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Problems of Sustainable Transport of Large-Sized Roundwood

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Abstract: When considering the economic and environmental aspects of forestry, especially the issues related to timber harvesting, emphasis should be placed on the importance of the availability of raw material resources for the sustainable flow of goods. It would also be difficult to disregard certain issues related to transport, which play a key role in the efficient flow of wooden raw materials. It has to be noticed that timber transport options are limited by a number of factors, including the considerable fragmentation of wood resources and the lack of adequately developed railway transport facilities. This paper focuses on issues related to the road transport of timber carried out by transport companies. Observations to date of large-sized roundwood (thicker than 14cm and longer than 3m) transport in Poland indicate a relatively frequent occurrence of overloaded vehicles, exceeding the permissible total weight limit. Empirical evidence also suggests that in many cases, it is an effect of improperly endorsed standards with regard to the density of the transported material. Moreover, there is a clear correlation between the loading volume and economic as well as environmental factors. Therefore, the aim of this article was to show both the current situation in the transport of bulky timber and to present the possibilities for its optimization, from the point of view of locational, economic and environmental factors.

Keywords: softwood; transport of timber; costs; environment

1. Introduction

Forest management is one of the areas that largely contribute to natural resource management. Due to sustainability requirements, optimization must be achieved between the environmental, social and economic aspects, at both local and global levels. Although forest management is not governed by EU legislation [1], the role of the EU in meeting these assumptions cannot be disregarded [2]. The scope of the actions and the problems identified by the EU in the field of sustainable forest management are laid out in different Union documents, including the "Green Paper on forest protection and information in the EU: preparing forests for climate change" and the European Parliament resolution of April 28, 2015 on "A new EU Forest Strategy: for forests and the forest-based sector" (2014/2223(INI)) [3,4].

Sustainable forest management means taking action to use and structure forests in such a manner as to preserve their biological wealth, while ensuring that they remain highly productive in the future and make efforts to maintain the "protective, economic and social functions of forests at local, national and global level without detriment to other ecosystems" [5]. Raw material transport is an important topic in sustainable forest management. According to the national norm PEFC PL 1003:2012 (Requirements for sustainable forest management, Chapter 4. Criteria for sustainable forest management, Item 4.3.8), "An adequate transport infrastructure, i.e., roads, transport routes and bridges, need to be planned, built and maintained in order to ensure an efficient system for the delivery of products and services while reducing the adverse environmental impacts" [6]. European Union institutions have also made statements in that respect. It is clear from the position adopted by the EU that the international community should make efforts towards the decarbonization of transport [7]. Moreover, measures taken in that respect should focus on controlling noxious exhaust emissions and promoting the means of transport based on renewable energies [8]. Hence, transport issues related to forest management are extremely important not only from the perspective of smooth deliveries of wood raw materials but also in view of their environmental impact.

Timber transport is among the most demanding and problematic types of road transport. This is primarily because of the particularities of the cargo, especially when it comes to various types of oversized sawlog. Therefore, safety measures play an extremely important role in that respect [9]. However, these issues are not governed by any general regulations within the European Union. As a consequence, any irregularities in timber transport should be viewed in light of the applicable internal regulations of member countries [10]. In Poland, the guidelines for timber transport and safety are set out in the Regulation of the Minister of Infrastructure of January 25, 2018, which describes both the proper arrangement of raw materials transported and the related transportation security measures [11]. Another important aspect of timber transport is the maximum permissible laden mass, as set out in Article 61, Para. 15 of the Road Traffic Act, is 40–42 Mg (Polish internal regulations). Depending on the vehicle type and structure, the maximum authorized volume of raw materials to be transported is 25–30 m3 [12]. However, some irregularities occur despite the applicable legal regulations. Often, they result from the uninformed actions by the persons responsible for the loading and transporting operations. The most frequently reported breaches include exceeding the maximum permissible laden mass [13]. This is the offence most often reported by traffic police forces in charge of controlling the transport of cargo. According to the data of the Supreme Chamber of Control, in 2016, out of the total number of vehicles inspected by Voivodeship Road Transport Inspectorates, 12% carried a load beyond the maximum permissible laden mass. In 2017, that ratio was 30% [14]. The reasons for these irregularities include the varying apparent density of the wood, which depends on its type, form and harvesting period, and contributes to the high variability of cargo weight [15–19]. Furthermore, the inability to weigh wood at its initial loading location makes it impossible to precisely determine its weight. This often results in a failure to comply with timber transport regulations [20].

Germany has a maximum permissible laden mass at a level similar to that applicable in Poland, with ongoing discussions on increasing it to 44 Mg [21]. According to German business associations, such a level is already permitted in Belgium, Luxembourg and the Czech Republic. Moreover, the maximum permissible laden mass for trucks is even higher in some European countries, including the Netherlands (50 Mg) and Denmark (54 Mg). In turn, the maximum permissible laden mass in the Nordic countries is ca. 60 Mg, and yet, there is an ongoing discussion on whether it should be increased [21–23].

Such a great diversity in the levels of the maximum permissible laden mass, and the fact that discussions on relevant amendments are in progress in many countries, point to the need for a more in-depth examination of timber transport issues. Both the volatility of regulations and the diversity of customer needs require that proposals be made to address the need to increase the loading volume and load capacity of vehicles. The identification of the factors responsible for the problems in the transport of large-sized timber and, as a result, the changes that should be implemented in practice will not only affect the economic situation of operators. They can contribute to further environmental reduction measures, with not only a local effect.

2. Materials and Methods

The north-west part of Poland was selected as the research area. The study period was January–December 2018. The study focused on 53 forestry authorities and 10 medium-sized sawmills located in the region concerned. An analysis was carried out based on 167 thousand cubic meters of softwood raw material, transported from the storage facilities of the selected forestry authorities to the customers (sawmills). In accordance with the qualitative and dimensional classification, this case study focused on the transport of large-sized roundwood. This is because the type of wood determines the range of deliveries and the type and the maximum permissible laden mass of the vehicle. According to the PN-D-95,000 standard, when calculating the volume of a piece of wood with a length of 3-5 m, conversion factors are used (0.61 m^3 = 1 stacked cubic meter), and in the case of wood with a length of more than 5 m, each unit was measured. The measurement was taken at the place of wood storage. Regardless of the used method of calculation, there was a 25 m^3 or a 30 m^3 load of wood without bark and without free spaces (depending on truck capacity). The delivery of raw materials was outsourced to transport companies. In accordance with the guidelines provided in the Road Traffic Act, this case study covered vehicles with maximum permissible loads of 25 m^3 and 30 m^3. These were self-loading vehicles (with a maximum permissible load of 25 m^3) and vehicles with no auxiliary equipment (with a maximum permissible load of 30 m^3) [24]. Therefore, their maximum permissible load was taken into consideration in the analyses.

Transport costs (the fee paid by sawmills) are largely determined by fuel costs. Its share in total transport costs is considerable and may vary in function of factors such as fuel price and fuel consumption which, in turn, depends on vehicle loading, traffic conditions and other aspects. Tables 1 and 2 present a summary of fuel prices in Poland in 2018. Prices in euro are calculated based on exchange rates delivered by the National Bank of Poland.

Table 1. Average fuel price in 2018.

Type of Fuel/Price	E 95	E98	Diesel	LPG
		PLN/liter		
Min	4.58	4.89	4.49	1.96
Max	5.27	5.56	5.3	2.57
Avg	4.9	5.2	4.9	2.3
		EUR/liter *		
Min	1.07	1.15	1.05	0.46
Max	1.24	1.30	1.24	0.60
Avg	1.15	1.22	1.15	0.54

* according to 2018 average level. Source: own elaboration based on https://www.wnp.pl; http://www.nbp.pl [25,26].

Table 2. Monthly average price of diesel fuel in 2018 for the northwest region of Poland.

Months	1	2	3	4	5	6	7	8	9	10	11	12
						Average price of diesel fuel						
PLN/liter	4.56	4.55	4.56	4.69	4.98	5.04	5.03	5.02	5.06	5.14	5.29	5.21
EUR/liter*	1.1	1.1	1.08	1.12	1.16	1.17	1.16	1.17	1.18	1.19	1.23	1.21

Source: own elaboration based on https://www.wnp.pl; http://www.nbp.pl [25,26].

The calculations take account of both fuel prices and monthly quantities of raw wood material transported in 2018. The following was determined as a result of the study:

- the percentage share of monthly deliveries,
- the number of journeys, depending on a vehicle's load capacity and delivery distances,
- the total distance traveled by vehicles with maximum permissible loads of 25 m^3 and 30 m^3 for transport orders placed by the sawmills covered by this study,
- the estimated excess weight of the cargo transported,
- the estimated monthly transport costs in function of the vehicles' load capacity set out above.

3. Results

This study considered a total of 167 thousand m^3 of large-sized roundwood transported to sawmills, and identified the share of monthly quantities of wood transported in 2018 (Figure 1). As shown in Graph 1, the quantities of roundwood harvested and delivered during the summer months follow a noticeably downward trend. Peak demand for roundwood was recorded at the beginning of the calendar year. The maximum was attained in April which accounted for 10% of the total quantity of wood transported.

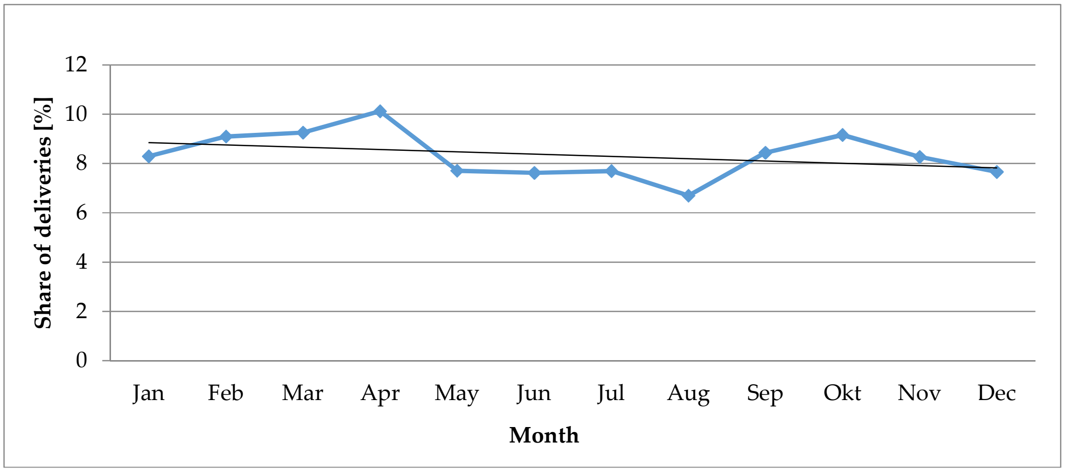

Figure 1. Monthly volumes of wood transported in 2018. Source: own elaboration.

The number of journeys necessary to transport the amount of raw material covered by this study was calculated accounting for the provisions of the Road Traffic Act and the maximum permissible volume of wood transported within a single journey. The maximum radius of deliveries was indicated based on the range of wood transport operations (the supply of raw material was marked in 10 km intervals). The data were obtained from the shipping documents for raw material deliveries. Transport companies use vehicles with 25m3 load capacity, which are equipped with additional loading equipment and vehicles with 30m3 without loading equipment. Hence, the calculations simulated deliveries for vehicles of two loading sizes. This indicates the impact of the loading volume on the number of transport cycles. As shown by this study, while the maximum distance covered by the raw material was 240 km, such trips constitute a small share in the total volume of yearly transport. Figure 2 shows that deliveries within a 60 km radius represented the largest share, and the coefficient of determination R2 for their descending curves was 0.6.

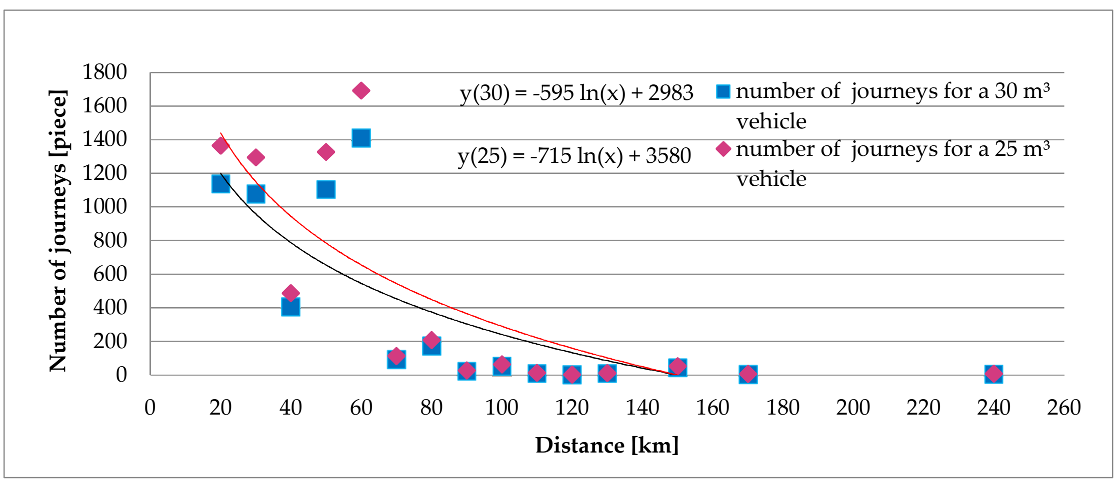

Figure 2. Number of journeys traveled in function of the distance and volume of raw material transported. Source: own elaboration.

As the next step, this study calculated the total distance traveled by vehicles with a maximum permissible load of 25 m^3 and 30 m^3 in order to transport the wood cargo. The total distance is the sum of the distance to get the wood and return to the sawmill. In this structure, the range of deliveries and the resources of raw material transported were the determinants of the variable 'distance traveled by softwood.' The curves that describe these relationships are represented by the following regression equations: y(25) = −39,536 ln(x) + 211,232 for the maximum permissible load of 25 m³ and y(30) = −32,946 ln(x) + 176,026 for the maximum permissible load of 30 m³ (Figure 3).

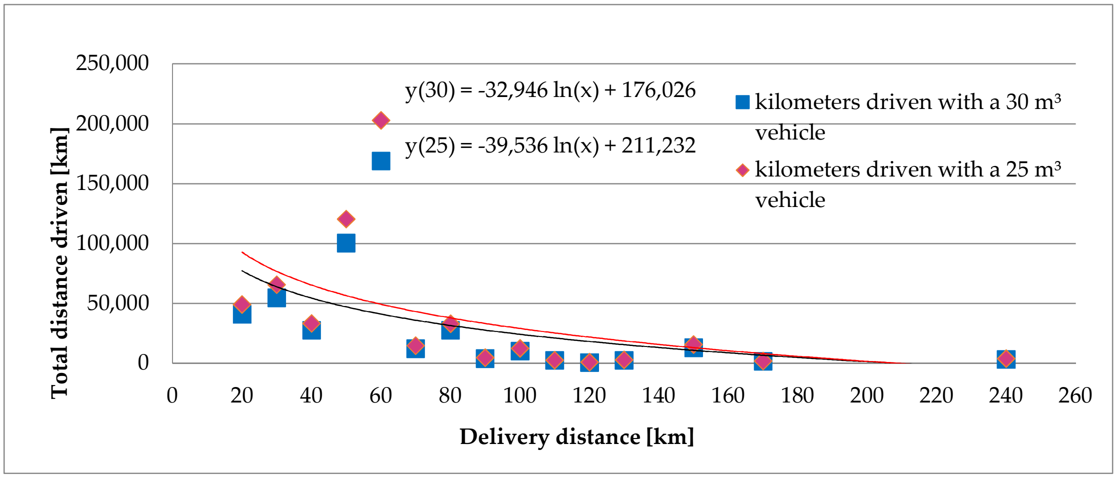

Figure 3. Total delivery distance in function of the vehicles' load capacity. Source: own elaboration.

It follows from the above examination that most cargo was delivered within a distance of 51–60 km; the distance of 41–50 km was ranked second. The difference in the number of deliveries between vehicles with a maximum load of 25 m³ and vehicles with a maximum load of 30 m³ was 200 journeys. When converted into distance, this amounted to 5000–33,000 km. Also calculated were the differences between the number of kilometers traveled by vehicles with a maximum load of 25 m³ and vehicles with a maximum load of 30 m³. In a 51–60 km delivery distance, the difference in kilometers traveled was 33,000 km; in 41–50 km distance, it was ca. 20,000 km within a year.

The excess weight of cargo transported was determined based on the varying apparent density of fresh pinewood (measured all year round). The density of pinewood (0.740 Mg/m³), as set out in the Regulation of the Minister of the Environment and of the Minister of the Economy of May 2, 2012 on the determination of wood density, was used as reference level (Figure 4).

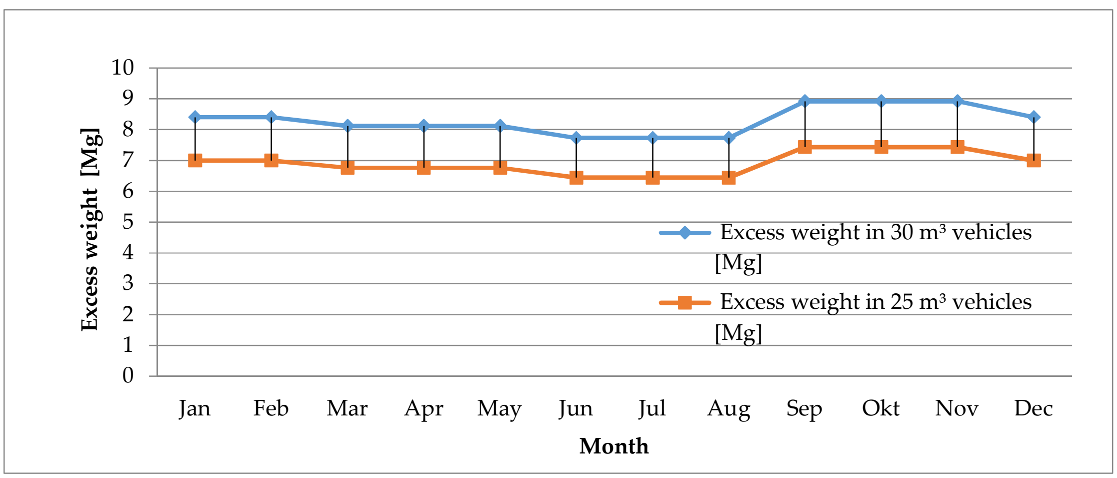

Figure 4. Excess weight above the maximum permissible laden mass in 2018 (on a year-round basis). Source: own elaboration.

It follows from the analyses that the apparent density of wood oscillated between 0.998 and 1.037 Mg/m³. Hence, the differences in vehicle overloading varied in the range of 6.4 to 7.4 Mg for a 25 m³ load and in the range of 7.7 to 9.9 Mg for a load of 30 m^3. At the same time, the study confirms that the highest overload levels were recorded during fall season (Figure 4).

Next, this analysis focused on fuel consumption and its impact on transport costs. Fuel costs were calculated based on the fuel consumption of vehicles carrying a cargo of 25 m^3 or 30 m^3. Keeping the above in mind, and considering the monthly prices of fuel within the study period and the average euro exchange rates, provided by the National Bank of Poland in 2018, the authors calculated monthly fuel costs involved in the transport of raw material batches (Figure 5).

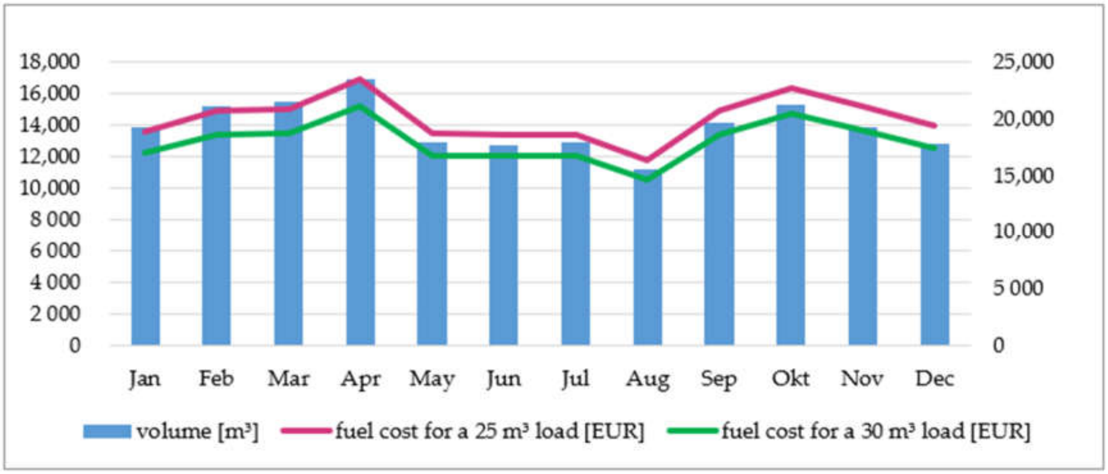

Figure 5. Monthly fuel costs in function of the fuel price and the cargo transported. Source: own elaboration.

The conclusion from Graph 5 is that the fuel cost is proportional to the quantity of goods carried. The highest levels were recorded during fall and winter and the lowest during summer. The fuel costs were calculated considering the fuel cost per unit and the volume of freight transported. For vehicles with a loading capacity of 25 m^3 or 30 m^3, it was 239,663.1 EUR and 215,413.7 EUR respectively. Monthly costs served as basis for calculating the total fuel cost for all raw material transported. The annual total was 455,076.8 EUR.

4. Discussion

The analysis of the deliveries of coniferous raw materials to selected wood processing plants in northwest Poland determined the structure of fully loaded transports related to the periodic demand for raw material from the sawmills covered by this study. The structure is the consequence of the changes in production intensity, which characterize the periodicity of market demand for wood products. At the same time, the scale of the deliveries results from the rationale behind timber harvesting which is subject to qualitative conditions. Increased deliveries during fall, winter and spring reflect the tendency to deliver timber under weather conditions that restrict the depreciation of large-sized timber.

When analyzing the transport of roundwood, emphasis should be placed on the maximum permissible laden mass of vehicles. With regards to the differences between the European Union countries presented in this paper, an important aspect is the discussion on increasing the maximum load in road transport [27,28]. It is conditioned by the verification of actual load of vehicles carrying wet wood with an apparent density beyond what is specified in the volume tables for specific types of wood raw materials in different member countries. The values of the apparent densities of fresh pinewood vary throughout the year; the figures found by this study are corroborated by the literature [19]. Furthermore, based on the study of the volatility of the apparent density, it should be noted that it varies greatly throughout the annual vegetation cycle. The excess weight identified by researchers could be indicative of the vehicles being overloaded, which is in breach of the current regulations.

With regards to the sawmills' demand for raw material, two structures of road deliveries were observed, those which use vehicles with a load capacity of 25 m^3 and 30 m^3. The patterns presented in this study significantly differ in the number of journeys made when traveling a specific distance. If the volume of a single load increases from 25 m^3 to 30 m^3, the number of transport journeys goes down by 1113 within a year. Such a considerable difference suggests that it would be purposeful to make full use of the maximum permissible laden mass of roundwood transport vehicles. Indeed, a smaller number of journeys results in lower fuel costs.

Despite the significant financial benefits derived from the use of vehicles with a greater load capacity, that solution is not always put into practice. This is a result of a number of factors, including the availability of a specific vehicle fleet when a transport order is placed. Therefore, the loading figures often contradict the commitment to reduce the consumption of fossil fuels used to power transport vehicles.

Measures taken in many European countries suggest that reducing fuel consumption is the target set for the transport sector, especially including the transport of goods [29]. Although currently, such measures are primarily taken due to environmental concerns, they will have economic impacts. In accordance with Commission Regulation (EU) 2019/318 of February 19, 2019 amending Regulation (EU) 2017/2400 and Directive 2007/46/EC of the European Parliament and of the Council with regards to the determination of the CO_2 emissions and fuel consumption of heavy-duty vehicles, heavy-duty vehicles will need to reduce their CO_2 emissions and, as a consequence, reduce their fuel consumption. The Regulation assumes that CO_2 emissions by trucks should be reduced by 15% by 2025 and by 30% by 2030. Truck exhaust emission figures recorded in late 2019/early 2020 should be used as a reference level [30].

The entry into force of the increased maximum permissible load in road transport should be accompanied by the actual identification of the weight and volume conversion rates for the mixture of wood raw material types. As a consequence, it will be possible to reduce the number of loads beyond the maximum permissible weight. The considerations on whether the maximum permissible laden mass can be further increased as it is the case in other European countries, together with the increase in the volume of freight, could drive additional savings. It also needs to be noted that the load capacity of roads must be taken into account too. With regards to the planned modernization of roads used to carry wood raw materials, the discussion should start by increasing the load capacity of these roads which, in the long run, would also be beneficial to the state. Some of the relevant experiences should be sought in countries which have already implemented such solutions, e.g., Finland. All of these measures significantly contribute to reducing the carbon footprint at different stages of the supply chain, and can also support the sustainability policies of the participating enterprises.

In the transport sector, sustainable development is based on the analysis of its environmental impacts, which are the consumption of fossil fuels and CO_2 emissions. According to ICCT (International Council on Clean Transportation) data, fuel consumption by trucks was at a level of ca. 36 l/100 km between 2000 and 2015. The data come from real-life tests carried out in EU countries [31,32]. This case study assumes that fuel consumption for a fully loaded vehicle and an empty run (after unloading the raw material) is 35 l/100 km and 25 l/100 km, respectively. In turn, a study by Fuć, Merkisz and Ziółkowski [2012] found that the average fuel consumption for a vehicle with a maximum permissible laden mass of 40 Mg is 19 l/100 km when empty or 8 l/100 km more when fully loaded [33]. A similar study was carried out by Lastauto Omnibus, a journal specializing in German road transport issues. According to their findings, fuel consumption for a vehicle with a maximum permissible laden mass of 40 Mg is currently 31.9 l/100 km [34]. In turn, a study by Nils-Olof Nylund and Kimmo Erkkilä from the VTT Technical Research Center of Finland, discovered a relationship between the load and the fuel consumption in 40–42 Mg vehicles. They found that extra-urban fuel consumption increases linearly with load [35].

5. Conclusions

1. This study demonstrated that in the case of medium-sized sawmills, raw material is primarily harvested within a distance of 60 km from the customer's location.
2. The size of deliveries depends both on the processing volume and on the capacity to store raw material in order to maintain continuous operations. Hence, there is a strong, noticeable trend towards the procurement of larger quantities of wood during spring, followed by a gradual reduction in the quantity of timber during summer where sawmills usually plan shutdowns and repair work. Moreover, it is important to take into consideration the seasonality of sawmill production. It is a reflection of all-year-round deliveries.
3. The key drivers of transport costs were identified based on delivery distance intervals (verified through research). These include the vehicles' load capacity, fuel consumption and the availability of adequate sources of raw material in forests. With regards to the differences between the 25 m^3 and the 30 m^3 loads, the smaller volume results in a considerable 17% increase in the number of journeys.
4. The change in the volume of timber loaded and the possible amendment regarding the maximum permissible vehicle weight could result in reducing both fossil fuel consumption and CO_2 emissions. In addition to environmental effects, the economic aspect is also important as is it enables a reduction in the consumption of diesel fuel. With 167,000 m^3 of pine raw material transported, the annual savings reach 24,249.43 EUR.

Author Contributions: This work is a result of research carried out in selected sawmills processing large-size roundwood, which the authors worked on in order to determine the raw material flow with the use of wheeled means of transport (conceptualization, methodology, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, writing-review and editing and visualization: K.M. and M.W.). Both authors have agreed to publish a version of the manuscript.

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