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ORIGINAL SCIENTIFIC PAPER

Productivity of HSM 208F forwarder in selective cutting and mountainous area

Produktivnost HSM 208F forvardera u prebirnim sječama i planinskom području

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ABSTRACT

Forwarders have been used in the forest harvesting in the world for decades and are irreplaceable in the first phase of wood transportation. The use of forwarders in Bosnia and Herzegovina is still in its initial phase. Although they are used sporadically, there are still many uncertainties about the operation of forwarders in selection stands. Especially if we take into account that the current practice is that machinery in the stand is allowed to move only along pre-defined routes, trail. This practice has been used for years with winch skidders. In this research, which was carried out in selective cutting and mountainous areas, it was determined that the most important influencing factors on the productivity of the forwarder is the unloaded drive distance, loaded drive distance and distance of load collecting drive. The productivity of 7.17 m^3/h was determined for a loaded drive distance of 700 m and load collecting distance of 200 m. Forwarders require a different forest infrastructure than skidders if we want them to have competitive productivity.

Key words: *forwarder, influencing factors, productivity*

INTRODUCTION – *Uvod*

Forwarders are self-propelled vehicles intended for the transport of trees or their parts loaded in the vehicle bunk area. The development of the first forwarder started in Sweden around 1950s. Forwarders were originally used in cut-to-length timber harvesting, where the felling of trees was performed by harvester, and extracting by forwarder. In different countries, forwarders are used in difference ways. For example, in Croatian forestry forwarders are mostly used in lowland forests, particularly for the extraction of timber from shelterwood felling and late thinning (Poršinsky, 2002). From a scientific point of view, the research of forest operations includes the study of timber harvesting, ergonomics, mechanization, construction, economic aspect and planning of operations, all within the framework of a sustainable forestry development (Samset, 1992). The research of forestry operations, and hence also timber forwarding, is based on time study and on monitoring the influencing (quality and quantity) factors, data analysis, and mathematical mo-

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delling of time consumption of individual components of the working process (Samset, 1990). Similarly as other forms of timber extraction, forwarding also has the characteristics of a cyclic working process (Stankić et al., 2012). Forwarder efficiency is affected by numerous factors. The most important factors influencing the efficiency of timber forwarding is the travel distance (Sever, 1988). With the increase of the travel distance, the impact of the load volume on the vehicle productivity is also increased (Raymond, 1989). Apart from the forwarding distance, productivity is also affected by the average assortment volume, number of pieces in the load and quantity of timber on a felling site, which is more pronounced in thinning stands (Tufts and Brinker, 1993; Tufts, 1997). The highest share of time consumption in forwarder operations is related to the so-called terminal times, and namely loading and unloading of timber (Minette et al., 2004). Optimization of load volume and forwarding distance, and giving preference to downhill forwarding are the key factors for improving the productivity of forwarders (Tiernan et al., 2004). Terrain slope higher than 30% considerably decreases the productivity of forwarders because on such terrains vehicle mobility is limited (Zimbalatti and Proto, 2010). Terrain classification aimed at determining the optimum machine for timber extraction shows that in hilly-mountainous area the share of timber suitable for forwarding is considerable (Mihelič and Krč, 2008; Pentek et al., 2008). On steep terrain, up to 60%, it is possible to use forwarders with winch, the so-called cable forwarders (Kühmaier and Stampfer, 2010). The use of semi-tracks in conditions of limited soil bearing strength increases fuel consumption but provides vehicle mobility. Apart from travel distance, load volume and terrain conditions, forwarder productivity is also affected by the type of felling, length and type of assortment, driver's skill and knowledge, as well as characteristics of hydraulic crane and vehicle load space (White, 2004). The increase of the average assortment volume and terrain slope in travel direction (downhill forwarding) result in the decrease of time consumption (Ghaffarian et al. 2007). The density of secondary forest roads (forest trails) also affects the forwarding productivity (Mederski, 2006). Up to date planning methods, i.e. spatial optimization of working cycle shifts based on data on quantity and locations of assortments and possible travel areas of the felling site also increase the timber forwarding productivity (Flisberg et al., 2007). Comparative research of skidding/forwarding machines carried out in stands of small coniferous trees showed that, in terms of costs, figures speak in favour of timber forwarding, as forwarder productivity is twice higher than the productivity of the cable skidder with winch (Li et al., 2006). Forwarder efficiency depends on the type of the vehicle used, i.e. on its nominal carrying capacity, as forwarders of higher carrying capacity achieve lower costs and higher productivity per product unit (Jiroušek et al., 2007). Nowadays forwarders are not conceptually different from those of a half a century ago, but they have made serious progress in terms of environmental soundness, ergonomics and steering automation (Pandur et al., 2009). One of the ways to increase productivity is the use of dynamic system for changing the volume of the bunk area i.e. its height and width. Attaching the trailer with the loading space behind the rear end of the standard forwarder may increase the system productivity (Lindroos and Wasterlund, 2011). Investigations were performed of the use of »flats« or »swop bodies«, where timber is not unloaded from the forwarder nor loaded into the truck, as they are used with both kinds of transport, thus increasing productivity and simplifying primary transport of timber, but with increased costs.

Productivity of timber forwarding is higher than the productivity of timber skidding in lowland forests of Croatia, and the increase depends on stand and terrain conditions and ranges between 28 and 126% (Bojanin and Krpan, 1994). The operation of forwarders in Croatia, unlike the Scandinavian assortment method (CTL), makes no use of felling and processing machines. This is the effect of natural factors (natural forests, trees of large size, considerable share of broadleaved trees, etc.), but also of tradition (Bojanin and Krpan, 1997). One of the issue arising is the definition and determination of the mean distance of timber forwarding. Some authors consider that the distance of timber forwarding is the distance between the roadside landing and the point in the felling site when the bunk area is half loaded with timber (Nurminen et al. 2006). Accordingly, the mean distance of timber forwarding would be equal to the sum of travel distance of unloaded vehicle and half the travel in timber loading i.e. the travel between the loading points (Suvinen, 2006). According to Poršinsky (2002, 2005) and Stankić (2010) when investigating forwarders in Croatian lowland forests, the distance of timber forwarding was considered to be the arithmetic mean of the sum of distances travelled by fully loaded and unloaded forwarder, while the time consumption of the vehicle movement during loading process was defined depending on felling density, i.e. net timber volume per hectare. The forwarder classification is usually based on their loading capacity (payload) to light (<10 t), medium (10 t – 14 t) and heavy forwarders with the load capacity over 14 t (Brunberg, 2004).

Studies have shown also that the major determinants of forwarder productivity are extraction distance and load size (Spinelli et al., 2004; Tiernan et al., 2004; Ghaffariyan et al., 2012; Walsh and Strandgard, 2014). Other factors that have been found to impact forwarder productivity include log size (Kellogg and Bettinger, 1994; Plamondon and Pitt, 2013), log length (Gingras and Favreau, 2005), log pile size (Nurminen et al., 2006; Väätäinen et al., 2006), total wood volume (Nurminen et al. 2006) and assortment wood volume per strip road distance (Manner et al., 2013), number of assortments per load (Nurminen et al. 2006; Manner et al. 2013) and on the harvesting site, driving speed (Lileng, 2007) and slope (Tiernan et al., 2004).

Forwarders can be used on slope up to 45% (McEwan et al. 2013). The high centre of gravity restricts forwarders to operating up and down slope on steeper slopes (Visser and Stampfer, 2015) and the lack of traction restricts the maximum slope a forwarder can operate. Traction can be increased by using a forwarder with more wheels and using traction aids, such as band tracks (McEwan et al., 2013). Stangard et al. (2017) investigated performance of Valmet 890.3 on a slope terrain and cut-to-length harvesting system. They established productivity of 46 m^3/h and extraction distance and load volume as a statistically significant variable in productivity regression model. Slope did not have a significant impact on forwarder cycle time. The forwarder in this study had an 18 t nominal load capacity, and belongs to the group of heavy forwarders. That is one of the reasons for such a high productivity. Stankić et al. (2012) found that mean time consumption for heavy forwarders was 0.84 min/cycle, whereas for medium forwarders it amounted to 0.73 min/cycle. This phenomenon can be explained with the higher initial acceleration of medium forwarders. Additional time factor amounts to 1.33, or 33% of the effective time. Nurminen et al. (2006) also found extraction distance to be significantly related to travel empty time. Variation in loaded travel times was mainly due to the proportion of travel time that occurred in the stand, where travel speeds were significantly slower than on the trail. This proportion varied between cycles depending on the point in the stand at which the forwarder had collected a full load. Nurminen et al. (2006) also found that products with a lower log volume/ha had increased loading times as fewer logs were available at each loading stop. Moving during loading time has been found in some studies to be related to the loading distance, which in turn is dependent on the log concentration along the strip road (Nurminen et al., 2006; Manner et al., 2013).

The use of forwarders in Bosnia and Herzegovina is still in its initial phase. Although they are used sporadically, there are still many uncertainties about the operation of forwarders in selection stands. Especially if we take into account that the current practice is that machinery in the stand may only move along pre-defined routes, trail. This practice has been used for years with winch skidders. Forwarders require a different forest infrastructure if we want them to have competitive productivity. The goal of this research is to analyse the work of the HSM 208F forwarder that works in high forests in the mountainous area.

MATERIALS AND METHODS – *Materijal i metode*

Investigation was done in the area of municipality Ribnik, where state forests are managed by a company PFE "Šume Republike Srpske"; FA "Ribnik". Data collecting was done in compartment 10, which is located in the area of FU "Dimitor" (Table 1). The compartment has mountainous conditions, with an altitude of 1000-1300 m, a selective management system, and the dominant tree species is beech.

Table 1. Research site characteristics

Tabela 1. Karakteristike područja istraživanja

Forest Company	PFE "Šume Republike Srpske" FA "Ribnik" Ribnik
Compartment	10 FU "Dimitor"
Inclination	NW
Altitude	1000-1300 m
Soil	A combination of brown and acid brown soils on a series of silicate rocks
Stand	GK 1101 - High beech forests on deeply acidic silicate soils GK 4111 - Beech coppice forests on a series of predominantly deep limestone soils
Area	84.61 ha

The analysed forwarder is HSM 208F, owned by a private company that performs works for FA "Ribnik". HSM forwarder machines are available in various performance categories and versions. They feature a wide range of applications, long or short timber – hardwood or softwood – thick trees or thin. HSM has developed a modular system that permits the implementation of specific requirements. Medium-heavy forwarder HSM

Table 2. HSM 208F - specifications (www.hsm-forest.net)

Tabela 2. HSM 208F - specifikacije (www.hsm-forest.net)

Engine	Hydraulic system	Transmission	Loading area	Crane
VOLVO PENTA Power: 185 kW (252 HP) from 1600 rpm 1150 Nm from 1100 - 1500 rpm Max. torque: 1175 Nm at 1400 rpm Displacement: 7,7 liters	Load sensing Variable pump: flow rate: 304 l/min from 1600 rpm, pressure: up to max. 350 bar Hydraulic oil: saturated synthetic ester Panolin HLP SYNTH with Kleenoil microfiltration WGK 1	NAF 2 speed transfer gearbox; HSM High Speed Drive (series 71); speed at 1st gear 0-14 km/h	4 rungs Length: 4400 mm Cross section: 4,0 m^2 / Option 4,3 m^2 Load capacity: 11 t	EPSILON M70 F80 Lifting moment 102/68 kNm Range 8,0 m Gripper type FG43S

208F with eight wheels, has a nominal capacity of 11 t, whose overall dimensions and other characteristics are shown in the Figure 1. and Table 2. The weight distribution is such that 60% falls on the front and 40% on the rear axle. The cross-sectional area of the cargo area is 4.2 m^2, and the length is 4.4 m.

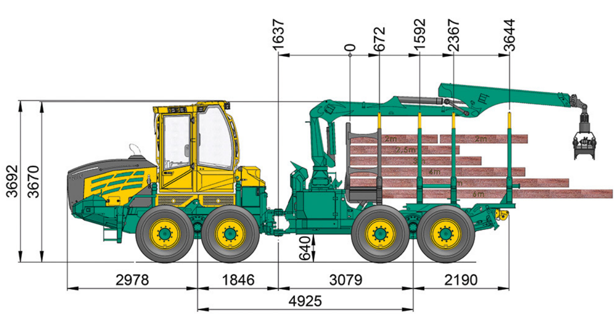


Figure 1. Dimensions of forwarder HSM 208F 11t (www.hsm-forest.net)

Slika 1. Dimenzije forvardera HSM 208F 11t (www.hsm-forest.net)

Extraction of timber by forwarders usually has the characteristics of cyclic work. Each cycle (turn) usually consists of five main work operations: unloaded drive, load collecting drive, loading, loaded drive and unloading. Other work components are added as an allowance time in the form of coefficient. The work and time study of forwarder was carried out by snapback collecting data method, using manual digital chronometer. Besides the time study, all factors influencing the work process were detected and measured. Forwarding distance was measured by hand GPS devices Garmin GPSMAP 62st.

Figure 2. Forwarder HSM 208F in the area FA "Ribnik" (Foto: Z. Bilaković)

Slika 2. Forvarder HSM 208F na području Š.G. "Ribnik" (Foto: Z. Bilaković)

RESULTS AND DISCUSSION – *Rezultati i diskusija*

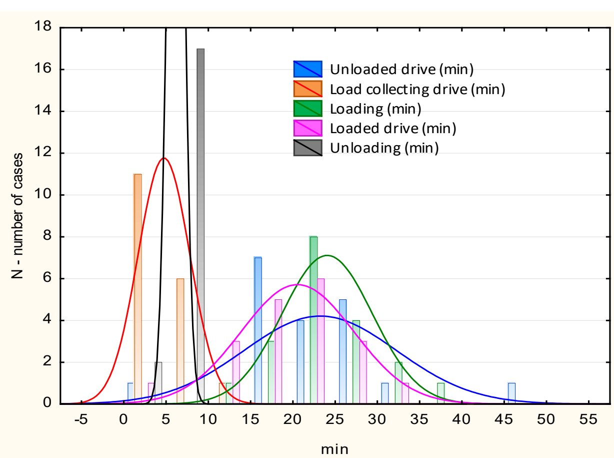
A total of 19 transport cycles were recorded. From the analysis of the work time structure, it can be seen that the work operations Unloaded drive, Loading, Loaded drive and Unloading were evidenced in all cycles and Load collecting drive was recorded in 18 cycles. In one cycle it was absent due to the fact that in that cycle the forwarder practically loaded all the timber in one place. In average, the work operation Load collecting drive took the shortest time, 4.7 min/cycle, with variations from 1 to 12.67 min. Unloading averaged 6.09 min/cycle, ranging from 4.5

Table 3. Productive work time

Tabela 3. Produktivno radno vrijeme

Work operation	N	Mean	Sum	Min	Max	Std.Dev.
Unloaded drive (min)	19	23.09	438.72	2.68	48.37	9.006
Load collecting drive (min)	18	4.70	84.53	1.00	12.67	3.050
Loading (min)	19	23.91	454.20	14.50	36.50	5.331
Loaded drive (min)	19	20.41	387.77	4.00	30.33	6.636
Unloading (min)	19	6.09	115.79	4.50	7.50	0.906
Cycle time (min/cycle)	19	77.95	1481.01	29.18	106.28	16.001

to 7.5 min. Loaded drive lasted an average of 20.41 min/cycle and Unloaded drive 23.09 min/cycle. The Loaded drive took less time than the Unloaded drive, which at first glance is contrary to expectations, but the explanation is that the movement routes did not match, as well as the fact that the Loaded drive was mostly downhill, and the Unloaded drive was uphill. Loading of wood is a work operation that lasted an average of 23.91 min/cycle, varying from 14.5 to 36.5 min (Table 3, Graph 1).

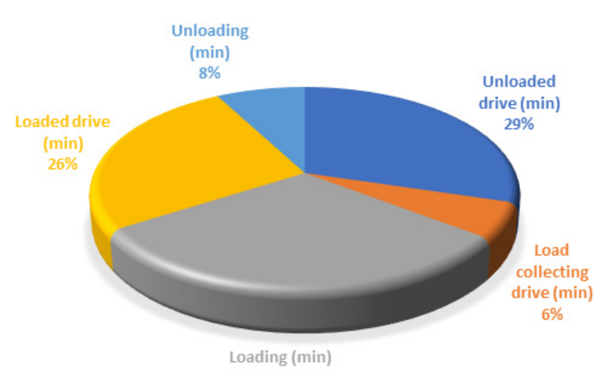


Graph 1. Distribution of duration work operations

Grafikon 1. Distribucija trajanja radnih operacija

The average productive time per cycle was 77.95 min, ranging from 29.18 to 106.28 min. The allowance time were recorded but not used for analysis due to the fact that the sample is relatively small and insufficient to objectively determine the share. For productivity calculation the coefficient 1.33, obtained in other, more extensive research under similar conditions was adopted (Stankić, 2010). However, the establishment of the allowance time factor is always subject of doubt because there are a large number of influencing factors. The higher the number of recordings, the more likely the allowance time will be credibly captured. This again contradicts the economics of conducting labor studies. A compromise is needed, where usually data from own and other researches are combined.

When looking at the relative share of work operations in productive work time, it can be seen that the largest share refers to Loading (31%), followed by Unloaded drive (29%) and Loaded drive (26%), and a significantly smaller share is spent on Unloading (8%) and Load collecting drive (6%) (Graph 2). Loading, Load collecting drive and Unloading account for 45% of working time, which is less than the 75% achieved by Manner et al., (2013), and Manner et al., (2016). The reason for that lies in the fact that in this case the wood was previously partially concentrated near the trails, with the cable skidder. Therefore, the forwarding distance is not always the main productivity factor, requiring an analysis of the factors that affect load formation and unloading (Stankić et al., 2012; Eriksson and Lindroos, 2014).



Graph 2. Relative share of work operations in productive work time

Grafikon 2. Relativni udio radnih operacija u produktivnom radnom vremenu

Table 4. Distance parameters

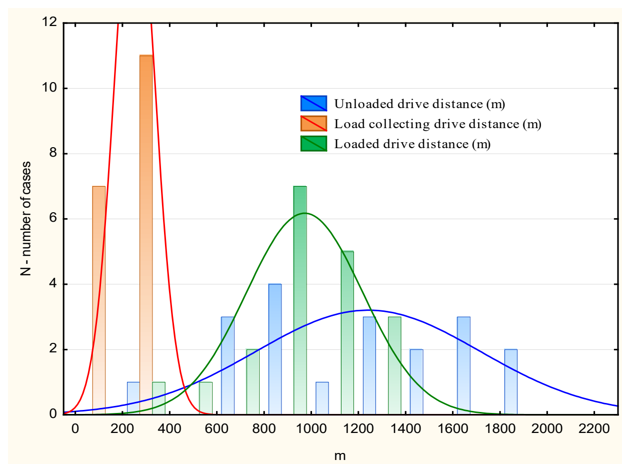
Tabela 4. Parametri distanci

Distance	N	Mean	Sum	Min	Max	Std.Dev.
Unloaded drive distance (m)	19	1234.74	23460.00	300.00	2000.00	472.915
Load collecting drive distance (m)	18	250.00	4500.00	100.00	400.00	85.612
Loaded drive distance (m)	19	966.84	18370.00	300.00	1300.00	245.471

Three forwarder movement distances were recorded, Unloaded drive distance, Load collecting drive distance and Loaded drive distance. The average distance of the Unloaded drive distance was 1234.74 m, and it varied from 300 to 2000 m. During the work operation Load collecting drive distance, the forwarder moved an average of 250 m per cycle, varying from 100 to 400 m. The Loaded drive distance was 966.84 m on average, varying from 300 to 1300 m (Table 4).

Load collecting drive distance depended on the distribution of assortments along the line of movement of the forwarder. Since the selective management system and selective cutting were used, the assortments were unevenly distributed throughout the felling site and along the lines of movement of the forwarder, so that the forwarder covered distances of 50 m and even up to 400 m to collect the full load. In most cases, the Loaded drive distance ranged from 600 to 1400 m. Essentially, these are shorter distances than the Unloaded drive due to the fact that the forwarder took routes when picking up the load and when loaded. Also, since the load was collected mostly by starting from the farthest point towards the landing site, part of the distance is covered during the collection itself, so that the distance of the Loaded drive is shortened. Distribution of distances is presented in Graph 3.

The average number of pieces in the load was 27.79, and it varied from 13 to 43. The average volume of the tour was 10.27 m^3, with a range of 8 to 12.1 m^3. The average volume of the piece was 0.4 m^3. In most cases, the load was uniform and the number of pieces ranged from 25 to 30 (Table 5).



Graph 3. Distribution of forwarder moving distances

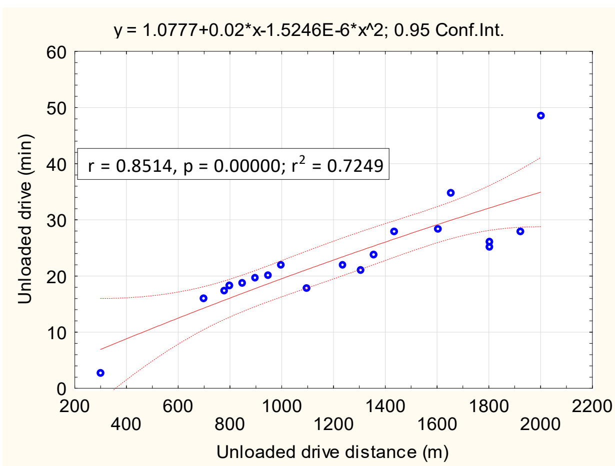
Grafikon 3. Distribucija distanci kretanja forvardera

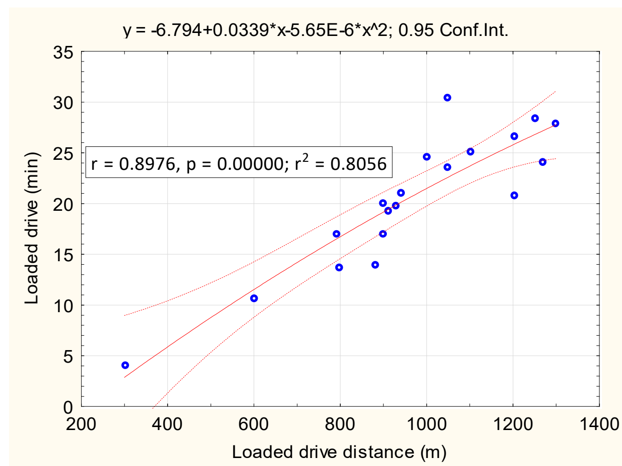
Examination of the influence of certain factors on the duration of work operations is carried out by regression analysis. In cases where statistically significant dependence was determined, a mathematical model was defined that was used to calculate standard times, and where no impact was determined, the mean value of the time achieved for that work operation was used. Regression models, correlations and level of significance are showed in Graphs 4-7. Unloaded drive showed dependence from Unloaded drive distance, presented with quadratic equation and R = 0.85. Load collection drive showed dependence from distance only and it is presented with quadratic equation and R = 0.80. Loaded drive showed dependence from Loaded drive distance, presented with quadratic equation and R = 0.90. Loading showed dependence from volume of piece, presented with linear equation and R = 0.45. Other examined factors did not have a statistically significant influence and are not shown. Work operation Unloaded did not show dependence on any factor and the mean achieved time of 6.09 min/cycle was used for further analysis.

Table 5. Load parameters

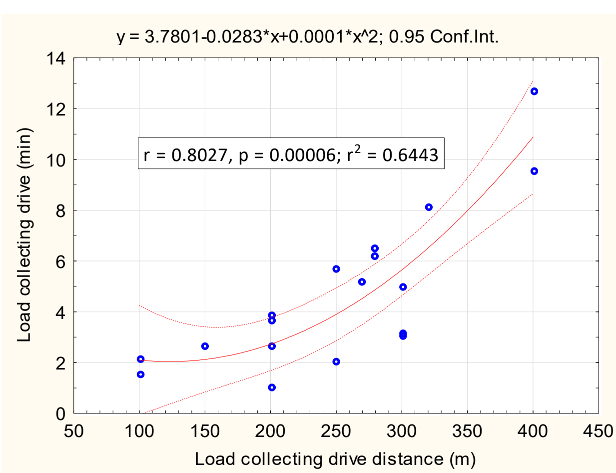
Tabela 5. Parametri tereta

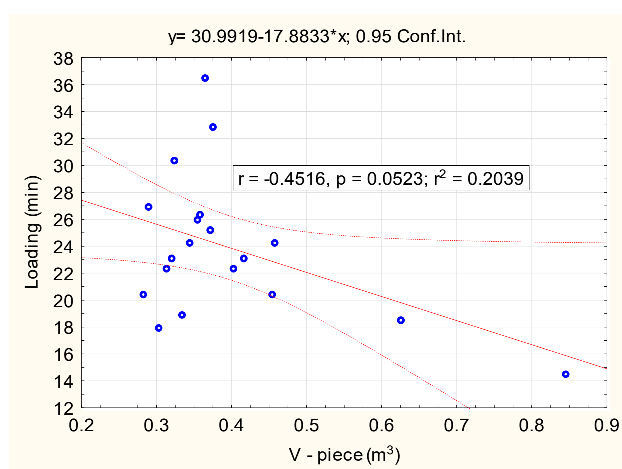
	N	Mean	Sum	Min	Max	Std.Dev.
Pieces/load	19	27.79	528.00	13.00	43.00	6.828
V (load) m^3	19	10.27	195.10	8.00	12.10	0.785
V (piece) m^3	19	0.40		0.28	0.85	0.135





a **c**

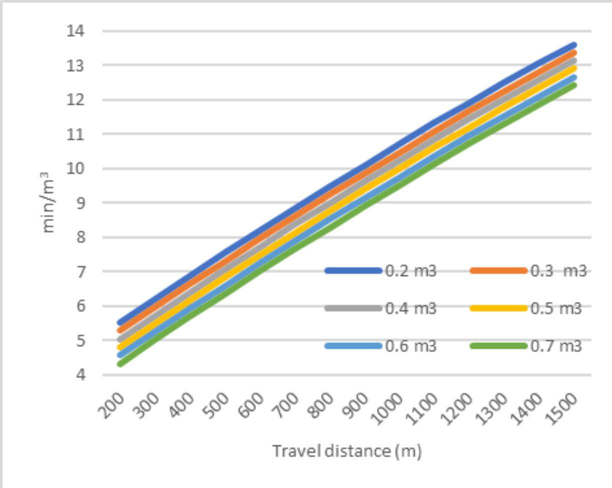




b **d**

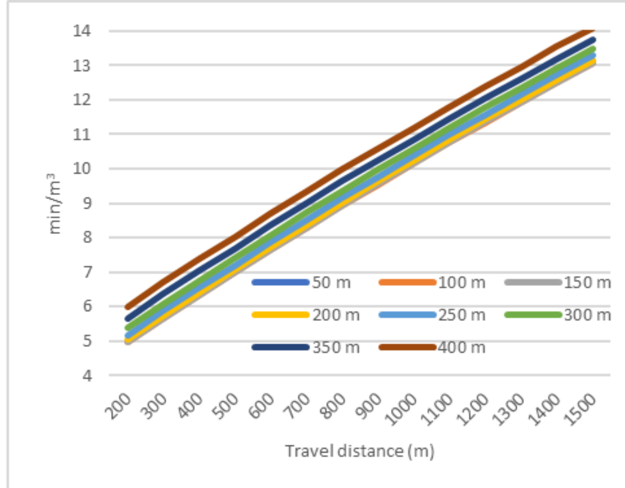
Graphs 4-7. a - Dependence of Unloaded drive from Unloaded drive distance; b - Dependence of Load collecting drive from Load collecting drive distance; c- Dependence of Loaded drive from Loaded drive distance; d - Dependence of Loading from V of piece.

Grafikoni 4-7. a - zavisnost prazne vožnje od distance prazne vožnje; b - zavisnost vožnje na prikupljanju tereta od distance vožnje na prikupljanju terete; c - zavisnost pune vožnje od distance pune vožnje; d - zavisnost utovara od V komada



Graph 8. Standard time (200 m Load collecting distance; 0.2-0.7 m³ piece size) Graph

Grafikon 8. Norma vremena (200 m distanca vožnje na prikupljanju tereta; 0.2-0.7 zapremina komada)



Graph 9. Standard time (0.4 m³ piece size; 50-400 m load collecting distance)

Grafikon 9. Norma vremena (0.4 m³ zapremina komada; 50-400 m distanca vožnje na prikupljanju tereta)

Standard time was calculated in the way that time for each work operation was calculated with regression equation for cases where significant dependence of influencing factors was established or using the average values if there was no dependence. The sum of work operation time was multiplied with allowance time coefficient and divided with the volume of transported load. Productivity is inverse value of standard time, adjusted to hourly. It was taken that the average load volume for HSM 208F is 10 m³, as determined in this research.

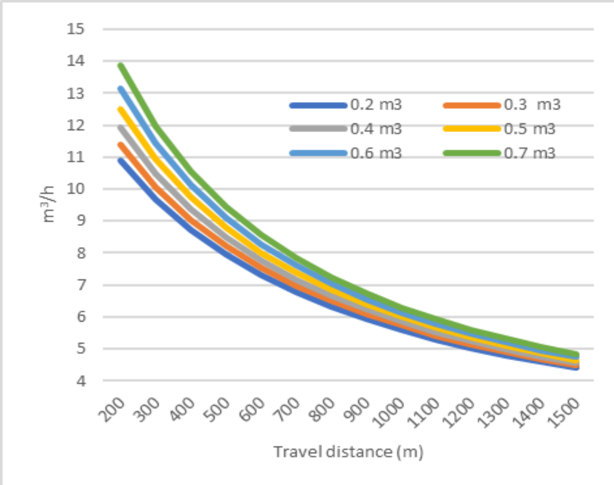
From Graphs 8-11 it can be seen that as the distances increases the time required to transport m³ of wood increases, that is, productivity declines. Mean load collecting drive distance and mean piece size also affect standard time and productivity, but to a lesser extent.

For example, for distance of 700 m and mean piece size of 0.4 m³, if the load collecting drive increase from 150 m to 400 m, productivity increase from 6.4 to 7.2 m³/h.

If we observe the change in productivity at a fixed distance of the load collecting drive (200 m) for travel distance of 700 m and at a different average volume of pieces, can be seen that productivity increases from 6.97 m³/h for 0.3 m³ piece to 7.84 m³/h for 0.7 m³ piece. Borz et al. (2021) investigated HSM 208F HVT-R2 forwarder and established for an average forwarding distance of about 1.5 km, net productivity and efficiency rates were estimated at 14.4 m³/h and 0.07 h/m³. Productivity is related to the availability of wood, and improvement is possible via better organization of tree felling and processing. Study of Proto et al. (2018) has indicated productivities in the range of 15 to 25 m³/h at extraction distance about 750 m. The same authors in case study developed in Calabria (Italy) indicated a productivity of about 15 m³/h for a John Deer 1110E, having a capacity of 12 t, that operated in selective cuts on a slope of 25%, which is comparable to this study, and for an average extraction distance of 700 m. Proto et al. (2017) have found productivities of 14.4 and 15.7 m³/h for extraction distances of approximately 300 and 600 m, respectively, for two John Deere machines (1110D and 1010D) operating on slopes of 26 and 29%, respectively. Pandur et al. (2018) found a productivity of approximately 18 m³/h on flat terrain and the extraction distance about 1.1 km. For steep terrain and an extraction distance of 0.8 km, Dinev et al. (2015) found productivities of 44–53 m³/day. For an extraction distance of 1.1 km, a payload of 12–13 m³ Slamka and Radocha (2010) found a productivity of 11 m³/h on mild to moderate slopes. Comparing the results obtained in this research with the results of other research presented here, it can be said that the productivity is comparable in some cases and in some cases, it is lower. The reason lies partly in the difficult terrain conditions, and partly in the fact that due to selective cutting and regulations, the forwarder had to move on the trails and could not search for the optimal route to the load.

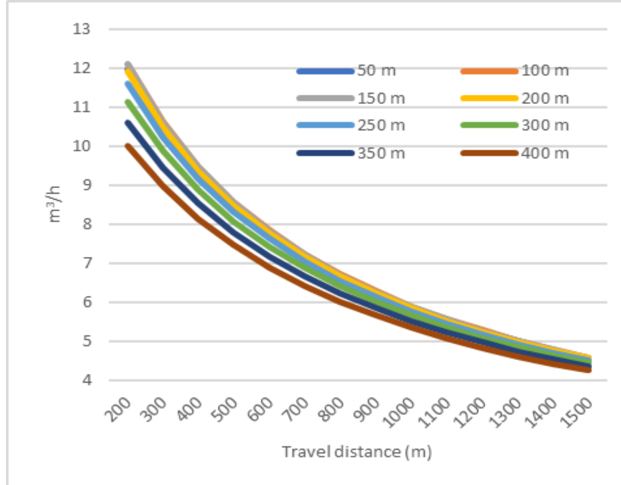
CONCLUSIONS – *Zaključak*

While the original system consisted of a harvester and a forwarder, for many reasons that affect the level of mechanization, such as the regulatory system, forest type, acceptability of practices and intensity of extracti-



Graph 10. Productivity (200 m Load collecting distance; 0.2-0.7 m^3 piece size)

Grafikon 10. Produktivnost (200 m distanca vožnje na prikupljanju tereta; 0.2-0.7 zapremina komada)



Graph 11. Productivity (0.4 m^3 piece size; 50-400 m load collecting distance)

Grafikon 11. Produktivnost (0.4 m^3 zapremina komada; 50-400 m distanca vožnje na prikupljanju tereta)

ons, in some parts of the world, forwarders are used today in partly mechanized systems that integrate motor-manual felling and processing of trees (Vusić et al. 2013). This is also the case in this research. Forwarders can successfully replace or supplement the skidders in the first phase of wood transportation, even in selective felling, but it is necessary to properly prepare the infrastructure in the compartments. In addition to the skid trails, which are the basis of the secondary opening, it is necessary to mark the lines between the skid trails that the forwarders could use to collect the wood.

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SAŽETAK

Forvarderi su samohodna vozila namjenjena za transport drveća ili njegovih dijelova utovarenih u tovarni prostor. U različitim zemljama, forvarderi se koriste na različite načine. Na primjer, u hrvatskom šumarstvu uglavnom se koriste u ravničarskim šumama, posebno za izvoz drveta iz oplodne sječe i kasnih proreda (Poršinski, 2002). Upotreba forvardera u Bosni i Hercegovini je još u početnoj fazi. Iako se koriste sporadično, još uvek postoje mnoge nejasnoće u vezi s njihovim radom u prebirnim sastojinama. Pogotovo ako se ima u vidu da je dosadašnja praksa da se mehanizacija u sastojini može kretati samo po unapred definisanim vlakama, koja se godinama koristi kod skidera sa vitlom još uvijek standardna. Forvarderima je potrebna drugačija šumska infrastruktura ako se želi postići konkurentna produktivnost. Cilj ovog istraživanja je analiza rada forvardera HSM 208F koji radi u prebirnim sastojinama u planinskom području. Istraživanje je vršeno na području opštine Ribnik, gdje državnim šumama gazduje preduzeće JPŠ "Šume Republike Srpske", ŠG "Ribnik". Prikupljanje podataka je vršeno u odjelu 10, koji se nalazi u prostoru PJ „Dimitor" (Tabela 1). Odjel ima planinske uslove rada, sa nadmorskom visinom od 1000-1300 m, prebirnim sistemom gazdovanja, a dominantna vrsta drveća je bukva. Analizirani forvarder HSM 208F je vlasništvo privatne firme koja izvodi radove za ŠG „Ribnik". Snimljeno je ukupno 19 transportnih ciklusa. Iz analize strukture radnog vremena vidi se da su radne operacije Prazna vožnja, Utovar, Puna vožnja i Istovar evidentirane u svim ciklusima, a Vožnja na prikupljanju tereta evidentirana je u 18 ciklusa. U prosjeku, radna operacija Vožnja na prikupljanju tereta trajala je najkraće, 4,7 min/ciklus, sa varijacijama od 1 do 12,67 min. Istovar je u prosjeku iznosio 6,09 min/ciklus, u rasponu od 4,5 do 7,5 min. Puna vožnja trajala je u proseku 20,41 min/ciklus, a Prazna vožnja 23,09 min/ciklus. Prosečna distanca prazne vožnje iznosila je 1234,74 m, a varirala je od 300 do 2000 m. U toku rada na prikupljanju tereta, forvarder se kretao u prosjeku 250 m po ciklusu, varirajući od 100 do 400 m. Dužina pune vožnje bila je u prosjeku 966,84 m, varirajući od 300 do 1300 m. Prosječan broj komada u teretu iznosio je 27,79, a varirao je od 13 do 43. Prosječna zapremina ture iznosila je 10,27 m^3, sa rasponom od 8 do 12,1 m^3. Prosječna zapremina komada bila je 0,4 m^3. U većini slučajeva teret je bio ujednačen i broj komada se kretao od 25 do 30 (Tabela 5). Ispitivanje uticaja pojedinih faktora na trajanje radnih operacija vršeno je regresionom analizom. Prazna vožnja je pokazala zavisnost od distance prazne vožnje, predstavljenu kvadratnom jednačinom i R = 0,85. Vožnja na prikupljanju tereta je pokazala zavisnost samo od distance i predstavljena je kvadratnom jednačinom i R = 0,80. Puna vožnja je pokazala zavisnost od distance, predstavljenu kvadratnom jednačinom i R = 0,90. Utovar je pokazao zavisnost od zapremine komada, predstavljeno linearnom jednačinom i R = 0,45. Ostali ispitani faktori nisu imali statistički značajan uticaj i nisu prikazani. Radna operacija Istovar nije pokazala zavisnost ni od jednog faktora, a za dalju analizu je korišćeno srednje postignuto vreme od 6,09 min/ciklus. Iz grafikona 8-11 se može vidjeti da se povećanjem distance povećava vrijeme potrebno za transport m^3 drveta, odnosno produktivnost opada. Srednje rastojanje za prikupljanje tereta i srednja zapremina komada takođe utiču na normu vremena i produktivnost, ali u manjoj mjeri. Forvarderi mogu uspješno zamijeniti ili dopuniti skidere u prvoj fazi transporta drva, čak i u prebirnoj seči, ali je potrebno pravilno pripremiti infrastrukturu u odjelima. Pored vlaka, koje su osnova sekundarnog otvaranja, potrebno je obilježiti linije između vlaka koje bi forvarderi mogli koristi za prikupljanje drveta.

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