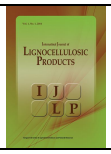

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Optimized locating of fluting paper plant from agricultural residues using AHP (based on benefit and cost approach)

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Abstract

A suitable location plays an important role in the competitiveness of a plant in the market and should be selected such that it allows access to strategic advantages compared with other competitors. The aim of the current study was identification optimized location of fluting paper plant from agricultural residues in Mazandaran province using the Analytical Hierarchy Process (AHP). After performing pilot studies, indices effective in selection of a place for establishing fluting paper plant was identified in Mazandaran province; then, a hierarchy of indices and sub-indices were designed based on the benefit and cost structure; and finally, value-weighted index of each of them was determined using questionnaire and data analysis in expert choice software medium. In the second stage, alternatives have been prioritized based on the benefits to costs ratio (B/C) in order to determine the best place among the alternatives of east, west and center of the province. Results show that the eastern part of Mazandaran province has the highest benefit to cost ratio and is the best place for establishing fluting paper plant from agricultural residues in Mazandaran province.

Keywords: Agricultural residues, Analytical Hierarchy Process, Fluting paper, Mazandaran province.

1. Introduction

There were some problems in supplying raw materials for pulp & paper in industries in the country. The problems were due to factors such as population growth, increase in demand of wood and paper products in the country, limited surface of commercial forests and competition of paper and pulp industries plants in preparation of wooden raw material. Thus, it is necessary to use non-wooden lignocellulosic resources such as agricultural residues in order to solve the problem. Based on the studies conducted in Iran and abroad, using agricultural residues can appropriately compensate for the shortage of fiber raw material required for the paper industry in Iran.

Studies on the production of paper and pulp in Iran have recently focused on non-wooden lignocellulosic resources, including wheat straw (Mahdavi, 1995), cotton stem (Shokoei, 1997), wheat and rice straw (Kashani, 1997), bagasse (Jafari Petrodi, 2000), sunflower stem (Roodi, 2001), wheat straw (Moradian, 2002), and cotton stem (Yaghoubi., 2004) through various processes. The results of these studies indicate that the above-mentioned non-wood resources are suitable for producing paper. Muarkami et al. (1990) and Rowell et al. (1997) reported similar results (Sefidgaran et al., 2006). Some of researchers have identified different internal and external qualitative and quantitative factors which are considered as important determinants in selection of a manufacturing facility. These attributes include availability of skilled workforce (Galbraith et al., 2008), access to supplier (Cheng et al., 2007), proximity to customer market (Kodali and Routroy, 2006), availability of infrastructure (Partovi, 2006), transporting/trucking facilities (Stewart and Lambert, 2008), and utilities and community environments (Viswanadham and Kameshwaran, 2007).

The goal of this study was to find an optimized location for fluting paper plants utilizing the AHP method using agricultural residue in Mazandaran province. In order to select suitable place for establishing paper plant using agricultural residue, Stovall (1980) regarded factors such as access to the desired agricultural residues, transportation facilities, access to skilled labor force, fuel price, tax, water resources, laws and regulations, environmental laws, residue disposal conditions, and cultural and social specifications of the region as important ones. Mazandaran province is one of the important agricultural Zones in the country due to its considerable lignocelluloses resources (Statistics of Agriculture, 2011). It is very important to identify the regions in the province which have the best condition for establishing such plants. If technical, economical and regional issues are considered in construction, the plant will be successful in competitive production. The following points can be considered in locating different plants for wood industries.

Bayat Kashkooli et al. (2009) studied development of wood and paper industry in Sistan and Baluchestan Province, using Analytical Hierarchy Process. In this province, priority of the mentioned alternatives for construction of wood and paper plants was over Zahedan, Chabahar, Zabol and Iranshah. Ramazan Zadeh et al. (2009) introduced the most important indices which are effective in locating Medium Density Fiber (MDF) plant in Mazandaran province, such as ensuring supply of raw material, granted facilities, lower environmental damages, purchasing cost of raw material and identifying the best place for construction of new MDF units in eastern Mazandaran. Vali (2010) also mentioned the most important indices which are effective in locating fluting paper plant in Golestan province, such as residues supply cost, ensuring supply of residues, access to water resources and amount of residues. Based on the results obtained in this research, Gonbad city was identified as the most suitable alternative for constructing fluting paper plant. Mohebi Gargari et al. (2010) introduced Mazandaran, Guilan, Tehran and Ghom provinces as priorities for constructing new units of this industry by evaluating effective indices and locating wood drying units in the country, using TOPSIS method. Azizi et al. (2003) selected the best location for constructing laminate and coat plants, based on benefit, opportunity, cost and risk factors, from among five provinces of Guilan, Mazandaran, Kurdistan, West Azerbaijan and Ghazvin, using Network Analysis Process Method. Burdurlu and Adjer (2003) used AHP method to determine the best location for constructing furniture manufacturing plant in Turkey and introduced Istanbul as the most suitable place for construction of new units of furniture production based on indices such as urban population (market volume), population growth speed and easy transportation of products to other regions. Mc Causley and Caulfield (1990) identified important indices effective in locating oriented strand board manufacturing plant as accessibility to raw material, transportation, access to suitable labor force, plant capacity, production costs, profitability, market considerations and investment requirements. Weber (1929), in his book on the Location of Industries', suggested that industrial location was an optimal consideration of two major factors, i.e. transportation costs and labor costs; where optimal location was the least-cost production location within the triangle formed by fixed locations of the market and two sources of raw material.

The present research seeks to find optimized location for fluting paper plant from agricultural residues in Mazandaran province. Accepting the hypothesis that eastern Mazandaran will have the higher priority for establishing the desired plant due to more facilities and cultivated surface for most of crops, other regions of Mazandaran province have the second priority. Saaty (1980) introduced AHP model which is structured method to incorporate the tangible and intangible measurements/preference opinion in a multi-criteria process. This method decomposes complex and unstructured problem into a set of components in a multi level hierarchic form (Yang and Lee, 1997).

2. Materials and methods

First, indices effective in the location of fluting paper plant using agricultural residues in Mazandaran province were identified through documentary and library studies and interview with experts, university authorities and investors. Then, they were classified into five groups (product, equipment and regional limitations, laws and regulations, economic, technical and human) and 33 sub-indices (Figure 1). Twenty sub-indices were classified into benefits index (Figure 2) and 13 costs sub-indices (Figure 3). In order to determine weight and to prioritize alternatives, the Analytic Hierarchy Process (AHP) has been used based on benefit and cost approach. After drawing a hierarchical tree of indices and sub-indices, three series of questionnaires were designed as follows:

First-type questionnaire: paired comparison of indices and sub-indices: after drawing a hierarchy of the mentioned indices and specifying different levels (Figure 1), a questionnaire was designed for paired comparison of indices and sub-indices and their effect (weight of indices) and distributed among university experts (35%), Industries and Mines Organization (22%), Agricultural Jihad and Natural Resources (13%), and Industry (30%).

Second-type questionnaire based on structure of benefits and costs: in the second stage of research, indices were divided into two parts, i.e. positive indices (Figure 2), and negative indices (Figure 3), which were designed to find significance degree of indices and their prioritization (for more accurate evaluation of comparing indices relative to alternatives). Indices were classified into two groups of positive indices (benefits) and negative indices (costs) not to neutralize effects of each other (Jesuk, 2005; Wedley et al., 2001).

Third-type indices, in the third-type questionnaire: different regions of the province were tested and interpreted relative to indices effective in the location of fluting paper plant (related alternatives include East of Mazandaran province (Sari, Neka, Behshahr and Ghaemshahr), Center of Mazandaran province (Babol, Amol, SavadKooh, Noor), and West of Mazandaran province (Ramsar, Tonekabon, Noshahr and Chalus). Then, utility of different regions of the province has been specified in terms of these indices. At the end, the suitable region has been studied according to Analytic Hierarchy Process in terms of weighted value of different indices, and its sensitivity has been analyzed. In order to select the best location for the establishment of fluting paper plant from agricultural residues in Mazandaran province, three alternatives were considered. In order to prioritize alternatives, indices were divided into benefits and costs. Alternatives were once under paired comparisons relative to benefits. Then, the alternatives were compared with each other and priority of alternatives was separately examined regarding the benefits and costs index. By calculating benefit to cost ratio for each one of the alternatives, the alternatives which has the highest ratio has been selected as the top alternative.

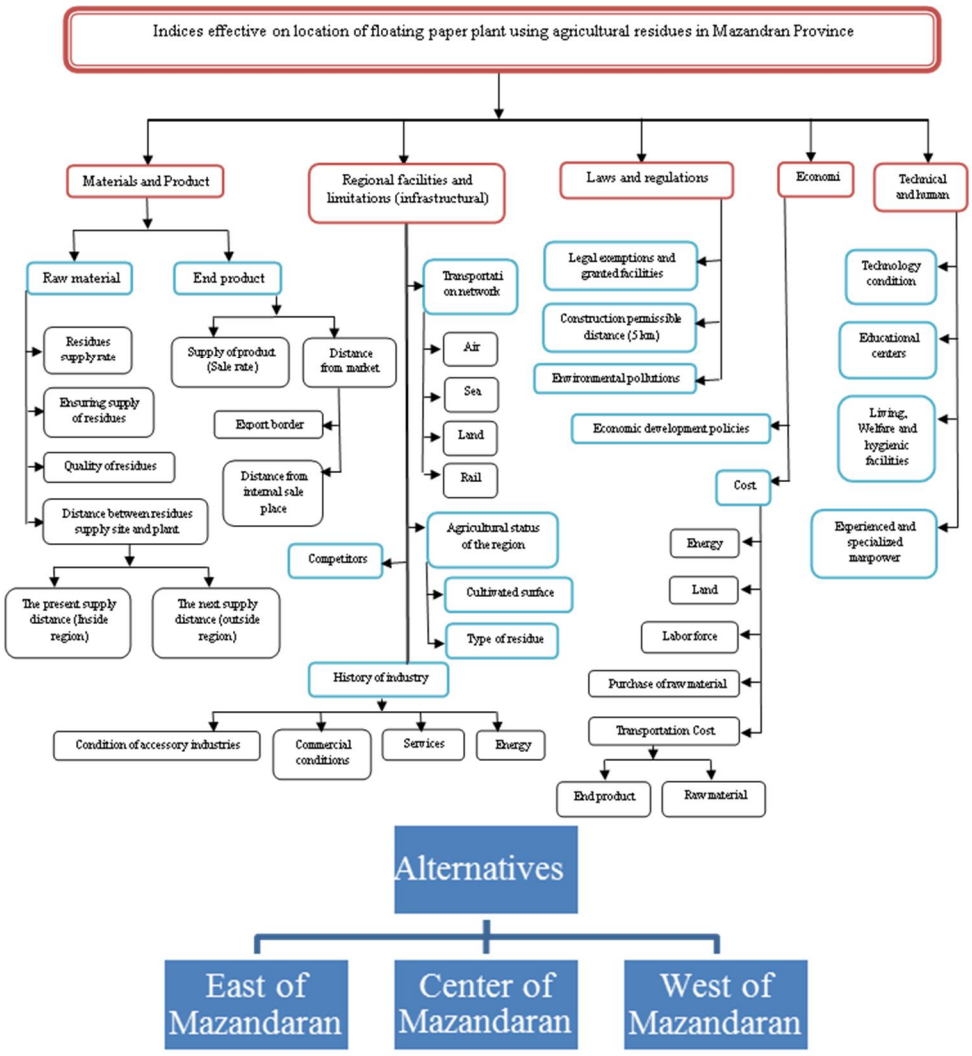

Figure 1. Hierarchical structure of indices and sub-indices.

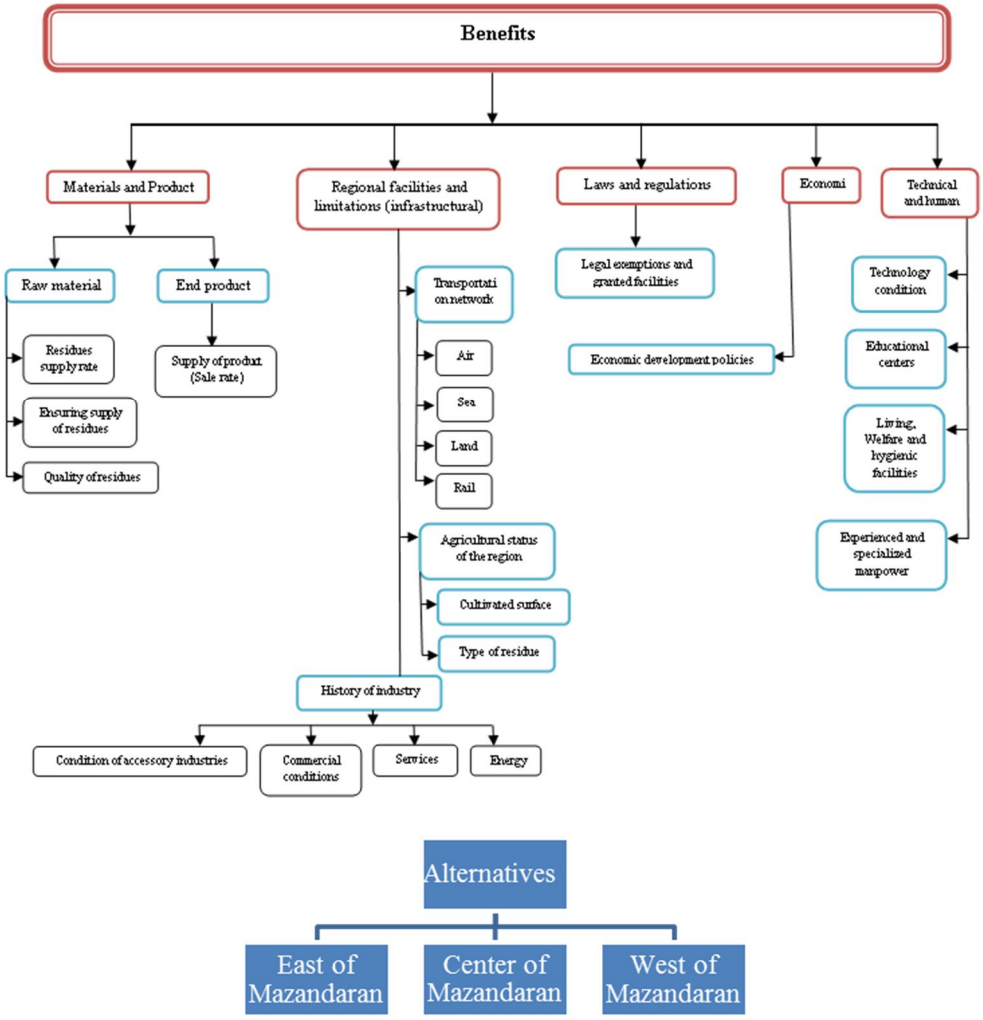

Figure 2. Hierarchical structure based on benefits.

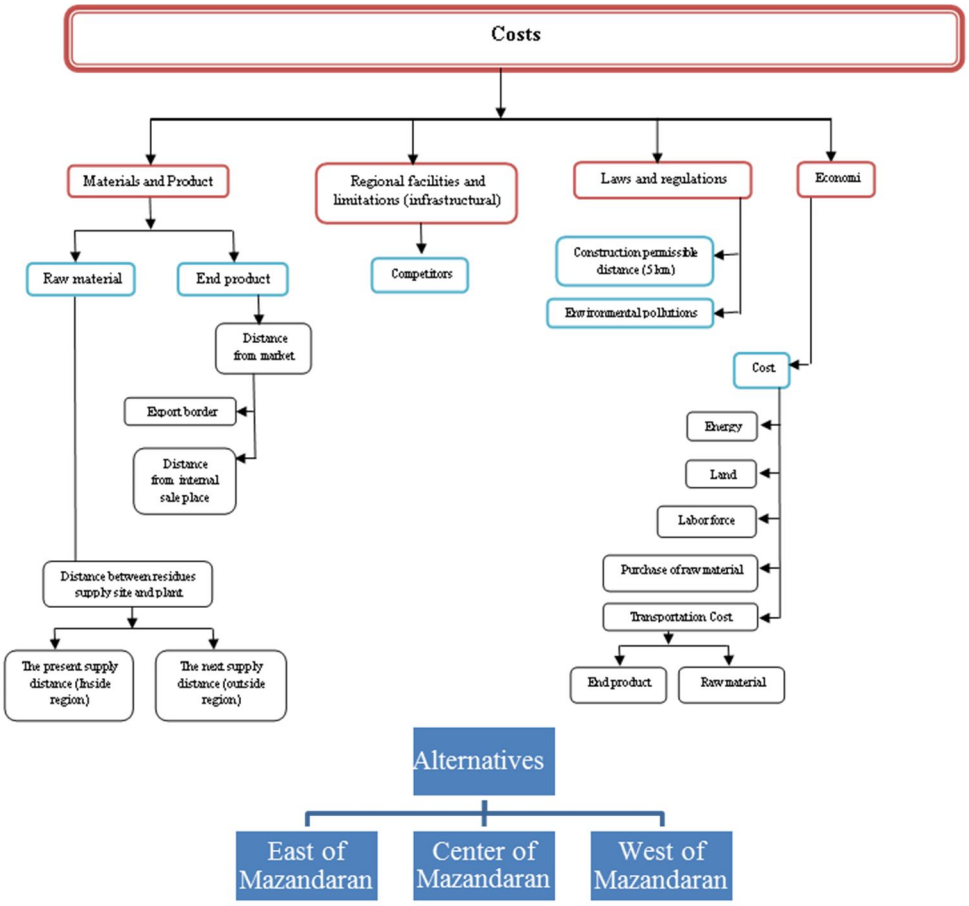

Figure 3. Hierarchical structure based on costs.

2.1. Analytic hierarchy process (AHP) for determining significance degree (value-weighted index) of each attribute

The Analytic Hierarchy Process (AHP) is a method of decision making with which one can make some decisions based on several attributes or multi-criteria decisions. Using AHP method, the structure is prepared; and then, suitable criteria for decision making are compared with each other and their value-weighted index is determined. The numbers which are used for paired comparison ranges from 1 to 9 which is a standard measurement form.

AHP application is based on three principles:

A- creating the structure and arranging it based on subject

B- establishing priority through paired comparison

C- establishing logical consistency through measurement
Application mechanism of this method is such that a hierarchy is designed for criteria and sub-criteria effective on selection of optimized location of fluting paper plant from agricultural residues in Mazandaran province. Then, a questionnaire is prepared for paired comparison of criteria and sub-criteria and the experts are asked about significance degree of these criteria and sub-criteria as paired comparison matrix. Then, value -weighted index of each one of the criteria and sub-criteria is obtained.
Geometrical mean for the cells of matrices is obtained with the following formula:

$$(a12) = [(a12)1 * (a12)2^{*}\ldots.^{*} (a12)\, n]\, 1\, n \quad (1)$$

After calculating geometrical means of all matrices cells, results are normalized and value -weighted index of criteria and sub-criteria is obtained by combining weight of the low rank elements with weight rate of the high rank elements of the hierarchy – an important point which should be considered is inconsistence rate of matrix. According to Mr. Saaty, developer of the AHP method, in order for the judgments to be compatible, it is necessary that inconsistence rate of matrices is equal to or below 0.1. If inconsistence rate of some matrices is above 0.1, it is necessary that the expert revise his judgment to make matrices compatible; and then, geometrical mean of cells of matrices is obtained from comparative matrices (Saaty, 2000; Ghodsipour, 2001).

3. Results and discussion

3.1. Weight of indices effective

Weight of indices effective on locating fluting paper plant using agricultural residues and results obtained from paired comparison in the experts' view which has been calculated with Expert choice software are presented in two sections: main indices and sub-indices, and prioritization of alternatives based on structure of benefits and costs.

3.2. Results of main indices prioritization

Results obtained from the first type questionnaire show that index of material and product supply with score of 0.376, the most important index and indices (economic, infrastructural, laws and regulations, technical and human) with scores of 0.241, 0.187, 0.119, and 0.077, have the next priority in location of fluting paper plant with agricultural residues (Figure 4).

Figure 4. Prioritization of main indices of fluting paper plant location using agricultural residues in Mazandaran province (inconsistence rate =0.04).

3.3. Prioritization of alternatives

In this stage of research, alternatives paired comparison relative to positive and negative indices was separately formed and information of the second type questionnaire which relates to paired comparison of indices was obtained. In order to prioritize alternatives relative to indices, third type questionnaire has been also used. Prioritization of alternatives relative to benefits and costs (Figures 5 and 6) and B/C ratio (Table 1) is presented in this section.

3.4. Prioritization of benefits and costs indices

3.4.1. Prioritization of positive indices (benefits)

Prioritization of Positive Indices are shown in Figure 5, According to results, residue supply rate and ensuring residue supply have gained the highest priority.

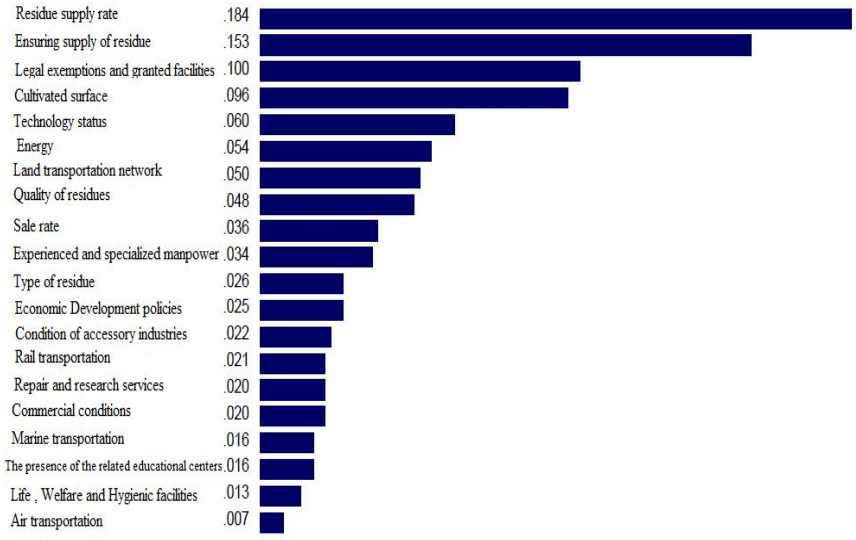

Figure 5. Prioritization of 20 positive sub-indices (Inconsistence Rate =0.03).

3.4.2. Prioritization of negative indices (costs)

Prioritization of Negative Indices are shown in Figure 6, According to results, row material purchase cost and distance between residues supply site and plant at present have gained the highest priority.

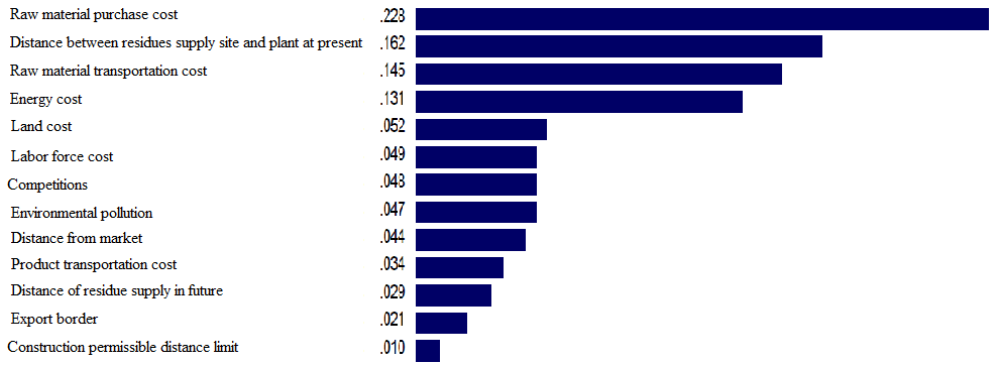

Figure 6. Prioritization of 13 negative sub-indices (Inconsistence Rate =0.02).

3.5. Prioritization of alternatives in terms of benefits and costs indices

3.5.1. Prioritization of alternatives in terms of benefits indices

Alternatives are prioritized in terms of positive indices in the East, Center and West of Mazandaran province, with weights of 0.499, 0.375 and 0.126 (Figure 7).

Figure 7. Final prioritization of alternatives based on benefits (inconsistence rate =0.03).

3.5.2. Prioritization of alternatives in terms of costs indices

Alternatives are prioritized in terms of negative indices in the West, Center and East of Mazandaran province, with weights of 0.619, 0.282 and 0.198. The related diagram is as follows (Figure 8):

Figure 8. Final prioritization of alternatives based on benefits (inconsistence rate =0.02).

3.6. Final prioritization of alternatives based on benefits to costs (B/C)

In order to find the best alternative among three alternatives, we should obtain benefit to cost ratio (B/C) for each one of the alternatives and the alternative which has the highest value is the best alternative. East of Mazandaran province is the best alternative for construction of fluting paper plant using agricultural residue in Mazandaran province due to more B/C (Table 1).

Table 1. Ratio of positive to negative indices (B/C).

Alternatives	(Benefits)	(Costs)	B/C Ratio
E (East of Mazandaran)	0.499	0.198	2.5201
C (Center of Mazandaran)	0.375	0.282	1.3297
W (West of Mazandaran)	0.126	0.519	0.2428

4. Discussion

Results show that sub-index of residue supply rate and index of material and product have the highest priority and eastern Mazandaran has the highest benefit, the lowest cost; and as a result, it has had the highest benefit to cost and was selected as the best alternative.

4.1. Prioritization of alternatives

4.1.1. Prioritization of alternatives based on Structure of Benefits Indices

Considering the obtained results, Eastern Mazandaran (0.499) has been introduced as the best alternative. Considering Figure 5, sub-index of residue supply (0.184), ensuring residue supply (0.153), legal exemptions and granted facilities (0.100), cultivated surface (0.096) and technology condition (0.060) are the best sub-indices respectively (Figure 5).

Ensuring residue supply of raw materials and residue supply rate

Considering the obtaiend results, eastern Mazandaran has considerabe priority over other two alternatives, especially western Mazandaran, in terms of positive indices of raw materials such as residue supply rate and ensuring supply of raw materials inside the region. More than 52% of the stover cultivated surface and 55% of the cultivated surface of all kinds of agricultural plants are located in eastern Mazandaran. As a result, raw material supply certainty is higher in this region – total cultivated surface of cereals in eastern Mazandaran is 167643 hectare, in the Center of Mazandaran is 138231 hectare, in western Mazandaran is 10682 hectare; also total cultivated surface of agricultural plants in eastern Mazandaran is 253713 hectare, in the Center of Mazandaran is 193762 hectare, and in western Mazandaran is 15658 hectare (Table 2). Azizi et al. (2003) have mentioned sub-indices of certainty of raw material supply as an important priority for selecting location of the laminate and coat unit (Azizi et al. 2003).

Table 2. Average cultivated surface of cereals and agricultural plants (hectare) in east, center and west of Mazandaran province.

Regions	Total cultivated surface of cereals in each region (hectare)	Total cultivated surface of agricultural plants in each region (hectare)
East of Mazandaran	167643	253713
Center of Mazandaran	138231	193762
West of Mazandaran	10682	15658
Total	316556	463133

Reference: based on information obtained from Mazandaran Agricultural Jihad, 2011.

Legal Exemptions and Granted Facilities

Center of Mazandaran has the first priority because it has more underprivileged regions with little difference from eastern Mazandaran, which can use granted facilities, incentives and tax exemptions and employment allowance which are allocated by the government to underprivileged parts of the country and encourage the investors to make more investment in this region than other regions at the center of Mazandaran due to the location of Savad Kooh city in this region (underprivileged regions include West of Mazandaran (Kajoor and Noshahr), Center of Mazandaran (Bandpi, Babol, Babol Kenar, Larijan, Amol, SavadKooh, Baladeh and Noor,) and East of Mazandaran (Kiasar, Dodangeh, Neka and Galoogah) (Monitoring and Evaluation Office, Iran's Ministry of Industry & Mine, 2011).

Cultivated Surface

The cultivated surface of agricultural plants in eastern Mazandaran is higher than that of two other regions; and as a result, agricultural residue rate is more abundant as raw material and this confirms the obtained result.

Technology Condition

Human knowledge and awareness are developing. Different universities give new tools and other new techniques and technology to the humans. Sari has priority over other regions of the province because it is the center of the province and the University of Agricultural Sciences and Natural Resources which train skilled manpower of wood and paper industries are located there–center of the province is better than other parts of the province in terms of hardware, equipment and the related organizations.

4.1.2. Prioritization of alternatives based on Structure of Costs

Considering the obtained results, western Mazandaran with weight degree of 0.421 has the highest priority in terms of costs. Considering Figure 6, sub-indices of raw material quantity (outside the region), competitors, raw material purchase cost, distance from market, distance of raw material supply at present, and land purchase cost are the preferred negative sub-indices.

Indices of raw material (raw material purchase cost and distance between residue supply site and plant at present)

Considering that rate and accessibility of raw material in eastern Mazandaran are higher than those of other regions, high volume of raw material is supplied from the region; and as a result, distance between raw material supply and raw material purchase cost will be shorter than other regions.

Raw material transportation cost

Due to high volume of these materials naturally (low density), very high costs prevent transportation of residues in long distances. The shorter the distance between raw material supply site and agricultural lands, the lower the transportation cost. Because raw material rate in eastern Mazandaran is higher than that of other regions and more raw materials are supplied inside the region, raw material cost will be lower than other regions.

Energy cost

By excluding duel subsidy from industry, its importance and cost which is spent for supplying energy of industries are enhanced, and because there is no gas piping in all industrial estates of Mazandaran, cheap transportation (rail

transportation) causes decrease of energy cost. eastern Mazandaran is more preferred due to rail lines.

Land cost

Land purchase cost in eastern region is lower than that of other regions. Averagely, price of each cubic meter of land is 15 dollar in industrial estate in eastern Mazandaran, 20 dollar in central Mazandaran and 25 dollar in western Mazandaran (Iran's Ministry of Industry & Mine, 2011). Generally, price of land in Mazandaran province increases from east to west, because western Mazandaran is recreational and tourist region.

4.2. Sensitivity analysis

Since different judgments are made on comparison of indices and its sub-indices, we use sensitivity analysis in order to provide stability and consistence of analysis (Saaty, 2000). With increase or decrease of the indices, we will conclude that ratio of other indices will not change. For example, when index of laws and regulations in benefits structure increases from 0.161 to 0.781, prioritization of alternatives changes from E-C-W to C-E-W state (Table 3). Sum of other indices will be equal to 0.219 and new weight of other indices will be as follows: materials and products (with weight of 0.093), infrastructure (with weight of 0.090), economic (with weight of 0.011), technical and human (with weight of 0.025). Regarding hierarchy of costs, alternatives prioritization changes three times more with increase of infrastructure index from zero to one and this affects the results (Table 3). With increase of infrastructure index (competitors) from 0.091 to 0.524, prioritization of alternatives will change from W-C-E to C-W-E. By changing weight of infrastructure index (competitors) from 0.091 to 0.524, weight of material and product, laws and regulations and economic indices changes to 0.214, 0.045 and 0.216 , respectively. With increase of infrastructure index (competitors) from 0.091 to 0.524, prioritization of alternatives will change from W-C-E to C-E-W and cause to change weight of material and product, laws and regulations and economic indices changes to 0.187, 0.039 and 0.189. With increase of infrastructure index (competitors) from 0.091 to 0.912, prioritization of alternatives will change from W-C-E to E-C-W and cause to change weight of material and product, laws and regulations and economic indices changes to 0.040, 0.008 and 0.040.

Table 3. Changes in prioritization of alternatives based on structure of benefits, costs and results of sensitivity analysis.

Structure of benefits				
Index	Base weight	Changed weight	Alternative	Sensitivity
Materials and products	0.358	0-1	E-C-W	None
Infrastructure	0.345	0-1	E-C-W	None
Laws and regulations	0.161	0.781	C-E-W	Yes (once)
Economic	0.042	0-1	E-C-W	None
Technical and human	0.095	0-1	E-C-W	None
		Structure of costs		
Materials and products	0.410	0-1	W-C-E	None
Infrastructure	0.091	0.524	C-W-E	Yes (thrice)
		0.584	C-E-W	
		0.912	E-C-W	
Laws and regulations	0.085	0-1	W-C-E	None
Economic	0.414	0-1	W-C-E	None

E: East, C: Center, W: West

5. Conclusions

Results show that main indices studied in this research can help selecting optimized location of fluting paper plant using agricultural residues in Mazandaran province. Materials, product and economic and infrastructural indices are the main indices effective on the location of fluting paper plant using agricultural residues in Mazandaran province. The most important factors are materials and product. Generally, the residue supply rate has the highest effect on location of fluting paper plant using agricultural residues in Mazandaran province, considering all sub-indices studied in this research. Raw material Sub-index is one of the most important effective factors and eastern Mazandaran is the best alternative due to its higher B/C ratio considering the obtained results.

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