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Developing a rating model for selection solar wood drying location

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Abstract

Solar energy is one of the free and clean sources of energy supply without any destructive influence on the environment. Solar energy has been used in different forms for a long time. Concentrators of solar radiation can be used to produce unlimited, clean and free energy and save fossil fuels considerably. One of important applications of solar energy is to manufacture solar wood drying units. Iran has been located in an appropriate situation in the world with respect to receiving solar energy. The aim of the present paper is to propose a multicriteria methodological approach based on Analytic Hierarchy Process (AHP) useful for the “*Determination of Effective Criteria on Site Selection for Solar Wood Drying Units in Iran”*. The methodological approach is divided in 3 steps. In first step experts of kiln wood drying were interviewed for preliminary investigation. In the second step, hierarchy of criteria was designed and weighing values of them were calculated by Analytic Hierarchy Process. Finally, in the third step, model was used rating for prioritizing capable provinces. Results showed that Qom province, with average temperature, has the highest priority as a criterion and alternative.

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Keywords: Solar energy, wood drying, AHP, criteria, land use, forests.

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1. Introduction

Solar energy is one of the freest and cleanest sources of energy in the world which has no destructive effect on the environment. It has been used in various ways by the people for a long time. In the case of solar radiation for 40 days required energy for one century can be reserved. Thus by applying solar radiation concentrators along with the use of this free and clean and endless energy, the saving of fossil fuel consumption will also be possible (Fernández-García et al., 2010).

Iran has been located between 25-40 degrees of northern latitude and regarding solar energy receiving has highest level in the world. The amount of sun radiation is between 1800-2200 (kWh)/m3 in a year which is higher than world average. In Iran more than 280 days are sunny which is very notable (www.suna.org.ir). One of the possible

and valuable applications of solar energy is in wood industry and manufacturing solar wood dryer. In solar dryers, solar energy is used for drying material indirectly or directly and air flow helps to moisture displacement naturally or in an under controlled way which accelerate wood drying process.

The solar drying kiln is the most cost effective way for the craftsman to get quality boards for wood working from green lumber. Today there are many band saw operators cutting boards from trees that grow in abundance in much of America. The solar kiln is the link between this resource and the shop. A wood kiln is any space used for controlling heat and humidity where lumber is dried. The solar drying kiln harnesses the free energy of the sun. It operates on the regular cycle of day and night to prevent wood stress that can ruin lumber in other systems (Wilson, 2006). Solar drying is one of the important thermal applications, where solar energy can be utilized efficiently. Drying depends on the air ability to evaporate water (drying potential); hence its relative humidity is a key factor. The lower the relative humidity of the drying air, the more water of air evaporates from the product, resulting in lower final product moisture content. Drying potential is influenced by air temperature as well as relative humidity. Much work on solar energy has been concerned with the use of solar heated air (naturally or mechanically circulated) to remove the moisture from materials placed inside an enclosure where the heated air is blown past the material. Solar drying provides up to 50% reduction of final moisture content and drying time compared with air-drying (Helwa et al 2004). Over the last few decades, much research and development has been conducted into the use of solar kilns for timber drying. This has led to the commercial use and availability of solar kilns in the timber industry over recent years (Desch and Dinwoodie, 1996). The present study aims to identify the effective criteria on best site selection to establish solar wood drying units in Iran via Analytic Hierarchy Process model. Among the various MCDM techniques proposed, the AHP proposed by Saaty (1980) is very popular and has been applied in wide variety of areas including planning, selecting a best alternative, resource allocation and resolving conflicts (Aragonés-Beltrán et al., 2006; De Felice and Petrillo 2013). Decision-making involves prioritizing our ideas according to the circumstances we face now or might face in the future (Pomerol and Romero, 2000; De Felice and Petrillo, 2014). A fundamental problem in decision-making is how to measure intangible criteria and how to interpret measurements of tangibles correctly so they can be combined with those of intangibles to yield sensible, not arbitrary numerical results (Islam, 2010). A crucial test is whether actual measurements can be used precisely as they are when needed. AHP method helps us to achieve this goal. The AHP method is based on three steps: model structure; comparative judgment of the alternatives and criteria; and synthesis of the priorities. In the literature, the main developments in AHP have been widely used to solve many complicated decision-making problems (Ishizaka and Labib, 2011). For selecting the best wood panel, intensities of the criteria and sub criteria obtained. Then the wood panels have been ranked according to the AHP evaluation. The results indicate that the density of the product and its high intensity has the highest priority. The Ghazvin panel has the highest priority, and the moisture percentage criterion is very sensitive in comparison with other criteria (Azizi, 2012).

2. Material and Methods: Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) breaks down a decision-making problem into several levels in such a way that they form a hierarchy with unidirectional hierarchical relationships between levels.

The AHP for decision making uses objective mathematics to process the inescapably subjective and personal preferences of an individual or a group in making a decision (Saaty, 1990). With the AHP, one constructs hierarchies or feedback networks, then makes judgments or performs measurements on pairs of elements with respect to a controlling element to derive ratio scales that are then synthesized throughout the structure to select the best alternative (Saaty and Vargas, 1991).

The top level of the hierarchy is the main goal of the decision problem. The lower levels are the tangible and/or intangible criteria and sub-criteria that contribute to the goal. The bottom level is formed by the alternatives to evaluate in terms of the criteria (Saaty and Khouja, 1976). The modeling process can be divided into different phases for the ease of understanding which are described as follows:

1) *Pairwise comparison and relative weight estimation.* Pairwise comparisons of the elements in each level are conducted with respect to their relative importance towards their control criterion. Saaty suggested a scale of 1-9 when comparing two components. For example, number 9 represents extreme importance over another element. And number 8 represents it is between *''very strong important''* and *''extreme importance''* over another element. For a general AHP application we can consider that $A_1, A_2, \ldots, A_m$ denote the set of elements, while a_{ij} represents a quantified judgment on a pair of A_i, A_j. Through the 9-value scale for pairwise comparisons, this yields an [m x m] matrix A as follows:

$$A = a_{ij} = \begin{array}{c|cccc|} & A_1 & A_2 & \ldots & A_m \\ A_1 & 1 & a_{12} & \ldots & a_{1m} \\ A_2 & 1/a_{12} & 1 & \ldots & a_{2m} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ A_m & 1/a_{1m} & 1/a_{2m} & \ldots & 1 \end{array}$$

where $a_{ij} > 0$ (i, j = 1, 2,..,,m), $a_{ii} = 1$ (i = 1, 2,…,m), and $a_{ij} = 1/a_{ji}$ (1; 2;…,m). A is a positive reciprocal matrix. The result of the comparison is the so-called **dominance coefficient** a_{ij} that represents the relative importance of the component on row (i) over the component on column (j), i.e., $a_{ij}=w_i/w_j$. The pairwise comparisons can be represented in the form of a matrix. The score of 1 represents equal importance of two components and 9 represents extreme importance of the component i over the component j. In matrix A, the problem becomes one of assigning to the m elements $A_1, A_2, \ldots, A_m$ a set of numerical weights $w_1, w_2, \ldots, w_m$ that reflects the recorded judgments. If A is a consistency matrix, the relations between weights w_i, w_j and judgments a_{ij} are simply given by $a_{ij} = w_i/w_j$ (for i,j = 1, 2, …, m) and

$$A = \begin{array}{c|cccc|} & w_1/w_1 & w_1/w_2 & & w_1/w_m \\ A_1 & w_2/w_1 & w_2/w_2 & & w_2/w_m \\ A_2 & & & & \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ A_m & w_m/w_1 & w_m/w_2 & \ldots & w_m/w_m \end{array}$$

If matrix w is a non-zero vector, there is a λ_{max} of $Aw = \lambda_{max}w$, which is the largest eigenvalue of matrix A. If matrix A is perfectly consistent, then $\lambda_{max}w = m$. But given that a_{ij} denotes the subjective judgment of decision-makers, who give comparison and appraisal, with the actual value (w_i/w_j) having a certain degree of variation. Therefore, $Ax = \lambda_{max}w$ cannot be set up. So the judgment matrix of the traditional AHP always needs to be revised for its consistency.

2) *Priority vector*. After all pairwise comparison is completed, the priority weight vector (w) is computed as the unique solution of Aw = λmaxw, where λmax is the largest eigenvalue of matrix A.

3) *Consistency index estimation*. Saaty [27] proposed utilizing consistency index (CI) to verify the consistency of the comparison matrix. The consistency index (CI) of the derived weights could then be calculated by: $CI = (\lambda_{max} - n)/ n - 1$. In general, if CI is less than 0.10, satisfaction of judgments may be derived.

2. The Model

First step for finding capable provinces of Iran to establish solar wood drying units 30 questionnaires were distributed among qualified people who were academic members (10%), Industries and mines organization; planning and budget organization (14%), members of furniture union (30%) and owners of industries (46%) and provinces which had no capability for establishing solar wood drying units were deleted. Capable Provinces which had appropriate site to establish solar wood drying units are as follow: Tehran, Qom, Khorasan Razavi, Markazi, Fars, Mazandaran, Isfahan, Ghazvin, Alborz. Climate changes is a limitation in this study. We studied the provinces in a stable situation regarding climate. The changes can be considered for future researches.

Second step for identifying effective criteria in site selection of solar wood drying units establishment, a hierarchy (Figure 1) with five major criteria was planned then 20 questionnaires were distributed among experts of wood drying units. Collected data processed in Expert Choice© software and weighing values of criteria and sub criteria were determined.

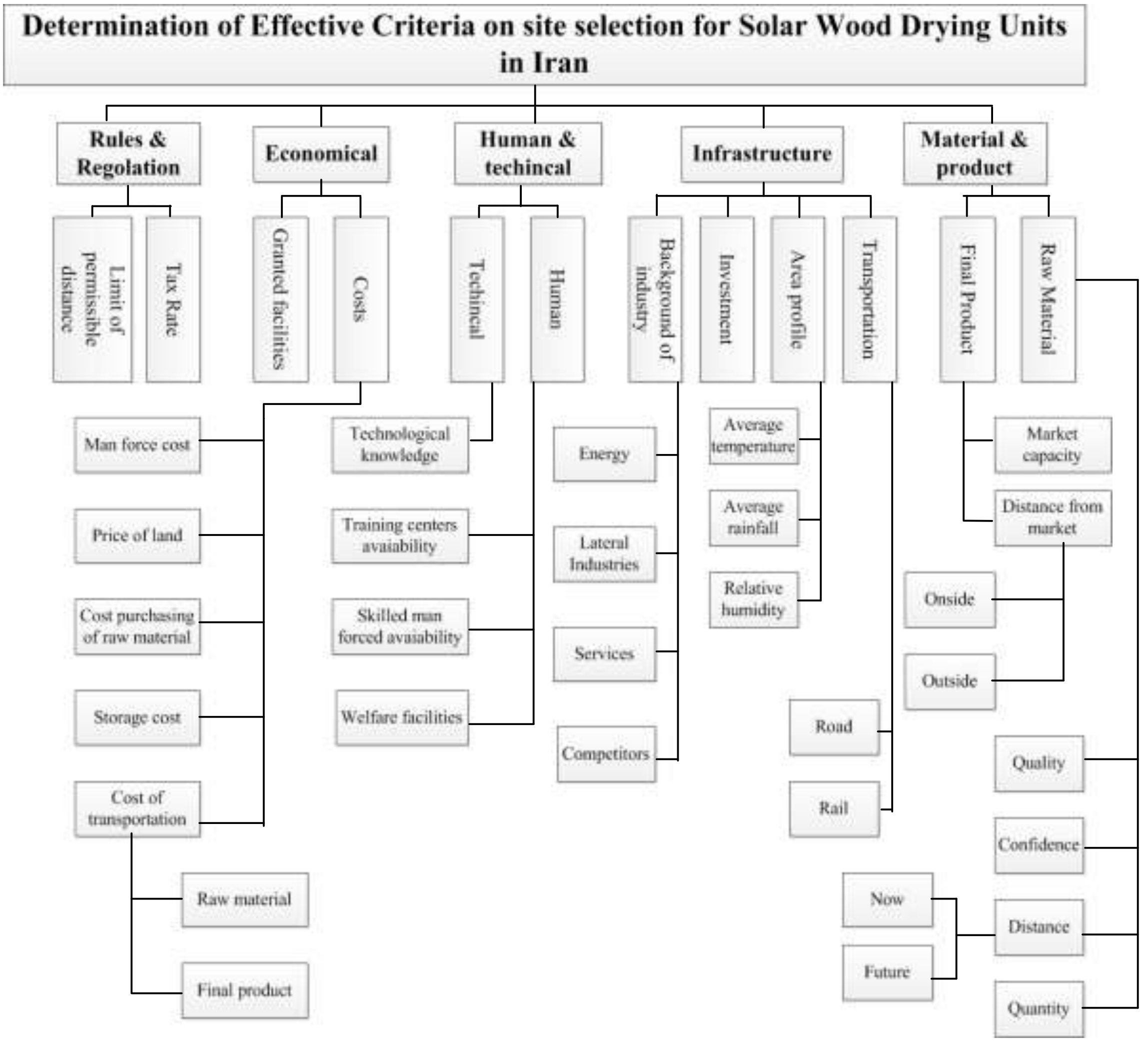

Figure 1: Hierarchy of effective criteria in site selection of solar wood drying units

Criteria and sub criteria of solar wood drying location selection and their weighing values are shown in Table 1.

Table1 shows that below average temperature criteria (0.159), granted facilities, market capacity, labor force availability and price of raw material, have highest priority for site selection of solar wood drying units respectively.

Radiation is amount of energy of electromagnetic on area unit per unit of time which has been named as flux. Solar energy is an opportunity which there is extended programs for developing its application in the world. Programming for solar energy application is a capacity building for using a very large resource which is not comparable with other current energy resources because amount of solar energy is more than several times of energy consumption which man uses energy throughout the year, that is accessible (solar energy) on the earth per hour.

The application of enormous solar energy resources for electricity energy production, dynamic usage, heating generation for areas and buildings, drying agricultural products, chemical changes and so on, are the strategies which have been started in former years. The amount of solar energy obtained from sun radiation in one point of earth area throughout the year, depends on the intensity and duration of sun radiation in that region.

Results of the interview with the experts indicated that maximum radiation of sun throughout the year in the region is the most important criteria for site selection of solar wood drying units. Iran has various climates. Air temperatures, humidity, radiation of sun, rate of rain are different in the regions. Hence it will be logical that the average of air temperature or incoming energy from the sun in each region has the highest priority for site selection of solar wood drying units.

Table 1: Factor table, criteria and sub criteria of solar wood drying location selection and their weighing values

Code	Criteria	Weighing value (Global)	Weighing value (Local)
1	Raw material & product: raw material: quality	0.015	0.316
2	Raw material & product: raw material: Confidence	0.009	0.335
3	Raw material & product: raw material: distance: Now	0.006	0.667
4	Raw material & product: raw material: distance: Future	0.002	0.0067
5	Raw material & product: final product: Market capacity	0.073	0.863
6	Raw material & product: raw material: Quantity	0.015	0.224
7	Raw material & product: final product: distance from market: outside	0.004	0.691
8	Infrastructure. Transportation network: Road	0.028	0.681
9	Infrastructure. Transportation network: Rail	0.014	0.319
10	Infrastructure, Area profile, Average rainfall	0.053	0.35
11	Infrastructure, Area profile, Amount of absorbed solar energy	0.159	0.279
12	Infrastructure, Area profile, Relative humidity	0.053	0.371
13	Infrastructure, Investment	0.033	0.078
14	Infrastructure, Background of industry, Energy	0.028	0.453
15	Infrastructure, Background of industry, Lateral industries	0.037	0.204
16	Infrastructure, Background of industry, Services	0.013	0.142
17	Infrastructure, Background of industry, Competitors	0.018	0.201
18	Human & technical: Human training centers availability	0.01	0.172
19	Human & technical: Human skilled man force availability	0.071	0.679
20	Human & technical: Human welfare facilities	0.1	0.148
21	Human & technical: Techinical Technological knowledge	0.021	0.626

22	Economical: Costs: Man force cost	0.002	0.406
23	Economical: Costs: Price of land	0.02	0.085
24	Economical: Costs: Cost purchasing of raw material	0.071	0.340
25	Economical: Costs: Storage cost	0.016	0.066
26	Economical: Costs: Cost of transportation Raw material	0.026	0.685
27	Economical: Costs: Cost of transportation Final product	0.009	0.315
28	Economical Granted facilities	0.142	0.895
29	Rules & regolation: tax rate	0.02	0.383
30	Rules & regolation: limit of permissible distance	0.02	0.617

3. Analysis of the model

With using rating model of Expert choice© software each recognized criterion of second step was divided in different intensities and amounts of intensities were calculated regarding comparisons. Then the relations between quality and quantity amounts of these criteria with intensities were determined. The intensity importance rate of these criteria which has been obtained in first step was studied for each capable province.

3. Results

Results of the research obtained by Expert Choice Software © and Rating model. Results are shown in Table 2.

Table 2: Results of Rating model for location selection of solar wood drying (L is Local)

Ideal Mode	Ratings							
Alternative	Raw material & product: raw material: quality (L= 0.316)	Raw material & product: raw material: Confidence (L= 0.335)	Raw material & product: raw material: distance: Now (L= 0.667) (Km)	Raw material & product: raw material: distance: Future (L= 0.667) (Km)	Raw material & product: raw material: Quantity (L= 0.224)	Raw material & product: final product: Market capacity (L= 0.863)	Raw material & product: final product: distance from market: onside (L= 0.691) (Km)	product: final product: distance from market: outside (L= 0.309) (Km)
Tehran	Very high	Very high	50-100 High	50-100 High	Very high	Very high	Less than 50 Very high	300-600 High
Qom	Very high	Very high	50-100 High	50-100 High	Very high	Very high	50-100 High	300-600 High
Alborz	Very high	Very high	150-200 km Low	50-100 High	High	High	Less than 50 Very high	300-600 High
Qazvin	Medium	Medium	More than 200 Very Low	150-200 Low	Low	Low	200-300 Low	600-1000 Medium
Markazi	Medium	Medium	More than 200 Very Low	50-100 High	Medium	Medium	More than 300 Very Low	1000-2000 Low
Mazandaran	Very high	Very high	Less than 50 Very High	Less than 50 Very high	Very High	Medium	More than 300 Very Low	600-1000 Medium
Fars	Low	Medium	More than 200 Very Low	150-200 Low	Low	Low	More than 300 Very Low	More than 2000 Very Low
Esfahan	Medium	High	More than 200 Very Low	More than 200 Very Low	Low	High	Less than 50 Very high	600-1000 Medium
Khorasan	High	High	150-200 Low	100-150	Low	Ver high	Less than 50	600-1000

				Medium			Very high	Medium

Table 2: Continued

Ideal Mode	Ratings							
Alternative	Infrastructure Transportation network: Road (L=0.681)	Infrastructure Transportation network: Rail (L=0.319)	Infrastructure Area profile Average rainfall (L=0.350) mm))	Infrastructure Area profile Amount of absorbed solar energy (L=0.279) (cal/cm2(	Area profile Relative humidity (L=0.371) (%)	Infrastructure Investment (L=0.078)	Infrastructure Background of industry Energy (L=0.453)	Infrastructure Background of industry Lateral industries (L=0.204)
Tehran	Very high	Very high	100-200 High	390-430 High	30-40 High	Very high	Very high	Very high
Qom	Very high	Very high	100-200 High	390-430 High	30-40 High	Very high	Very high	Very high
Alborz	High	Medium	300-400 Low	390-430 High	40-50 Medium	High	High	High
Qazvin	Medium	Low	Less than 100 Very high	390-430 High	50-60 Low	Low	Medium	Low
Markazi	High	High	200-300 Medium	390-430 High	40-50 Medium	High	High	Medium
Mazandaran	High	High	More than 400 Very low	Less than 350 Very low	More than 60 Very low	High	High	Medium
Fars	High	Medium	Less than 100 Very high	More than 430 Very high	30-40 High	Medium	Medium	Low
Esfahan	Very high	Very high	200-300 Medium	More than 430 Very high	Less than 30 Very high	Medium	High	Medium
Khorasan	Very high	Very high	100-200 High	390-430 High	40-50 Medium	Very high	Very high	High

Table 2: Continued

Ideal Model	Ratings						
Alternative	Infrastructure: Background of industry: Services (L=0.142)	Infrastructure: Background of industry: Competitors (L=0.201)	Human & technical: Human: Training centers availability (L=0.172)	Human & technical: Human: Skilled man force availability (L=0.679)	Human & technical: Human: Welfare facilities (L=0.148)	Human & technical: Technical: Technological knowledge (L=0.626)	Economical: Costs: Man force cost (Monthly wage: Rial) (L=0.406)
Tehran	Very high	Medium	Very high	Very high	Very high	Very high	4500000-6000000 Medium
Qom	Very high	High	Very high	Very high	Very high	Very high	4500000-6000000 Medium
Alborz	High	Medium	High	High	Medium	Medium	4500000-6000000 Medium
Qazvin	Medium	High	Low	Low	High	Medium	4500000-6000000 Medium
Markazi	Low	High	High	Medium	High	High	4500000-6000000 Medium
Mazandaran	Medium	Low	High	High	High	Medium	4500000-6000000 Medium
Fars	Low	High	Low	Medium	High	Medium	4500000-6000000 Medium
Esfahan	Medium	Medium	High	Medium	Medium	Medium	4500000-6000000 Medium
Khorasan	High	High	Very high	High	Very high	High	4500000-6000000 Medium

Table 2: Continued

Ideal Mode	Ratings							
Alternative	Economical Costs Price of land (L=0.085) (per m2:Rial)	Economical: Costs: Cost purchasing of raw material (L=0.340)	Economical: Costs: Storage cost (L=0.066) (Daily: Rial)	Economical: Costs: Cost of transportation: Raw material (L=0.685)	Economical: Costs: Cost of transportation: Final product (L=0.315)	Economical: Granted facilities (L=0.895)	Rules & regulations: Tax rate (L=0.383) (Annual :%)	Rules & regulations: Limit of permissible distance (L=0.617)

				(Per10km:Rial)	(Per 10km:Rial)			(Km)
Tehran	1500000-3000000 Medium	Medium	200000-250000 Medium	300000-400000 Medium	300000-400000 Medium	High	25 Medium	More than 60 Very Low
Qom	Less than 500000 Very high	Medium	200000-250000 Medium	200000-300000 High	300000-400000 Medium	High	25 Medium	45-60 Low
Alborz	500000-1500000 High	Medium	150000-200000 High	400000-500000 Low	400000-500000 Low	High	25 Medium	45-60 Low
Qazvin	Less than 500000 Very high	Low	100000-150000 Very high	400000-500000 Low	400000-500000 Low	Medium	25 (0.135)	45-60 Low
Markazi	Less than 500000 Very high	Medium	100000-150000 Very high	More than 500000 Very Low	400000-500000 Low	High	25 Medium	45-60 Low
Mazandaran	500000-1500000 High	High	100000-150000 Very high	100000-200000 Very high	300000-400000 Medium	High	25 Medium	45-60 Low
Fars	Less than 500000 Very high	Medium	100000-150000 Very high	400000-500000 Low	200000-300000 High	High	25 Medium	45-60 Low
Esfahan	1500000-3000000 Medium	Medium	150000-200000 High	400000-500000 Low	400000-500000 Low	High	25 Medium	45-60 Low
Khorasan	1500000-3000000 Medium	Medium	150000-200000 High	400000-500000 Low	400000-500000 Low	Medium	25 Medium	45-60 Low

Table 3 shows the final outcome.

Qom province (see Table3) is not only the closest province to the largest furniture consumption market of Iran but also has appropriate infrastructure similar ideal transportation network between Qom and Tehran, many equipped industrial towns with low distance to Tehran, extended facilities and preferences for investment attractions. For these reasons Qom province actually has changed the largest regional industrial town near to Tehran. Permitted distance for establishing industrial units from Tehran as center of Iran is more than 120 km; in this regard Qom province obtains higher priority to establish industrial units. According to the existence of skillful man force criteria, Qom province has good background in wood industry and in this province access to skillful and knowledgeable man force has proper situation.

In this province man force cost and price of land for establishing a factory is lower than Tehran. Average of air temperature or incoming energy from the sun in Qom province with weighing value 0.308 has favourite situation so that division of different regions of Iran regarding average of air temperature shows this province is located in the region with high radiation of sun. Accordingly the selection of Qom province as an appropriate alternative for establishing solar wood drying units is logical and justified.

Table 3: Final Outcome

Ideal mode / Alternative	Total
Tehran	0.326
Qom	0.331

Alborz	0.271
Qazvin	0.145
Markazi	0.239
Mazandaran	0.262
Fars	0.244
Esfahan	0.26
Khorasan	0.209

4. Conclusions

In this paper a multicriteria model based on AHP was proposed in order to define effective criteria on site selection for solar wood drying units in Iran. In our opinion AHP is powerful method that helps to solve complex decision making problem in simply way. The AHP is fundamentally a way to measure intangible factors by using pairwise comparisons with judgments that represent the dominance of one element over another with respect to a property that they share. Many examples are worked out by knowledgeable people without entering all the judgments but only contrasting ones that form a spanning tree which covers all the elements thus shortening the time in which the exercise is done. The AHP has found useful applications in decision making which involves numerous intangibles. It is a process of laying out a structure of all the essential factors that influence the outcome of a decision. Numerical pairwise comparison judgments are then elicited to express people's understanding of the importance, preference or likely influence of these elements on the final outcome obtained by synthesizing the priorities derived from different sets of pairwise comparisons.

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