AN EFFICIENCY INDEX FOR SELECTION OF BRUSH WEED CUTTER

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The brush weed cutters tested at Rubber Research Institute of India were ranked based on the comparative performance from a techno-economic perspective. The parameters used for evaluvating the brush weed cutters were assigned weights by expert judgement method and statistical method. The statistical method of assigning weights is preferred due to its unbiased nature. The final rankings of the weed cutters were influenced by the changes in weights given by the methods.

Keywords: Efficiency index, Expert judgement, Ranks, Statistical method, Weights

Various machineries and products are tested and certified by the Rubber Research Institute of India (RRII) for their performance. Though the selection and certification of machineries/products are based on certain parameters, no scientific attempt has been made to compare the performance from a techno-economic perspective. The construction of an efficiency index is useful for an in-house understanding on the comparative performance and for commercial application depending on the requirements.

This paper is a preliminary attempt to develop an index for comparison and ranking of brush weed cutters using their field test results.

The relevant data were obtained from the test results of brush weed cutters conducted in Central Experiment Station (CES), Chethackal of RRII. The data included price of the cutters, fuel consumption, thread consumption, time taken to weed per unit area, weight of the equipment, fuel tank capacity, type of engine (2/4stroke) and working conditions.The following steps were involved in the construction of index:

- The parameters of different units/ scales were normalized.
- An index was constructed by signing weights to the parameters.
- Weights to the parameters were assigned in two ways, *viz.*,
  (i) Expert judgment method
  (ii) Using statistical methods.
- The weights were multiplied with the normalized scores of parameters to obtain the index.
- The brush cutters were ranked based on the indices.

Table 1 provides the data as recorded at CES, Chethackal against the parameters considered. The methodology used in UNDP's Human Development Index

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Table 1. **Parameters considered for evaluation of brush weed cutters**

Cutters*	Cost of the equipment (Rs)	Stroke	Fuel consumption (L ha^{-1})	Thread consumption (m ha^{-1})	Time taken to weed ha h^{-1}	Jerks at high speed	Weight of the equipment (kg)	Fuel tank capacity (mL)
WP	17400	4	7.13	13.2	11.71	No	7.2	750
MB	15000	2	9.00	10.00	10.00	No	8.0	900
OM	35700	4	10.2	15.90	11.30	No	8.1	1500
SM4	25500	4	7.41	14.30	11.40	No	8.0	650
SM2	19500	2	8.75	12.10	11.00	Yes	8.0	900

* Codes are given instead of commercial names of the cutters for the purpose of anonymity.

(UNDP, 2006) was used to normalize the data. The normalised scores are obtained by using the following formula based on the functional relationship of the parameters considered with the selection of the equipment

(a) When a positive relationship was expected between the parameter and selection of the equipment, then

$$Yid = (Xid - MinXid)/(MaxXid - MinXid)$$

(b) When a negative relationship was expected between parameter and selection of the equipment

$$Yid = (MaxXid - Xid)/(MaxXid - MinXid)$$

Where,

Yid = Normalised score of the indicator

Xid = Value of the indicator

MaxXid = Maximum value of the indicator

MinXid = Minimum value of the indicator

Table 2. **Functional relationship of parameters**

Parameter	Functional relationship
Cost of the equipment	↓
Engine Stroke	↑
Fuel consumption	↓
Thread consumption	↓
Time taken to weed per ha	↓
Jerks at high speed	↓
Weight of the equipment	↓
Fuel tank capacity	↑

The functional relationship between the parameters considered and selection of the equipment is furnished in Table 2. Based on the functional relationship, the normalized scores for the parameters were worked out and furnished in Table 3.

Table 3. **Normalized scores of the parameters**

Cutter	Cost of the equipment	Stroke	Fuel consumption (L ha^{-1})	Thread consumption (m ha^{-1})	Time taken to weed ha h^{-1}	Jerks at high speed	Weight of the equipment (kg)	Fuel tank capacity (mL)
WP	0.884	1.000	1.000	0.458	0.000	1.000	1.000	0.118
MB	1.000	0.000	0.391	1.000	1.000	1.000	0.111	0.294
OM	0.000	1.000	0.000	0.000	0.240	1.000	0.000	1.000
SM4	0.493	1.000	0.909	0.271	0.181	1.000	0.111	0.000
SM2	0.783	0.000	0.472	0.644	0.415	0.000	0.111	0.294

Table 4. **Ranks given to parameters by the judges**

Parameter	Ranks given by Judges											Average
	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	rank
Cost of the equipment	2	2	2	1	2	1	5	5	2	3	5	2.73
Fuel consumption	3	1	3	2	1	2	3	4	3	2	1	2.27
Thread consumption	5	5	6	5	8	5	8	6	7	5	2	5.64
Time taken	1	3	1	4	4	3	1	1	1	1	4	2.18
Weight of the equipment	6	6	4	3	5	4	2	2	4	6	6	4.36
Vibration/working condition (Jerks at high speed)	4	7	8	6	3	6	4	3	5	7	3	5.09
Engine (2/4 stroke)	7	4	7	7	6	7	6	7	6	4	7	6.18
Fuel tank capacity	8	8	5	8	7	8	7	8	8	8	8	7.55

After computing the normalized scores the index was constructed by giving weights to the parameters. Weights to the parameters were assigned by expert judgment and by using statistical methods. In expert judgment, weights were assigned based on the expert's opinion hence is a subjective method while statistical methods which makes use of the variability of the data, is more reliable and unbiased. Both the above mentioned methods were employed and compared in this study.

To assign weights through expert judgment, the parameters considered for evaluating the brush weed cutters were ranked by 11 experts of Rubber Research Institute of India. The ranks given by the judges and the average rank were presented in Table 4.

The unanimity among the judges in ranking the parameters was tested by applying Kendall's coefficient of concordance (Kendall and Babington, 1939). This test static is defined by

$$W = \frac{12S}{m^2(M^3-M)}$$

Where 'm' is the number of judges and 'M' is the number of parameters ranked.

$$S = \sum_{i=1}^{i=M} (Ri-\bar{R})^2$$

Ri – sum of the ranks of i^{th} equipment

$$\bar{R} = \frac{m(M+1)}{2}$$

W lies between 0 and 1. When W=1, it indicates that there is perfect unanimity among the judges in ranking the parameters. On the other hand if W=0 there is no overall trend of agreement among the judges. The significance of W can be tested using the statistic

$$\chi^2 = m\,(M-1)\,W$$

This has a chi-square distribution with M-1 degrees of freedom.

From Table 4 using the above formulae we obtain W = 0.65 and χ^2 = 50.05 which is significant (P=0.01). This shows the concordance among the judges in ranking the parameters.

The ranks given by the judges were converted into weights by using the rank-sum rule (Barron and Barret, 1996). The rank-sum rule is defined by

$$W(i) = \frac{2(n+1-i)}{n(n+1)} \quad ; i = 1.....n$$

Where 'n' is the number of criteria, 'i' is the priority of i^{th} criterion.

The average rank in Table 4 was converted into weights by using the rank-sum rule and furnished in Table 5.

Table 5. **Weights obtained from ranks given by the experts**

Parameter	Weights
Cost of the equipment	0.17
Fuel consumption	0.19
Thread consumption	0.09
Time taken to weed one ha	0.19
Weight of the equipment	0.13
Working condition (Jerks at high speed)	0.11
Engine type (2/4 stroke)	0.08
Fuel tank capacity	0.04

The expert judgment is subjective and therefore, a statistical method was also employed to develop the index. The Iyengar and Sudarshan (1982) method for assigning weights for construction of composite index from multivariate data was used for this purpose. In this method weights (w_i) are obtained as below

$$wi = \frac{k}{\sqrt{Var(yi)}} \quad ; i = 1.....n$$

$$k = \left[\sum_{i=1}^{n} \frac{1}{\sqrt{Var(yi)}} \right]^{-1}$$ where 'yi'- is i^{th} parameter

The weights obtained are presented in Table 6.

Table: 6. **Weights for parameters**

Parameter	Weights
Cost of the equipment	0.13
Fuel consumption	0.13
Thread consumption	0.14
Time taken to weed one ha	0.13
Weight of the equipment	0.13
Working condition (Jerks at high speed)	0.12
Engine type (2/4 stroke)	0.09
Fuel tank capacity	0.13

The weights were multiplied with the normalised scores of parameters (Table 3) and added up to get the total score for the equipment.

$$\bar{y}d = \sum_{i=1}^{m} wiYid$$

The equipment with highest total score was ranked as first.

The index and ranks obtained by assigning weights by the above two methods are presented in Table 7. The cutters WP, MB and SM4 were ranked 1 to 3 in both the methods. The last two ranks were reversed due to changes in weights assigned in the methods.

Table 7. **Index and rank of the equipment**

Equipment	Using weights by expert judgement		Using weights by statistical method	
	Index	Rank	Index	Rank
WP	0.71	1	0.66	1
MB	0.66	2	0.63	2
SM 4	0.52	3	0.46	3
OM	0.27	5	0.37	4
SM 2	0.38	4	0.36	5

Any equipments/materials tested for their performance can be ranked by following the above mentioned methodology.

All the parameters considered for field testing of equipment can be used for construction of the index. Given the unbiased nature of assigning weights in the statistical method, the probability of obtaining consensual results are more compared to the expert judgment method.

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