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Multi-Attribute Evaluation of Water Jet Weaving Machine Using Analytical Hierarchy Process

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The objective of this research is to perform multi-attribute evaluation of water jet weaving machine alternatives using Analytical hierarchy process (AHP). During the selection process of alternatives, determination of the importance weight of customer requirement is essential and decisive step. The Analytical Hierarchy Process (AHP) has been used in weighting the importance between attributes. A hierarchical structure is constructed for the water jet weaving machine alternatives and attributes. One example is illustrated to demonstrate the multi- attribute evaluation of water jet weaving machine alternatives using Analytical hierarchy process.

Keywords: Water jet weaving machine; alternative; multi attribute evaluation; Analytical hierarchy process

1. Introduction

Weaving is the textile art in which two distinct sets of yarns or threads, called warps and fillings or wefts, are interlaced with each other to form a fabric or cloth. The term weaving machine replaced the term "loom" during the last two decades because the weaving machines have been developed with great precision aimed at high speed operation.

Currently, the rapid increase in demand of weaving machines; the manufacturers are developing new weaving machines with modern technology. A few of modern weaving machineries are; Rapier weaving, water jet weaving, Collar making machine, Lace braiding machine ,Air jet weaving, Jacquard weaving machine, Computerized jacquard ribbon loom, etc.

Water jet weaving machine (WJWM) inserts the weft yarn by highly pressurized water. The relative velocity between filling yarn and water jet provides the traction force. Water jets can handle a wide variety of fiber and yarn types, which are widely used for apparel fabrics. Water jet weaving machines (WJWM) have been shown to be most economical for producing certain types of plain continuous-filament fabric, especially when they are produced from hydrophobic synthetic-fiber yarns.

Nowadays, the water jet weaving machines are widely used in small and medium scale textile industries due to its large demand and great potential water jet-weaving machine. In addition, in the textile industry numbers of weaving machine with different criteria are available in the market. Hence, buyer or customer of the weaving machines always in conflict for selection of appropriate weaving machine due to its large variety of weaving machine available in the market. The selection of weaving machines do not depends on single criteria like cost but its selection also depends on other criteria like filling insertion rate**,** production capacity, noise level, reed width, area utilized, speed, power consumption, weft density, etc. Hence, the selection of proper weaving machine is an important task for the buyers or customers and the selection of water jet weaving machine is a multi attribute decision-making problem.

In the current study, multi attribute assessment of water jet weaving machine is carried out using Analytical hierarchy process (AHP) method. This paper will briefly review the concept of multi attribute decision -analysis, the AHP implementation steps, and demonstrate the AHP method for the selection of water jet weaving machine. It is anticipated that a proposed methodology for the selection of water jet weaving machine is useful in the entire area of the textile industry.

Criteria (B_j)	B_1	B_2	…..	B_M
	Weights (W_j)			
Alternatives (A_i)	W_1	W_2	…..	W_n
A_1	x_{11}	x_{12}	…..	x_{1n}
A_2	x_{21}	x_{22}	…..	x_{2n}
: :	: :	: :	: :	: :
A_m	x_{m1}	x_{m2}	…..	x_{mn}

Figure 1. Decision matrix

2. Multi Criteria Decision-Making

A multi attribute decision-making method is a major part of the decision theory and analysis. An MADM methods on the other hand are generally discrete, have a limited number of predetermined alternatives. An MADM is an approach which is employed to solve problems involving selection from among a finite number of alternatives with multiple criteria. An MADM method specifies how attributes information is to be processed in order to arrive at a choice [1-3].

The solving each MADM problem begins with constructing decision matrix as shown in Figure.1. Let A = {A_i for i = 1,2,3,…N} be a set of alternative, B = {B_j for j =1,2,3,…,M } be a set of decision criteria or attributes, W = {W_j for j =1,2,3,…,M } be a set of weight of criteria B_j and x_{ij} = performance of alternative A_i when it examined with criteria B_j.

3. The Analytical Hierarchy Process (AHP)

The AHP method is a potential decision making tool developed by Saaty [4, 5]. The AHP is particularly useful for evaluating complex multi-attribute alternatives involving subjective or objective criteria. The AHP decomposes a decision-making problem into a system of hierarchies of goal, criteria and alternatives.

According to Saaty [4, 5] evaluation phase of any problem is divided into various steps as described below:

Step I: Define the problem and determine its goal.

Step II: Structure the decision-making problem as a hierarchical decomposition, in which the goal is set at the top level, criteria used in the evaluation are in the middle levels, and the alternatives are at the lowest level as shown in Figure 2.

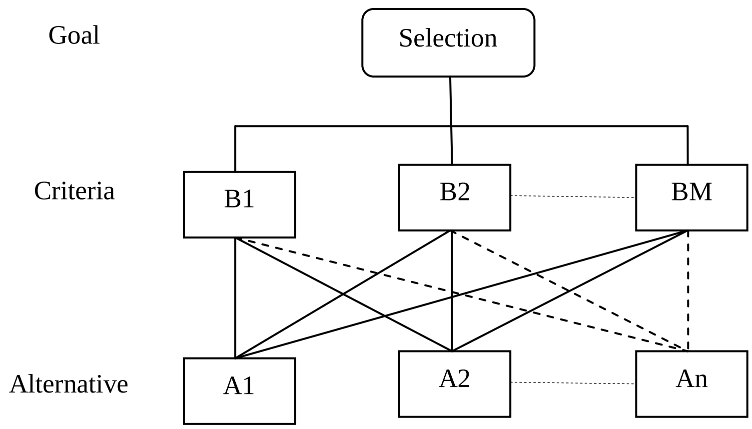

Figure 2. A hierarchy of the decision making problem

Step III: Generate pair wise matrices.
A pair-wise comparison matrix is formulated to create the decision at each level of the hierarchical decomposition as shown in Figure 2. A pair wise comparison matrix is constructed using a scale of relative importance as shown in Table 1. Let, there are M attributes are involved in the decision making, the pair wise comparison of attribute i with attribute j yields a square matrix $A1_{M\ x\ M} = [a_{ij}]_{M\times M}$, where a_{ij} denotes the comparative importance of attribute i with respect to attribute j. In the matrix, $a_{ij} = 1$ when i = j and $a_{ji} = 1/a_{ij}$.

$$A1_{MxM} = \begin{array}{c} B1 \\ B2 \\ B3 \\ - \\ - \\ BM \end{array} \begin{bmatrix} 1 & a_{12} & a_{13} & -- & -- & a_{1M} \\ a_{21} & 1 & a_{23} & -- & -- & a_{2M} \\ a_{31} & a_{32} & 1 & -- & -- & a_{3M} \\ -- & -- & -- & 1 & -- & -- \\ -- & -- & -- & -- & 1 & -- \\ a_{M1} & a_{M2} & a_{M3} & -- & -- & 1 \end{bmatrix}$$

Table 1**.** Scale of relative importance [4, 5]

Scale	Importance	meaning for attributes
1	equal importance	Two attributes are equally important
3	moderate importance	One attribute is moderately important over the other
5	strong importance	One attribute is strongly important over the other
7	very importance	One attribute is very important over the other
9	absolute importance	One attribute is absolutely important over the other
2,4,6,8	compromise importance between 1,3,5,7 and 9	

Step IV: Determination of relative normalized weight.

A relative normalized weight at each level of hierarchy structure is calculated using Equation (1) and Equation (2).

$$GM_j = \left[\prod_{j=1}^{M} a_{ij}\right]^{\frac{1}{M}} \qquad (1)$$

$$W_j = \frac{GM_j}{\sum_{j=1}^{M} GM_j} \qquad (2)$$

Step V: Consistency Test.

If the judgment matrix or comparison matrix is inconsistent then judgment should be reviewed and improved it to obtain the consistent matrix. Hence, consistency test will be carried out using following steps.

- Calculate matrices
  A3 = A1 x A2 and A4 = A3 / A2
  Where; A1= $[a_{ij}]_{M\times M}$, A2 = $[W_1, W_2, \ldots, W_j]^T$
- Calculate Eigen value λ_{max} (average of matrix A4)
- Calculate the consistency index: CI = (λ_{max} - M) / (M - 1)
- Calculate the consistency ratio: CR = CI/RI, select value of random index (RI) according to number of attributes used in decision-making [4, 5].
- If CR < 0.1, considered as acceptable decision, otherwise judgment of the analyst about the problem under study.

Step VI: Perform the steps III –V for all the levels in the hierarchy.

Step VI: Determine synthesize priority score.

Now, in this step the overall rating or composite performance scores or synthesize priority score for every alternative is computed by multiplying the relative normalized weight (W_j) of each attribute with its corresponding priority weight value for that alternative. A priority score is determined using following equation.

$$P_i = \sum_{j=1}^{M} W_j \times AP_{ij} \qquad (3)$$

Where, P_i = Overall rating or synthesize priority score

W_j = weight of attribute, j

AP_{ij} = priority weight of Alternative with respect to attribute, ij

Step VII: Select or rank alternative as the first alternative with highest synthesize priority score.

4. Formulation of Water Jet Weaving Machine Selection Problem

Today in the market broad variety of water jet weaving machines are available with multiple criteria or attributes. In present work a survey of various textile industries, various catalogues of manufacturers, experience of users or customers, a water jet weaving machine selection problem is formulated with four alternative and ten attributes as shown in the following Table 2. In this study, not single names of manufacturers are written in reference to avoid the conflict.

Table 2. Objective and subjective data in water jet weaving for selectied attributes

Attribute	WJ-1	WJ-2	WJ-3	WJ-4
Reed Width	170,190,210,230, 250 cm	170,190,210,230,250, 280,340,360 cm	170,190,210,23,250 cm	190,210,230,250 cm
Filling Insertion Rate	2280 m/min.max	2280 m/min.max	2280 m/min.max	2280 m/min.max
Power	3.5, 4.6 Kw	2.5 ,3.5 , 4.6 Kw	2.2 ,2.5 ,2.8 Kw	2.2 ,2.8 , 3.5 Kw
Weft Density	5-60 picks/cm	5-60 picks/cm	5-60 picks/cm	5-60 picks/cm
Cost (Lacks)	4.5 TO 5.5	6 TO 7	5.5 TO 6	5.75 TO 6.50
Maintenance	Low	Very Low	Medium	High
Area required	910×2130 mm	925×2130 mm	890×2100 mm	900×2120 mm
Production rate	400-450 m/day	450-500 m/day	350-375 m/day	325-350 m/day
Noise	Low	Very Low	Medium	Medium
Speed	800 rpm (max)	1200 rpm (max)	1000 rpm (max)	1200 rpm(max)

Table 2 shows the objective and subjective data of water jet weaving machine. A few of the above data like cost, reed width, and production rate are uncertain it means it should be varied according to manufacturer or users, so all these data are converted in linguistic form or as s subjective data by taking view of expert of weavers and it is shown in Table 3. In above Table 2, filling insertion rate and weft density are the same for all types of WJWM. Hence, these parameters are not considered in the selection process.

Table 3 Subjective data in water jet weaving for selected attributes

Attribute		WJ-1	WJ-2	WJ-3	WJ-4
Reed Width	(B1)	Medium	Very High	Medium	High
Power	(B2)	Very High	High	Low	Medium
Cost	(B3)	Low	Very High	Medium	High
Maintenance	(B4)	Low	Very Low	Medium	High
Area required	(B5)	Medium	High	Low	Medium
Production rate	(B6)	High	Very High	Low	Very Low
Noise	(B7)	Low	Very Low	Medium	Medium
Speed	(B8)	Low	High	Medium	High

5. Illustration of example using AHP

A simplified Water jet-weaving machine (WJWM) selection example given in Table 3 is demonstrated for the illustration purpose using AHP methodology.

Step 1: A water jet weaving machine selection problem is decomposed according to the AHP procedure described in the Section 3, the hierarchy of the problem can be developed to evaluate water jet weaving machine is shown in Figure 3.

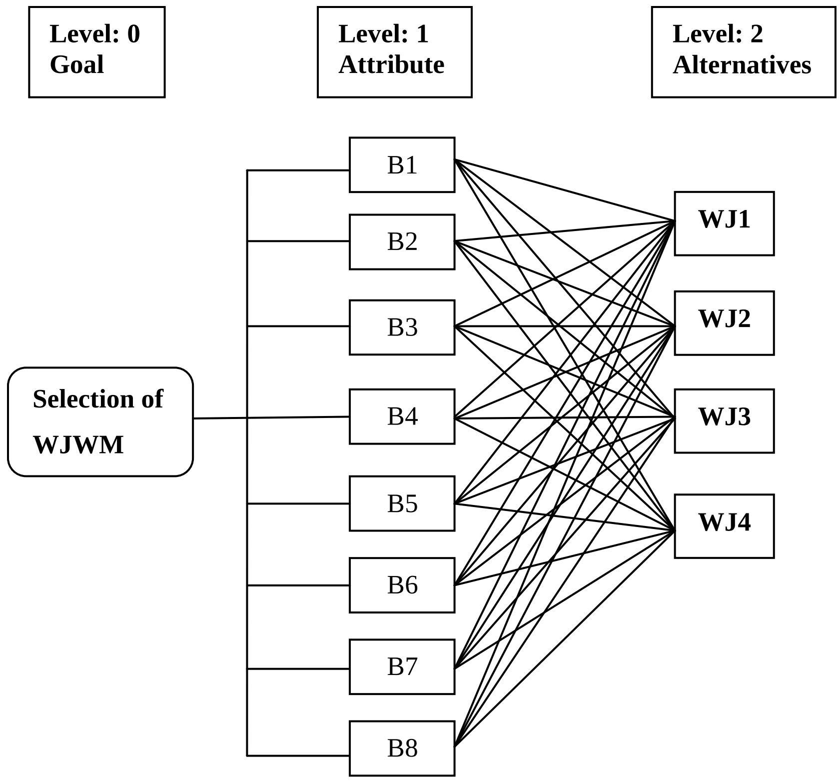

Figure 3. A hierarchy of WJWM selection problem

Step 2: A relative importance of between attributes is assigned with respect to the goal to calculate the relative normalized weight of attributes. A pair-wise comparison matrix is constructed using help of users or customers and experts of water jet machines shown in the following decision matrix. The judgments are entered using the fundamental scale of the AHP method as shown in Table 1. An attribute compared with itself is always assigned the value 1. So the main diagonal entries of the pair-wise comparison matrix are all 1.

	Attribute	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**
	B1	1	3	1\4	3	2	1\5	2	3
	B2	1\3	1	1\3	4	5	1\2	4	1
	B3	4	3	1	4	4	1\3	3	3
A1 =	**B4**	1\3	1\4	1\4	1	2	1\3	1\2	1\2
	B5	1\2	1\5	1\4	1\2	1	1\6	1\3	1\4
	B6	5	2	3	4	6	1	6	3
	B7	1\2	1\4	1\3	2	3	1\6	1	1
	B8	1\3	1	1\3	2	4	1\3	1	1

Step 3: A relative normalized weight of attributes are calculated using Equation (1) and Equation (2) and its values are shown in the following Table 4.

Table 4. Relative normalized weight of attribute

Attribute		W_j
Reed Width	(B1)	W1=0.1202
Power	(B2)	W2=0.1173
Cost	(B3)	W3=0.2156
Maintenance	(B4)	W4=0.0462
Area required	(B5)	W5=0.0329
Production rate	(B6)	W6=0.3182
Noise	(B7)	W7=0.0654
Speed	(B8)	W8=0.0836

Step 4: Now, this step demonstration of consistency test of the taken judgment is illustrated and its calculated values are given below:

$$A3 = A1 \times A2 = \begin{bmatrix} 1 & 3 & 1/4 & 3 & 2 & 1/5 & 2 & 3 \\ 1/3 & 1 & 1/3 & 4 & 5 & 1/2 & 4 & 1 \\ 4 & 3 & 1 & 4 & 4 & 1/3 & 3 & 3 \\ 1/3 & 1/4 & 1/4 & 1 & 2 & 1/4 & 1/2 & 1/2 \\ 1/2 & 1/5 & 1/4 & 1/2 & 1 & 1/6 & 1/3 & 1/4 \\ 5 & 2 & 3 & 4 & 6 & 1 & 6 & 3 \\ 1/2 & 1/4 & 1/3 & 2 & 3 & 1/6 & 1 & 1 \\ 1/3 & 1 & 1/3 & 2 & 4 & 1/3 & 1 & 1 \end{bmatrix} x \begin{bmatrix} 0.1202 \\ 0.1173 \\ 0.2156 \\ 0.0462 \\ 0.0329 \\ 0.3182 \\ 0.0654 \\ 0.0836 \end{bmatrix} = \begin{bmatrix} 1.1746 \\ 1.0828 \\ 1.9177 \\ 0.3893 \\ 0.2891 \\ 2.8260 \\ 0.5544 \\ 0.7082 \end{bmatrix}$$

$$A4 = A3 / A2 = \begin{bmatrix} 1.1746 \\ 1.0828 \\ 1.9177 \\ 0.3893 \\ 0.2891 \\ 2.8260 \\ 0.5544 \\ 0.7082 \end{bmatrix} \div \begin{bmatrix} 0.1202 \\ 0.1173 \\ 0.2156 \\ 0.0462 \\ 0.0329 \\ 0.3182 \\ 0.0654 \\ 0.0836 \end{bmatrix} = \begin{bmatrix} 9.7720 \\ 9.2310 \\ 8.8947 \\ 8.4264 \\ 8.7872 \\ 8.8812 \\ 8.4771 \\ 8.4713 \end{bmatrix}$$

λ_{max} = Average of matrix A4 = 8.8676
CI = (λ_{max} - M) / (M-1) = 0.8676/7 = 0.1240
CR = CI /RI = 0.1240 /1.4 = 0.0886, as the value of CR is less than 0.1, the judgments are acceptable.

Step 5: Compare the alternatives (A_i) pair wise with respect to how much better in satisfying each of the attributes. Similarly, pair wise comparison matrix is constructed between alternative with respect to each attribute and its priority weight (AP_{ij}) is determined using step 2 to step 4 as described in this Section and its results are shown in Table 5 to Table 12.

Table 5. Pair wise comparison of WJWM with respect to reed width

A_i	WJ-1	WJ-2	WJ-3	WJ-4	AP_{ij}
WJ-1	1	1/5	1	1/3	0.0990
WJ-2	5	1	5	2	0.5181
WJ-3	1	1/5	1	1/3	0.0990
WJ-4	3	1/2	3	1	0.2838

λ_{max} = 4.2174 CI = 0.074 CR=0.081 < 0.1 (OK)

Table 6. Pair wise comparison of WJWM with power

A_i	WJ-1	WJ-2	WJ-3	WJ-4	AP_{ij}
WJ-1	1	1/2	1/5	1/4	0.0809
WJ-2	2	1	1/3	1/2	0.1546
WJ-3	5	3	1	2	0.4764
WJ-4	4	2	1/2	1	0.2879

λ_{max} = 4.0208 CI = 0.0006933 CR=0.0079 < 0.1 (OK)

Table 7. Pair wise comparison of WJWM with cost

A_i	WJ-1	WJ-2	WJ-3	WJ-4	AP_{ij}
WJ-1	1	6	2	4	0.4983
WJ-2	1/6	1	1/5	1/2	0.0680
WJ-3	1/2	5	1	3	0.3133
WJ-4	1/4	2	1/3	1	0.1209

λ_{max} = 4.0333 CI = 0.00111 CR=0.01247 < 0.1 (OK)

Table 8. Pair wise comparison of WJWM with maintenance

A_i	WJ-1	WJ-2	WJ-3	WJ-4	AP_{ij}
WJ-1	1	1/2	2	4	0.2755
WJ-2	2	1	4	6	0.5127
WJ-3	1/2	1/4	1	2	0.1377
WJ-4	1/4	1/6	1/2	1	0.0739

λ_{max} = 4.00099 CI = 0.0033 CR=0.0037 < 0.1 (OK)

Table 9. Pair wise comparison of WJWM with area require

A_i	WJ-1	WJ-2	WJ-3	WJ-4	AP_{ij}
WJ-1	1	3	1/4	1	0.1736
WJ-2	1/3	1	1/6	1/3	0.0688
WJ-3	4	6	1	4	0.5839
WJ-4	1	3	1/4	1	0.1736

λ_{max} = 4.0596 CI = 0.001986 CR=0.0223 < 0.1 (OK)

Table 10. Pair wise comparison of WJWM with production rate

A_i	WJ-1	WJ-2	WJ-3	WJ-4	AP_{ij}
WJ-1	1	1/2	2	4	0.2755
WJ-2	2	1	4	6	0.5127
WJ-3	1/2	1/4	1	2	0.1377
WJ-4	1/4	1/6	1/2	1	0.0739

λ_{max} = 4.0099 CI = 0.0033 CR=0.0037 < 0.1 (OK)

Table 11. Pair wise comparison of WJWM with noise

A_i	WJ-1	WJ-2	WJ-3	WJ-4	AP_{ij}
WJ-1	1	1/2	2	2	0.250
WJ-2	2	1	4	4	0.500
WJ-3	1/2	1/4	1	1	0.125
WJ-4	1/2	1/4	1	1	0.125

λ_{max} = 4.00 CI = 0.0000 CR=0.00 < 0.1 (OK)

Table 12. Pair wise comparison of WJWM with speed

A_i	WJ-1	WJ-2	WJ-3	WJ-4	AP_{ij}
WJ-1	1	1/6	1/3	1/6	0.0597
WJ-2	6	1	3	1	0.3469
WJ-3	3	1/3	1	1/3	0.1464
WJ-4	6	1	3	1	0.3969

λ_{max} = 4.0199 CI = 0.0066 CR=0.0079 < 0.1 (OK)

Step 5: The overall rating or composite performance scores or synthesize priority score for every WJWM alternative are calculated using Equation (3) and its results of the WJWM selection shown in Table 13.

Table 13. Results using AHP method

A_i	Reed width	Power	Cost	Maintenance	Area	Production rate	Noise	Speed	Synthesize priority score	RANK
W_i →	**0.1202**	**0.1173**	**0.2156**	**0.0462**	**0.0329**	**0.3182**	**0.0654**	**0.0836**	**P_i**	
WJ-1	0.0990	0.0809	0.4983	0.2755	0.1736	0.2755	0.250	0.0597	**1.7125**	**3**
WJ-2	0.5181	0.1546	0.0680	0.5727	0.0688	0.5127	0.500	0.3969	**2.7918**	**1**
WJ-3	0.0990	0.4764	0.3133	0.1377	0.5839	0.1317	0.125	0.1464	**2.0134**	**2**
WJ-4	0.2838	0.2879	0.1209	0.1209	0.1736	0.0739	0.125	0.3969	**1.5829**	**4**

6. Results and Discussion

For the illustrative example, Table 3 shows the result in terms of relative normalized weight of every WJWM selection criteria at level 1 of the hierarchy of the WJWM decision making problem. Similarly, Table 5 to Table 12 shows the priority weight of WJWM alternative with respect to every selection criteria at level 2 of the hierarchy of the WJWM decision making problem. The ranking scores of WJWM alternatives are calculated by combining the weights of WJWM selection criteria (Table 3) with the priority weights of WJWM alternatives (Table 5 to Table 12). Table 13 presents the summary of the results; synthesize priority score and ranking order of the WJWM alternatives. The alternative with the highest ranking score is selected for recommendation to the user or customer. In addition, the consistence test at each level shows that the decisions taken for the formulation of pair wise comparison matrices at each level of the hierarchy are consistent and transparent.

Finally, the WJWM alternatives are arranged in the descending order according to the value of synthesize priority score and selection order is WJ-2 > WJ-3 > WJ-1 > WJ-4. For the illustrative example, water jet weaving machine -1 is recommended for the given application in the textiles industry, WJ-3 is the second choice, WJ-1 is the third choice and WJ-4 the worst or last choice of the decision maker.

7. Concluding Remarks

The following most important concluding remarks have been noticed during this research work.

- In order to get effective selection of a water jet-weaving machine, it is necessary to consider possible alternatives and attributes.
- The MADM method, the AHP provides opportunity to select the best alternative of water jet weaving machine considering with multi attributes having different measures.
- The priority or ranking of alternatives depends on attributes weight or relative importance assigned between attributes and on the values of the selected attributes. The AHP can handle tangible (objective) as well as non-tangible (subjective) attribute measures. In the AHP method, there is no need to normalization of attribute measures like other MADM methods.
- The research has concluded that the AHP method is adequate for complex evaluation of water jet weaving machine alternative. Applying this method, the best water jet weaving machine alternative will be selected, and implemented.
- The selection and evaluation of water jet weaving machine alternative is helpful to the different interests of various textile industries groups, users or customer and experts of water jet weaving machines.

References

1. S.J. Chen, C.L. Hwang, *Fuzzy multiple attribute decision making-methods and applications*, Lecture Notes in Economics and Mathematical Systems, Springer, New York,1992.
2. C.L. Hwang, K.P. Yoon, *Multiple attribute decision-making methods and applicati*ons, Springer, New York, 1981. 3. R.V. Rao, *Decision making in the manufacturing environment using graph theory and fuzzy multiple attribute decision making method*, Springer-Verlag,London,2007.
4. T.L. Saaty, *The analytic hierarchy process*, McGraw Hill, New York, 1981.
5. T.L. Saaty, *Fundamentals of decision-making and priority theory with the AHP*, RWS Publications, Pittsburg, 2000.