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# Optimized Location of Floating Paper Plant from Agricultural Residues Using AHP (Based on Benefit and Cost Approach)

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

**Key words:** Location · Analytical Hierarchy Process · Agricultural Residues · Floating paper · Mazandaran province.

## INTRODUCTION

Today, considering population growth, increase in consumption 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 caused some problems in supply of pulp and paper industries raw material in the country and it is necessary to use non-wooden lignocellulosic resources such as agricultural residues in order to solve this 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 paper industry in Iran.

In recent years, studies on production of paper and pulp in Iran have focused on non-wooden lignocellulosic resources, including wheat straw [1], cotton stem [2], wheat and rice straw [3], bagasse [4], sunflower stem [5], wheat straw [6] and cotton stem [7] through various processes. The results of these studies indicate that the mentioned non-wood resources are suitable for producing paper. *Muarkami et al*. (1990) and *Rowell et al*. (1997) reported similar results [8, 9]. Some of researchers have identified different internal and external qualitative and quantitative factors which are considered important determinants of selection of a manufacturing facility. These attributes include availability of skilled workforce [10] access to supplier [11], proximity to customer market [12]

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availability of infrastructure [13], transportation/ trucking facilities [14], utilities and community environments [15].

Goal of this study is optimized location of floating paper plants using agricultural residue in Mazandaran Province. In order to select suitable place for establishment of paper plant using agricultural residue, *Stovall et al*. (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 and residue disposal conditions, cultural and social specifications of the region as important [16]. Mazandaran Province is one of the important agricultural poles in the country due to their considerable lignocelluloses resources [17]. It is very important to identify the regions of this province which have the best condition for establishment of such plants and if technical, economic and regional issues are considered for construction of such plant, this plant will be successful in competitive production. The following points can be considered in location of different plants of 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 Iranshahr [18]. *Ramazan Zadeh et al.* (2009) introduced the most important indices effective on location of Medium Density Fiber (MDF) Plant in Mazandaran Province such as ensuring supply of raw material, granted facilities, lower environmental damages and purchasing cost of raw material and the best place for construction of new MDF units in east of Mazandaran Province [19]. *Vali et al.* (2010) also mentioned the most important indices effective on location of floating paper plant in Golestan Province such as residues supply cost, ensuring supply of residues, access to water resources and supply of residues and Gonbad city was introduced as the most suitable alternative for construction of floating paper plant based on results obtained from this research [20]. *Mohebi Gargary et al.* (2010) introduced Mazandaran, Guilan, Tehran and Ghom provinces as construction priorities of new units of this industry by evaluating effective indices and locating wood drying units in the country using TOPSIS method [21]. *Azizi et al.* (2003) selected the best location for constructing laminate and coat plants based on benefit, opportunity, cost and risk among five Guilan, Mazandaran, Kordestan, West Azarbayejan and Ghazvin provinces using Network Analysis Process Method [22]. *Burdurlu, Adjer* (2003) used AHP method to make decision about selection of the best location for construction of furniture manufacturing plant in Turkey and introduced Istanbul city as the most suitable place for construction of new units for furniture production based on indices such as urban population (market volume), population growth speed, easy transportation of product to other regions [23]. *Mc Causley and Caulfield* (1990) determined important indices effective on location of oriented strand board manufacturing plant, accessibility to raw material, transportation, access to suitable labor force, plant capacity, production costs, profitability, market considerations and investment requirements [24]. *Alfred Weber* (1929) in his book About ?the Location of Industries? suggested that industrial location was an optimal consideration of two major factors, i.e. transportation costs and labour 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 [25].

The present research seeks to find optimized location of floating paper plant from agricultural residues in Mazandaran Province to answer this question that what region of Mazandaran province is more able to establish floating paper plant. By accepting this hypothesis that east of Mazandaran will have higher priority for establishment of the desired plant due to cultivated surface of most crops as well as more facilities and 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 [26]. This method decomposes complex and unstructured problem in to a set of components in a multi level hierarchic form [27].

Goal of this study is to select the best location for construction of floating paper plant using agricultural residues in Mazandaran province by using AHP method.

## MATERIALS AND METHODS

First, indices effective on location of floating paper plant using agricultural residues in Mazandaran province were identified through documentary and library studies and interview with experts, university authorities and

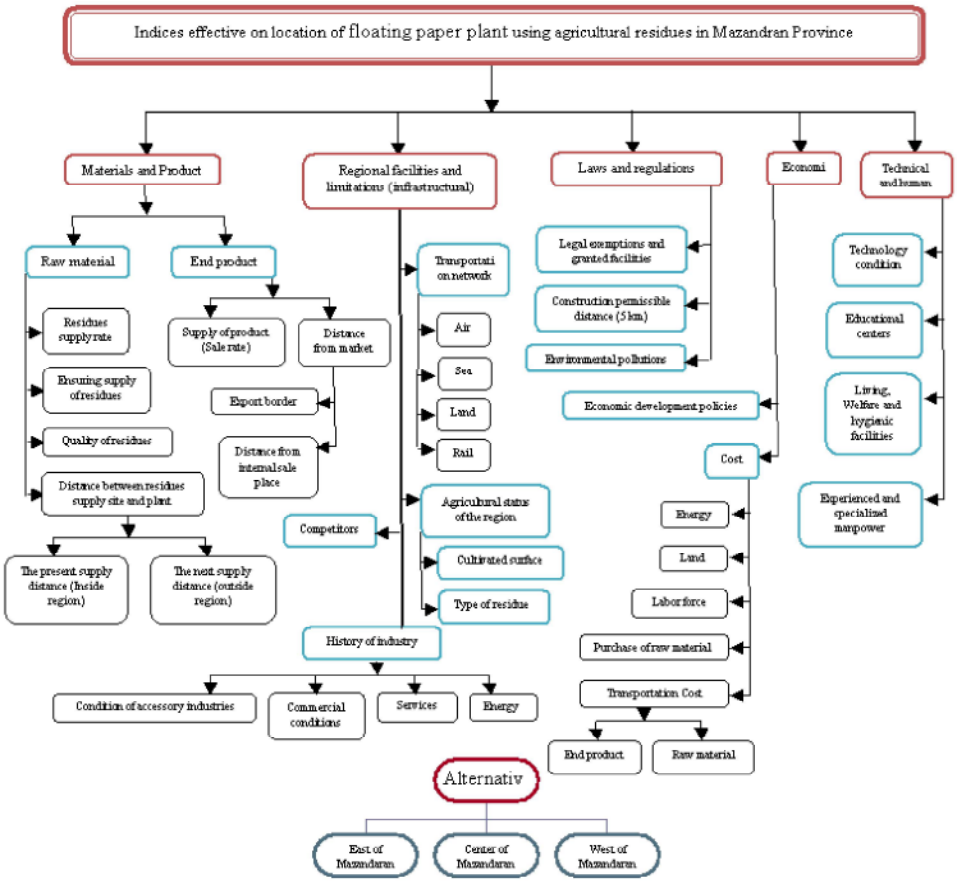


Fig. 1: Hierarchical structure of indices and subindices

investors and classified into five groups (product, equipments and regional limitations, laws and regulations, economic, technical and human) and 33 subindices (Figure 1). 20 subindices were classified into benefits index (Figure 2) and 13 costs subindics (Figure 3). In order to determine weight and prioritize alternatives in this research, Analytic Hierarchy Process (AHP) has been used based on benefit and cost approach. After drawing hierarchical tree of indices and subindices, three series of questionnaires were designed as follows:

- First type questionnaire: paired comparison of indices and subindices: after drawing hierarchy of the mentioned indices and specifying different levels (Figure 1), a questionnaire was designed for paired comparison of indices and subindices and their effect (weight of indices) and was 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 [28, 29].
- Third type indices: in the third type questionnaire, different regions of the province were tested and interpreted relative to indices effective on location of floating paper plant (related alternatives include: First alternative, East of OF Mazandaran Province (Sari, Neka, Behshahr and Ghaemshahr); Second alternative, Center OF Mazandaran Province (Babol, Amol, SavadKooh, Noor); Third alternative, West of Mazandaran Province (Ramsar, Tonekabon, Noshahr and Chalus). Then, utility of different regions of the

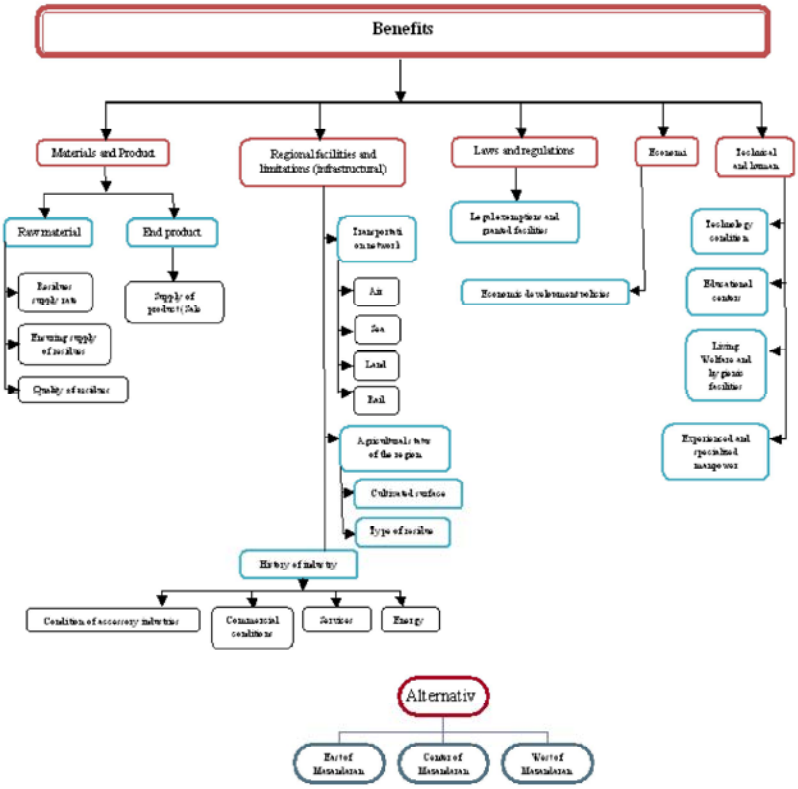


Fig. 2: Hierarchical structure based on benefits

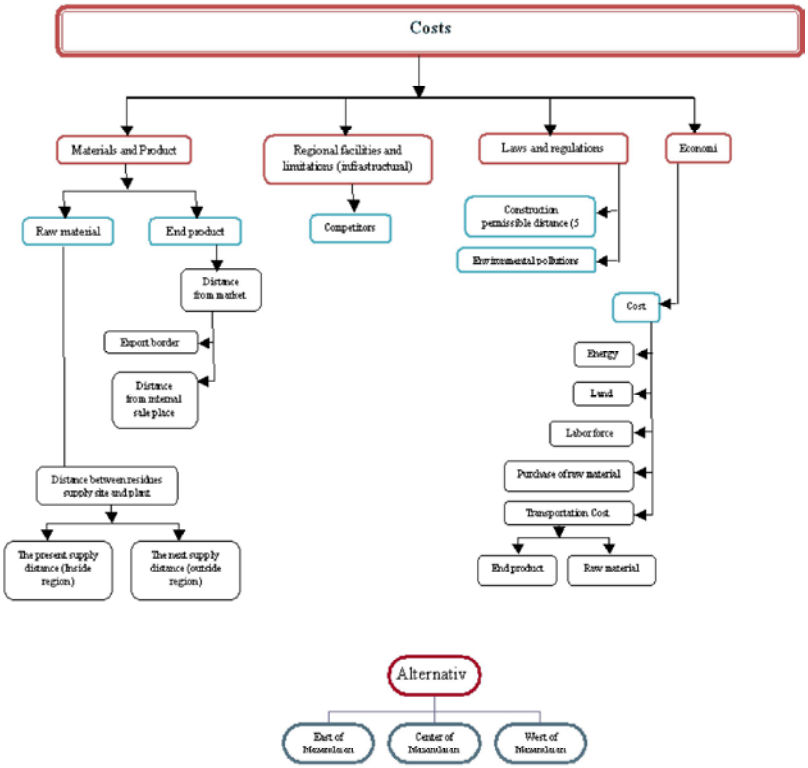


Fig. 3: Hierarchical structure based on costs

province has been specified in terms of these indices. At the end, 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 establishment of floating 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 calculated relative to 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.

**Analytic Hierarchy Process (Ahp) for Determining Significance Degree (Value -Weighted Index) of Each Attribute:** Analytic Hierarchy Process (AHP) is a method for decision making with which one can make some decisions based on several attributes or multi-criteria decisions. With 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 1.9 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 hierarchy is designed for criteria and subcriteria effective on selection of production manager in furniture unit. Then, a questionnaire is prepared for paired comparison of criteria and subcriteria and the experts are asked about significance degree of these criteria and subcriteria as paired comparison matrix. Then, value -weighted index of each one of the criteria and subcriteria is obtained.

Geometrical mean for the cells of matrices is obtained with the following formula:

(a12) = [(a12)1 * (a12)2*….* (a12) n] 1 *n* (1)

After calculating geometrical means of all matrices cells, results are normalized and value -weighted index of criteria and subcriteria is obtained by combining weight of the low rank elements with weight rate of the high rank elements of hierarchy. An important point which should be considered is inconsistence rate of matrix. According to *Mr. Saaty*, innovator of AHP method, in order for the judgments to be compatible, it is necessary that inconsistence rate of matrices 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 [30, 31].

## RESULTS AND DISCUSSION

### Results

**Weight of Indices Effective on Location of Floating Paper Plant Using Agricultural Residues:** Weight of indices effective on location of floating paper plant using agricultural residues and results obtained from paired comparison resulting from the experts' view which has been calculated with Expert choice software are presented in two sections 1: main indices and subindices, 2: prioritization of alternatives based on structure of benefits and costs in this section.

**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 floating paper plant with agricultural residues (Figure 4).

**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, 6) and B/C ratio (Table 1) is presented in this section.


Fig. 4: Prioritization of main indices of floating paper plant location using agricultural residues in Mazandaran Province (inconsistence rate =0.04)

**Prioritization of Benefits and Costs Indices**

**Prioritization of Positive Indices (Benefits)**

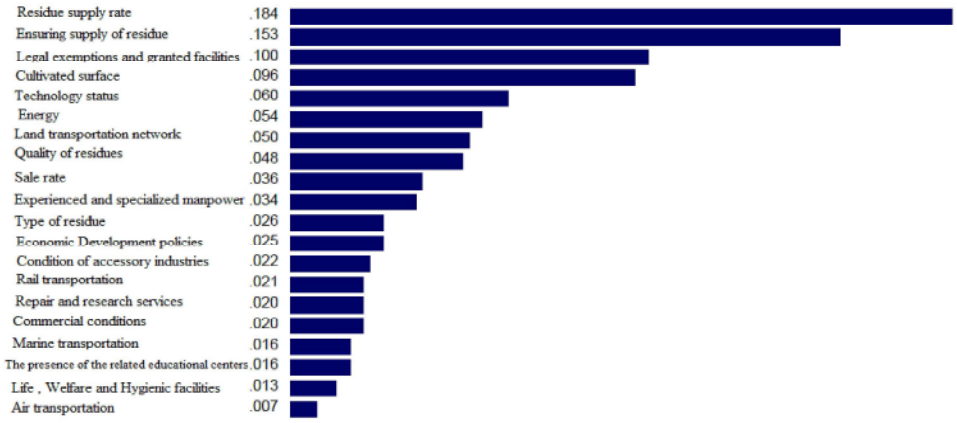


Fig. 5: Prioritization of 20 Positive Subindices (Inconsistence Rate =0.03)

**Prioritization of Negative Indices (Costs)**

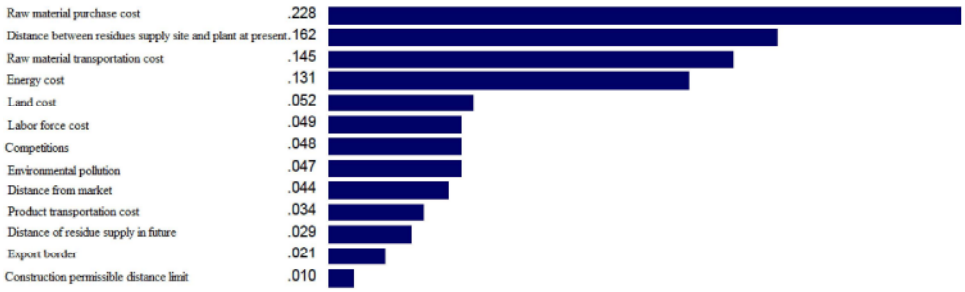


Fig. 6: Prioritization of 13 Negative Subindices (Inconsistence Rate =0.02)

**Prioritization of Alternatives in Terms of Benefits and Costs Indices**

**Prioritization of Alternatives in Terms of Positive Indices (Benefits):** Alternatives are prioritized in terms of positive indices in east of Mazandaran Province, center of Mazandaran Province and west of Mazandaran Province, with weights of 0.499, 0.375 and 0.126 (Figure 7).

**Prioritization of Alternatives in Terms of Negative Indices (Costs):** Alternatives are prioritized in terms of negative indices in west of Mazandaran Province, center of Mazandaran Province and east of Mazandaran Province, with weights of 0.619, 0.282 and 0.198. The related diagram is as follows (Figure 8):

**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


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


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

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

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

alternative for construction of floating paper plant using agricultural residue in Mazandaran Province due to more B/C (Table 1).

## DISCUSSION

Results show that subindex of residue supply rate and index of material and product have the highest priority and east of Mazandaran Province 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.

### Prioritization of Alternatives

**Prioritization of Alternatives Based on Structure of Positive Indices (Benefits):** Considering the obtained results, east of Mazandaran (0.499) has been introduced as the best alternative. Considering figure 5, subindex 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 subindices respectively (figure 5).

**Ensuring Supply of Raw Materials and Quantity of Raw Material: Indices of Raw Matreial (Residue Supply Rate and Ensuring Residue Supply):** Considering the obtaiend results, east of Mazandaran has considerabe priority over other two alternatives especially west of 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 in east of Mazandaran are located in east of Mazandaran. As a result, raw material supply certainty is higher in this region (Total cultivated surface of cereals in East of Mazandaran Province: 167643 hectare, Center of Mazandaran Province: 138231 hectare, West of Mazandaran Province: 10682 hectare and also Total cultivated surface of agricultural plants in East of Mazandaran Province: 253713 hectare, Center of Mazandaran Province: 193762 hectare, West of Mazandaran Province: 15658 hectare [17]. Azizi *et al*. (2003) have mentioned subindices of certainty of raw material supply as an important priority for selecting location of the laminate and coat unit [22].

**Legal Exemptions and Granted Facilities:** Center of Mazandaran has the first priority because it has more underprivileged regions with little difference from east of 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 center of Mazandaran due to 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) [32].

**Cultivated Surface:** The cultivated surface of agricultural plants in east of 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 technique and technology to the humans. Sari University of Agricultural Sciences and Natural Resources in this region which train skilled manpower of wood and paper industries and location of the province

center in this region caused priority of this region over other regions of the province (center of the province is better than other counties of the province in terms of hardware, equipment and the related organizations).

**Prioritization of Alternatives Based on Structure of Costs:** Considering the obtained results, west of Mazandaran with weight degree of 0.421 has the highest priority in terms of costs. Considering figure 6, subindices 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 subindices.

**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 east of 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 east of Mazandaran is higher than that of other regions and more raw materials are supplied inside the region, as a result, 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. East of Mazandaran is more preferred due to rail lines.

**Land Cost:** Land purchase cost in eastern region is lower than that in other regions. Averagely, price of each cubic meter of land is 15 dollar in industrial estate in east of Mazandaran, 20 dollar in center of Mazandaran and 25 dollar in west of Mazandaran [32]. Generally, price of land in Mazandaran province increases from east to west, because west of Mazandaran is recreational and tourist region of Mazandaran province.

Table 2: Changes in prioritization of alternatives based on structure of benefits, costs and results of sensitivity analysis

| Index | Base weight | Changed weight | Alternative | Sensitivity |
|---|---|---|---|---|
| Structure of benefits | | | | |
| 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 | |
| | | 0.584 | C-E-W | |
| | | 0.912 | E-C-W | *Yes (thrice)* |
| Laws and regulations | 0.085 | 0-1 | W-C-E | *None* |
| Economic | 0.414 | 0-1 | W-C-E | *None* |

E: east of Mazandaran, C: Center of Mazandaran, W: west of Mazandaran

**Sensitivity Analysis:** Since different judgments are made about comparison of indices and its subindices, we use sensitivity analysis in order to provide stability and consistence of analysis [30]. 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 2). 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 2). 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.

## CONCLUSION

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

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