Selection and Ergonomic Evaluation of Hand Tractors Design Based on Va & Fahp

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Abstract

The objective of this research is to find out the dominant factors on hand tractor's selection. This factor can be used for evaluation criterion and further modification on former design. The survey descriptive analysis has applied to accomplish this research. The methods of analysis are used to obtain comprehensive information, such as: the multivariate statistical analysis; value analysis method; analytical hierarchy process method in fuzzy decision making environment and analysis of ergonomic of hand tractor's design. Considering six model of hand tractors design which is generally used by common farmers in West Java Province, the BTL8 model has the highest Value index based on value analysis accordance with the most farmers preference. Meanwhile, the hand tractor design with the highest performance index based on fuzzy analytical hierarchy process method was the AST85L model. This research also give some recommendations concerning with further design modification for BTL8 type is focused on transmission system component, air filter mechanism, noise absorber and function enhancement utility. Meanwhile, the AST85L type can be modified on frame design and accessory.

Keywords: hand tractors, multivariate, value analysis, fuzzy analytical hierarchy process

Introduction

The use of hand tractors in Indonesia was begun around 1970's while the controversial between agree and not agree opinion arose in that time. Some farmers think that hand tractor can accelerate their activities in the field and take more benefit to them, while the others worried about the substitution of farm worker impact. The introduction of hand tractors in the 1980's era actually was very important specially in order to solve the lack of farm labour problem due to labour migration from agriculture to industrial sector.

Many hand tractors promote to the farmers but the information about their performance and functions generally are not satisfied to the farmer preference. So that in actual, the farmer is often confuse to select hand tractor with the best performance and value.

One of the methods for farm machinery selections is Fuzzy Analytical Hierarchy Process (Fuzzy AHP) method. The method is based on pairwise comparison between all alternatives and decision criterion that is constructed by hierarchy structure of the specific problem (Figure 1). The best alternative is located at the focus as a level 1. It uses the fuzzy set concept in order to anticipate the complex value of decision criterion such as the qualitative data or quantitative data that describe user preferences unpredictable exactly. The data is often expressed by range value between minimum and maximum so that by using the

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fuzzyfication and defuzzyfication process it could be easier to solve. The fuzzy AHP method in this case is mainly used to select the design performance of hand tractor.
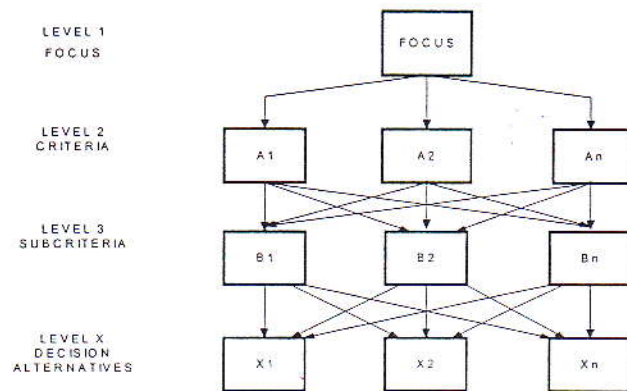

Figure 1. Hierarchy system for fuzzy analytical hierarchy process.

The evaluation of the best-selected design is done by using the ergonomic aspect, the use value of hand tractor and dominant factors of user preference obtained by multivariate statistical analysis. The analysis is focused on variable reduction from several predicted variables that is assumed effect the selection of hand tractors in the field by user. Only just a few variables grouped on dominant factors can be considered in further evaluation. All of the analysis is aimed for modified design recommendation if there is any problem found on the design.

Materials and Methods

The research was held in west Java province which is mainly produces paddy rice and has major population of hand tractors in Indonesia. The respondent of the research was the owner of hand tractors and for this occasion was arranged by using the descriptive survey method.

Data was collected from respondent as a primary data, Statistic Bureau, and related Government Agencies in the province. The objective data was mainly focused on user preference of hand tractors design selection, existing condition of the area sampling and engineering aspect of the tractors from manufacturer.

In order to make the analysis easier, the SPSS for windows ver. 6.0 and Fuzzy Analytical Hierarchy Process (Fuzzy AHP) based computer support system were used. Its procedures consist of several steps. Meanwhile, the hierarchy models for fuzzy AHP was constructed by arranging all variables identified for factor analysis. Variables describe all aspect decision criterions such as technical aspect, economical aspect, ergonomical aspect, social aspect and environmental aspect.

Decision analysis for hand tractor's selection using the Fuzzy AHP method is based on a few stages as follows:

1. Pairwise comparison among alternatives and variable analysis
2. Rating for *fuzzy* criterion
3. Weighting for *fuzzy* criterion by using the eigen vector gradient, and
4. Maximum and minimum pairwise elimination method

Results and Discussion

Considering 5 major type of hand tractors that were used by most farmer in the field e.g. BTL8, BG1, BG9, AST85L and ATS105 type. The AST85L is hand tractor with the best performance according to all criterion analyzed (Table 1). If all of hand tractor's performances are compared by its production cost index, the BTL8 type in this case has the highest use value index (Table 2). The use value index is a value reach for specific performance of the design with specific production cost to fulfil its performance (Miles, 1972). The use value can be expressed by formula as follows:

$$Value\ index = \frac{Performance\ Index}{Cost\ index}$$

Performance index is obtained from fuzzy AHP method, while cost index from standardized production cost of each alternatives design.

Table 1. Performance index from fuzzy ahp of 5 hand tractors.

NO.	TYPE OF HAND TRACTOR	MINIMUM PERFORMANCE INDEX	MAXIMUM PERFORMANCE INDEX	AVERAGE PERFORMANCE INDEX
1	BTL8	20.50	100.00	60.25
2	BG1	25.40	100.00	62.70
3	BG9	20.70	100.00	60.35
4	AST85L	34.60	100.00	67.30
5	ATS105	20.25	100.00	60.25

Table 2. Performance index, production cost index and use value index of 5 hand tractors.

NO.	TYPE OF HAND TRACTOR	AVERAGE PERFORMANCE INDEX	PRODUCTION COST OF HAND TRACTOR [1]	PRODUCTION COST INDEX OF HAND TRACTOR [2]	VALUE INDEX
1	BTL8	60.25	2210000 (~1005 US$)	48.57	1.240
2	BG1	62.70	2860000 (~1300 US$)	62.86	0.998
3	BG9	60.35	2600000 (~1102 US$)	57.14	1.056
4	AST85L	67.30	3087500 (~1404 US$)	67.86	0.992
5	ATS105	60.25	4550000 (~2069 US$)	100.00	0.603

Notes: [1] On Rupiah basis before monetary crisis on 1997 (1 US dollar equal to 2200 Rupiah)
[2] Standardized on percentage basis and it is obtained by dividing all production cost with the highest value

There are three major factors as dominant factors on hand tractors design selection by respondent from multivariate analysis (Table 3). The results are summarized below: *First factor* is the factor that expresses the characteristic of ergonomic. such as vibration. noise level. load factor. gas and heath exhausted in relation with air cooling system of hand tractor

design and its design performance. *Second factor* is the factor accordance with technical characteristic like lifetime of the system. functional aspect. type of work. accessibility and the local component content percentage of hand tractor. *The third factor* is the factor that determines the social and economical aspect. such as how much benefit and how easy to adopt information about hand tractor technology and operation by farmer as a user.

Table 3. Variable selected by factor analysis.

NO.	ASPECT	VARIABLE	GROUP FACTOR
1.	Technical Aspect	Cooling system	
2.		Vibration	
3.		Noise level	Ergonomic Factor
4.	Ergonomical	Load factor	
5.	Aspect	Gas and heath exhausted	
6.		Type of design	
7.		Life time	
8.	Technical Aspect	Functional aspect	
9.		Type of work	Technical Factor
10.	Economical Aspect	Local component content	
11.	Environmental	Accessibility	
12.	Economical Aspect	Beneficial aspect	Socio-economic Factor
13.	Social Aspect	Knowledge level and information of product	

The BTL8 type is the most popular design for the farmers in west Java province. It has the cheapest selling price if compare with others. The BTL8 has to be modified on the design according to its performance especially on transmission system. It needs more human body power to drive and turning because it does not have specific transmission gear for turning movement. Considering overall performance in the field. the farmers need hand tractor's design like the AST85L. but unfortunately its price too expensive for most farmers. So that. the tractor with the best overall performance is not guaranteeing concordance with user preference to select. It is because the highly production cost of hand tractor can make the higher selling price consequently. Logically. the higher selling price can make the barrier to entry of the product in the market.

The ergonomic evaluation has been done to both types of hand tractors (BTL8 type and AST85L type). Generally. the BTL8 type has higher noise level than AST85L type on optimum engine operating speed basis (about 1300 - 1650 rpm) as shown in Table 4. In this case. BTL8 has 96 dB(A) noise level while AST85L has 86 dB(A). Therefore. it is recommended that for BTL8 type is not used longer than 10 hour continuously. For safety operation it can be used around two up to four hour interval between rest and operation. According to Occupational Safety and Health Act / OSHA (1983). the time exposures limit for working condition with noise level 100 dB(A). 95 dB(A) and 90 dB(A) are 2. 4 and 8 hour respectively.

Table 4. Noise level for hand tractor BTl8 type and AST85l type on different engine operating speed

	RPM1	RPM2	RPM3	RPM4	RPM5
HAND TRACTOR BTL8					
Engine Speed Range (RPM)	660 – 670	893 - 919	1295 - 1311	1628 – 1638	2213 - 2227
Average Noise Level dB(A)	82	84	86	96	96
HAND TRACTOR AST85L					
Engine Speed Range (RPM)	665 – 683	865 - 912	1300 - 1309	1629 – 1932	2228 - 2235
Average Noise Level dB(A)	78	79	86	86	90

The dimension of both hand tractors has been measured based on farmers' anthropometric data that has familiar using farm machinery and equipment. In general. the dimension of both hand tractors is appropriate for the farmer. except handle height position for AST85L (Table 5). It needs modification to fit in with user preference. It is better to set the height of handle column position of AST85L type lower than 111.50 cm to become range of height among 69.75 up to 108.00 cm.

Table 5. Optimum height and width position of handle column driven from existing design and based on field measurement

DIMENSION VARIABLE	HAND TRACTOR TYPE		OPTIMUM POSITION
	BTL8	AST85L	MEASURED
Handle height (cm)	87.00	111.50	69.75 - 108.00
Handle width (cm)	70.00	71.00	42.30 - 72.89

Design improvement of BTL8 type on transmission system component (transmission gear. V-belt cover and cage wheel). air filter mechanism. noise absorber and function enhancement utility. Modification has to be done concerning its ergonomic performance and the problem on turning mechanism in the field. On AST85L type. there is no doubt to use it in the field. except it should be modified on height position of handle column for easy driving mechanism. So that. the focus of design improvement is on frame design and accessory such as puddler. leveller. and cage wheel.

The recommendation for further development of hand tractor design comes from the result of factor analysis. This viewpoint of user opinion can be observed deeply by the evaluation of the design has been done. It is easy to take more information for this stage by using attribute analysis from user response to the general performance of the observed design. Further analysis about the attribute analysis and component modification selection on this paper is not discussed.

Conclusion

The dominant factors that affect user preferences on hand tractor's design selection were mainly related on ergonomic factor characteristic. technical factor characteristic and socio-economic factor characteristic. The result selection from 5 type of hand tractors that was analyzed by fuzzy AHP based computer support system is AST85L for the best overall performance. Meanwhile the BTL8 has better use value than AST85L due to lower production cost. although it overall performance is not as big as AST85L type has. Therefore.

in actual condition user prefer the BTL8 type compare to AST85L type. The BTL8 selling price is more attractive for most farmers in the field.

Ergonomic evaluation has shown that both hand tractors have strength in one side and weakness on the other side. The BTL8 has poor performance on noise level that should be reduced. while the AST85L has to be modified on handle column height to make the operator (user) comfortable. The focus of BTL8 design modification is mainly on technical aspect such as transmission system. cage wheel. v-belt cover. cooling system and ergonomic aspect such as noise reduction. There is no need to modify for the general system of the AST85L type except to match the position of handle column bar lower and to become appropriate for user in operation.

References

Bridger. R.S. 1995. *Introduction to Ergonomics*. Mc Graw Hill International International Editions. Singapore.

Central Berau of Statistic. 1997. Indonesian Statistic. BPS Jakarta.

Cheng - Chuang Hon. Yuh - Yuan Guh. Kou - Ming Wang. 1996. Fuzzy Multiple Attributes and Multiple Hierarchical Decision-Making. *Computers Math. Application* Vol. 32. No.12. 109-199.

Dillon W.R. Matthew Goldstein. 1984. *Multivariate Analysis*. Methods and Applications. John Wiley & Sons. USA

Kramadibrata. A.M.. W. Daradjat & R. Kastaman. 1999. Study of farmers anthropometric characteristics for agricultural machinery design and modification. Research Report. Research Division. Padjajaran University.

Miles. L. D. 1972. *Techniques of Value Analysis and Engineering*. Mc. Graw Hill Book Company. New York.

Norusis M. J. 1990. *SPSS/PC+ Statistics 4.0 for the IBM PC/XT/AT and PS/2*. Statistical Data Analysis. SPSS Inc. Chicago. USA.

Sanders. Ernest J. Mc Cormick. 1987. *Human Factors in Engineering and Design*. Sixth Edition. Mc Graw Hill Book Company. Singapore.

Xu Ruoning. Zhai Xiaoyan. 1992. Extensions of the Analytic Hierarchy Process in Fuzzy Environment. *Fuzzy Sets and Systems*. Vol. 52. 251-257.