Article

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Elena Camelia Mușat * , Gheorghiță Lucian Abutnăriței , Dumitrel Daniel Hogea , Lucian Denis Miu , Vasile Nicolae Avram , Ștefan Saicu , Rudolf Alexandru Derczeni

Posted Date: 2 August 2024

doi: 10.20944/preprints202408.0141.v1

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Abstract: One of the main products of the forest, which has the greatest economic impact, is wood. Due to its characteristics, the wood requires certain types of vehicles for transport it. For this reason, the accessibility of the stands with forest roads plays significant role in the efficiency of the wood logging process, which aims to bring the wood from the forest to the harvesting area located, frequently, next to a permanent transport route. The process of wood transport from the forest initially takes place on forest roads and after that on public roads. The technological process of wood transport represents an important stage in this process, and its good organization can have implications on the final price of the wood material. Based on those mentioned above, the paper aims to highlight the factors that can influence productivity in the case of loading wood in forestry trucks and forestry platforms, in different conditions. Thus, the research was carried out in four counties in Romania and addressed the loading of wood in different forestry trucks and platforms, with or without trailers. Following the evaluation of the work phases specific to the process of round wood loading in vehicles of transport, it was found that sometimes a significant importance is given to the working phases that can be carried out before the loading process, as phases of preparation of the wooden material in order to load it. Also, the facilities of the transport vehicles, the assortments of wood material, as well as the experience of the operators are the main factors that can lead to an increase in productivity.

Keywords: wood transport; round wood; forestry trucks; forest; accessibility; Romania

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1. Introduction

Forests represent a public good, with multiple benefits for society, be they economic, ecological or even social [1,2]. At the Romania's level, forests occupy a significant area of approximately 6.9 million hectares [3], being mostly located in the mountain regions [4]. The great geomorphologic and climatic diversity of the country's territories leads to a wide variety of compositions in terms of tree species from forests. All of these involve different management works, as best suited to the various types of forests that, in Romania, have either protection or production functions, or protection and production functions [3,5].

Since the superior utilization of all forest products [6,7] contributes to Romania's GDP by approximately 4% [3], the designing and construction of forest roads is imperative [4,5], especially since the long-term storage of wood in improper conditions leads to its downgrading and quality reduction [8–11], with financial losses. Unfortunately, the accessibility of the national forest fund is below the optimal level [3,4,12–14], so the Romanian forests are accessible in proportion to 65% [4,5,15], which leads to a density index far below the level of other countries with similar terrain and relief [5], at large distances to logging [4] and repercussions on the final cost of the wood [6,14,16,17].

Even though, over the time the means of transport have varied a lot [18,19], currently the transport of forest products being carried out almost entirely on forest roads (over 90% [5,12,20]), a similar situation being encountered in Finland [9,21,22]. The use of forest roads as the main transport routes is due to several factors [12,13,23–25]. Thus, forest roads penetrate deeper into the forest [26], which leads to a more uniform opening of the forest stands [5,10]. In addition, forest roads can accommodate a wide range of transport vehicles, safely and at steeper gradients than railways [26,27]. On the other hand, the forest roads network can ensure access to the forest both for all those involved in forest management [5,18,29], as well as for those who need to reach some isolated areas, either because they live there [30], whether they have to carry out their professional activities there or they just want to escape from the daily tumult [1]. In addition, forest roads can also provide transportation needs for other sectors of the economy [1,18].

To fulfill all these functions, forest roads must be designed and built to withstand the traffic of various means of transport [4,28], in safety and comfort conditions [1,10,14,18], especially since the length and distribution of the transport network, its structure and condition can directly influence the activity of forest transport, especially the transport of wood [31,32], it being known that the biggest impact on wood costs is given by transport [10,11,16,17,24,33].

Wood, as the main product of the forest [24], must be brought from the forest to various beneficiaries [1,3,16,29,34] with the help of different vehicles [10,26,35,36], which differ a lot, with different brands and models on the market [12,16,24,27]. The choice of a certain type of vehicle depends on a number of factors related to: the nature of the work performed in the forest [20,33]; the types of wood that have to be transported [6,10–12,20]; the category of the road used and the transport distances from the forest to the beneficiaries [9,24,32]; the constructive characteristics of vehicles and their loading capacity [10,20,22,26], as well as the distribution of loadings on axles [12,17,28,31,35].

Thus, when transporting wood, it can be used trucks, with or without a trailer, forestry platforms, with or without a semi-trailer, container trucks, all used for transporting wood over long distances [1,6,9,17,20,26,33,35,37], but also tractors with trailers or even animal-drawn vehicles, in the case of short transport distances [1,26]. Transport vehicles intended for round wood are usually equipped with their own loading systems [16,27,36], either of the type of hydraulic cranes or of the type of cable loading systems [18,20,24,26], but there are also vehicles that do not have these features. The choice of a particular type takes into account the characteristics of the area from which the wood is loaded [10], of the wood storage where the wood reaches [10,20], but also the availability of a certain model [10,33].

For the efficiency of transport, it has to be mentioned that the organization of transport activities, as well as the scheduling of the vehicles fleet, are of particular importance [6,17,19,33,38]. These aspects take into account, above all, the quantities and types of wood to be transported, but also the main characteristics of forest road transport, which consist in the fact that transport activities have a periodic character [14,28,34,39], depending on the type of cuts and the restrictions related to the harvesting areas [20], differentiating an “empty transport” - to the forest, and a “full transport” - to the beneficiary [6,23,25], but also by the fact that the harvested wood is temporarily stored in the harvesting area located, in most cases, along a forest road [1,10,20].

The assortments and quantities of wood to be transported dictate, to a large extent, the type of transport vehicle [6,10,20,37], with consequences on the efficiency and productivity of work [21,33]. Currently, the constructive characteristics of vehicles have been greatly improved and adapted to the need to ensure economical transport [14–16,32], vehicles with 2 to 6 axles being available [24] or even 9 axes [17] which ensures a better distribution of the loading on the wheel-road contact surface [12,22,23,35] and high loading capacities [13,29,33,37].

However, the use of vehicles of transport at maximum capacity is not always possible due to the regulations regarding the circulation on forest roads and public roads, related to the allowable gross vehicle weight [9,10,17,21,23,24,26,31]. Thus, in Romania, vehicles transporting wood must be 2.5 m wide, 4.0 m high and 18 m long [26,31]. Regarding the allowable gross vehicle weight this is 38 t [23,28,32], but a number of remarks are made regarding the distribution of the loading on the axles [23,24,31]. Since these regulations must be respected in order not to end up with penalties or traffic

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restrictions [24], the only available method for the efficiency of wood transport consists in evaluating all the work phases corresponding to this process [10,16,21]. In this sense, time studies can be used which, even if they involve a large consumption of time for their application [10,16], they can highlight the aspects that can be improved, so as to reach a better productivity of the transport activity [19] and to reduce interruptions or delays due to adjacent factors [6,10,16].

The aim of the paper was to evaluate the wood loading process in various types of transport vehicles in terms of the time consumption for each working phases and the factors that can affect productivity. Thus, the following objectives were settled:

- To evaluate the transport distances when the wood has to be transported to locals or to economic agents;
- To evaluate the productivity when loading round wood in forestry trucks (ATF) and forestry platforms (APF) either in the harvesting area or from a wood storage;
- To analyze the working time and the phases of wood loading in forestry trucks;
- To highlight the factors that can influence the productivity at wood loading in different vehicles.

2. Materials and Methods

2.1. Study Area

The study area (Figure 1) and the methodology are presented in accordance with the objectives set to achieve the proposed goal. The research to evaluate the transport distances in the case of wood transported to the locals was carried out in Brasov County, within the management unit II Codlea, in the forests managed by Codrii Cetă'ilor Forest District. The specific natural environment of management unit II Codlea is characterized by altitudes between 500 and 1287 m. The terrain has an undulating configuration being dominated by moderate, steep and very steep slopes. From the climatic point of view, the studied region presents a moderate-continental climate, corresponding to the hills, which offers optimal conditions for the development of the beech trees. In the field investigations were taken into account five compartments, which differ in terms of the treatment applied, the harvesting volume and the distance between the harvesting area and the municipality of Codlea, because there are the locals who need firewood. Thus, in a compartment were applied progressive cuts, obtaining main products with a volume of 424 m^3. In other two compartments were applied hygiene cut, and were harvested 51 m^3 – beech, and 249 m^3 beech and spruce, respectively. In other two compartments were thinning cuts, from where volumes of 16 m^3 were harvested for hornbeam and beech, and 169 m^3 – hornbeam, sessile oak and beech. In all cases, the wood material harvested and prepared for transport was found in the form of assortments and multiples of assortments.

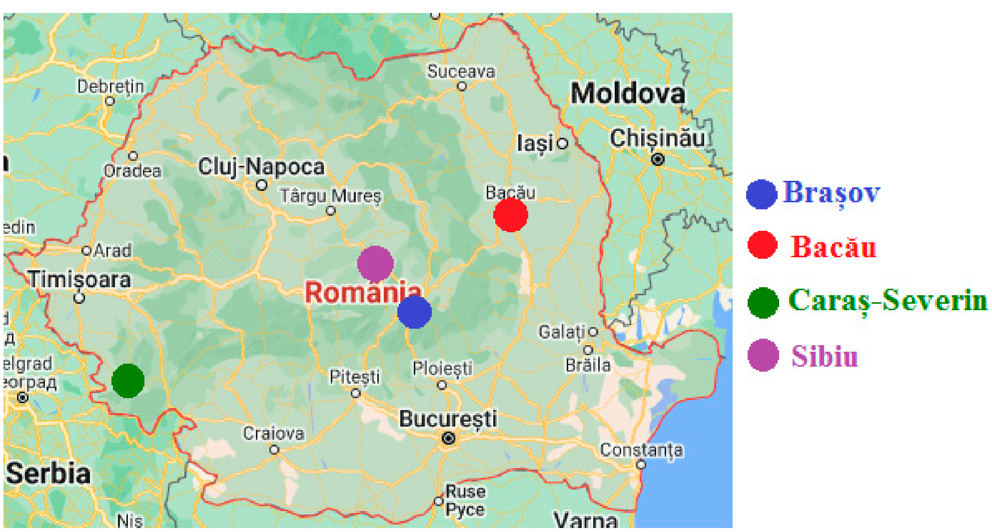

Figure 1. The study areas.

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In order to evaluate the transport distances in the case of wood intended for economic agents, field measurements were carried out in three different compartments administered by private Lignum Forest District (Bacău county), but also in the wood storage managed by the same forest district. In two of the three management units, namely Coasta Uzu and Băzăuța, were applied hygiene cuts, and in the third one conservation cuts (Plopu Lapoș). In the end, there were harvested trees of the following species: fir, spruce, beech, Scots pine and mountain maple.

The study of the loading process and the determinations regarding the productivity at loading were carried out in three locations in the country, namely Bacău County, Sibiu County and Caraș-Severin County. In Sibiu County, some of the research was carried out in the compartment 13A, in the management unit I Miercurea Sibiului, under the administration of Miercurea Sibiului Forest District. There were applied progressive cuts and it was obtained a volume of 254.48 m^3 of sessile oak logs. In Caraș-Severin County, the field investigations were carried out in different compartments administrated by ocșa Montană Forest District (management unit IV Smidă) and the Bocșa Română Forest District (management unit IX Dagnecea). The treatments applied in these compartments were progressive cuts, and the wood resulting after harvesting was in the form of assortments and multiple assortments, from various deciduous species.

2.2. Methodology

The determinations regarding the transport distances, carried out in Brasov County, involved the study of 200 transport documents, specific for each transport, because in Romania all vehicles that transport wood, regardless of assortment and quantity, must be accompanied by such documents which attests the provenance and the traceability of wood. From the transport documents were extracted data about the transported assortments, the quantity and dimensions of the logs (by species), the type of vehicle, as well as the loading and unloading points. A Garmin Montana 680 GPS was utilized to establish the coordinates for each harvesting area, used in the next phase for calculating the distances between the uploading and unloading points. Based on these, the distances from the harvesting area (loading points) to the various beneficiaries (unloading points) were determined with the help of Google Maps Pro.

Within the Lignum Forest District, the fieldwork involved the evaluation of transport distances and the evaluation of the loading time when there were used two types of vehicles for wood transport – Mercedes Benz Arctros 3348 (Figure 2a) - and MAN TGS 33.480 (Figure 2b,c), equipped with hydraulic crane for loading. To determine the distance, the same methodology described previously was applied. Instead, to evaluate the timber loading process, the entire process was timed, from the moment in which the operators got on the hydraulic crane, until the moment when they got off at the end of the process, after placing the grapple in the position of transport and cargo insurance. Using a forest caliper and a tape were measured the dimensions of each log (diameter and length).

a. b. c.

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Figure 2. Vehicles used for wood transport in Lignum Forest District: a. Mercedes Actros 3348; b. MAN TGS 33.480 with tipper c. MAN TGS 33.480 with semi-trailer for logs.

It should also be noted that the wood loading process was studied both when the wood was loaded from the harvesting area (7 transports) (Figure 3), as well as when the wood was loaded from a wood storage area of the same forest district (3 transports) (Figure 4), because the entire amount of harvested wood from the forests managed by Lignum Forest District, regardless the assortment (working wood or firewood) is initially transported to their wood storage, from where it is sorted and utilized differently according to market requirements.

Figure 3. Loading wood from the harvesting area (Lignum Forest District).

Figure 4. Loading wood from the wood storage area (Lignum Forest District).

In order to observe whether there are differences in the loading of long logs from the harvesting area in various types of vehicles, research was carried out in Caraș-Severin County. They imposed the same working principle applied to Lignum Forest District, but additional determinations were made regarding the loading times of each individual load, because there were used forestry trucks (ATF) equipped with hydraulic cranes (Figure 5) and forestry platforms (APF) ROMAN, equipped with a TA – 2 AM winch (Figure 6).

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Figure 5. Forestry truck (ATF) equipped with hydraulic crane.

Figure 6. Forestry platform (APF) equipped with TA-2 AM winch.

In Sibiu County, the field investigations were carried out to evaluate the staggering of work phases when the wood is loading in forest trucks. The entire loading process was filmed, considering the preparation of the transport vehicle as the starting point and the completion of the transport documents as the end point. There were made investigations for 11 different forest trucks, but at one of them - the Man TGS 33.510 (with 6x6 traction), equipped with trailer - the working process was divided into productive time and non-productive time, in agreement with the working phases. The working process of loading logs in forestry trucks, equipped with a hydraulic crane and a trailer, was structured taking into account the following working phases, codified to facilitate the centralization and interpretation of data (Figures 7 and 8): a. vehicle preparation (PA); b. actuation of the levers that activate the hydraulic arm and the grapple (IPZ); c. log measurement (CL); d. transfer of the log to the truck/trailer (TBC); e. placement/arrangement of log in truck/trailer (AABC); f. returning the hydraulic arm and grapple from the truck/trailer to the log (RB); g. other activities (AA); h. cross-cut technical break (PTS); i. stop of loading process by placing the hydraulic arm in the transport position (II); j. getting off the crane (CM).

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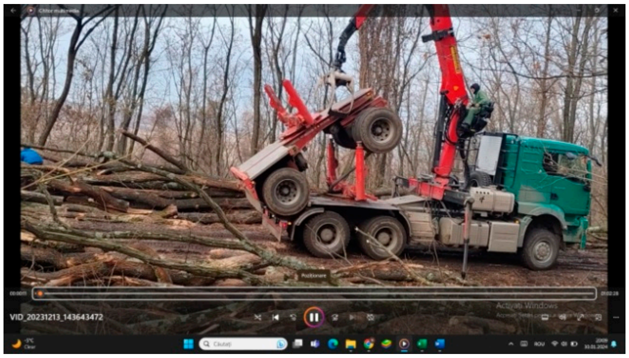


Figure 7. Vehicle preparation (PA).

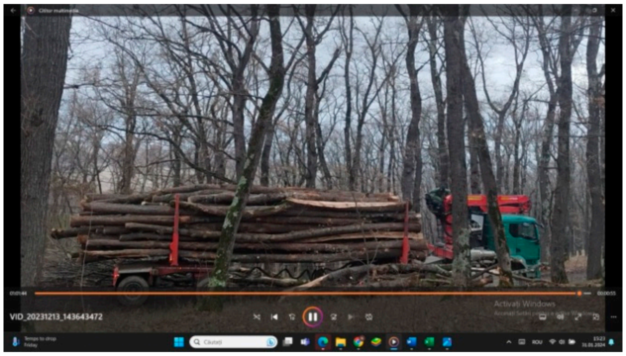


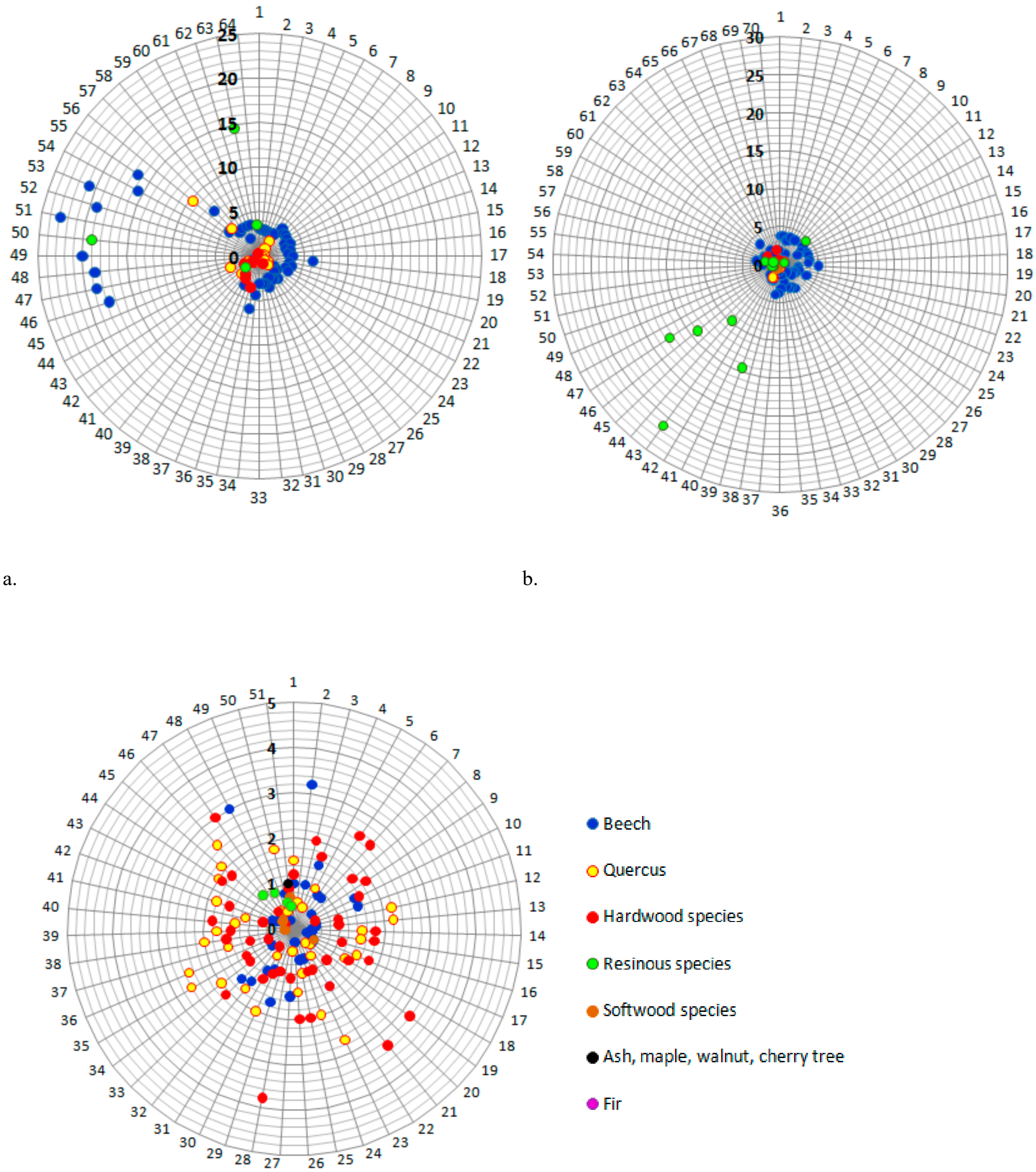
Figure 8. Getting off the crane (CM) after loading.

3. Results

3.1. Evaluation of Wood Transport Distances in the Case of Locals and Economic Agents

In order to evaluate the wood transport distances to various beneficiaries, information was taken from 200 transport documents emitted for the wood harvested from the forests administered by Codrii Cetăților Forest District. The 200 transport documents correspond to five compartments, from where 64, 13, 2, 70 and 51 transport documents were issued. The harvested volumes differ in relation to the applied cuts in each compartment. It should be mentioned that in most cases the wood transport from the harvesting areas was carried out with low-capacity vehicles, such as vans and tractors with trailers, because the wood was for to the locals.

From the analysis of the graphs illustrated in Figure 9, corresponding to the compartments with the large number of issue of transport documents, it can be easily observed the predominance of deciduous species, especially beech, followed by the oak species. But resinous species also appear, in a much reduced proportion. Related to the transported volumes, it is also noted that these are reduced, most of the time being less than 5 m^3 (Figure 9). However, there are some situations in which the transported volumes were between 15-25 m^3. A closer look at Figure 9 shows that when larger volumes were transported, they were made up of single specie or a group of species. For example, from one compartment - covered with progressive cuts - there were performed transports only of beech wood, while in another one - covered with hygiene cuts - there were performed wood transport only of resinous species.



a. b. c.

Figure 9. The volumes by species from each transport carried out at Codrii Cetăților Forest District: a. compartment 18B; b. compartments 86B, 87 and 88); c. compartment 22A.

When analyzing the volumes transported within the Lignum Forest District from the harvesting area in the wood storage, it is found that most of them were smaller than 15 m^3, and there were predominated by pine and beech species (Figure 10). On the other hand, when analyzing the transport documents issued from the wood storage to various beneficiaries, it is found that the volumes increased considerably and consisted almost entirely of fir wood (Figure 10a), from the cellulose round wood assortment, which was transported to Rădăuți (Suceava County). Another forest truck, loaded with resinous species (fir and spruce), transported wood from the storage area to a processing company, located 63 km distance (Figure 10b).

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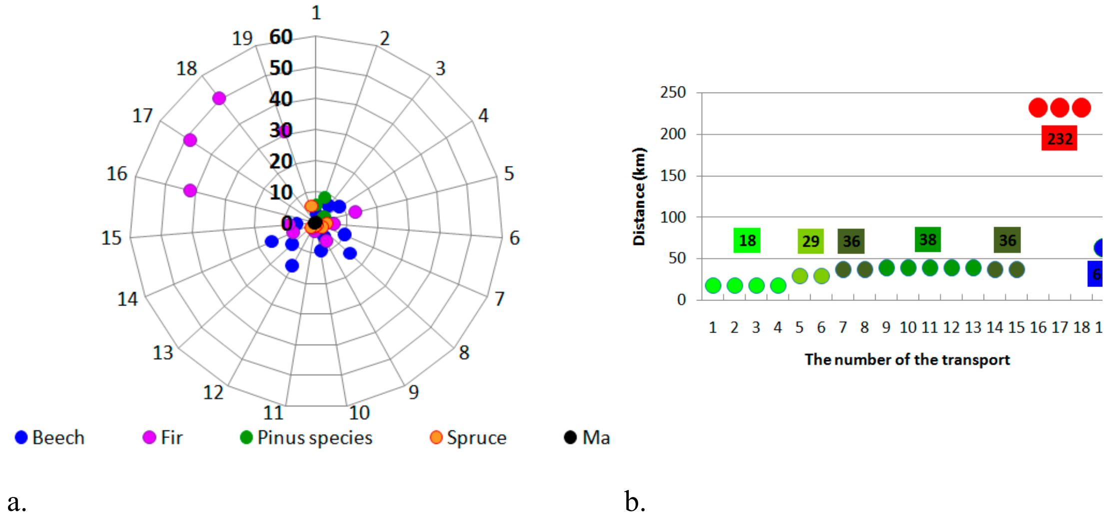

Figure 10. The volumes by species from each transport carried out at Lignum Forest District (a.) and the transport distances (b.).

At Codrii Cetătilor Forest District the situation is completely different (Figure 11), in the sense that the wood was transported over short distances, of 3-16 km, being intended for heating the houses of the locals.

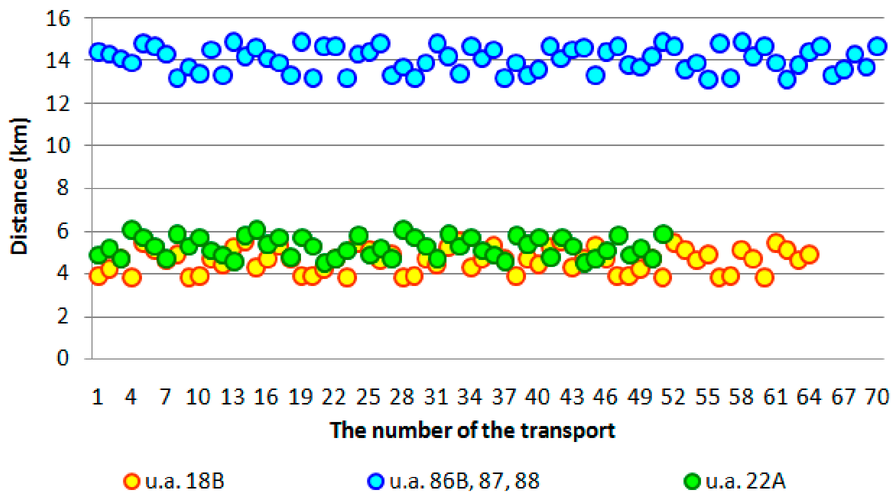

Figure 11. Transport distances specific to Codrii Cetăților Forestry District.

3.2. Comparisons between the Loaded Volumes and the Loading Times of Wood for Forestry Trucks (ATF) and Forestry Platforms (APF)

The research concerning the comparison of the two most common vehicles for wood transport in Romania, respectively forestry trucks (ATF) and forestry platforms (APF), were carried out at two forest districts in Caraș-Severin County. From the analysis of the graph illustrated in Figure 12, it can be seen that in forestry trucks can be loaded larger volumes of wood. For the analyzed situations, the volume transported varied between 10 and 30 m^3 in forestry trucks, while for the forestry platforms the volumes varied from 10 to 14 m^3.

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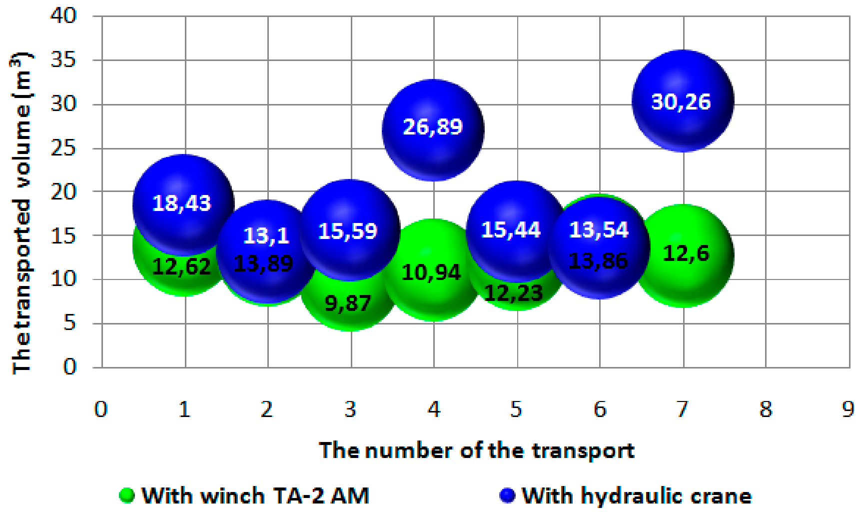

Figure 12. The volumes transported by forestry trucks (ATF) and forestry platforms (ATF) in Boșca Montană and Bocșa Română forest districts.

Regarding the uploading times of each type of vehicle (Figure 13), a very large variation could be found, from 25 to 75 minutes for forestry trucks (ATF), respectively from 35 to 50 minutes for forestry platforms (APF). This very large variation in the case of forestry platforms may be due to the fact that the loads involve several logs loaded at the same time with the help of cables and, when are used forestry platforms there are required additional maneuvers for each individual loading.

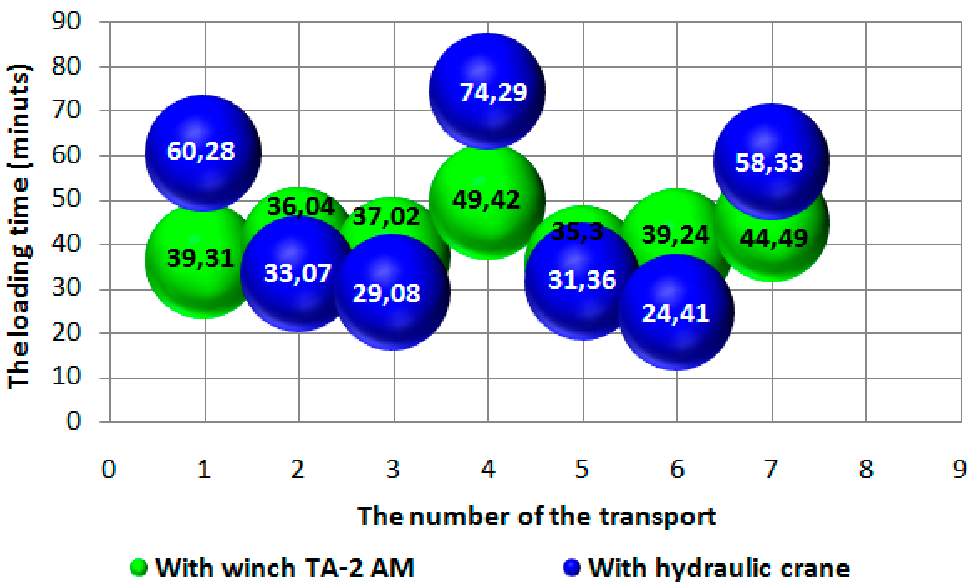

Figure 13. The overall time of loading wood in forestry trucks (ATF) and forestry autoplatforms (APF) in Boșca Montană and Boșca Română forestry districts.

Comparing the loading times of each loading in forestry trucks (ATF - Figure 14) and in forestry platforms (APF - Figure 15), could be observed clear differences between the two types of vehicles. Thus, at forestry trucks (ATF) the loading of a load takes on average 1 minute (Figure 14), while at forestry platforms (APF) the average duration varies between 9 and 12 minutes (Figure 15). In addition, it was found that the maximum loading time for a loading was close to 2 minutes at forestry trucks (ATF - Figure 14), while at forestry platforms (APF) the maximum loading time varied widely, from 11 to 17 minutes (Figure 15).

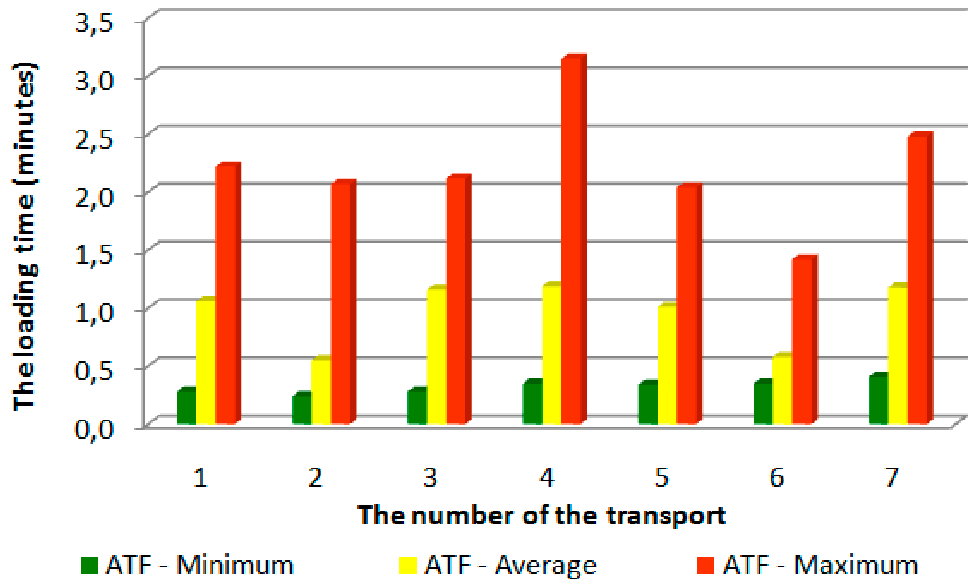

Figure 14. Descriptive statistical indicators for loading times of each loading in forestry trucks (ATF).

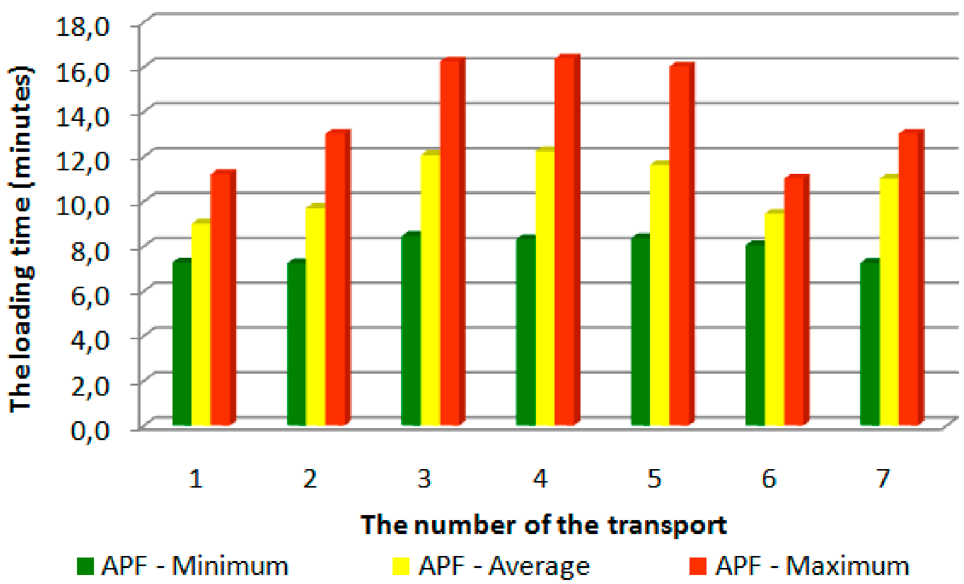

Figure 15. Descriptive statistical indicators for loading times of each loading in forestry platforms (APF).

On the other hand, all these aspects were correlated with the volumes of a loading. At forestry trucks (ATF) loading involves fewer logs included in a loading if they have large volumes, or more logs if they have reduced volumes. In the present case, the loadings consisted of 1 to 6 logs. Thus, loadings of 0.04 – 0.47 m^3 as minimum values, respectively of 0.83 – 1.16 m^3 as maximum values, were loaded at the same time, with an average between 0.33 and 0.67 m^3 (Figure 16).

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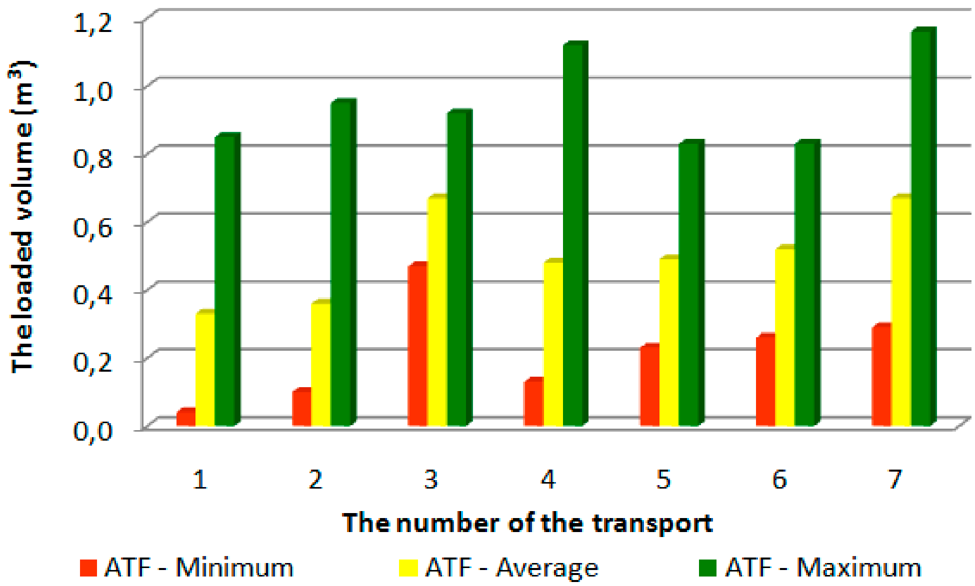

Figure 16. Descriptive statistical indicators regarding the volumes for each loading in the case of forestry trucks (ATF).

By comparison, in the forestry platforms (APF) the loadings were made up of 4 – 10 logs and 8 - 15 logs, respectively, the large number of logs indicating, to some extent, also the volume corresponding to a loading. In this sense, from the analysis of Figure 17, it could be seen that the minimum volumes per loading varied between 1.90 and 2.98 m^3, while the maximum values oscillated between 3.67 and 5.93 m^3, with an average of 2.73 – 4.07 m^3.

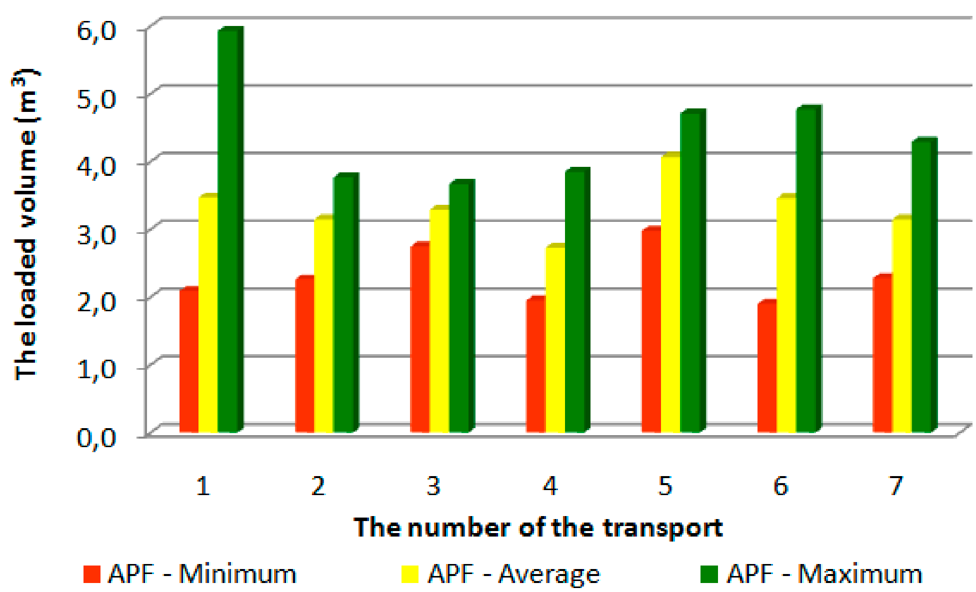

Figure 17. Descriptive statistical indicators regarding the volumes for each loading in the case of forestry platforms (APF).

3.3. Evaluation of the Loading Process of Wood in Forestry Trucks

A MAN TGS 33.510 forestry truck (ATF - with 6 x 6 traction) was chosen for the evaluation of the wood loading process. The driver has 16 years of experience and has only worked in this field.

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After measuring the wood, it could be observed that the loaded logs were 5.5 - 13 m long, with diameters between 20 and 40 cm.

In Figure 18 is showed the sequence of working phases specific to the loading of wood in forestry trucks. From the figure could be seen the cyclic nature of the loading process, where are repeated the following working phases: actuation of the levers that activate the hydraulic arm and the grapple (IPZ – Figure 19a, encoded with 2); log measurement (CL – Figure 19b, encoded with 3); transfer of the log to the truck/trailer (TBC – Figure 19c, encoded with 4); placement/arrangement of log in truck/trailer (AABC – Figure 19d, encoded with 5); returning the hydraulic arm and grapple from the truck/trailer to the log (RB – Figure 19e, encoded with 6).

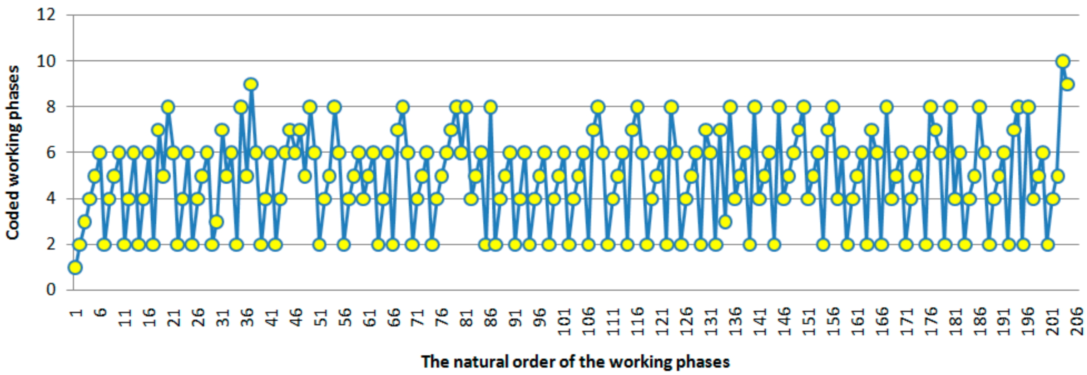
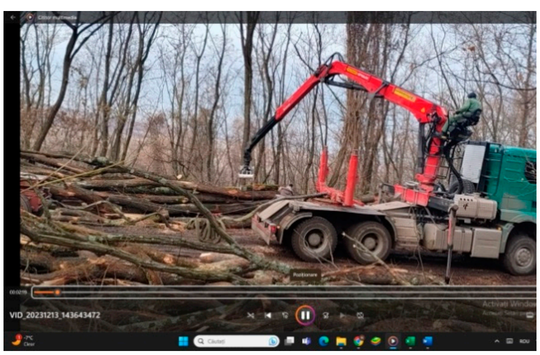
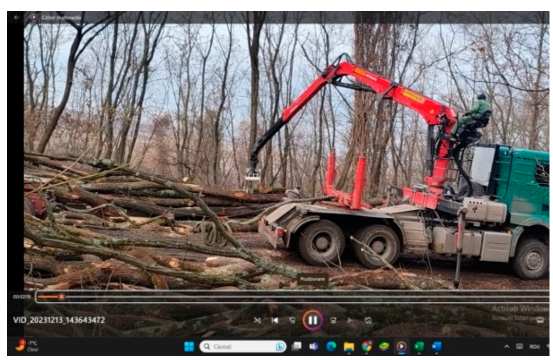
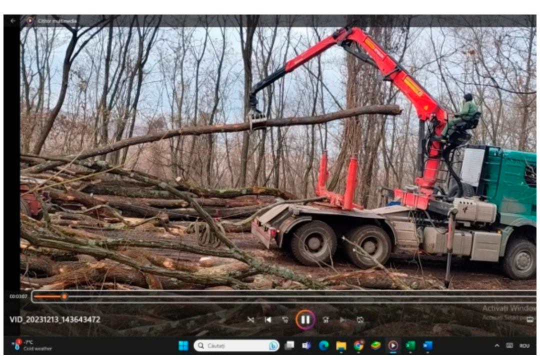


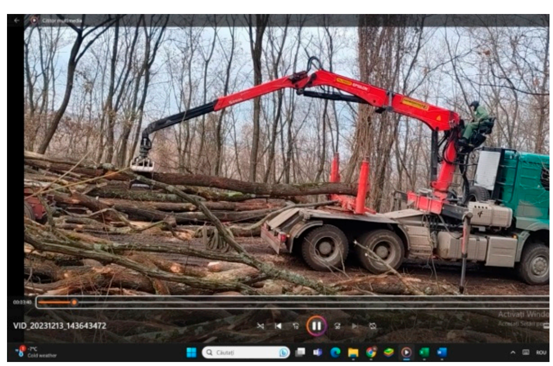
Figure 18. The sequence of working phases from loading wood into a forestry truck: 1 - vehicle preparation (PA); 2 – actuation of the levers that activate the hydraulic arm and the grapple (IPZ); 3 – log measurement (CL); 4 – transfer of the log to the truck/trailer (TBC); 5 – placement/arrangement of log in truck/trailer (AABC); 6 – returning the hydraulic arm and grapple from the truck/trailer to the log (RB); 7 – other activities (AA); 8 – cross-cut technical break (PTS); 9 – getting off the crane after loading (CM); 10 – stop loading by placing the hydraulic arm in the transport position (II).



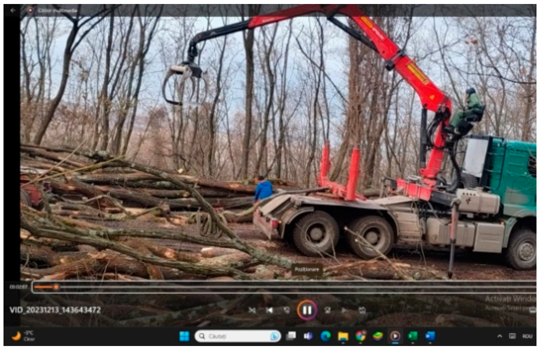


a. b.





c. d.



e.

Figure 19. The working phases of the loading process: a. actuation of the levers that activate the hydraulic arm and the grapple (IPZ); b. log measurement (CL); c. transfer of the log to the truck/trailer (TBC); d. placement/arrangement of log in truck/trailer (AABC); e. returning the hydraulic arm and grapple from the truck/trailer to the log (RB).

From the Figure 20, it could be found that the largest share belongs to the technical break imposed by the working method (cross-cut technical break PTS - 23%), followed by the transfer of the log from the stack to the truck/trailer (TBC - 22%) and placing/arranging logs in the truck/trailer (AABC). From the perspective of classifying working phases into productive and non-productive categories of time, it is observed that in 64% of the time productive activities are carried out, while non-productive phases have a weight of 36%. From the graphic illustration of the productive activities (Figure 21), it could be seen the predominance of the working phases that involve the transfer of the logs from the stack to the truck/trailer (TBC), followed by the placement/arrangement of the logs in the truck/trailer (AABC). From the category of non-productive times, the technical break imposed by the need to cross-cut the wood had the largest share (64%).

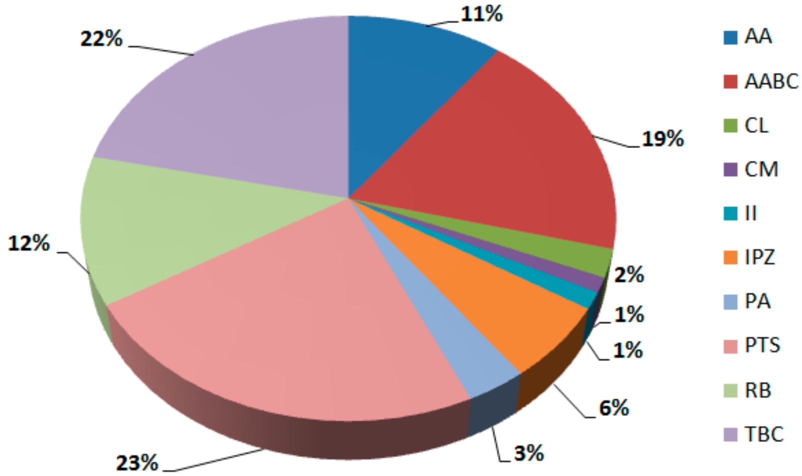


Figure 20. The weight of working phases from the wood loading in the TG 33.510 forestry truck: PA – vehicle preparation; UM – climbing the crane; IPZ – actuation of the levers that activate the hydraulic arm and the grapple; TBC – transfer of the log to the truck/trailer; AABC – placement/arrangement of log in truck/trailer; RB – returning the hydraulic arm and grapple from the truck/trailer to the log; II

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– stop loading by placing the hydraulic arm in the transport position; CM – getting off the crane after loading; CL – log measurement; PTS – cross-cut technical break; AA – other activities.

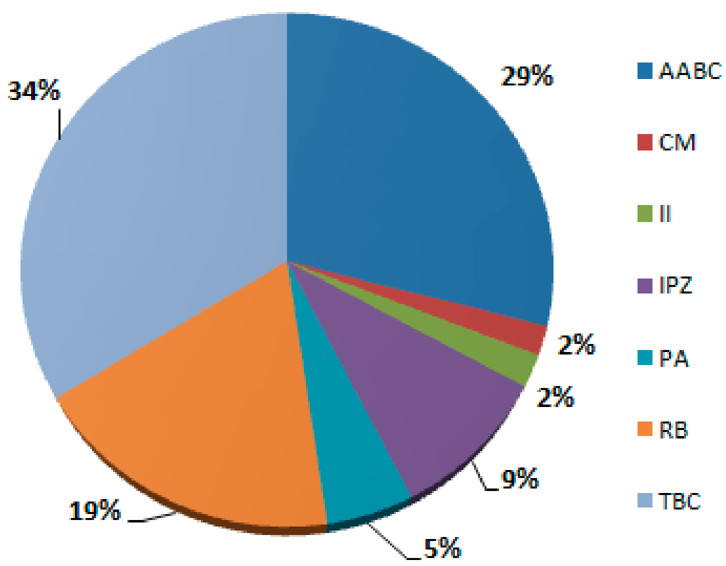

Figure 21. The weight of working phases from the wood loading in the TG 33.510 forestry truck, as productive times: AABC – placement/arrangement of log in truck/trailer; CM – getting off the crane after loading; II – stop loading by placing the hydraulic arm in the transport position; IPZ – actuation of the levers that activate the hydraulic arm and the grapple; PA – vehicle preparation; RB – returning the hydraulic arm and grapple from the truck/trailer to the log; TBC – transfer of the log to the truck/trailer.

3.4. The loading Productivity When Are Used Forestry Trucks (ATF) and Forestry Platforms (APF)

Knowing both the loaded volumes loaded and the corresponding durations for each loading, a series of determinations were made regarding the productivity. From the analysis of the two types of vehicles (Figures 22 and 23), it was very easy to see the multitude of tasks corresponding to the loading process in the forestry trucks (ATF) compared to those specific to the forestry platforms (APF). In addition, it can be found that the productivity when loading wood in forestry trucks (ATF) was predominantly around 0.5 m^3/loading (Figure 22), while in forestry platforms (APF) it varied between 0.2 and 0.6 m^3/loading, approximately (Figure 23). This variation could be due to the specificity of loading process for each type of studied vehicle. The impact of the wood assortments cannot be very large, since progressive cuts were applied in both forests, resulting in large-sized wood material.

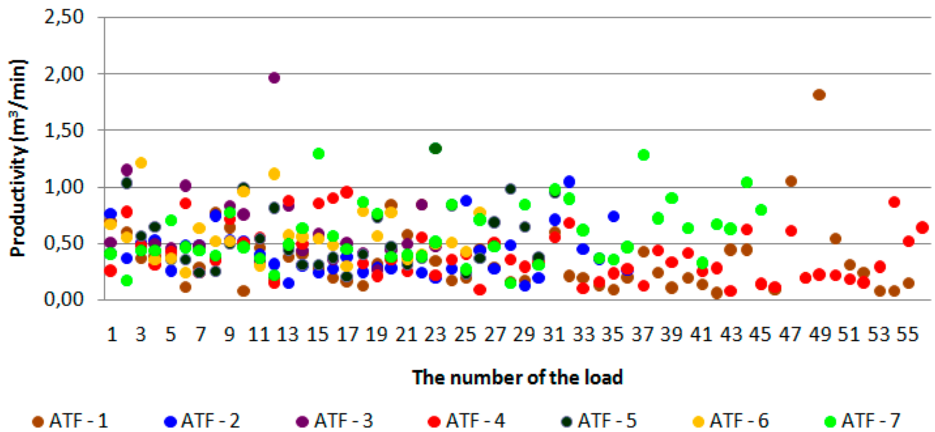

Figure 22. Productivity of wood loading in forestry trucks (ATF).

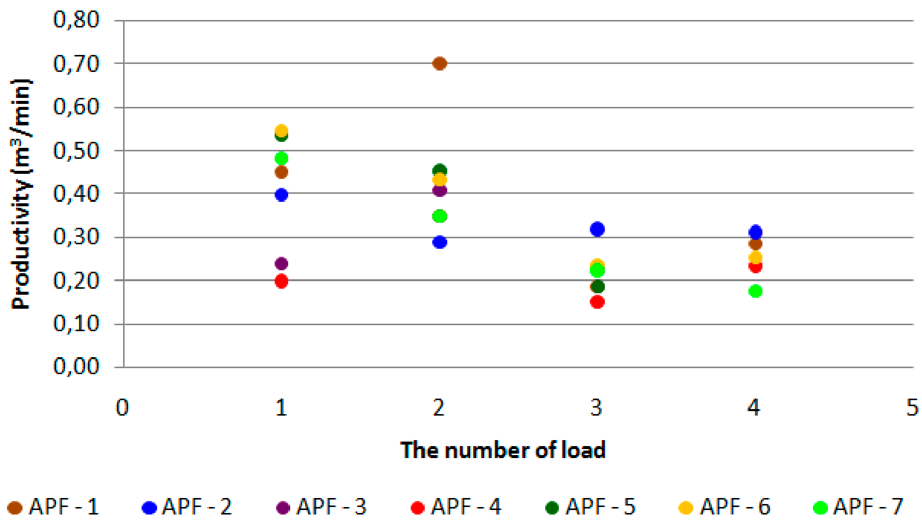

Figure 23. Productivity of wood loading in forestry platforms (APF).

It should also be mentioned that the productivity in the case of forestry platforms (APF) decreases more and more after the first loaded loading, while in the case of forestry trucks (ATF) there are variations in productivity, regardless of the number of loaded loadings.

4. Discussion

The need for wood at the level of society is constantly increasing, which requires efficiency of the transport process [6,9,13,17,24]. Mainly, the transport of wood from the forest to various beneficiaries is carried out with vehicles of different capacities and types [9,17,24,26,27,37,40], which allow different payloads on the vehicle, but also lower or higher demands on the transport routes [1,35,41]. Thus, roads can condition the use of heavy vehicles, through the constructive characteristics, the area in which they are built, but also the condition in which they are [10,16,17,42]. On the other hand, the transport distances and the types of transported wood are directly influenced by the type of cutting, the type of stand, but also by the way the forest administrator chooses to sell the wood [1,3,10].

In Romania, in the situation of some compartments administered by state through the National Forest Administration [13,32,43] or forest districts that manage the forests of the local public authorities (U.A.T.s), part of the harvested wood is sold to the locals near the forested areas [32]. This means that the timber is sold directly from the harvesting area and the buyers have to provide their own transport [26]. Because the wood is sold to locals, the volumes are reduced and in accordance with the needs of each individual family and the means of transport must be chosen accordingly [1,32,37]. Thus, analyzing the volumes of wood transported between the years 2014 and 2019 on a forest road in Romania, located near a town, Bitir et al. [32] mentions that small capacity means of transport were used, which had loadings of up to 5 m^3, including animal traction. Even if these kinds of transports were numerous, they represented only 2% of the total volume transported during the analyzed period and it was consisted of 90% of firewood. In another study made by Potocnik and his collaborators [1], which assesses the impact of traffic characteristics on forest roads in Slovenia, it is mentioned that 15% of the wood was transported by tractors with trailers, being intended for domestic needs. A similar situation also appears in the present research, when the transport distances vary between 3 and 16 km for the wood sold to locals, near the Codrii Cetăților Forest District. Conversely, it has been found that when was transported working wood of one or related species, the distances increase, sometimes considerably, which means that the wood was sold to economic agents. These situations appeared when the wood was transported to a local contractor 63 km away,

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and when the pulpwood was transported 232 km away. In a study of Mușat and his collaborators [40], which analyzes the transport distances of a factory that purchases wood for the production of oriented stand boards (OSB), it is mentioned that the transports were made with high-capacity vehicles, which traveled between 50 and 370 km from the place of loading to the destination. Also related to transport distances, Kärhä and his collaborators [17] mention that in some countries such as Bulgaria, Poland, Turkey and Uruguay transport distances exceed 200 km, and in others they are at most 60 km (Denmark, Estonia, Japan and Slovenia).

In contrast, in the case of private forest districts as was the case of Lignum Forest District, the wood was no longer delivered from the harvesting area, but from its own wood storages area. For this reason, when transporting the wood from the harvesting area to the storage area, different types of high-capacity transport vehicles were used, some of which were held by the forest district, an aspect also mentioned by Acuna [6] who states that the wood is transported mainly by trucks either held by the company, either rented. In this regard, Mousavi and Naghdi [10] mention that the wood from the harvesting area must be transported to a storage area at the right time, because otherwise its quality is reduced due to the attack of insects and fungi [36]. In the storage area, the wood is sorted and delivered to various beneficiaries or to processing companies, which requires large distances and specialized vehicles for transport [10,22,40], such as forestry trucks with or without trailers.

In Romania, although the vehicles used to transport wood are very varied, forestry trucks (ATF) and forestry platforms (APF) predominate [20,26,28,43]. The type of vehicle used to transport wood can greatly influence the loaded volume [17,37]. Thus, the field investigations carried out in the forests managed by the Caraș-Severin Forest District indicated that smaller wood volumes were loaded in the forestry platforms (APF) compared to the forestry trucks (ATF).

Due to the loading method, in the two studied cases both the loaded volumes and the loading times varied. For the considered forestry platforms (APF), the number of logs loaded at the same time influenced the loading time, which was bigger than at forestry trucks (ATF), but the same happen with the volumes of each loading (they were bigger at forestry platforms). According to Kärhä et al. [17], the higher the gross vehicle weight and the loaded volume for a transport, the lower the long-distance transport costs for round wood. However, trucks with or without their own loading systems are the main transport vehicle for wood from the forest to the beneficiaries also in other countries, such as Slovenia [1], Austria [16], Iran [10], Ireland [24], Australia [33].

The loading method can also influence the volume loaded at the same time. Thus, in the case of forestry platforms (APF), loading involved a variable number of logs that were loaded at the same time, by cables [20,26]. In the case of forestry trucks (ATF), the loading was carried out with the help of the hydraulic crane (arm and grapple) of the truck [20,26]. This allows loads to be made up of one or more logs (6 in the present case), depending on them diameter and length. In this regard, thick logs are loaded successively, and thin logs can be loaded more at the same time, depending on the capacity of the hydraulic crane. All these aspects also influenced the time of a loading, which means that in the present situation the durations were minimal for forestry trucks (ATF) and longer for forestry platforms (APF).

Forestry trucks (ATF) through the way of loading allow an optimal arrangement of the logs in the truck or in the trailer, which leads to reaching the maximum loading capacity of the vehicle [20,26,36]. In addition, with the grapple and the hydraulic arm, the logs can be better handled to be placed in the truck/trailer, which leads to a stabilization of the load during transport [26]. On the other hand, at forestry platforms (ATF) the logs must be arranged by the workers before the cables were stretched [26], which means more time consumption, increased risk of injury [44,45] and great physic effort on the part of the workers [46].

Sometimes loading of vehicles without their own loading systems requires another means of loading, such as a front loader or other tractors equipped with loading equipment [10,26]. All these aspects influence the productivity of wood transport by trucks, especially the working phases that involve loading and unloading the wood [17]. In addition, vehicle configuration can have a major impact on loading potential through the vehicle design and the equipments on it [16,31,33]. In this regard, Sosa and his collaborators [24] mention that there is an inverse relationship between the

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variability of the gross vehicle mass and the average net load, which means that the less the gross weight varies, the higher the net load.

Within the studied working processes, it was found that the productivity at loading wood in forestry trucks (ATF) was somewhat uniform, of 0.5 m^3/loading, while at forestry platforms (APF) it varied a lot, according to the number of loaded loadings (0.2 – 0.6 m^3/loading). Thus, the volume loaded at the same time decreased from the first to the last loading, the first one being the most voluminous and made in the shortest time [20,26]. In other words, the equipment of the vehicle played a particularly important role in increasing productivity, along with the type of loaded wood and the experience of the driver [17,47,48].

In addition to the type of vehicle used for transport, the type of loaded wood, and the place where the loading is carried out can have a special importance on productivity [17]. Thus, if the loading was carried out in the harvesting area, the working process was more difficult because, most of the time, the wood was not initially cut to length and measured, which imposed a series of breaks in the working process, for carrying out these activities. When the loading was carried out in wood storage areas, productivity was higher because the logs were already cut to the dimensions desired by the beneficiary and were placed in stacks. These details ensured that the loading process was not interrupted, thus ensuring greater efficiency.

On the other hand, forestry platforms (APF) required more maneuvering space for loading wood compared to forestry trucks (ATF) ([20,26], for stretching cables and manually arranging logs for loading, which required a significant amount of physical effort [46]. A recommendation in this regard is rendered by Mousavi and Naghdi [10] which recommend that harvesting areas to be placed on both sides of the road, so that the wood loading in vehicles to be easier and possible from both sides of the truck. In addition, the productivity at loading wood in forestry platforms (APF) could be also conditioned by placing the logs directly on the ground and not on some crossbars, which could help during the stretching of cables [20,26]. Thus, with the logs placed directly on the ground, additional activities were required to allow the loading cables to be inserted under the pieces of wood in order to be loaded, including a manual rolling of the logs, which involves a high demand on the workers.

From another perspective, productivity in wood transport is also conditioned by delays [6,16] due to factors related to the organization of transport and to the reception of the wood at the factories [17,49]. Reducing loading and waiting times can have important effects on the duration of a complete transport [50]. In Romania, the average duration of a transport is 3.5 - 4 hours [28,34], which means that is possible to make two transports per day. This duration includes the rest times for drivers, the loading and unloading times, and the effective moving. Thus, the loading time of high-capacity vehicle is on average one hour per transport, and the unloading time is 0.5 hours [34]. In the analyzed vehicles, the loading times varied greatly, mainly in relation to the type of loaded wood, between 25 and 75 minutes for the forestry trucks (ATF) and between 35 and 50 minutes for the forestry platforms (APF), respectively.

As for the loaded volumes, they varied in the given situations between 10 and 30 m^3 for forestry trucks (ATF) and between 10 and 14 m^3 for the forestry platforms (APF), the regulations regarding the payload allowed of 38 tons being respected [51]. This limit varies from country to country [9,10,24,35], depending on the road category, so that in some countries the allowable gross vehicle weight is less than 35 tons, and in others it reaches double values [17].

The analysis of the case study carried out for the forestry truck MAN TGS 33.510 with the aim of highlighting the working phases specific to wood loading indicated the predominance of productive activities, of which the most common involved the effective loading of logs. This can be attributed to the fact that the number of loaded logs was large, and the loading of the vehicle involved repetitive activities through which the logs were brought into the truck/trailer and the hydraulic arm was brought back from the truck/trailer to the logs that must be loaded. On the other hand, the non-productive times are greatly influenced by the working phases in which the logs were cut to lengths imposed by the vehicle and/or by the beneficiary. In addition, each transport must be accompanied by a series of transport documents certifying both the origin of the material, the species and the type of material, in the qualitative sense (round wood - working wood - firewood), and quantitative (dimensions and volume). For the drawing up of the transport documents, which accompanying the transport from the place of loading to the place of unloading, the dimensions of the logs are needed. As they were not prepared prior to the transport, and were cut to length just before being loaded, each log was measured and the data were entered into a specific program. All these working phases, considered unproductive for loading, imposed interruptions in the working process. In addition, carrying out these activities at the time of loading involved a very high degree of risk for the workers who made them [44,45], as they moved among the logs and very close to the vehicle while uploading the wood.

5. Conclusions

From the forests managed by the state and from the forests owned by the local public administrations, the fuelwood reach, mainly, at locals, and the working wood at some wood processing companies.

Transports with low volumes of wood from several species involve short distances from loading point to the first or to the only unloading point.

The type of vehicle used to transport wood can greatly influence the volume of loaded wood.

At forestry platforms (APF) the loading process is done with cables, which allows loading several pieces at the same time, but this leads to longer durations related to each loaded loading, and also to a lower volume loaded in the vehicle.

At forestry trucks (ATF) the loading capacity can be achieved relatively easily by loading logs one by one, and they can be properly placed to ensure stability during transport and its efficiency.

At forestry trucks (ATF) the loading time of a single load is somewhat constant, while at forestry platforms (APF) it varies a lot, with differences observed from the first to the last loading.

Forestry platforms (APF) require more available space for loading wood compared to forestry trucks (ATF).

The working process of loading forestry platforms is more laborious and requires more physical labor and a larger number of workers compared to forestry trucks where loading is done only by the operator of the vehicle, by acting commands that involve attention and concentration, but not physical effort.

Loading wood from the storage areas is more efficient than loading wood from the harvesting areas, where the logs must be measured and sometimes cut to length.

Author Contributions: Conceptualization, E.C.M.; methodology, E.C.M.; software, E.C.M. and R.A.D.; validation, E.C.M., G.L.A., D.D.H., L.D.M., V.N.A. and S.S.; formal analysis, G.L.A., D.D.H., L.D.M., V.N.A. and S.S.; investigation, G.L.A., D.D.H., L.D.M., V.N.A., S.S.; resources, E.C.M. and R.A.D.; data curation, E.C.M. and R.A.D.; writing—original draft preparation, E.C.M.; writing—review and editing, E.C.M.; visualization, E.C.M.; supervision, E.C.M.. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Acknowledgments: The author would like to thank to the Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements, Faculty of Silviculture and Forest Engineering, Transilvania University of Brasov, for the logistics and equipment needed to carry on this study. The author would like to thank to eng. George MUSAT and eng. Marian ARIBASOIU, for their great support in collecting the field data.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Potočnik, I.; Pentek, T.; Pičman, D. Impact of traffic characteristics of forest roads due to forest management. *CROJFE* **2005,** *26(1)*, 51-57.
2. Grulois, S.; Pellegrini, M.; Lingua, E.; Grignolato, S.; Protti, F.; Vitali, A.; Rebolj, L.; Grum, A.; Ginet, C.; Corette, T.; Hairzer, E.; Stöhr, D. General presentation of the wood transport sector in the alpine space. Interreg Alpine Space Project, 2014, project no. 2-3-2-FR.

3. Fornea, M.; Bîrda, M.; Borz, S.A.; Popa, B.; Tomašić, Ž. Harvesting conditions, market particularities or just economic competition: a Romanian case study regarding the evolution of standing timber contracting rates. *Šumarski List* **2018,** *9-10(CXLII),* 403-409. doi: 10.31298/sl.142.9-10.5.
4. Iordache, E.; Niță, M.D.; Clinciu, I. Planning forest accessibility with a low ecological impact. *CROJFE* **2012,** *33(1),* 143-147.
5. Popovici, V.; Bereziuc, R.; Clinciu, I. Extinderea rețelei de drumuri pentru accesibilizarea fondului forestier și, în general, a pădurii. *Bucovina Forestieră* **2003,** *XI(2),* 36-40.
6. Acuna, M. Timber and biomass transport optimization: a review of planning issue, solution techniques and decision support tools. *CROJFE* **2017,** 38(2), 279-290.
7. Bitir, I.; Mușat, E.C.; Derczeni, R.A.; Ciobanu, V.D. The influence of the increased tonnage upon the superstructure of forest roads. Conference Proceedings Water Resources, Forest, Marine and Ocean Ecosystems, Albena, Bulgary, June 28-July 7, 2019, SGEM, 19(3.2), 853-860.
8. Beldeanu, E. *Produse forestiere.* Transilvania University Press: Brasov, Romania, 2008, 331 p.
9. Tahvanainen, T.; Anttila, P. Supply chain cost analysis of long-distance transportation of energy wood in Finland. *Biomass and Bioenergy* **2011,** 3360-3375. doi: 10.1016/j.biombioe.2010.11.014.
10. Mousavi, R.; Naghdi, R. Time consumption and productivity analysis of timber trucking using two kinds of trucks in northern Iran. *J. For. Sci.* **2013,** *59(5),* 211-221. doi: 10.17221/10/2013-JFS.
11. Zanuncio, A.J.V.; Carvalho, A.G.; da Silva, M.G.; Lima, J.T. Importance of wood drying to the forest transport and pulp mill supply. *Cerne* **2017,** *23(2),* 147-152. doi: 10.1590/01047760201723022223.
12. Olteanu, N. *Drumuri forestiere. Proiectare.* Transilvania University Press: Brasov, Romania, 1995, 173 p.
13. Muşat, E.C.; Alexandru, V.M.; Ciobanu, V.D.; Săceanu, S.C-tin.; Antoniade C.; Vişan, J. The type and the extension of the degradations caused by the introduction in the timber transportation of the increased weight vehicles. *Revista Pădurilor* **2014,** *129(5-6),* 38-43.
14. Epstein R.; Karlsson J.; Rönnqvist M.; Weintrab A. *Forest Transportation*. Handbook on Operations Research in Natural Resources. Springer, New York, 2007, pp. 391-403.
15. Bereziuc, R.; Alexandru, V.; Ciobanu, V.; Muşat, E.C.; Dumitraşcu, A.E.; Antoniade, C.; Vişan, J. The density index of the forest road network managed by the National Forest Administration (R.N.P.). *Proceedings of the International Conference "Forest and Sustainable Development"* **2015,** 196-203.
16. Holzleitner, F.; Kanzian, C.; Stampfer, K. Analyzing time and fuel consumption in road transport of round wood with an onboard fleet manager. *Eur. J. Forest Res.* **2011,** *130,* 293-301. doi: 10.1007/s10342-010-0431-y.
17. Kärhä, K.; Seuri, M.; Donagh, P.M.M.; Acuna, M.; Kanzian, C.; Petković, V.; Gonçalves, R.R.C.; Costa, L.H.S.; da Cruz, R.C.; Krumov, T.; Bradley, A.; Röser, D.; Pinto, C.; Dian, W.; Pandur, Z.; Dvořák, J.; Jørgensen, M.T.; Muiste, P.; Irdla, M.; Ginet, C.; Purfürst, T.; Dietz, H.-U.; Spinelli, R.; Suzuki, Y.; Shirasawa, H.; Lazdiņš, A.; Visser, R.; Harvey, C.; Skjølaas, D.; Moskalik, T.; Trzciński, G.; Borz, S.A.; Muşat, E.C.; Triplat, M.; Oberholzer, F.; Talbot, B.; Tolosana, E.; von Hofsten, H.; Akay, A.O.; Bakay, B.; Conrad IV, J.; Olivera, A. Overview of global long-distance road transportation of industrial roundwood. *CROJFE* **2024,** *25(1),* 217-236. doi: 10.5552/crojfe.2024.2286.
18. Bereziuc, R. Realizări și perspective în domeniul căilor forestiere de transport. *Analele Universității „Ștefan cel Mare" Suceava* **2004,** *2,* 9-14.
19. Asikainen, A. Simulation of logging and barge transport of wood from forests on islands. *J.For.Eng.* **2001,** *12(2),* 43-50. doi: 10.1080/14942119.2001.10702445.
20. Ciubotaru, A. *Exploatarea pădurilor.* Lux Libris Publishing House: Brasov, Romania, 1998, 176 p.
21. Malinen, J.; Nousiainen, V.; Palojärvi, K.; Palander, T. Prospects and challenges of timber trucking in a changing operational environment in Finland. *CROJFE* **2014,** *35(1),* 91–100.
22. Palander, T.; Kärhä, K. Potential traffic levels after increasing the maximum vehicle weight in environmentally efficient transportation system: the case of Finland. *J.S.D.E.W.E.S.* **2017,** *5(3),* 417-429. doi: 10.13044/j.sdewes.d5.0154.
23. Normativ privind proiectarea drumurilor forestiere PD – 003 – 11. Emis prin Ordinul Ministrului Mediului şi Pădurilor nr. 1374 din 04.05.2012, 272 p. Available online: https://gov.ro/ro/guvernul/procesul-legislativ/note-de-fundamentare/nota-de-fundamentare-hg-nr-33-18-01-2024&page=8 (accessed on: 21 May 2024).
24. Sosa, A.; Klvac, R.; Coates, E.; Kent, T.; Devlin, G. Improving log loading efficiency for improved sustainable transport with the Irish forest and biomass sector. *Sustainability* **2015,** *7,* 3017-3030. doi: 10.3390/su7033017.
25. Mușat, E.C.; Greșiță, C.I.; Maican, I. Analysis of transported volumes and unloading times of raw material used in manufacturing OSB boards. Conference Proceedings of the 19th International Multidisciplinary Scientific Geoconference SGEM 2019, vol. 19, issue 1.4. Science and Technologies in Geology, Oil and Gas Exploration, Water Resources, Forest Ecosystems, Vienna, Austria, December 2019(a), 335-342.
26. Oprea, I.; Sbera, I. *Tehnologia exploatării lemnului.* Tridona Publishing House: Oltenița, Romania, 2004, 369 p.

27. Palander, T.; Viitamäki, K.; Borz, S.A. Impacts f using larger and heavier vehicles on operations and profitability of timber transportation: the case of Finish operating environment. *Ann. For. Res.* **2023,** *66(2),* 45-68. doi: 10.15287/afr.2023.2992.
28. Derczeni, R.A; Salcă, E.A.; Ciobanu, D.V.; Bitir, I.; Mușat, E.C. Research on establishing criteria for calculating the tax/road tolling for vehicles used for timber transport on forest roads. Proceedings of the International Conference "Forest and Sustainable Development", Brașov, Romania, October 25-27, 2018, 161-170.
29. Palander, T.; Haavikko, H.; Kortelainen, E.; Kärhä, K.; Borz, S.A. Improving environmental and energy efficiency in wood transportation for a carbon-neutral forest industry. *Forests* **2020,** *11(11),* 1194. doi: 10.3390/f11111194.
30. Navarro Maroto, P.J.; Rodriques Bayo, J.; Codina i Palou, M.; Dominquez i Tores, G.; Lopes Vicens, Y. Prospects for the market supply of wood and other forest products from areas with fragmented forest ownership structure. Task II. Case study: Catalonia, Spain. Centre Tecnologic Forestal de Catalunya, 14-48. Available online: https://op.europa.eu/en/publication-detail/-/publication/b67b91af-efcd-4b46-87c6-c4f4d23448b8 (accessed on 15 November 2022).
31. Jucan, V. Autovehiculul, drumul sau încărcătura? (I). *Bucovina Forestieră* **1994,** *II(1),* 98-100.
32. Ryan, T.; Phillips, H.; Ransay, Y.; Dempsey, J. Forest road manual. Guidelines for the design, construction and management for forest roads. Available online: https://www.semanticscholar.org/paper/Forest-road-manual%3A-guidelines-for-the-design%2C-and-Ryan-Phillips/529ca8ab9771c8e728bf29a966b67cc7857b8c2b (accessed on 12 May 2024).
33. Brown, M.W. Evaluation of the impact of timber truck configuration and tare weight on payload efficiency: an Australian case study. *Forests* **2021,** *12*, 855. doi: 10.3390/f12070855.
34. Mușat, E.C.; Ciobanu, V.D.; Vișan, J.; Antoniade, C.; Săceanu, S.C. Analiza variantelor de structuri rutiere în contextul sporirii capacității portante a drumurilor forestiere. *Revista Pădurilor* **2016,** *131(3-4),* 91-99.
35. Mușat, E.C.; Bitir, I. Evaluating the forest road systems subjected to different loadings by using the Finite Element Method. *Forests* **2022,** *13,* 1872. doi: 10.3390/f13111872.
36. Kogler, C.; Rauch, P. Lead time and quality driven transport strategies for the wood supply chain. *R.T.B.M.* **2023,** *47,* 100946. doi: 10.1016/j.rtbm.2023.100946.
37. Knight, C.R.D.; Bolding, C.; Conrad IV, J.L.; Barrett, S.M. Log truck transportation challenges and innovative solutions: evaluating the perspectives of truck drivers, logging business owners, and forests. *J. For. Eng.* **2023,** *37(5),* 113-121. doi: 10.1080/14942119.2023.2273123.
38. Palmgren, M. Optimisation methods for log truck scheduling. Thesses nr. 880, Linköping University, Suedia, 2001.
39. Horodnic, S. *Bazele exploatării lemnului.* Ștefan cel Mare University Publishing House: Suceava, Romania, 2003, 294 p.
40. Mușat, E.C.; Iancu, B.I.; Derczeni, R.A.; Ciobanu, V.D. Analysis of transport distances and wood volumes purchased by a woodworking company. Conference Proceedings of the 19th International Multidisciplinary Scientific Geoconference SGEM 2019, vol. 19 – Water Resources. Forest, Marine and Ocean Ecosystem, issue 3.2, Albena, Bulgaria, iulie 2019(b), pp. 617-624.
41. Olsson, L.; Lohmander, P. Optimal forest transportation with respect to road investments. *Forest Policy Econ.* **2015,** *7,* 369-379. doi: 10.1016/j.forpol.2003.07.004.
42. Kärhä, K.; Rantala, T. The biggest bottlenecks and the most potential development measures in long-distance road transport of industrial roundwood in Finland. Proceedings of the Joint 44th Annual Meeting of Council on Forest Engineering (COFE), the 54th International Symposium on Forest Mechanization (FORMEC), and IUFRO All-Division 3 Meeting; Chung, W., Kanzian, C., McNeary, P., Eds. One Big Family – Shaping Our Future Together, Corvallis, OR, USA, October 4–7, 2022, 74 p.
43. Bitir, I.; Mușat, E.C.; Lunguleasa, A.; Ciobanu, V.D. Monitoring the transport on the Ciobănuș forest road within the Bacău Forestry Department. *Recent Journal* **2021,** *1(63),* 10-16. doi: 10.31926/RECENT.2021.63.010.
44. Iftime, M.; Mușat, E.C.; Ciobanu, V.D. Analysis of the working accidents recorded during the harvesting of the trees, between 2013 – 2018, for workers of the National Forest Administration, Romsilva, Romania. *J.E.P.E.* **2019,** *20(4),* 1717-1726.
45. Iftime, M.D.; Mușat, E.C. Accidentele de muncă la recoltarea lemnului în România, expresia organizării și funcționării sistemului de muncă. *Revista Pădurilor* **2022,** *137(3),* 1-14.
46. Mușat, E.C.; Borz, S.A. Learning from acceleration data to differentiate the posture, dynamic and static work of the back: an experimental setup. *Healthcare* **2022,** *10(5),* 916. doi: 10.3390/healthcare10050916.
47. Koirala, A.; Kizha, A.R.; De Hoop, C.F.; Roth, B.E.; Han, H.- S.; Hiesl, P.; Abbas, D.; Gautam, S.; Baral, S.; Bick, S.; Sahoo, K. Annotated bibliography of the global literature on the secondary transportation of raw and comminuted forest products (2000–2015). *Forests* **2018,** *9(7),* 415. doi: 10.3390/f9070415.
48. Smidt, M.F.; Mitchell, D.; Logan, K.K. The potential for effective training of logging truck drivers. *J. Agric. Sat. Health.* **2021,** *27(1),* 29-41. doi: 10.13031/jash.14084.

doi:10.20944/preprints202408.0141.v1

49. Conrad J.L. Evaluating profitability of individual timber deliveries in the US South. *Forests* **2021,** *12,* 437. doi: 10.3390/f12040437.
50. Deckard, D.L.; Newbold, R.A.; Vidrine, C.G. Benchmark roundwood delivery cycle-times and potential efficiency gains in the southern United States. *For. Prod. J.* **2003,** *53(7),* 61-69.