A DECISION MAKING MODEL REGARDING WOOD PANEL SELECTION

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ABSTRACT

Identification of preferable wood panels according to market share, competition and quality is necessary until the investors and manufacturers help to develop the industry and preserve the market share. The quality and quantity of Iranian wood panels is growing successfully. The preservation of market share will need to identify preferable wood panels taking into consideration several criteria and their intensities. Wood panel's criteria include moisture percentage, density, thickness swelling percentage, water absorption percentage, and bending strength. Each one of the criteria has three levels of intensity. In this paper, the criteria and their intensities have been evaluated by applying AHP. Then, the wood panels have been ranked according to the AHP evaluation. The results indicate that density of the product and its high intensity has the highest priority. The Ghazvin panel has the highest priority, and moisture percentage criterion is very sensitive in comparison with other criteria.

Keywords: AHP, wood panel, intensity, attribute, priority

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1. Introduction

Wood panel is one of the major products of Iranian wood industries. At present, the panel's quality and quantity are growing. In the past decade, the growth in production of the panel has been fast especially in constructional panel consumption. Iranian wood panels production increased by 87.8% from 1997 (382 322 m^3) to 2007 (718003 m^3), and again increased by 18% from 2003 to 2004. It decreased slightly in 2005 due to national economic conditions (Azizi et al , 2009). Also, in the same period, per capita consumption of particleboard in Iran increased by 60% and population increased by 17.7%. As a matter of fact, the increase of consumption of particleboard panels in the past decade has led to the consideration of the quality of specifications of the panel product. There are 17 particleboard panels factories in the country, including 10 factories in the North, 3 factories in the Northwest, 2 factories in the Center and 2 factories in the south.

In the current research we performed three steps to identify preferable wood panels according to market share, competition and quality. First, we determined the major criteria which affect specification of the particleboard product. We selected five criteria based on expertise from the Institute of Standards and Industrial Research of Iran. The attributes which were considered the most relevant by the experts were (1) moisture percentage, (2) density, (3) thickness swelling percentage (4) water absorption percentage, and (5) bending strength. To be more precise, the Institute of Standards and Industrial Research of Iran use number 2496 as the national standard for16 millimeter thickness particleboard (Cellulose and Packaging Research Group, 2002). The numbers 814, 813, 2489, 2488 and 2332(national standard numbers) are related to moisture percentage; density; thickness swelling percentage; water absorption percentage and bending strength, respectively. In the second step, three levels of intensities have been evaluated for each of the criteria: high (H), medium (M) and low (L) (Figure 1). In the third step, we extracted five of the factories which included Gorgan A , Ghaemshahr, Gorgan B, Ghazvin and Neka units, and then obtained the specifications of the panels according to the Institute of Standards and Industrial Research of Iran. These factories were selected because their distribution and location were suitable, and most were located in the North of Iran. Specifications of the particleboard panels are shown in Table1.

Table 1
Specification of particleboard panel (Institute of Standards and Industrial Research of Iran)

Criteria	Humidity (%)	Density (g/cm^3)	Thickness swelling (%)	Water absorption (%)	Bending strength(kg/cm^2)
Standard amounts	6-8	0.6-0.8	12	50	160
Overall amounts	6-8	0.6-0.8	6.65-23	25-75	160-210

To select the best panel, the Analytic Hierarchy Process method was used. This method was first invented by Thomas L. Saaty in 1970s, and is used in decision making processes which have qualitative and quantitative criteria (Saaty, 2000). For example, the AHP was used to select the best facial tissue according to the customer's perspective by Azizi and Noori (2007). Azizi (2008) used the AHP method to determine effective criteria to locate selection of wood composite units in the Khuzestan province, and also obtained the highest priority city. Alkaner and Das (2008) used the AHP in their research which indicated a framework to select the optimal technological alternative within the context of generic ship dismantling facility development. Feglar (2008) developed the AHP model to allow comparison of a public based project management with two private based project management systems. Bruno et al (2009) suggested using multi-criteria models and methods in reference to supplier selection problems (SSP). An overview of the current proposals based on AHP and its variants to cope with the SSP is provided in his paper. In Azizi and Taheri (2009), a hierarchy was used to prioritize benefits, costs, opportunities and risks (BOCR) regarding the proper selection of cooperatives management in Iran's northern forests using the Analytic Hierarchy Process ratings approach. The final synthesis of the system showed collective management of the having the highest priority. The Analytic Hierarchy Process and group decision making have also been used to calculate non-development criteria values for the particleboard industry. In this study, the results indicated that lack of raw material, non-expert elements, lower production quality, changing of management, long decision making process and ancient technology are the preferable criteria, respectively (Azizi, 2009). The AHP was applied to identify and prioritize the cleaner production implementation of a paper making mill. (Ghorbannezhad et al, 2009). Finally, Azizi (2005) applied AHP to determine effective criteria to select the best choice of raw material procurement in paper making factories in Iran. The results showed no harm on environment was the highest priority in terms of benefits.

2. Methodology

2.1. Preparing questionnaire for the first and second stage

In order to analyze the candidate products and identify the preferred ones, the initial step was to identify the criteria. A comprehensive list of factors was prepared, and a hierarchy of these factors was constructed to establish their weight using the Analytic Hierarchy Process. Then, a questionnaire was designed to evaluate each criterion's contribution to the decision process. This questionnaire was distributed among six experts in Iranian wood panel factories. The individual judgments were checked for consistency, and the aggregated opinion was derived using TEAM- EC 2000.

In the second stage, a questionnaire was prepared with regard to the intensities of the criteria and specifications of the test data to select the best alternative. Then, the questionnaire was distributed to two experts in the Institute of Standards and Industrial Research of Iran, one academic, and two experts in Iranian wood panel factories. The questionnaires were gathered and synthesized by Expert Choice 2000.

2.2. Description of the criteria

1. *Moisture percentage*: This is with respect to the national standard number 814. The precision of measurement to determine moisture percentage of the product is 0.1% and the range of the moisture is 6-8%. In other words, moisture content has been calculated via moisture content's arithmetical means of all of the related test samples (Institute of Standards and Industrial Research of Iran, 2002). The moisture test has been done on samples with every form and size whose surface is a minimum 50*50 mm^2. Every sample was weighted with a precision of 0.01 gram during sampling. Every test sample is dried at 103±2°C to reach a constant weight. The test sample is fanned in dry air and then weighted as soon as possible so that increasing moisture percentage is not more than 0.1 %. The moisture percentage of each test sample is obtained with the following formula with a precision of 0.1 %, and the minimum number of the samples is four.

Moisture percentage is calculated as following (Equation 1):

$$\mathbf{H= (M_H – M_{O)}: M_O *100} \qquad \mathbf{(1)}$$

M_H: Test sample weight before drying (gram)
M_O: Test sample weight after drying (gram.)
H: Moisture percentage of sample test (%)

2. *Density*: This is with respect to the national standard number 813.The range of the product is 0.6-0.8 g/cm^3. Precision of the density measurement is 0.01 g/cm^3, and the size of the test sample is 50*50 mm^2. The minimum number of the samples is six.

3. *Thickness swelling percentage*: This is according to the national standard number 2489, and is based on floatation of the sample in water 20±2 °C with the dimension of the sample being 100*200 mm^2.The variation of the thickness is 12% after 2 hours of floating. The minimum number of samples is eight.

4. *Water absorption percent*: This is according to the national standard number 2488, and based on floating of the sample in distilled water 20±2 temperature for 2 hours and then measuring the weight of the water absorption percentage in relation to dry position. The standard water absorption percentage is 50%. The size of the test sample is 152*152 mm^2, and the minimum number of the samples is four.

5. *Bending strength*: This is according to the national standard number 2332. The bending strength is measured and limitation of the strength 160 kg/ cm^2 is defined. However, the size of the test sample is calculated as following:
L= 24t+50
L: length of test sample (millimeter)
t: thickness of test sample (millimeter)
Width of the test sample:
If the nominal thickness is more than 6 millimeters, the width of the sample test will be 76 millimeters. If the nominal thickness is equal or less than 6 millimeters, the width of the sample test will be 50 millimeters. The minimum number of the samples is four.

2.3. Selection of the product with greatest overall manufacturer's preference (Saaty, 2000)

Step 1: Determine the manufacturer's preferred attributes by developing a matrix that compares attributes in pairs considering product desirability (Table 2).

Step 2: Determine manufacturer's preferred intensity of the attributes by developing five matrices that compare intensity levels in pairs with respect to each attribute (Tables 3-7).

Next, we want to synthesize these evaluations to obtain the set of overall priorities that will indicate the preferable product to manufacture.

Step 3: Group the priorities of the intensities (H, M, and L) for each of the five attributes in columns and enter the priorities of the attributes. Then multiply each column by the priority of the corresponding attribute to obtain the weighted vectors of priority for the intensities (Table 9).

Step 4: Select from each column the element with the highest priority to obtain the vector of desired attribute intensities.

Then, add this row and divide each entry by the total to get the normalized vector of desired attribute intensities.

Step 5: Determine the perceived product standings by developing matrices that compare the five panels (Gorgan A , Ghaemshahr, Gorgan B, Ghazvin and Neka) in pairs with respect to the most desired attribute intensities (Tables 10-14).

Step 6: Group the priorities of the panels according to each of the desired attributes intensity in columns and enter the normalized priorities above the columns. Then, multiply each column by the normalized priority of the corresponding attribute intensity to obtain the weighed vectors of priority for the desired attribute intensities for each panel (Tables 3-7).

Step 7: Add each of the five rows to obtain the overall priorities of the five panels (Tables 15-16).

Step 8: Perform a sensitivity analysis (Table 17).

2.4. Analytic Hierarchy Process

AHP is a decision-making method which enables decisions to be made which are dependent on several criteria or multi-criteria decisions. According to the AHP method, first the given structure and then the criteria relevant to decision making are compared with each other. Then the priority rate of each criterion is determined specifically. The numbers 1-9 are the standard scale which is used in two-by-two comparisons (Saaty, 2000). The Analytic Hierarchy Process has several advantages. These include: 1) ability to break criteria into manageable components, 2) allows a group to make a specific decision for consensus or tradeoff, 3) provides an opportunity to examine disagreements and stimulate discussion and opinions, 4) offers opportunities to change criteria and modify judgments, 5) forces one to face the entire problem at once, 6) offers an actual measurement system by enabling one to estimate relative magnitudes and derive ratio scale priorities accurately, 7) organizes, prioritizes and synthesizes complexity within a rational framework, 8) interprets experiences in a relevant way without reliance on a black box technique like a utility function, and 9) makes it possible to deal with conflicts in perception and judgment (Saaty, 2000). Figure 1 shows the hierarchy of effective criteria for the panels.

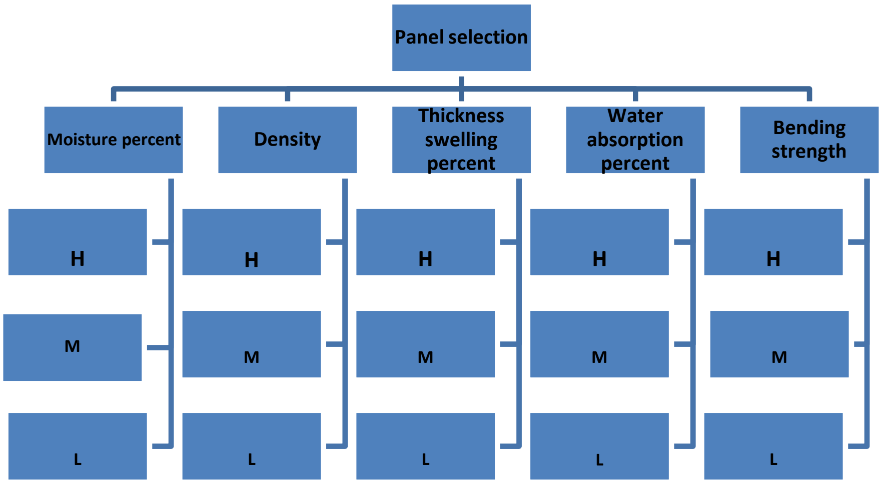

Figure 1 Hierarchy of effective criteria for the panels (H: high intensity, M: medium intensity, L: low intensity)

3. Results

The group of experts, with the aid of Expert Choice Software 2000, were able to participate in group decision making and produce a comparison matrix of the first level, comparison matrices of their intensities, weighted values of the effective criteria and their intensities, comparison matrices of the alternatives with respect to criteria and their intensities, and a sensitivity analysis (Tables 2-17).

Note that in all the following tables the judgments on the diagonal a_{ii} = 1, so those cells are left blank. Also a_{ji} = 1/ a_{ij} so as the cells below the diagonal are determined by the values above the diagonal, the cells below are left blank as well. In these tables, when the judgment is a number greater than 1, the row element is dominant. For example, (Moisture percentage, Water Absorption) =1.097, and thus Moisture percentage is more important. When the judgment is less than one the number is written as an inverse in these tables, so inverses always mean the column element is dominant. For example, the judgment for (Moisture percentage, Density) is 1/1.978 and thus Density is more important than Moisture percentage.

Table 2
Comparison matrix of the first level with respect to goal

GOAL	Moisture percentage	Density	Thickness Swelling	Water Absorption	Bending strength
Moisture percentage		1/1.978	1/1.142	1.097	1/1.014
Density			2.116	2.334	1.233
Thickness Swelling				2.466	1.170
Water Absorption					1/1.912
Bending strength					

Inconsistency = 0.02

Table 3
Comparison matrix of the intensities with respect to moisture percentage

	High	Medium	Low
High		1.508	1.057
Medium			1.0
Low			

Inconsistency = 0.01

Table 4
Comparison matrix of the intensities with respect to density

	High	Medium	Low
High		1.944	3.797
Medium			1.0
Low			

Inconsistency = 0.03

Table 5
Comparison matrix of the intensities with respect to thickness swelling

	High	Medium	Low
High		1/1.442	1/1.985
Medium			1/1.647
Low			

Inconsistency = 0.00

Table 6
Comparison matrix of the intensities with respect to water absorption

	High	Medium	Low
High		1/1.817	1/2.129
Medium			1/1.829
Low			

Inconsistency = 0.00

Table 7
Comparison matrix of the intensities with respect to bending strength

	High	Medium	Low
High		3.532	5.514
Medium			3.301
Low			

Inconsistency = 0.06

Table 8
Results of comparing the importance of the criteria with respect to the goal

Criteria	Moisture percentage	Density	Thickness Swelling	Water Absorption	Bending strength
Weighting value	0.163	0.313	0.209	0.115	0.200

Table 9
Results of comparison matrices for criterion intensities

Criteria \ Intensities	High	Medium	Low
Moisture percentage	0.386	0.289	0.325
Density	0.545	0.335	0.12
Thickness Swelling	0.225	0.304	0.472
Water Absorption	0.199	0.311	0.49
Bending strength	0.665	0.241	0.094

Table 10
Comparison matrix of the alternatives with respect to moisture percentage (high intensity)

	GorganA	Ghaemshahr	GorganB	Ghazvin	Neka
GorganA		2.091	1.319	1.148	1.148
Ghaemshahr			1/1.903	1/2.338	1/1.820
GorganB				1.148	1.148
Ghazvin					1.430
Neka					

Inconsistency = 0.01

Table 11
Comparison matrix of the alternatives with respect to density (high intensity)

	GorganA	Ghaemshahr	GorganB	Ghazvin	Neka
GorganA		1.148	1.084	1.0	1.0
Ghaemshahr			1.148	1.107	1/1.037
GorganB				1/1.148	1/1.059
Ghazvin					1.084
Neka					

Inconsistency = 0.00

Table 12
Comparison matrix of the alternatives with respect to thickness swelling (low intensity)

	GorganA	Ghaemshahr	GorganB	Ghazvin	Neka
GorganA		1.319	3.021	1/1.974	2.177
Ghaemshahr			1.184	2.954	1/1.966
GorganB				1/2.954	1/1.469
Ghazvin					2.630
Neka					

Inconsistency = 0.02

Table 13
Comparison matrix of the alternatives with respect to water absorption (low intensity)

	GorganA	Ghaemshahr	GorganB	Ghazvin	Neka
GorganA		1/2.064	2.220	1/2.277	3.227
Ghaemshahr			3.898	1.0	1/3.936
GorganB				1/3.816	1/1.643
Ghazvin					4.565
Neka					

Inconsistency = 0.02

Table 14
Comparison matrix of the alternatives with respect to bending strength (high intensity)

	GorganA	Ghaemshahr	GorganB	Ghazvin	Neka
GorganA		1/1.245	1.0	1/2.352	2.70
Ghaemshahr			1.319	1.319	1/4.292
GorganB				1/2.550	3.446
Ghazvin					4.643
Neka					

Inconsistency = 0.02

Table 15
Comparison matrices results of the alternatives with respect to moisture percentage (high intensity), density (high intensity), thickness swelling (low intensity), water absorption (low intensity) and bending strength (high intensity)

Alternatives / Criteria	GorganA	Ghaemshahr	GorganB	Ghazvin	Neka
Moisture percentage (H)	0.237	0.108	0.219	0.232	0.203
Density(H)	0.209	0.203	0.184	0.205	0.200
Thickness Swelling(L)	0.237	0.161	0.103	0.380	0.118
Water Absorption(L)	0.18	0.324	0.074	0.34	0.82
Bending strength(H)	0.169	0.240	0.173	0.356	0.061

Table 16
Final outcome, overall inconsistency = 0.02

Alternatives	GorganA	Ghaemshahr	GorganB	Ghazvin	Neka
Weighing value	0.204	0.206	0.158	0.294	0.137
Ranking	3	2	4	1	5

Table 17
Sensitivity analysis results
Description: basic priority: Ghazvin (GN) - Ghaemshahr (GR) - GorganA (GA) - GorganB (GB) - Neka (N)

Criteria	Basic weight	New weight	New priority	Changes times
Moisture percent	0.163	0.208	GN - GA - GR - GB - N	4
		0.622	GN - GA - GB - GR - N	
		0.723	GN - GA - GB - N - GR	
		0.993	GA - GN - GB - N - GR	
Density	0.313	0.678	GN - GA - GR - GB - N	3
		0.812	GN - GA - GR - N - GB	
		0.985	GA - GN - GR - N - GB	
Thickness swelling	0.209	0.265	GN - GA - GR - GB - N	2
		0.805	GN - GA - GR - N - GB	
Water absorption	0.115	0.082	GN - GA - GR - GB - N	2
		0.877	GN - GR - GA - N - GB	
Bending strength	0.2	0.157	GN - GA - GR - GB - N	2
		0.958	GN - GR - GB - GA - N	

Table 18
Panel specifications of GorganA, Ghaemshahr, Gorgan B, Ghazvin and Neka units

Criteria	GorganA	Ghaemshahr	GorganB	Ghazvin	Neka
Humidity (%)	6.55	8	6.4	6	6.7
Density(g/cm^3)	0.71	0.72	0.74	0.8	0.797
Thickness swilling (%)	10.5	10.16	12	6.65	23
Water absorption (%)	42	25	55	25	75
Bending strength(kg/cm^2)	180	195	178	210	162

4. Discussion

4.1 Criteria analysis

Density has a weighted value of 0.313 which is the highest priority for the panel, and the overall consistency ratio of the current research is 0.02 (Table 8). Density of the product is one of the major criteria which has an influence on water absorption, dimension swelling, bending resistance and internal adhesive. Manufacturers tend to produce particle board that is high intensity density in comparison with other intensities (Table 9). With respect to density intensities, the density with a high intensity (0.545) has the highest priority (Table 9). Furthermore, the difference between high and low intensities of density is large, and this influences the quality and specification of particleboard in a distinctive range. This is confirmed by the standard organization. With respect to production condition, the density intensity influences the other specifications of the board.

Thickness swelling has the second priority with a weighted value of 0.209 (Table 8). The value of thickness swelling of the board is specified after 2 hours of floating. However, in the markets, panels which have high thickness swelling percentage are inappropriate boards and indicate an undesirable production situation with regard to raw material density and press conditions. In fact, the panels with low intensity of the thickness swelling have the higher priority. The low intensity of thickness swelling is considered (0.472) (Table 9). The difference between high and low intensities of thickness swelling is high too. According to the results of the standard organization, high and low intensities of thickness swelling are 23% and 6.65% respectively (Table1). This confirms the difference of low and high intensities in the current research. Also, the market tends to supply panels with low intensity of thickness swelling.

Bending strength of the panel has third priority (0.200), otherwise, the boards which have a desirable production situation in relation to raw material and press condition, will have high bending strength. In the panel bending, strength has high sensitivity. Considering the results, bending strength with high intensity is preferable. The high intensity of bending strength has a weighted value of 0.665 with highest priority, and low intensity has a weighted value of 0.094 (Table 9). The difference between high and low intensities for bending strength (0.571) is very high which indicates that this criterion is very sensitive and important in panel products. Otherwise, in the market, panels with low intensity of bending strength (160 kg/cm^2) in comparison with high intensity of bending strength (210 kg/cm^2) (Table1) do not have any advantage, according to the manufacturers. Desirability of the boards increases with high intensity of bending strength, however other criteria of the panels should not decrease due to it.

Humidity or moisture percentage has the fourth priority (0.163). This criterion depends on press temperature, dryer conditions and environment humidity. Humidity of the panel must be checked after press and dryer because the humidity of the board influences density, bending strength, color etc. In addition, the panels with high intensity of moisture percentage have higher priority. The range of humidity percentage is 6-8% (Table1). The results show that humidity percentage with high intensity (0.386) and low intensity (0.325) are not very different from each other

(Table 9). In fact, high intensity humidity is a favorable factor in the panel and increases bending strength and density of the panel.

Water absorption percentage has the lowest priority (0.115) in comparison with the other criteria. With respect to the standard measurements, the boards are floating during the test. There is not however a similar situation with regards to furniture and construction panels as well as water absorption impressed by density, press condition, glue and additive material. According to the results, the panels with low intensity of water absorption are preferable. The low intensity of water absorption with a weighted value of 0.49 is considerably different in comparison with the high intensity with a weighted value of 0.199(Table 9). According to the standard organization results, high and low intensities of water absorption are 75% and 25 % respectively (Table1). The large difference between high and low intensities indicates the significance of the intensities difference in the panels. Water absorption criterion has lowest priority in comparison with other criteria; however, the range of intensities variation is very effective in panel specification.

4.2 Alternative analysis

We evaluated five wood panels in Iran in terms of manufacturer' aspects under titles of GorganA, Ghaemshahr, GorganB, Ghazvin and Neka in order to improve the panels quality and procurement of market requirements. The research was based on criteria intensities. According to the final results, panels Ghazvin, Ghaemshahr, GorganA, GorganB and Neka have 0.294, 0.206, 0.204, 0.158 and 0.137 weighted values, respectively (Table 16). Accordingly, the Ghazvin panel had the highest priority in comparison with the other panels. According to the criteria, intensities of thickness swelling/l, water absorption/l and bending strength/h, Ghazvin panel had the highest priority. This is consistent with particleboard panel's data from the Institute of Standards and Industrial Research of Iran which shows the Ghazvin panel having the best conditions with regard to thickness swelling (6.65%), water absorption (25%) and bending strength (210 kg/cm^2). The results indicate that the derived scales (weighted values of the criteria) based on the judgments of comparison matrices in AHP and the actual relative weights are compatible (Table 18). The Ghazvin panel, which is the first alternative, has a higher priority concerning all of five criteria in comparison with the Ghaemshahr panel as the second alternative. The differences are as follows: thickness swelling (0.219), moisture percentage (0.124), bending strength (0.116), water absorption (0.016) and density (0.002). This influences the final priority as shown in Table 15.

The Ghazvin panel has a higher preference than the Ghaemshahr panel in regards to the results of the three criteria, thickness swelling, moisture percentage and bending strength. Of course, the range of changes in the weighted values of the panels with respect to the three above mentioned criteria is high (Table 15). Otherwise, the differences between the maximum and minimum of alternatives' weighted values as to thickness swelling (second criteria), bending strength (third criteria) and moisture percentage (forth criteria) are 0.277, 0.295 and 0.129 respectively. Therefore, these differences influence the panel's priorities. Moreover, thickness swelling is related to raw material density and press conditions, moisture percentage influences density, bending strength and color. Bending strength is very important in marketing panel products. The range of changes in weighted values of the panels in relation to density criterion is low (0.025) (Table 15). Accordingly, in spite of the fact that the density criterion has the highest priority among other criteria the importance of comparison of the panels regarding high density intensity indicated the alternatives' importance is very close together. The compatibility of this result can be shown in Table 18 when considering minimum (0.71) and maximum (0.8) density. Since there may be different judgments in the comparison of priority rates of the criteria or their sub-criteria, a sensitivity analysis is applied to achieve stability and compatibility of the analysis (Saaty, 2001). Within our criteria hierarchy, we find that the ratios of the alternatives could change by increasing or decreasing one of the criteria. Given these results (Table 17), all of the criteria are sensitive. Moisture percentage and density are more sensitive than the other criteria. Finally, changes in alternatives priorities are four and three times in relation to changes of moisture percentage and density' weighing values, respectively.

5. Conclusion

In this research panel products of five major plants were evaluated in order to develop the best wood panel and increase its market share and competition capability in Iran. After building a decision tree and obtaining weighted values of intensities, criteria and alternatives, we obtained the highest priority product which was the Ghazvin panel.

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