tare.

The volume of the load of transported timber, expressed as solid cubic volume ( $\text{m}^3$  under bark), was determined on the basis of transport vouchers, on which the payments are based of the delivered timber from the supplier to the recipient. Large-sized logs were measured individually by each piece. It should also be noted that when selling timber in Poland and later when it is transported, the given volumes and conversion factors do not apply to the bark. The share of bark is significant and can range up to a dozen or so percent for pine logs [26], influencing the weight of the transported cargo. Therefore, the analysis refers to the weight of the entire load (wood, bark, water) or the weight of  $1 \text{ m}^3$  of the load.

The load on the individual axles of high tonnage truck units was measured using Model DINI ARGEOWWSD portable truck scales with a 3590M309 weighing terminal with 0.01 Mg graduation. The scale system used is fully compliant with Polish regulations and allows vehicles in transit to be weighed. The loads on the individual wheel axles were measured successively for the whole unit: the vehicle and the trailer. During the measurement, the scales were placed on a flat maneuvering area of hardened concrete paving blocks, with no depressions. It was assumed that such a method of measuring the weight on a particular axle is close to the actual conditions of a forest road, whose longitudinal profile is never level, which in turn is the cause of increased wheel loads on the road surface. For this reason, the analyzed GVW was also determined based on weighing the vehicle on a weighbridge, and not on the sum of the load on individual axles. The weigh station was selected in such a way so as to maintain a level road scale, so that the measured axles were kept level.

The method of weighing vehicles used by the Polish Road Transport Inspectorate, which oversees compliance with permissible axle loads, assumes that measurements are taken with platform scales embedded in the surface, or by placing pads under unweighted axles, while maintaining a maximum allowed slope of 2%. The analysis was based on the results of measurements, taking into account a 5% allowable measurement error in accordance with the recommendations of the Polish Road Transport Inspectorate.

The obtained results were statistically analyzed with the STATISTICA 12 package. In all analyzed periods, the distribution of the variables for all parameters differed from the normal distribution. Therefore, the significance of the differences was mainly determined using the Kruskal–Wallis and Dunn tests.

### 3. Results

#### 3.1. Characteristics of the Parameters of Truck Units and Transported Timber

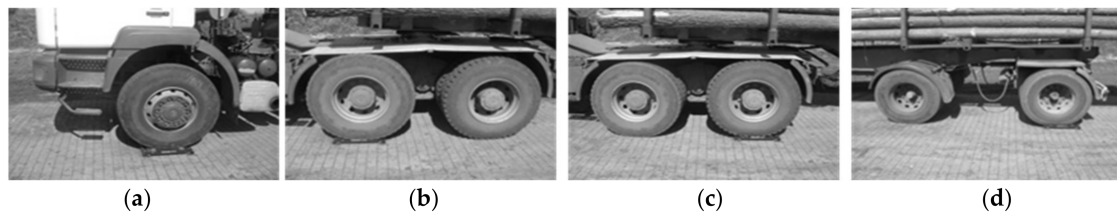
The study analyzed 376 transports of pine timber (mainly shortwood, 3.7–5.0 m long) at different times of the year. The parameters characterizing the truck units are presented in Table 1. Timber was transported using truck units consisting of a truck and trailer (181 observations), truck and semi-trailer (166), truck and lightweight platform semi-trailer (17), as well as truck and dolly (12) (Figures 1 and 2).

It was found that the total weight of the truck units (GVW) differed significantly depending on type, ranging from 43.60 (platforms) to 58.80 Mg (trailers). The lowest average value for a given truck unit, amounting to 45.98 Mg, was noted for deliveries made by a tractor with a platform trailer, while the highest was for a truck with a dolly (51.44 Mg). The arithmetic mean for all truck units was 50.56 Mg. The largest variation for empty weight (tare), ranging from 13.8–23.7 Mg, was observed for the truck and semi-trailer, which are also the heaviest means of transport, with an average weight of 20.5 Mg. The average values of 29.07–30.29  $\text{m}^3$  for transported timber volume were similar regardless of the analyzed truck unit.

**Table 1.** Selected measurements by type of truck unit.

Truck Unit	Measure	Mean	SD	Min	Max	Q1	Median	Q3
Semi-trailer	Gross vehicle weight (Mg)	50.436	2.473	45.000	56.750	48.850	50.225	51.750
Trailer		51.038	2.531	45.200	58.800	49.250	50.750	52.450
Platform		45.988	2.223	43.600	51.650	44.500	45.850	46.500
Dolly		51.438	1.810	49.400	54.400	50.100	50.600	53.250
Semi-trailer	Tare (Mg)	20.500	1.112	13.800	23.700	19.800	20.500	20.950
Trailer		20.224	0.879	17.900	22.000	19.700	20.300	20.900
Platform		14.941	0.311	14.220	15.250	14.800	15.000	15.200
Dolly		20.071	0.706	18.200	20.650	19.925	20.300	20.550
Semi-trailer	Volume of timber load (m <sup>3</sup> )	29.074	1.769	23.960	35.040	28.100	28.710	30.140
Trailer		29.707	1.836	25.670	36.790	28.210	29.610	30.860
Platform		30.292	1.795	27.570	34.500	29.150	30.040	30.420
Dolly		29.982	0.710	28.940	30.940	29.340	30.000	30.620
Semi-trailer	Weight of 1 m <sup>3</sup> of load (Mg)	1.030	0.055	0.869	1.159	0.995	1.028	1.071
Trailer		1.038	0.053	0.828	1.179	0.998	1.042	1.077
Platform		1.025	0.034	0.957	1.075	1.005	1.035	1.045
Dolly		1.046	0.044	0.984	1.136	1.016	1.038	1.073

Notes: SD, standard deviation; Q1, first quartile; Q3, third quartile.

**Figure 1.** Stages of weighing the wheel axles of a truck unit hauling timber: (a) front axle, (b) second axle of the truck, (c) third axle of the truck, (d) rear axle.**Figure 2.** Examples of truck units: (a) truck and trailer, (b) truck and semi-trailer, (c) truck and lightweight platform semi-trailer and (d) truck and dolly.

Due to the small number of measurements obtained for the units with a dolly (12) and platform trailer (17), all statistical analyses were only performed for the units with a trailer and semi-trailer.

The Mann–Whitney test was conducted to examine the significance of the selected features depending on the type of unit (semi-trailer or trailer). The results obtained are summarized in Table 2. The statistical analysis only showed a significant difference between the types of truck units for the weight of 1 m<sup>3</sup> of load (Table 2).



**Table 2.** Results of the analysis of significant differences between selected measures by type of truck unit.

Measure	Gross Vehicle Weight (Mg)	Tare (Mg)	Volume of Timber Load (m <sup>3</sup> )	Weight of 1 m <sup>3</sup> of Load (Mg)	Load Weight (Mg)
<i>p</i>	0.0263	0.0183	0.0029	0.1586	0.0011

The Kruskal–Wallis test was performed for trailers and semi-trailers (due to the heterogeneity of variances) for the significance of GVW, tare, m<sup>3</sup> load volume, weight of 1 m<sup>3</sup> of load and load weight between individual measurement periods (a significance level of 0.05 was adopted for the analyses). The results are summarized in Table 3. In addition, the test of multiple comparisons of mean ranks was performed. The statistical analysis (Table 3) confirmed the differences between the values of the studied measures for specific types of truck units depending on when the measurement was taken.

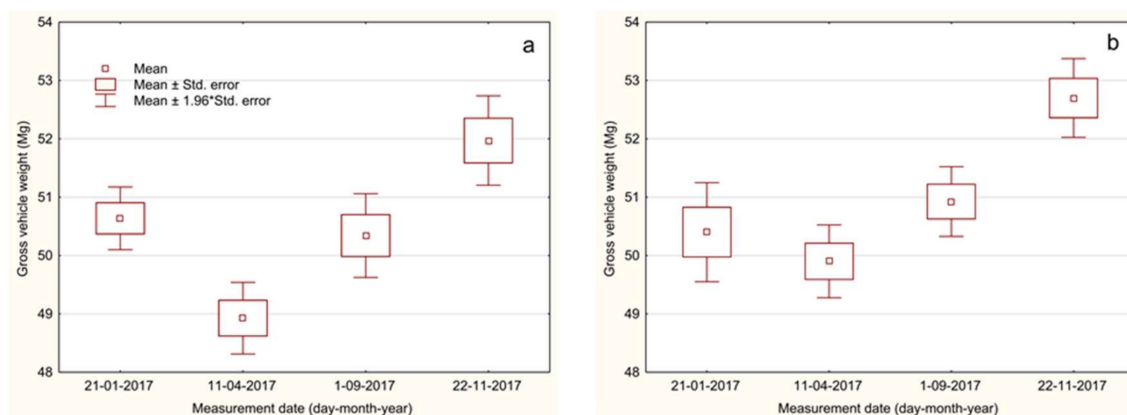
**Table 3.** Results of the analysis of significant differences between selected measures by type of truck unit.

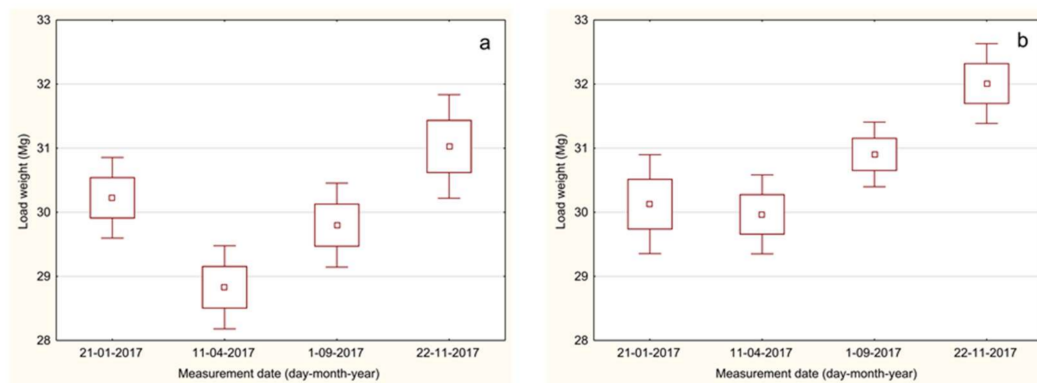
Type of Truck Unit	GVW (Mg)	Tare (Mg)	Volume of Timber Load (m <sup>3</sup> )	Weight of 1 m <sup>3</sup> of Load (Mg)	Load Weight (Mg)
Semi-trailer	0.0000	0.0218	0.1316	0.0000	0.0002
Trailer	0.0000	0.0002	0.0312	0.0000	0.0000

The range of the results obtained for the studied measures depending on type of truck unit and time of measurement is presented in Figures 3–6. In the case of units with a semi-trailer, statistically-significant differences were found for GVW (Figure 3a), tare (June measurement results differ from those of November, and this is the only significant difference), load weights (Figure 4a) and weights of 1 m<sup>3</sup> of load (Figure 5a).

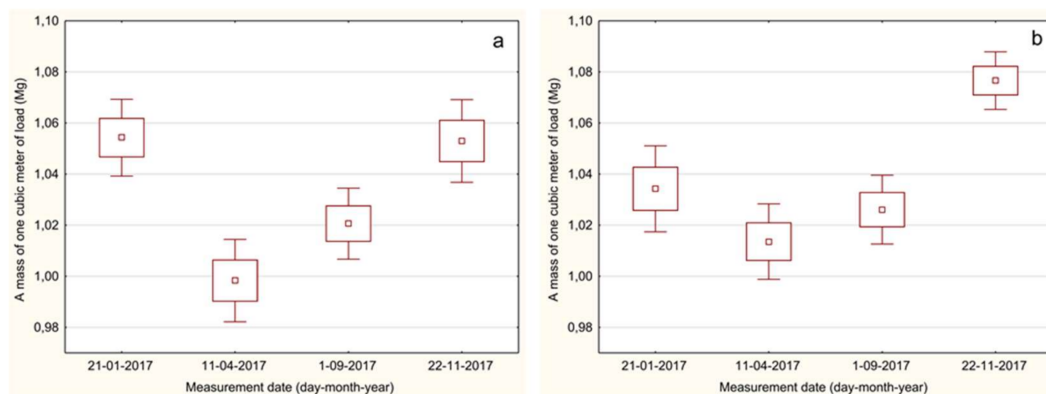
Differences in the values of load volume between individual measurement periods turned out to be not statistically significant (Figure 6a). For units with a trailer, statistically-significant differences were found for all variables (Figures 3b, 4b, 5b and 6b), although in most cases, these differences related to November results. In the case of the m<sup>3</sup> load volume, significant differences in comparison to other measurement dates were found only for data from September.

As shown in Figure 5, the differences are not very large, but they are statistically significant for the weight per cubic meter of transported round wood depending on the transport system used. However, in particular seasons of the year, not all differences have the same tendency. These differences could be explained by random factors, which may be related to various tree growth conditions influencing wood density or water content.

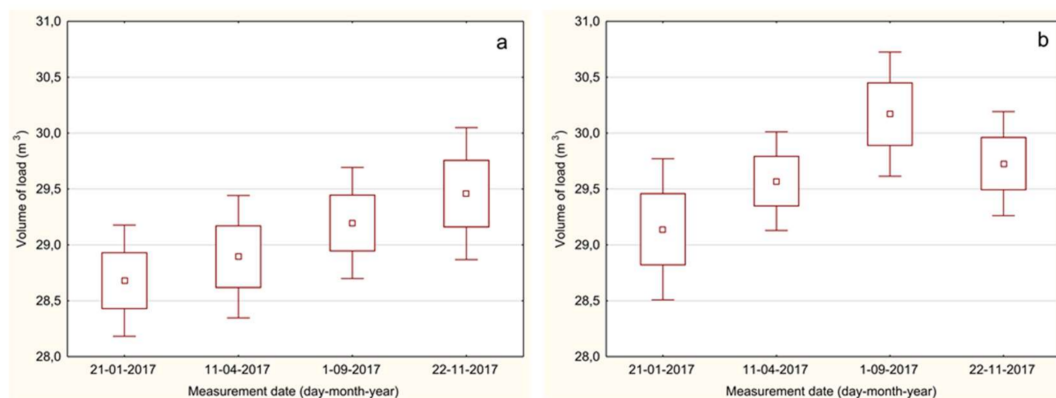
**Figure 3.** Comparison of average GVW values by measurement date for a unit with a semi-trailer (a) and a trailer (b).



**Figure 4.** Comparison of average load weight values by measurement date for a unit with a semi-trailer (a) and a trailer (b).



**Figure 5.** Comparison of average weight of 1 m<sup>3</sup> of load values by measurement date for a unit with a semi-trailer (a) and a trailer (b).



**Figure 6.** Comparison of average load volume values by measurement date for a unit with a semi-trailer (a) and a trailer (b).

### 3.2. Total Weight of Truck Units as a Function of the Tare and Volume of Transported Timber

When loading timber on a forest road, the driver is not sure how much wood to load so as to not overload the vehicle. Assuming that drivers know the mass of an empty unit (they are informed of this by the recipients after weighing) and knowing that the results of the measurement of the mass of 1 m<sup>3</sup> of cargo are not statistically significant (Table 2), an attempt was made to develop a two-factor regression model for the GVW (Mg) values as a function of the tare of the truck unit Mg and load

volume of the timber (m<sup>3</sup>). The presented linear model was developed using the least squares (OLS) method. The significance of the calculated coefficients was assessed using Student's *t*-test.

For the semi-trailers, it took the form of:

$$GVW = 1.04672 * Tare + 0.996916 * m^3 \quad (1)$$

The constant term was not taken into account because its value turned out to be not statistically significant. For the developed model, the standard error of the estimation was 1.59297, and the coefficient of determination  $R^2$  was 0.9990. The assessment of the model parameters is presented in Table 4.

**Table 4.** Assessment of the model parameters for semi-trailers.

Parameter	Parameter Value	Standard Error	<i>t</i> -Statistic	<i>p</i> -Value
Tare	1.04672	0.0662784	15.7927	0.0000
Load volume m <sup>3</sup>	0.996916	0.0467613	21.3193	0.0000

In the case of a unit with a trailer, the regression model describing the GVW values depending on vehicle weight (tare) and load volume m<sup>3</sup> took the form of:

$$GVW = 1.25897 * Tare + 0.860483 * m^3 \quad (2)$$

The offset also was not statistically significant in this case. The standard error of the estimation of the developed equation was 1.59736, and the coefficient of determination  $R^2$  was 0.9990. The assessment of the model parameters is presented in the Table 5.

**Table 5.** Assessment of the model parameters for trailers.

Parameter	Parameter Value	Standard Error	<i>t</i> -Statistic	<i>p</i> -Value
Tare	1.25897	0.0821727	15.3211	0.0000
Load volume m <sup>3</sup>	0.860483	0.0559386	15.3826	0.0000

### 3.3. Distribution of the Axle Loads of the Truck Units

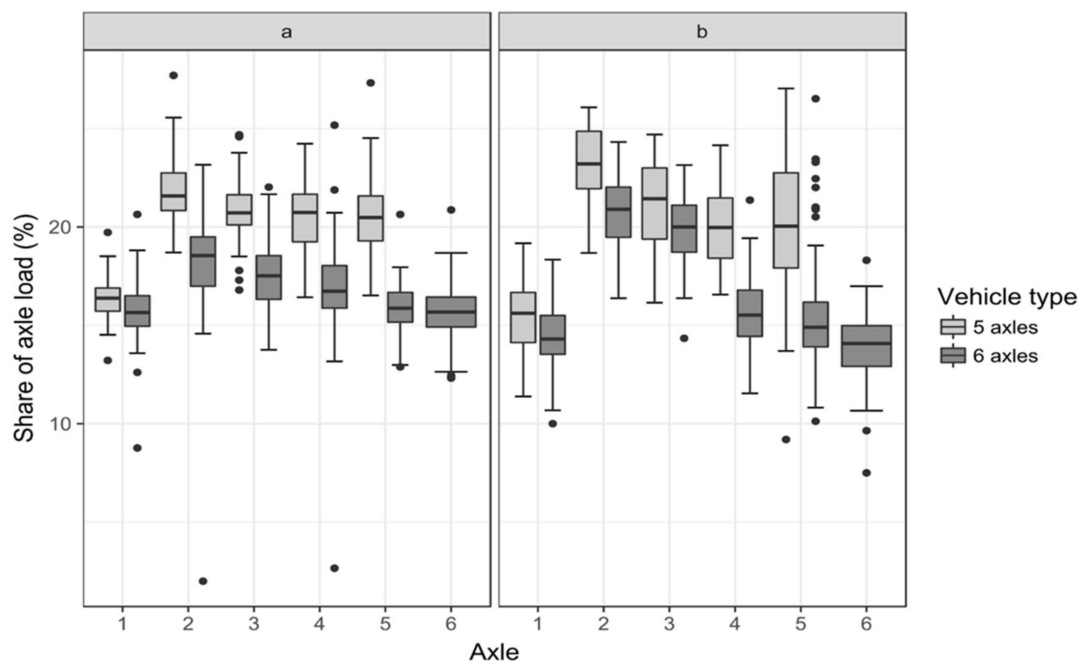
The analysis of axle loads was performed for 92 five-axle and 155 six-axle truck units consisting of a truck and semi-trailer, as well as 46 five-axle and 135 six-axle units of a truck and trailer. The basic statistics characterizing the absolute load values of individual axles of the units are presented in Table 6. The smallest axle load for all units was on the first axle, spanning average values of 74–80 kN, with a range of results from 42–102 kN. The highest average loads were at the level of 106–113 kN, located on the second and third axles in the five-axle units, with a maximum single axle load of 170 kN occurring on the fifth axle.

The analysis performed with the Friedman test showed the existence of statistically-significant differences in the level of the vehicles' axle loads. This analysis was performed for groups of different types of units and different numbers of axles.

It should be noted that for both five- and six-axle truck units, the lowest load is on the first axle. In the case of five-axle units, the load on the remaining axles is fairly even. However, six-axle units have the highest load on the second axle (Figure 7), which then decreases in the direction of the last axle that is similarly loaded as the first axle. Despite the uneven axle load of the six-axle units, their maximum loads are less than in the case of the five-axle units.

**Table 6.** Assessment of the model parameters for trailers.

Axle Load Values (kN)					
Unit	Axle	Mean	SD	Min	Max
five-axle semi-trailer	1	80.77	4.58	68.40	98.20
	2	111.02	11.64	86.60	143.40
	3	106.54	11.91	77.43	134.90
	4	107.60	19.89	75.90	157.70
	5	104.02	20.68	13.50	170.00
six-axle semi-trailer	1	80.55	6.01	42.56	102.03
	2	93.10	14.32	66.40	138.70
	3	89.28	11.84	63.65	137.75
	4	91.26	19.61	70.71	159.10
	5	84.95	13.21	53.30	126.70
	6	84.93	14.69	51.70	141.90
five-axle trailer	1	74.81	6.81	60.33	90.25
	2	113.07	10.18	90.25	135.19
	3	102.06	14.42	74.39	127.59
	4	97.93	15.04	73.34	141.08
	5	98.63	18.26	39.90	140.03
six-axle trailer	1	74.45	6.80	57.95	91.20
	2	106.94	9.99	83.60	129.20
	3	102.41	9.38	82.65	125.88
	4	80.85	8.74	62.70	104.69
	5	80.06	17.90	50.35	168.06
	6	72.18	9.51	36.77	101.65

**Figure 7.** Distribution of the axle loads of the truck units with a semi-trailer (a) and a trailer (b).

#### 4. Discussion

Transport plays an extremely important role in every area of the economy, including the forestry industry. The efficiency of transport depends on a number of factors, including, among others, the load capacity of the vehicle, driving time and fuel consumption [29,37]. When transporting timber, the high

variability of species, timber assortment and moisture content of the wood influence the determination of the weight of the transported timber and GVW [15,27,29]. In the studies carried out for the same species of Scots pine, as well as the large-sized assortments, statistically-significant differences were found for the tested parameters in different periods of the year, as evidenced by the study results of Owusu-Ababio and Schmitt [30]. Research conducted by Tomczak et al. [26] indicates a large variation in the density of pine wood. On a longitudinal section of the trunk, the highest density was found for wood at breast height ( $0.816 \text{ Mg/m}^3$ ), whereas the lowest was from the section closest to the apex ( $0.707 \text{ Mg/m}^3$ ). This differentiation obviously affects the variability of the weight of the transported timber. Calculated per  $1 \text{ m}^3$ , the weight of the wood raw material was estimated at  $0.979 \text{ Mg}$ . The ratio of the actual density ( $0.979 \text{ Mg/m}^3$ ) to the density provided in the tables ( $0.740 \text{ Mg/m}^3$ ) amounted to 1.3:1 [26]. The actual weight of the wood raw material was therefore about 30% higher than the weight that can be estimated on the basis of the wood density tables developed for the needs of road transport. The results of the tests of the mass of  $1 \text{ m}^3$  of cargo in the range of from  $0.828$ – $1.179 \text{ Mg/m}^3$  (Table 1) also indicate the need to verify the adopted table values. An erroneously-chosen indicator often contributes to overloading.

In the development of GVW regression equations, linear functions have been adopted, giving the possibility of their quick and easy application in the forest during timber loading. At the loading site, the driver obtains information about solid wood volume from the forester, who must be present during loading and issues a special receipt for each transport. In the case of large-sized wood, all loaded pieces are specified with their numbers and solid volumes in the receipt. For pulp wood, only one number and the general solid volume for every single stack are provided on the receipt. By applying the developed model, a driver can very quickly calculate GVW and determine in a simple way if the truck is overloaded or not. It seems to be a better solution than taking a tabulated value ( $0.740 \text{ Mg}$ ), which showed differences in real GVW. Of course, it is advisable to develop such dependencies for other species and assortments and verify the adopted tabulated conversion factors.

For the estimation of the gross vehicle weight model, the solid volume was applied. All obtained results refer to the large-sized logs measured individually by each piece. In the case of pulp wood, measured in stacked cubic volume (over bark), conversion factors must be applied to obtain the results in solid cubic volume ( $\text{m}^3$  under bark). According to Polish regulations for pine wood, the conversion factors are 0.65 (for a length of wood of 1.0 or 1.2 m), 0.62 (for a length of 2.0; 2.4 m) and 0.6 (for a length of 5.0–7.0 m). In all cases, the load of  $1 \text{ m}^3$  volume contains the wood itself, water and bark.

As was found in the research conducted, the total vehicle weights obtained from actual measurements differed significantly, ranging from  $43.60$ – $58.80 \text{ Mg}$ , with an average value of  $50.56 \text{ Mg}$  (Table 1). The exceeded permissible truck unit weight ( $40 \text{ Mg}$  in Poland) coincides with the results presented in the literature [9,28,30–32,37]. The actual GVW results obtained were compared to the calculated total vehicle masses, in which the mass of the load was determined based on the volume of transported timber ( $\text{m}^3$ ) and the conversion value of  $0.740 \text{ Mg/m}^3$  from the table in effect, which in this case provided GVW results of about 17% lower than the actual ones [38].

In recent years, a reduction in the weight of empty truck units allowing the loads of transported timber to be increased and the difference between a unit with a trailer (tare  $17.9$ – $22.0 \text{ Mg}$ ) and a truck with a semi-trailer ( $13.8$ – $23.1 \text{ Mg}$ ) have been observed. The obtained results confirm the possibility of improving the efficiency of wood transport indicated by Sosa et al. [5] and Šušnjar et al. [39], in particular through the use of lightweight platform semi-trailers.

The increased total weights of truck units (GVW) are usually the reason that legal limits have been exceeded:  $80 \text{ kN}$  for single axles and  $115 \text{ kN}$  for tandem axles. In a larger percentage of truck units, we have seen that the permissible total weight is exceeded rather than the axle limits, which coincides with the results presented by Owusu-Ababio and Schmitt [30] and Baumgras [40], or they were not exceeded at all [39]. In the timber truck units, we observed an increased load on the rear axles (Axles 2 and 3) of the vehicle or tractor, which is caused by the mounted loading device or the uneven distribution of the load and results from the demands on the driving axle of the vehicle. Transporting different lengths of



wood, both shortwood and long logs, does not always allow the load to be spread evenly across all axles, which is confirmed by the results obtained for Axles 5 and 6 of the six-axle units.

## 5. Conclusions

The conducted research allowed statistically-significant differences to be confirmed between the total weights of truck units and load weights in particular seasons of the year. The average total weight for all units was 50.56 Mg, ranging from 43.60–58.8 Mg. Lower values were observed with the use of platform trailers; higher ones for trucks with trailers.

The high variability of load volume and mass of 1 m<sup>3</sup> of load in relationship to the accepted normative conversion value (0.740 Mg/m<sup>3</sup>) results in greater actual GVW. In the majority of cases, these GVW values are over allowable limits.

In the analyzed period, the average weight of delivered timber loads, determined on the basis of weighing, was 29.76 Mg, oscillating in the range of 23.96–36.79 Mg. The relatively lightest loads, both in the case of trailers and semi-trailers, were transported in the early spring months, while the heaviest were in the autumn season. The decisive factor was the date when the wood was harvested and transported. During the dormant period of tree growth, the water content in wood tissue decreases, thus contributing to a reduction in the weight of the transported cargo.

In Poland, five- and six-axle units are most often used to transport wood. The load on individual axles of five-axle units is more or less even. However, for six-axle units, the highest load falls on the second axle, gradually decreasing on successive axles. From the point of view of achieving smaller maximum axle loads, timber should be transported with six axle units.

Vehicles are used for 90% of the transport of wood in Poland. As research has shown, in many cases, vehicles are excessively overloaded in relation to the road traffic regulations in force. In order to improve transport efficiency, it would be advisable in the future to increase the permissible load limits, using units with an increased number of axles, based on the example of the Scandinavian countries.

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