Economics, Management and Sustainability
journal home page: https://jems.sciview.net

Azizi, M. (2017). Strategic model for location selection of solar wood drying by applying TOPSIS. *Economics, Management and Sustainability, 2*(2), 15-23. doi:10.14254/jems.2017.2-2.2.

ISSN 2520-6303

Strategic model for location selection of solar wood drying by applying TOPSIS

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Article history:
Received: August 15, 2017
1st Revision: September 11, 2017
Accepted: October 11, 2017

JEL classification:
D4
L11
Q13

DOI:
10.14254/jems.2017.2-2.2

Abstract: The location of solar wood drying has not been selected in Iran yet. One of important applications of solar energy is to manufacture solar wood drying units. Effective indicators in location of solar wood drying were identified and a hierarchy was constructed based on five major groups of criteria. The weights of the indicators were then established by Analytical Hierarchy Process. The amounts of the indicators with regard to provinces were obtained from wood drying factories in public and private sectors. These weights were employed in TOPSIS to rank the provinces. Finally the potential provinces were identified according to the priorities obtained by this technique. The results showed that Qom Province, has the best priorities for establishment of solar wood drying.

Keywords: solar wood drying, TOPSIS, Analytical Hierarchy Process, location, priority.

1. Introduction

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. 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)/m^3 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). 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. 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

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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 & Dinwoodie, 1996). The present study aims to identify the effective criteria on best site selection to establish solar wood drying units in Iran via TOPSIS.

Studies on site selection for wood production by Michael et al (1998), identified a number of factors affecting the selection decision. They clustered the criteria into cost, market distribution, lower production cost and non-tangible factors. McCauley and Caulfield (1990) specified the effective criteria for selection of an OSB (Oriented strand board) factory and developed a mixed integer programming model to determine the optimal location of the OSB sites.

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 & 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. Modeling the selection problem

The modeling consists of three main stages, which are as follows:

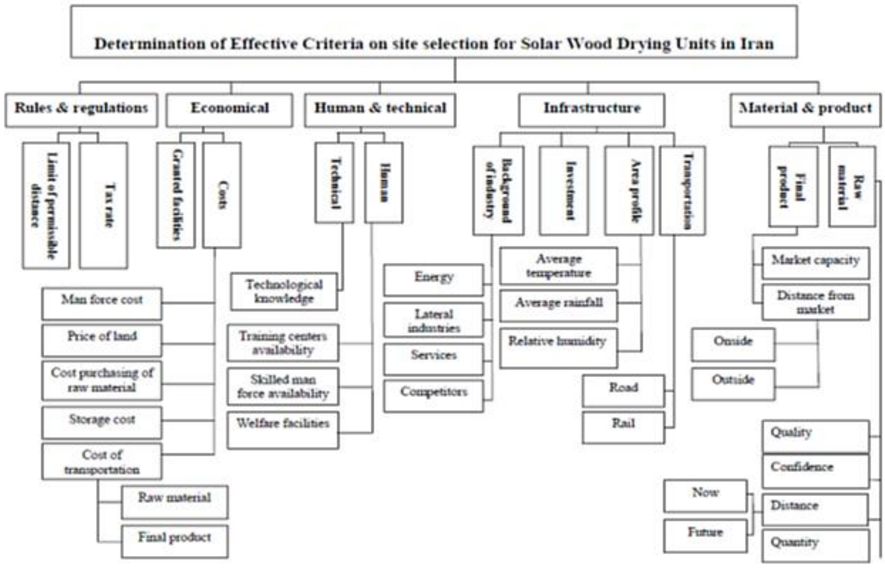
2.1 First stage

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.

2.2 Second Stage

In order to analyze the candidate locations and identify the most preferred ones, the initial step is to identify the criteria. A comprehensive list of factors was prepared and a questionnaire was designed to evaluate their contribution in decision process in the case of Iran. This questionnaire was distributed among experts in Iran wood drying factories. The final set of the attributes was concluded via a Delphi method. A hierarchy of these factors was constructed to establish their weights, using Analytic Hierarchy Process (AHP). The pair-wise comparison matrices were completed by 20 experts from industry and academia. The individual judgments were directed towards consistency and the aggregated opinion was derived using TEAM- EC 2000. Figure 1 shows the hierarchy structure of the attributes influencing decision on selection of solar wood drying.

Figure 1: The hierarchy of criteria and sub-criteria



2.3 Third stage

In the third stage, the data for the attributes were collected from the alternative locations. For this, the questionnaires were presented to the managers of the neighboring factories. Then the Fuzzy Decision Making (FDM) (Memariani, 2000), software was used to rank the location because the data for certain attributes were either qualitative or imprecise. This software is base of on Fuzzy version of TOPSIS (Technique for order- preference by similarity to ideal solution). It incorporates besides quantitative information, the imprecise (Fuzzy numbers) and qualitative (linguistic) data. Figure 2 shows the description of the problem in FDM.

Figure 2: Description of the problem in FDM

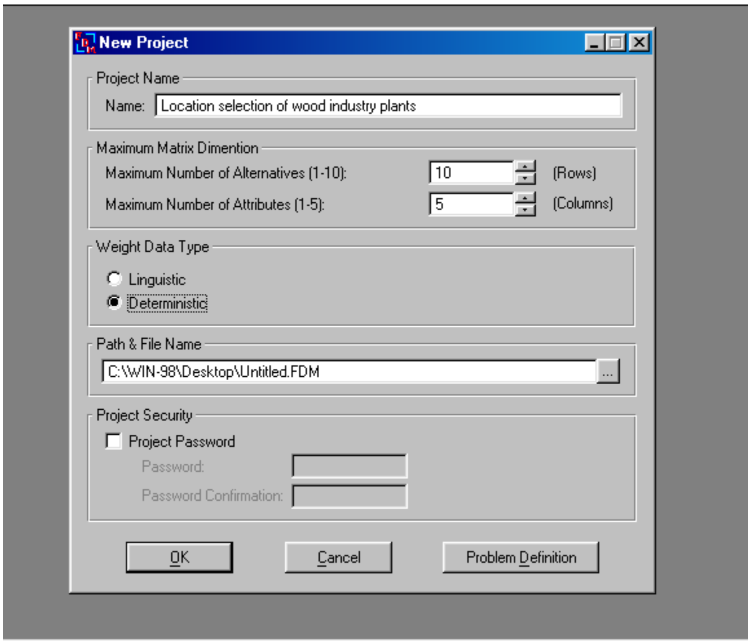


Table 1 shows the weighing value of the attributes influencing decision on selection of provinces for solar wood drying.

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

Row	Criteria	Form of data	Weighing value (Global)	Kind of criteria	Description
1	Raw material & product: raw material: quality	linguistic	0.015	benefits	Quality of raw material
2	Raw material & product: raw material: Confidence	linguistic	0.009	benefits	Confidence in supply
3	Raw material & product: raw material: distance: Now	deterministic	0.006	costs	Supply distance (present, Kilometer)
4	Raw material & product: raw material: distance: Future	deterministic	0.002	costs	Supply distance (future, Kilometer)
5	Raw material & product: final product: Market capacity	linguistic	0.073	benefits	Sale amount of product
6	Raw material & product: raw material: Quantity	linguistic	0.015	benefits	Quantity of raw material (inside the region, M3)
7	Raw material & product: final product: distance from market: outside	deterministic	0.004	costs	Distance from market (Kilometer)
8	Infrastructure Transportation network: Road	linguistic	0.028	benefits	Transportation network (road)
9	Infrastructure Transportation network: Rail	linguistic	0.014	benefits	Transportation network (rail)
10	Infrastructure Area profile Average rainfall	linguistic	0.053	costs	Average of rainfall in the province (mm)
11	Infrastructure Area profile Amount of absorbed solar energy	linguistic	0.159	benefits	Amount of absorbed solar energy In the province (cal/cm^2) in the province
12	Infrastructure Area profile Relative humidity	linguistic	0.053	costs	Ralative humidity in the province (%)
13	Infrastructure Investment	linguistic	0.033	benefits	Capital absorption
14	Infrastructure Background of industry Energy	linguistic	0.028	benefits	Industry background
15	Infrastructure Background of industry Lateral industries	linguistic	0.037	benefits	Background of industry Lateral industries
16	Infrastructure: Background of industry: Services	linguistic	0.013	benefits	Background of industry: Services
17	Infrastructure: Background of industry: Competitors	linguistic	0.018	costs	Competitors in the province
18	Human & technical: Human: Training centers availability	linguistic	0.01	benefits	Training centers availability
19	Human & technical: Human: Skilled man force availability	linguistic	0.071	benefits	Skilled man force availability
20	Human & technical: Human: Welfare facilities	linguistic	0.1	benefits	Welfare facilities
21	Human & technical: Technical: Technological knowledge	linguistic	0.021	benefits	Technological knowledge
22	Economical: Costs: Man force cost	linguistic	0.002	costs	Man force costs (Monthly wage: Rial)
23	Economical Costs Price of land	linguistic	0.02	costs	Price of land (per m^2: Rial)
24	Economical: Costs: Cost purchasing of raw material	linguistic	0.071	costs	Cost purchasing of raw material
25	Economical:	linguistic	0.016	costs	Storage cost

	Costs: Storage cost				(Daily: Rial)
26	Economical: Costs: Cost of transportation: Raw material	Triangular Fuzzy	0.026	costs	Cost of transportation: Raw material (Per10km:Rial)
27	Economical: Costs: Cost of transportation: Final product	Triangular Fuzzy	0.009	costs	Cost of transportation: Final product (Per 10km:Rial)
28	Economical: Granted facilities	linguistic	0.142	benefits	Granted facilities
29	Rules & regulations: Tax rate	linguistic	0.02	costs	regulations: Tax rate (Annual :%)
30	Rules & regulations: Limit of permissible distance	linguistic	0.02	costs	Rules & regulations: Limit of permissible distance (Km)

The software is also capable of generating detailed description and analysis of the decision problem in an intelligent report form. The weights are calculated as follows:

The questionnaires of the data for the attributes were distributed to the selected locations and then collected as the source of information. Some of the data were linguistic type while some of them were deterministic. Some kinds of attributes were divided into cost or benefits, depending on being considered as desirable or undesirable by the decision makers (Table 1). For applying FDM software, the linguistic data were converted to fuzzy data (Table 2). A sample of the attributes is shown in Fig. 3.

The Triangular Fuzzy data is in the form of *m*, *a* and *b*, where *'m'* means an approximate value, *'a'* the positive tolerance of *'m'* and *'b'* represents the negative tolerance of *'m'*. These results in a matrix of 31*9 has been presented in the attachment (Attachment 1).

In the next step, the fuzzy numbers are converted into real numbers by using de - fuzzification methods. Then, the matrices are normalized to do away with dimensions of indicators and their coefficients are multiplied by the related vector. We can obtain the radius value of any alternatives in an *'n'* dimensional space (where n means number of indicators) by finding ideally positive and negative solutions. The final advantage of each alternative is because of its relative proximity to positive ideal response (Hwang & Yoon, 1981).

Figure 3: Description of the criteria in FDM (A sample)

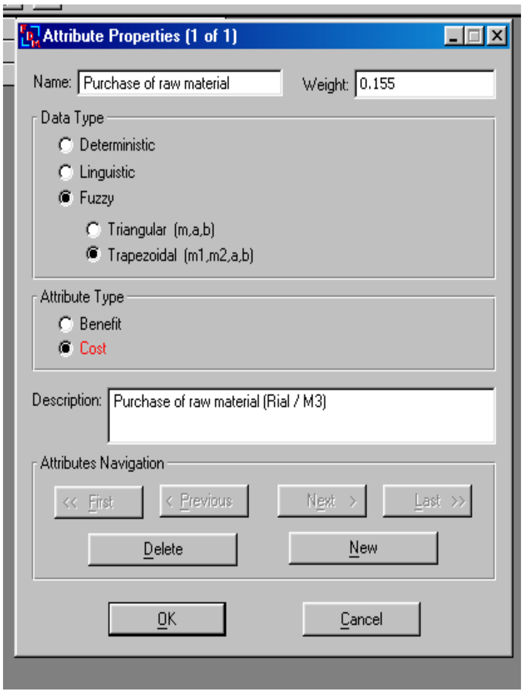


Table 2: The conversion of linguistic data to fuzzy data

Linguistic data	Fuzzy data(m1,m2, a, b)
Very low	0, 0.1,0,0.1
Low	0.2,0.2,0.1,0.1
Fairly low	0.3,0.4,0.1,0.1
Average	0.5,0.5,0.1,0.1
Fairly high	0.6,0.7,0.1,0.1
High	0.8,0.8,0.1,0.1
Very high	0.9,1,0.1,0

3. Results and conclusion

The 9 location candidates were ranked using FDM software and the ranking result is presented in Table 3.

Table 3: Final outcome

Rating	Priority	Province
2	85.71	Tehran
1	88.83	Qom
5	72.97	Alborz
9	47.66	Qazvin
7	63.29	Markazi
4	74.91	Mazandaran
8	61.44	Fars
6	70.86	Esfahan
3	76.48	Khorasan

3.1 Criteria

3.1.1 Amount of absorbed solar energy as the highest priority criteria

The result (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.

3.2 Alternatives

3.2.1 Prioritizing items using TOPSIS

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 is favorite 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.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://dx.doi.org/10.14254/jems.2017.2-2.2

Funding

The authors received no direct funding for this research.

Citation information

Azizi, M. (2017). Strategic model for location selection of solar wood drying by applying TOPSIS. *Economics, Management and Sustainability, 2*(2), 15-23. doi:10.14254/jems.2017.2-2.2.

References

Azizi, M. (2012). A decision making model regarding wood panel selection. *International Journal of Analytic Hierarchy Process (IJAHP), 4*(2).

Desch, H. E., & Dinwoodie, J. M. (1996). *Timber: Structure, Properties, Conversion and use*. London: Macmillan Press Ltd.

Helwa, N. H., Khater, H. A., Enayet, M. M., & Hashish, M. I. (2004). Experimental evaluation of solar kiln for drying wood. *Drying technology*, *22*(4), 703-717.

Hwang, C. L., & Yoon, K. (1981). *Multiple Attribute Decision Making*. Springer Verlag.

Ishizaka, A., & Labib, A. (2011). Review of the main developments in the analytic hierarchy process. *Expert systems with applications*, *38*(11), 14336-14345.

McCauley, C. K., & Caulfield, J. P. (1990). Using mixed-integer programming to determine the optimal location for an oriented strandboard plant in Alabama. *Forest products journal*, *40*(2), 39-44.

Memariani, A. (2000). *FDM Manual*. Tarbiat Modarres University, 11-24.

Michael, J. H., Teitel, J., & Granskog, J. E. (1998). Production facility site selection factors for Texas value-added wood producers. *Forest products journal*, *48*(7/8), 27-32.

Scientific, technical and statistical information provided by SANA (renewable energy organization of Iran). Retrieved from http://www.suna.org.ir/fa/home.

Wilson, J. (2006). Solar drying kilns: A cost effective and efficient way to take green board to usable lumber. *Popular wood working*, 74-79. Retrieved from http://washtenawcd.org/downloads/solarkiln.

Attachment 1

	Quality of raw material	Confidence of raw material	Distance of raw material km	Distance raw material future km
Alborz	very high	very high	150	50
Fars	low	medium	250	150
Isfahan	medium	high	250	200
Khorasan	high	high	150	100
Markazi	medium	medium	250	50
Mazandaran	very high	very high	50	50
Qazvin	medium	medium	250	150
Qom	very high	very high	50	50
Tehran	very high	very high	50	50

	Market capacity	Quality of raw material	Distance from market km	Transportation road	Transportation rail
Alborz	high	high	50	high	medium
Fars	low	low	350	high	medium
Isfahan	high	low	50	very high	very high
Khorasan	very high	low	50	very high	very high
Markazi	medium	medium	350	high	high
Mazandaran	medium	very high	350	high	high
Qazvin	low	low	250	medium	low
Qom	very high	very high	70	very high	very high
Tehran	very high	very high	50	very high	very high

	Background lateral industries	Background services	Background competitors	Training center availability
Alborz	high	high	medium	high
Fars	low	low	low	low
Isfahan	medium	medium	medium	high
Khorasan	high	high	low	very high
Markazi	medium	low	low	high
Mazandaran	medium	medium	high	high
Qazvin	low	medium	low	low
Qom	very high	very high	low	very high
Tehran	very high	very high	medium	very high

	Skill man force availability	Human welfare facility	Technical technological knowledge	Man force cost
Alborz	high	medium	medium	medium
Fars	medium	high	medium	medium
Isfahan	medium	medium	medium	medium
Khorasan	high	very high	high	medium
Markazi	medium	high	high	medium
Mazandaran	high	high	medium	medium
Qazvin	low	high	medium	medium
Qom	very high	very high	very high	medium
Tehran	very high	very high	very high	Relatively high

	Price of land	Purchase cost raw material	Storage cost	Transportation raw material cost
Alborz	low	medium	low	m:450000 a:50000 b 50000
Fars	very low	medium	very low	m:450000 a:50000 b 50000
Isfahan	medium	medium	low	m:450000 a:50000 b 50000
Khorasan	medium	medium	low	m:450000 a:50000 b 50000
Markazi	very low	medium	very low	m:550000 a:10000 b 20000
Mazandaran	low	low	very low	m:150000 a:50000 b:50000
Qazvin	very low	high	very low	m:450000 a:50000 b 50000
Qom	very low	medium	medium	m:250000 a:50000 b:50000
Tehran	medium	medium	medium	m:350000 a:50000 b:50000

	Transportation final product cost	Granted facility	Regulation tax rate	Regulation permissible distance
Alborz	m:450000 a:50000 b:50000	high	medium	high
Fars	m:250000 a:50000 b:50000	high	medium	high
Isfahan	m:450000 a:50000 b:50000	high	medium	high
Khorasan	m:450000 a:50000 b:50000	medium	medium	high
Markazi	m:450000 a:50000 b:50000	high	medium	high
Mazandaran	m:350000 a:50000 b:50000	high	medium	high
Qazvin	m:450000 a:50000 b:50000	medium	medium	high
Qom	m:350000 a:50000 b:50000	high	medium	high
Tehran	m:350000 a:50000 b:50000	high	relatively high	very high