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Determination of the Weights of Technical Criteria Influencing the Performance of Petrol-Powered and Battery Powered Chainsaws by Means of the Entropy Method

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Abstract

Chainsaws are widely used in the tree cutting phase of wood harvesting activity in forest operations. In general, there are two types of chainsaws: petrol-powered and battery-powered. The performance of petrol and battery-powered chainsaws is affected by different factors, including moisture content of the wood, the tree species, environmental conditions, the experience of the operator, and the different technical characteristics of the chainsaw (power, weight, chain rotation speed, and bar length). This study aims to determine the weight of technical criteria affecting performance of petrol-powered chainsaws and battery-powered chainsaws. In the study, the entropy method was used for weight determination of the criteria. As technical criteria, chain speed at maximum power, total cylinder capacity, power, bar length, chain pitch, and weight criteria were taken into consideration for petrol-powered chainsaws. In battery-powered chainsaws, chain speed at maximum power, bar length, chain pitch, weight, and battery voltage criteria were considered. When the weight values of the technical criteria are evaluated in general, the most important performance criterion in petrol-powered chainsaws is the power criterion, while the chain speed at maximum power criterion in battery-powered saws. Based on that the power factor is the important for both chainsaws. In general, the results of this study will be beneficial for users to know how effective the technical criteria are in terms of performance in the alternative selection of different types of chainsaws, which are frequently used in different activities such as during the tree cutting phase in forest operations, pruning, and garden maintenance in urban areas.

Keywords: Forest operations, logging, multicriteria-decision making method, wood harvesting.

1. Introduction

Wood harvesting, which is one forestry activity, includes different activities such as planning, tree felling, and skidding logs to landings as well as further transport of wood (Czyzowski et al., 2022). In the tree felling stage, chainsaws are widely used (Gulci et al., 2016; Bernardi et al., 2022; Antonić et al., 2023). In relation to that, Soenarno et al. (2022) stated that the ease of maintenance and operation of chainsaws reduces felling costs by increasing efficiency and effectiveness due to their high workability. Besides forestry, chainsaws are used in homes, gardens, agriculture, arboriculture, construction, and rescue activities; therefore, they are seen as cross-sectoral (Poje et al., 2018). There are two types of chainsaws: petrol-powered chainsaws and battery-powered chainsaws. According to Rukat et al. (2022), petrol-powered chainsaws are the most commonly used tool in logging activity. When examining the use of chainsaws in general, petrol-powered chainsaws are preferred mainly in forestry, while another type of chainsaws, battery-powered chainsaws, are used almost exclusively for professional garden maintenance and hobby purposes (Neri et al., 2022; Tomczak and Naskrent, 2022).

There are different factors affecting the performance of petrol-powered chainsaws and battery-powered chainsaws. These include the moisture content of the wood, the tree species, environmental conditions, the experience of the operator, and the different technical characteristics of the chainsaw such as power, weight, chain rotation speed, and bar length. Most of the previous studies are evaluated the performance out of the chainsaw depending on its technical characteristics. A study by Antonić et al. (2023) evaluated the effect of chainsaw power on fuel and oil consumption using two different petrol-powered chainsaws with different technical characteristics (cylinder capacity, power, bar length, and weight). The study results indicated that using two chainsaws with different powers instead of two large chainsaws save 26% in fuel consumption and 24% in oil consumption. Poje and Mihelič (2020) examined the effects of chain sharpness, tension setting, and

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battery-powered chainsaw type on energy consumption and cross-cutting time in battery-powered chainsaws. In another study, Pandur et al. (2023) compared the energy consumption and cutting performance of electric saws with three different technical features (weight, power, bar length, chain type, and chain speed), and the findings stated that more powerful chainsaw/battery combinations consumed less energy per cut and had better cutting performance. It indicated that high chain rotation speed reduces cutting time, and smaller chainsaws is suitable for cutting performance due to their low weight for small jobs such as pruning in urban areas. Otto and Parmigiani (2018) evaluated the cutting performance of low-kickback saw chains. Kaliniewicz et al. (2018) conducted a study focusing on the effect of chain type and wood species on kickback angle in chainsaws. Neri et al. (2022) evaluated the battery and petrol-powered chainsaws, which include three different technical characteristics (i.e., power, saw-bar length, chain pitch, chain speed, and total weight) regarding cutting time performance. The results showed that battery-powered chainsaws had a lower cutting performance than petrol-powered chainsaws compared to battery and petrol-powered chainsaws with similar power and weight. Marenče et al. (2017) conducted a study focusing on the cross-cutting efficiency and health risks of chain filing, tree species, and chain type for chainsaws, and the results stated that cutting chain selection and proper chain preparation are important in terms of high efficiency and reducing health risks. In another study, Laschi et al. (2023) compared the efficiency of the latest modes of electric and petrol-powered chainsaws on the conifer clear-cut site using two different chainsaws with different technical characteristics.

These previous studies concluded that battery powered and petrol-powered chainsaws have different technical characteristics that affect their performance. These technical characteristics can affect the performance of chainsaws, and accordingly, the efficiency may change. Hence, it is important to determine the importance of different technical characteristics in terms of alternatives when selecting electric and petrol-powered chainsaws; in other words, it is important to determine their criterion weights. Several methods have been introduced to determine these weights over the last few decades. These are objective and subjective methods. In subjective methods, weights are determined according to the preferences of decision-makers based on their knowledge and experience, which neglects objective information (Odu, 2019; Lescauskiene et al., 2020). In objective methods, mathematical models or algorithms are used based on preliminary research data, and decision-makers are not included in weight determination. Thus, different opinions are ignored (Kumar et al., 2021). Entropy method, one of the objective criterion weight evaluation methods, is widely used in evaluating weights such as flood risk assessment (Sun et al., 2020; Wu et al., 2022), sediment risk assessment (Akay et al., 2023), building energy performance assessment (Wang et al., 2017), material selection (Goswami and Behera, 2021), energy technology selection (Alao et al., 2020). The main advantage of the entropy method is that it can objectively calculate the weight of each criterion by taking into account the sample observation value of the criterion (Chen et al., 2015). Additionally, the method is relatively easy to use as the existing data in the decision matrix is used to weigh the criterion, and no further subjective judgement is required (Özgüner and Özgüner 2020).

In this context, this study aims to determine the weight of technical criteria that affect the performance of petrol-powered and battery-powered chainsaws. The Entropy objective weight determination method was used as the weight calculation method.

2. Materials and Methods

In the study, the weight values for technical factors, in other words, technical criteria that affect chainsaw performance, were determined. In this stage, the entropy method, which is objective weight method, was used. The Entropy method analysis was performed using the Microsoft Excel 2016. In the study, chainsaws are categorized into two types: petrol-powered chainsaws and battery-powered chainsaws. Technical criteria and their descriptions for both types are provided in Table 1. The technical specifications for two types of chainsaws were obtained from the Husqvarna brand's website (Husqvarna, 2024). Relevant criteria values were given in Tables 2 and 3 for petrol-powered chainsaws and battery-powered chainsaws, respectively.

In determining the weight of technical criteria of petrol-powered chainsaws using the entropy method, chain speed at maximum power (C1), total cylinder capacity (C2), power (C3), bar length (C4), chain pitch (C5), and weight (C6) criteria were used for the relevant chainsaw brand. Similarly, for battery-powered chainsaws, the criteria of chain speed at maximum power (C1), bar length (C4), chain pitch (C5), weight (C6), and battery voltage (C7) are taken into account. In the study, as for the number of chainsaw alternatives, a total of 12 alternatives for the relevant chainsaw brand for petrol-powered chainsaws and four alternatives for battery-powered chainsaws were considered.

2.1. Entropy Method

The Entropy concept proposed by Shannon handles uncertain information and missing data (Shannon, 1948). The Entropy method involves the following number of steps.

Step 1: Creation of the decision matrix:

$$X=\begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix} \quad (1)$$

Table 1. Technical criteria and their descriptions for petrol-powered chainsaws and battery-powered chainsaws

Technical Criteria	Descriptions	References
Chain speed at maximum power (m/s) (C1)	Chainsaw chain rotation speed at maximum power	Neri et al. (2022) Poje and Mihelič (2020)
Total cylinder capacity (cm^3) (C2)	Chainsaw total cylinder volume	Antonić et al. (2023)
Power (kw) (C3)	Value of chainsaw power output	Antonić et al. (2023) Poje and Mihelič (2020) Maciak et al. (2017)
Bar length (cm) (C4)	Chainsaw blade length	Ciubotaru and Câmpu (2018)
Chain pitch (inch) (C5)	Chainsaw chain tooth size	Pandur et al. (2023) Kaliniewicz et al. (2018) Poje and Mihelič (2020) Marenče et al. (2017)
Weight (kg) (C6)	Weight without cutting equipment and weight without cutting equipment and battery for petrol-powered and battery-powered chainsaws, respectively	Poje and Mihelič (2020) Pandur et al. (2023)
Battery voltage (V) (C7)	Batter voltage value for battery-powered chainsaws	Pandur et al. (2023)

Table 2. Technical criteria values for petrol-powered chainsaws

Petrol-powered Chainsaw Alternatives	Technical Criteria					
Brand and model	Chain speed at maximum power (m/s)	Total cylinder volume (cm^3)	Power (kw)	Bar length (cm)	Chain pitch (inch)	Weight (kg)
Husqvarna 120 Mark II (A1)	16.8	38.2	1.4	40	0.375	4.85
Husqvarna 445 (A2)	17.3	45.7	2.1	45	0.325	4.9
Husqvarna T525 (A3)	18.1	27	1.1	25	0.375	2.7
Husqvarna 450 (A4)	17.3	50.2	2.4	45	0.325	4.9
Husqvarna 543 XP (A5)	18.5	43.1	2.2	38	0.325	4.5
Husqvarna 550 XP Mark II (A6)	19.6	50.1	3	45	0.325	5.3
Husqvarna 365 X-Torq (A7)	22.7	70.7	3.6	50	0.375	6.4
Husqvarna 562 XP (A8)	21.3	59.8	3.5	50	0.375	6.1
Husqvarna 372 XP-Torq (A9)	22.7	70.7	4.1	50	0.375	6.6
Husqvarna 585 (A10)	23	86	5.1	60	0.375	7.5
Husqvarna 572 XP (A11)	22	70.6	4.3	50	0.375	6.6
Husqvarna 592 XP (A12)	23	92.7	5.6	60	0.375	7.4

Table 3. Technical criteria values for battery-powered chainsaws

Battery-powered Chainsaw Alternatives	Technical Criteria				
Brand and model	Chain speed at maximum power (m/s)	Bar length (cm)	Chain pitch (inch)	Weight (kg)	Battery voltage (V)
Husqvarna 120i (A1)	11.5	30	0.375	2.95	36
Husqvarna 330i (A2)	15	30	0.375	2.70	36
Husqvarna 535i XP (A3)	20	35	0.325	2.60	36
Husqvarna t535i XP (A4)	20	35	0.325	2.40	36

In Equation 1, x_{ij} is the evaluated value of i^{th} alternative on j^{th} criterion; *i* = 1. 2. …. *m; j = 1. 2. …. n.*

Step 2: Normalizing the standard decision-matrix using Equation 2:

$$f_{ij}=\frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \quad (2)$$

where f_{ij} is the normalized value of data of the standard decision-making matrix.

Step 3: Calculating the Entropy coefficient for each criterion using Equation 3 and Equation 4:

$$E_j=-k\sum_{i=1}^{n} f_{ij} ln f_{ij} \quad (3)$$

$0 \le E_j \le 1$

In which; entropy coefficient (*k*) is;

$$k=1/\ln(m) \quad (4)$$

Step 4: Calculating the Entropy objective weight (w_j) using Equation 5 and Equation 6:

$$d_j=1- E_j \quad (5)$$

$$w_j=\frac{1-E_j}{\sum_{j=1}^{n}(1-E_j)} \quad (6)$$

where $\sum_{j=1}^{n} w_j = 1$

3. Results and Discussion

In the study, , the weights of the technical criteria affecting the performance of petrol-powered chainsaws were obtained using the Entropy method. Accordingly, results obtained using the Entropy method steps were presented below. Equation 1 was used to create a decision matrix of relevant technical criteria and alternatives for petrol-powered chainsaws. (Table 4). The decision-making matrix was obtained and normalized using Equation 2. The normalized decision-making matrix results were listed in Table 5.

Table 4. Decision making matrix for petrol-powered chainsaws

Chainsaw Alternatives	C1	C2	C3	C4	C5	C6
A1	16.8	38.2	1.4	40	0.375	4.85
A2	17.3	45.7	2.1	45	0.325	4.90
A3	18.1	27	1.1	25	0.375	2.70
A4	17.3	50.2	2.4	45	0.325	4.90
A5	18.5	43.1	2.2	38	0.325	4.50
A6	19.6	50.1	3	45	0.325	5.30
A7	22.7	70.7	3.6	50	0.375	6.40
A8	21.3	59.8	3.5	50	0.375	6.10
A9	22.7	70.7	4.1	50	0.375	6.60
A10	23	86	5.1	60	0.375	7.50
A11	22	70.6	4.3	50	0.375	6.60
A12	23	92.7	5.6	60	0.375	7.40

Table 5. Normalized decision-making matrix

Chainsaw Alternatives	C1	C2	C3	C4	C5	C6
A1	0.0693	0.0542	0.0364	0.0716	0.0872	0.0715
A2	0.0713	0.0648	0.0546	0.0806	0.0755	0.0723
A3	0.0747	0.0383	0.0286	0.0448	0.0872	0.0398
A4	0.0713	0.0712	0.0625	0.0806	0.0755	0.0723
A5	0.0763	0.0611	0.0572	0.0681	0.0755	0.0664
A6	0.0808	0.0710	0.0781	0.0806	0.0755	0.0782
A7	0.0936	0.1003	0.0937	0.0896	0.0872	0.0944
A8	0.0879	0.0848	0.0911	0.0896	0.0872	0.0900
A9	0.0936	0.1003	0.1067	0.0896	0.0872	0.0974
A10	0.0949	0.1220	0.1328	0.1075	0.0872	0.1107
A11	0.0907	0.1001	0.1119	0.0896	0.0872	0.0974
A12	0.0949	0.1315	0.1458	0.1075	0.0872	0.1092

After obtaining normalized decision matrix, Entropy values were calculated using Equation 3 and Equation 4 for relevant criteria and alternatives (Table 6). In the next stage, the entropy coefficient k = 1/ln(12) = 0.4024 was calculated for the uncertainty values. Accordingly, uncertainty values (ej) and diversification values (dj) were calculated, and the results were given in Table 7. In the last stage of the entropy method, the weight values of the technical criteria were calculated using Equation 6. Technical criteria weight values obtained were given in Table 8.

Table 6. Entropy values

Chainsaw Alternatives	C1	C2	C3	C4	C5	C6
A1	-0.1850	-0.1580	-0.1207	-0.1889	-0.2127	-0.1887
A2	-0.1884	-0.1773	-0.1589	-0.2030	-0.1951	-0.1899
A3	-0.1937	-0.1249	-0.1017	-0.1391	-0.2127	-0.1284
A4	-0.1884	-0.1881	-0.1732	-0.2030	-0.1951	-0.1899
A5	-0.1964	-0.1708	-0.1638	-0.1829	-0.1951	-0.1801
A6	-0.2034	-0.1879	-0.1991	-0.2030	-0.1951	-0.1993
A7	-0.2218	-0.2306	-0.2219	-0.2161	-0.2127	-0.2228
A8	-0.2137	-0.2093	-0.2183	-0.2161	-0.2127	-0.2167
A9	-0.2218	-0.2306	-0.2388	-0.2161	-0.2127	-0.2268
A10	-0.2235	-0.2566	-0.2681	-0.2397	-0.2127	-0.2436
A11	-0.2178	-0.2304	-0.2451	-0.2161	-0.2127	-0.2268
A12	-0.2235	-0.2668	-0.2807	-0.2397	-0.2127	-0.2418

Table 7. Uncertainty and diversification values

	C1	C2	C3	C4	C5	C6
ej	0.9971	0.9786	0.9621	0.9917	0.9991	0.9881
dj	0.0028	0.0213	0.0378	0.0082	0.0008	0.0118

Table 8. Technical criteria weight values for petrol-powered chainsaws

	C1	C2	C3	C4	C5	C6
Weight Values (w)	0.0342	0.2567	0.4558	0.0996	0.0106	0.1427

When examining the results for the petrol-powered chainsaws, it can be seen that the most important criterion is the power (C3) (0.4558). This weight value is followed by total cylinder capacity (C2) (0.2567), weight (C6) (0.1427), bar length (C4) (0.0996), chain speed at maximum power (C1) (0.0342), and chain pitch (C5) (0.0106) (Table 8) (Figure 1). As given in Table 8, the three most important technical criteria for petrol-powered chainsaws are power, total cylinder capacity and weight criteria. Antonić et al. (2023) stated that the power of the chainsaw has an impact on fuel and oil consumption. Jourgholami et al. (2013) emphasized that chainsaw productivity increases with tree diameter at breast height as a power relationship.

Similar to our results, Maciak et al. (2017) emphasized that high chainsaw horsepower significantly impacts cutting efficiency and thus leads to increased performance. On the other hand, the high cubic capacity and power increase fuel consumption. Similarly, the five relevant technical criteria and their weight values were calculated for battery-powered chainsaws. The results for technical criterion weight values for battery-powered chainsaws are shown in Table 9.

When examining the technical criteria weights for battery-powered chainsaws, the most crucial criterion is the chain speed at maximum power (C1) (0.7455). It is followed by bar length (C4) (0.0910), weight (C6) (0.0848), chain pitch (C5) (0.0785) and battery voltage (C7) (0.0000) (Table 9) (Figure 2). As can be seen, the first three important technical criteria are chain speed at maximum power, bar length, and weight. In this context, Pandur et al. (2023) stated that power, high chain rotation speed, and weight factors affect the performance of battery-powered chainsaws. Poje and Mihelič (2020), in their study, stated that the reason for low efficiency in battery-powered chainsaws was due to the power of the chainsaw used and the low chain rotation speed. Similarly, Pandur et al. (2023) pointed out that low chain rotation speed factor in battery-powered chainsaws increases the cutting time and causes a decrease in efficiency. In addition, Otto and Perrmigiani (2015) stated that changes in chain speed affect the cutting force and, thus, affect energy consumption. On the other hand, in another study, Colantoni et al. (2016) indicated that chainsaws that increase performance and extended bar length due to high engine power in relation to the weight of the chainsaw will be suitable for forest use.

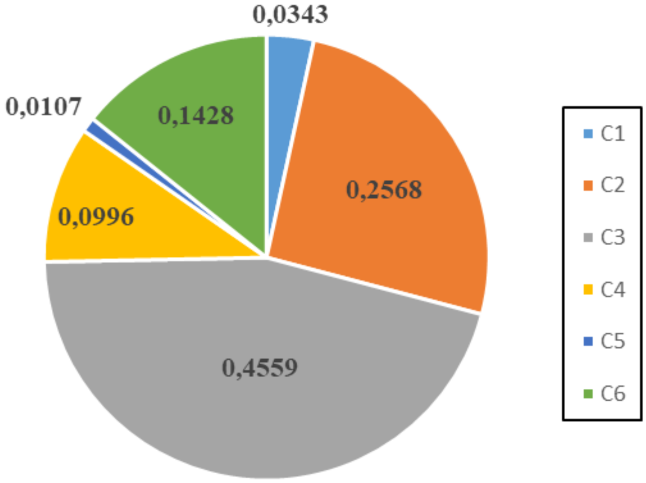

Figure 1. Distribution of technical criteria weight values for petrol-powered chainsaws

Table 9. Technical criteria weight values for battery-powered chainsaws

	C1	C4	C5	C6	C7
Weight values (w)	0.7455	0.0910	0.0785	0.0848	0.0000

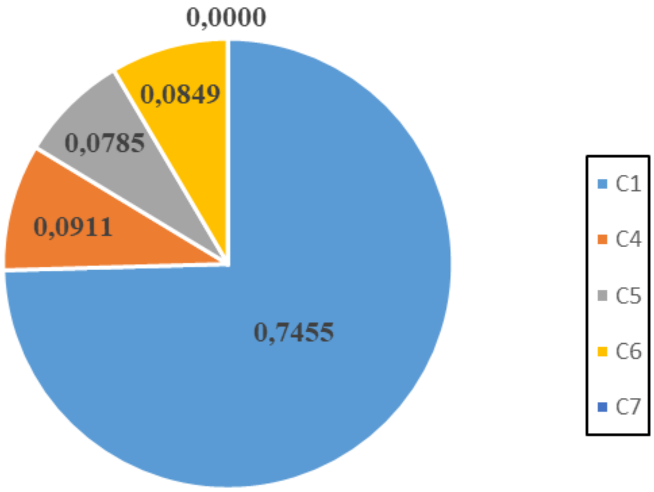

Figure 2. Distribution of technical criteria weight values for battery-powered chainsaws

4. Conclusion

In this study, technical criteria weights that affects chainsaws (petrol-powered and battery-powered) performance were determined. When the weight values of the technical criteria are evaluated, it has been concluded that power is the most important performance criterion in petrol-powered chainsaws. In contrast, the chain speed is at maximum power in battery-powered chainsaws. This situation reveals the importance of the power factor for both chainsaws. The Entropy method, which is an objective criterion weighting method, was used in the study. For future studies, the results can be obtained using different objective and/or subjective weighting methods, and then relevant results can be compared with the results of this study. Thus, the effect of method differences on criterion weights can be determined. In general, the results obtained from the study will be beneficial for users to know how effective the technical criteria are in terms of performance in the alternative selection of different types of chainsaws, which are frequently used in different activities such as during the tree cutting phase in forest operations, pruning and garden maintenance in urban areas. Moreover, the study will positively affect effective decision-making in the selection of different equipment for large-scale forest operations.

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