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A Strategic Model for Location Selection of Wood Industry: An Application of ANP

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Abstract: The objective of this research is to design a method for selection of an appropriate location to establish plywood and veneer plants in Iran. Due to the climate of this region as well as the destruction of the forests and lack of proper plantation, the supporting forests to feed this industry are limited. Thus, it is vital to optimize the other strategically factors in order to make these plants capable of competing with the foreign plants which have access to less expensive input materials. In case of improper utilization of the resources, this industry can not compete with the imported products. The decision is made within the framework of benefits, opportunities, costs and risks (BOCR). To evaluate the control criteria of the system a control hierarchy is also created and prioritized by applying the Analytic Network Process (ANP). This way, a total of seven major control criteria in the system are prioritized where each one controls a decision network evaluated using ANP. The final synthesis of the system shows province of Gilan is the best choice among five potential provinces which were selected primarily.

Key words: Plywood, Veneer plants, Gilan, Analytic Network Process (ANP)

INTRODUCTION

The need for establishing plywood and veneer products in Iran is high because of the large population of the country as well as the high rate of consumption rate. However, the supporting forests to feed the plywood and veneer plants are limited, due to the climate of this region, destruction of the forests and lack of required plantation. Therefore, it is vital to optimize the other strategically factors in order to make these plants capable of competing with the foreign plants which have access to less expensive input materials. Location is of the most important factors in this regard, economically and socially. It is of great importance for the investor where to establish the plywood and veneer plants. Although in literature one can find many methods of location selection for a variety of industrial and service facilities, they were not quite suitable for this case. The classical analytical methods do not work well because many aspects of this project, especially the social parts of it, can not be quantified properly. Furthermore, these methods are usually developed based on some simplifying assumptions. Otherwise, these problems can not be solved analytically. That is why some real world problems are far from the models constructed on the basis of these restrictive assumptions. On the other hand, the qualitative methods are not enough rigorous for this case. To model this problem, it seems the Analytic Network Process (ANP), developed by Saaty (2001a), to be an appropriate tool. That is why we develop our method of determining the optimal location for establishment of plywood and veneer units in Iran within the framework of the ANP. This paper is the result of an extensive study to select the optimal location for plywood and veneer plants in Iran.

To study the case, one important factor to consider is the availability of the forests to provide raw materials of the plants. Although, there are not enough forests in Iran, there are some regions which are potentially rich to feed plywood and veneer units. In the northern parts of Iran there are spread-leaf forests and in the northwestern as well as western parts of Iran there are rich poplar tree resources.

All of species that be used in Iranian plywood and veneer industries are hard wood.

Hard wood is conventional term for the wood of broadleaved trees (Table 1).

Of course, all the logs be used in green logs to produce plywood and veneer and are not dried.

As far as the location of the plant is concerned, we also studied different regions by investigating the market as well as the required infra structure and finally narrowed down to only five provinces, Gilan, Mazandaran, Kordestan, West Azarbaijan and Ghazvin. These Provinces were studied in depth and their wood

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Table 1: Species used in the Iranian plywood and veneer industries and their densities (Parsapajouh, 1984)

Name of species	Wood density (g cm^{-3})
Fagus orientalis	0.67
Acer insigne Boiss	0.53
Acer lætum	0.64
Tilia begonifolia	0.52
Ulmus glabra	0.65-0.68
Alnus subcordata	0.54
Juglans regia	0.6
Quercus castaneaefolia	0.79
Ulmus carpinifolia	0.74
Carpinus betulus	0.7
Fraxinus excelsior	0.71
Zelcova carpinifolia	0.75-0.8
Populus alba	0.5
Populus nigra	0.45

resources, particularly forest wood and poplar were estimated. In literature, one can find many studies to determine the optimal location. However, we review briefly some studies which specifically introduce the methods for wood industry locations. Azizi and Memariani (2004) developed a method for selecting the most suitable location for wood industry units by applying TOPSIS technique. Michael *et al.* (1998) studied the setting of effective criteria for location selection to establish wood industry secondary products such as cabinet, furniture and special products. They identified six groups of criteria and considered the sub-criterion of raw material purchase as top priority in selection of the location of these factories. For selection of OSB (Oriented Strand Board) factory McCauley and Caulfield (1990) specified the important factors as access to raw material, transportation, accesses to suitable manpower, factory capacity, costs of production, profitability, market observations and investment requirements. Alvisi *et al.* (1998) described the location for establishment of plywood, particleboard, fiberboard and finishing factories. They believe these industries depend on the suppliers of raw material. On the other hand, furniture industries that use about 90 % of panel products are in good conditions in terms of location and this is due to transportation costs. To ensure the supply of timber in future, the wood suppliers (especially poplar suppliers) and panel producers should agree to work closely to assure regular supply of raw material and contribute to economic growth.

Lin *et al.* (1996) studied the continuous supply of raw material in the location of an OSB company as the main criteria. They considered the economical productivity of the location of a manufacturing plant relevant to the supply of raw material. Krajewski and Ritzman (1999) considered the proximity to suppliers and resources of raw material as the main factors needed for selection of the factory site.

THE ANALYTIC NETWORK PROCESS (ANP)

Since the most suitable technique for our study seems to be the Analytic Network Process (ANP), we review it briefly in this section.

The Analytical Network Process (ANP), a generalization of the Analytic Hierarchy Process (AHP) method for multi criteria decision making, provides an even broader framework for decision making in complicated environments. The advantage of this new theory over the AHP (Analytic Hierarchy Process) is its ability to extend to cases of dependence and feedback and generalization of the super-matrix approach. It allows interactions and feedback within clusters (inner dependence) and between clusters (outer dependence). Feedback can better capture the complex effects of interplay in human society. The ANP provides a thorough framework to include clusters of elements connected in any desired way to investigate the process of deriving ratio scales priorities form the distribution of influence among elements and among clusters.

The ANP is a coupling of two parts. The first consists of a control hierarchy or network of criteria and sub-criteria that control the interactions in the system under study. The second is a network of influences among the elements and clusters. The network varies from criterion to criterion and a super-matrix of limiting influence is computed for each control criterion. Finally, each of these super-matrices is weighted by the priority of its control criterion and the results are synthesized through addition for all the control criteria.

A problem is often studied through a control hierarchy or system of benefits, a second for costs, a third for opportunities and a fourth for risks. The synthesized result of the four control systems are combined by taking the quotient of the benefits times the opportunities to the costs times the risks to determine the best outcome. Other formulas may be employed at times to combine results. The following are some of the features of the ANP that distinguish it from the AHP (Saaty, 2001b):

- Rather than a hierarchy, the basic structure of a network consists of clusters and nodes and logical connections between them. The judgment process is carried out by creating matrices of pair wise comparison judgments for nodes in a cluster linked to the same parent node.
- Sub-networks can be created for and attached to nodes in a network and they sub networks have the same structure as any network. There can be many layers of sub-networks. The sub networks at the bottom contain the alternatives of the decision.

- Super matrices are created in the sub-networks and the results integrated with the higher levels of networks.

One can find some in which the ANP is applied for decision making. There is a comprehensive example how to make the decision on national missile defense program. The US government faces the crucial decision whether or not to commit itself to the deployment of a National Missile Defense (NMD) system. By applying an ANP model, deploying NMD alternative is the best alternative (Saaty, 2001c). Alikafa and Ozdemir (2003) used ANP and BOCR structure to determine the best policy for EU and Turkey relationship. This study concludes that membership alternative seems to be more suggestible. The focus of the paper by Azis (2003) is to search for the most suitable form of RFA (Regional Financial Arrangement), the process of which involves a complex decision, having to include not just economic rationales but also political and other considerations. Poonikom *et al.* (2003) proposed a systematic framework using ANP for the selection of universities which offer engineering discipline. The purpose of the study by Ilker *et al.* (2004) is to develop a multi criteria model of organic food marketing strategies which are believed to improve the domestic market. The Analytic Network Process is utilized to construct such a model. The elements of the marketing mix are defined and the interrelationships among these elements are assessed via a Delphi type group decision making procedure. Cevik *et al.* (2004) presents an integrated framework based on ANP and utilizing Delphi Technique to select an ERP system.

THE ANP MODEL

Here, the ANP model for selection of the best location for plywood and veneer plants in Iran is developed. The alternatives are evaluated by the merits of benefits, costs, opportunities and risks (BOCR). We design a three level network representing this problem. The top level consists of a control sub model with four nodes, benefits, costs, opportunities and risks.

The alternatives: After many studies and investigations five provinces (out of thirty) were found to be potentially best suitable for plywood and veneer plants, Gilan, Mazandaran, Kordestan, West Azarbaijan and Ghazvin. The first four provinces are rich in raw materials while the fifth one is located in the center of Iran and close to the main market. Furthermore, this province has an industrial history. All five of them have know-how for wood industry.

Overall factors: In this research the merits of benefits, costs, opportunities and risks are weighted by three general factors, within the following broad categories:

- Environmental factors
- Social factors
- Economic factors

Two sub-criteria, forest reclamation and wood agronomy are included in the first criterion. The second criterion is composed of two sub-criteria, population growth and literacy level.

Figure 1 shows the hierarchy of the main factors and sub-factors as well as the results of pair wise rating. Furthermore, the resulting prioritizing of these factors is also indicated in Fig. 1. The ratings are done by pair-wise comparisons of the lower level factors and summing up for the main factors at the top level.

Prioritizing BOCR: Since benefits, opportunities, costs and risks are not equally important, it is necessary to prioritize them. To do that, they are rated with the lowest level of each criterion of the hierarchy in Fig. 1 and then summing them up. Five possible ratings ranging from very high to very low are used. The results of the influence of the overall factors on the merits of benefits, costs, opportunities, risks and the priority of the above mentioned merits are reported in Table 2.

Table 2 show that opportunities and benefits with the priority of 0.351 and 0.337, respectively, have higher priorities than costs and risks in this decision. The purpose of rating BOCR merits in this way is to link an

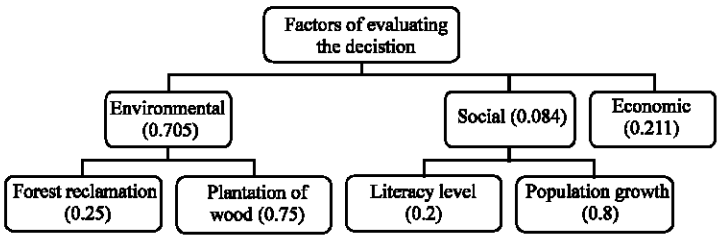

Fig. 1: Hierarchy for rating BOCR

Table 2: Priority rating for the merits: Benefits, costs, opportunities and risks very high (1), high (0.51), medium (0.252), low (0.124), very low (0.065)

Criteria	Sub criteria	Benefits	Costs	Opportunities	Risks
Economic (0.211)		Very high	High	Very high	High
Environmental (0.705)	Forest reclamation (0.25)	Very high	Low	Very high	High
	Wood plantation (0.75)	Very high	Medium	Very high	High
Social (0.084)	Population growth (0.8)	Low	Very high	Medium	Low
	Literacy level (0.2)	Medium	Low	Very high	Very low
Overall priorities		0.337	0.138	0.351	0.174

individual's or organization's overriding or superior values that remain relatively independent from one decision to another with the results of the model of factors related specifically to that decision.

BOCR merits: In macro-decision making such as selecting the most appropriate site for locating a factory, the best approach is to divide the criteria into favorable and unfavorable categories. The decision maker considers the favorable criteria as benefits and the unfavorable criteria as costs. The possible events are also divided into opportunities criteria and risks criteria, depending whether they are considered to be positive or negative (Saaty, 2001a). One example is making decision regarding the establishment of commercial ties with China (Saaty and Cho, 2001). They concluded Preferred Normal Trade Relations (PNTR) is the best choice.

Following the concept of BOCR merits, decisions are most generally approached by breaking them up into merits: benefits, costs, opportunities and risks. For each merit a sub-network is created with control criteria and for these control criteria in turn decision sub-networks are designed.

From the point of view of costs and risks, two alternatives are compared by asking which one is more costly or more risky. The reciprocals of the results are also used in synthesizing the results for the final answer.

Four hierarchies for the merits of benefits, costs, opportunities and risks, are introduced. We describe in more details each hierarchy which includes objective (benefits, costs, opportunities and risks) related sub-criteria. To see similar factors, one can refer to Haksever *et al.* (1990) and Krajewski and Ritzman (1999), Chase Aquilano and Jacobs (1998).

Benefits to producers or investors: Related to the merit of benefits, there are two sub-criteria, Production and Proximity to market.

Production includes the following factors:

- Natural Resources: Establishing wood industry in any area causes the growth of forests and plantation (poplar tree) as well as industrial development.
- Infrastructure: Adequate road, air and sea transportation is vital. Energy and telecommunications requirements must also be met. In addition, the local government's willingness to invest in upgrading infrastructure to some required levels may be an incentive to select a specific location.
- Good business climate: A favorable business climate can include the presence of other similar business, the presence of local and foreign companies in the same industry.
- Quality of labor: The educational and skillful labor pool must match the company's needs. Even more important is the willingness and ability of the labor force to learn.
- Suppliers: High-quality and competitive suppliers make a given location suitable. The proximity of the plants of main suppliers also supports the lean production systems.

Proximity to market: A location close to the market is important because of the ever-increasing need to be customer-responsive. This enables faster delivery of products to costumers. In addition, it ensures that customers' needs are incorporated into the products being developed and built.

Costs to producers or investors: We consider two classes of costs, economics and political/cultural conflicts.

Economic costs: includes the following factors and sub-factors.

- **Operational costs** which in turn includes three costs as follows:
  - Labor costs: Average monthly wages of the manpower employed in the manufacturing units.
  - Living costs: Costs for housing, food, health and welfare of the manpower employed in the manufacturing units.
  - Purchase of raw material: The finished cost for purchasing each cubic meter of forest wood, poplar or orchard wood from their supplying sources to produce the product.

- **Land/construction:** Average price of each square meter of land in the region, for utilization or construction of a factory.
- **Distribution/transportation:** For warehousing and distribution operations, transportation costs and proximity to markets are extremely important. With a warehouse nearby, many firms can hold inventory closer to the customer, thus reducing delivery time and promoting sales. Cost of raw materials trans partition from suppliers must be considered as well.

Political/cultural conflicts: The fast-changing geopolitical situations in numerous nations present exciting, challenging opportunities. But the extended phase of transformation that many countries are undergoing makes the decision to locate in those areas extremely difficult.

Opportunities for producers or investors:

- Community development: Construction of new manufacturing units in some areas results in the development of community attitudes and other amenities.
- Expansion of the industry: Establishment of the wood industries in some areas helps to improve the quality and quantity of the industry in that area.
- Future investment: Potential of the region in terms of absorption of capital or local facilities of the region which make the investor interested in commissioning the industry in future.

Risks for producers and investors:

- Lack of suitable markets: If an area is far from the main sale centers and consumers then that product may not suitable for the markets in those areas.
- Lack of financial support: For some areas such as border regions, security problems may exists. Therefore, the governmental financial support is less than other areas.
- Unreliability of raw material supply: The demand for raw material (forest wood and poplar) will be increased due to commissioning new units therefore there is not confidence for raw material supply. Forest wood is hard woods that grows in north of Iran for example Fagus orientalis. Poplar (populus) is kind of hard wood that almost be planted in north west, west and north of Iran.

Prioritizing criteria and sub-criteria: By pair-wise comparisons within the framework of ANP, the priorities of the criteria of four hierarchies, benefits, costs, opportunities and risks are obtained, as shown in Table 3. Among the sum of the priorities of 7 out of 18 criteria is for over 2.951 of the total. Thus the most important factors are infrastructure, natural resources, purchase of raw material, expansion of the industry, community development, unreliability of raw materials supply and lack of financial support. These factors are marked with bold fonts in Table 3. To economize effort, we only use these seven factors for analysis (Saaty, 2001c).

Networks of control criteria: After considering seven criteria, we renormalize their priorities within their respective merits and develop a network for each one. Figure 2 shows the network for natural resources, in which five alternatives (provinces) plus two decision makers forests organization and ministry of Industry are considered as factors. Similarly, the networks for other six criteria can be developed. In each network, in addition to five alternatives the other factors (as decision makers) are as follows.

- Infrastructure (government)
- Purchase of raw materials (forests organization, private persons)
- Community development (government, private persons)
- Expansion of the industry (government, manufacturers)
- Lack of financial support (government, manufacturers)
- Unreliability of supply (forests organization, private persons)

To apply the ANP method, the Super Decisions Software was used. In BOCR structure the following formula is used in calculations (Saaty, 2001b):

(Benefits)*(Opportunities)/(Costs)(Risks)

The priorities of the criteria of four hierarchies of benefits, costs, opportunities and risks are obtained by

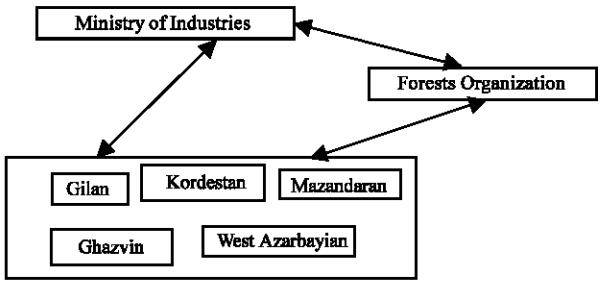

Fig. 2: Natural Resources Sub network under Benefits

Table 3 : Criteria and their priorities

Merits	Components	Elements		Local priorities	Global priorities
Benefits (0.337)	Production (0.875)	Natural Resources		0.492	**0.145**
		Infra structure		0.252	**0.074**
		Good business climate		0.062	0.018
		Quality of labor		0.034	0.01
		Suppliers		0.16	0.047
	Sales/ Proximity to market			0.125	0.042
Opportunities (0.351)	Community development			0.644	**0.226**
	Expansion of the industry			0.271	**0.095**
	Future investment			0.085	0.029
Costs (0.138)	Economic (0.875)	Operation costs) (0.747	Labor costs	0.052	0.005
			Living costs	0.198	0.018
			Purchase of raw material	0.749	**0.068**
		Construction /Land costs		0.06	0.007
		Distribution/Transportation costs		0.193	0.023
	Political/Cultural conflicts			0.125	0.017
Risks (0.174)	Lack of financial support			0.258	**0.045**
	Unreliability of supply			0.637	**0.111**
	Lack of suitable market			0.105	0.0182

Table 4: Synthesized priorities of the seven control criteria and sub-criteria

Merits	Criteria	Sub-Criteria		Ghazvin	Gilan	Kordestan	Mazandaran	West azarbayjan
Benefits (0.337)	Production (0.875)	Natural Resources (0.492)		0.0329	00.411	0.118	0.258	0.181
		Infra structure (0.252)		0.073	0.367	0.117	0. 303	0.139
	Benefits Synthesized			0.03	0.258	0.077	0.178	0.109
	Benefits Normalized			0.046	0.396	0.118	0.273	0.167
Opportunities (0.351)		Community Development (0.644)		0.042	0.349	0.156	0.276	0.177
		Expansion of the Industry (0.271)		0.414	0.451	0.053	0.344	0.111
	Opportunities Synthesized			0.038	0.347	0.115	0.271	0.144
	Opportunities Normalized			0.042	0.379	0.126	0.296	0.157
Costs (0.138)	Economics (0.875)	Operation (0.747)	Raw Material (0.749)	0.654	0.042	0.145	0.052	0.107
	Costs Synthesized			0.32	0.021	0.071	0.025	0.052
	Costs Normalized			0.654	0.042	0.145	0.051	0.106
	Costs Reciprocal			0.025	0.389	0.113	0.32	0.154
Risks (0.174)		Lack of financial Support (0.258)		0.214	0.082	0.366	0.078	0.261
		Unreliability of Supply (0.637)		0.652	0.075	0.077	0.084	0.113
	Risks Synthesized			0.47	0.069	0.143	0.074	0.139
	Risks Normalized			0.525	0.077	0.159	0.083	0.155
	Risks Reciprocal			0.048	0.327	0.159	0.304	0.163

Table 5: Final outcome

	Merits					
Alternatives	Benefits (0.337)	Opportunities (0.351)	Costs (0.138)	Risks (0.174)	Final outcome	Ranking
Ghazvin	0.046	0.042	0.025	0.048	0.042	5
Gilan	0.396	0.379	0.389	0.327	0.377	1
Kordestan	0.118	0.126	0.113	0.159	0.127	4
Mazandaran	0.273	0.296	0.32	0.304	0.293	2
West Azarbayjan	0.167	0.157	0.154	0.163	0.161	3

the ANP. To do that, the sub-criteria and choices are compared pair wise against each one of the above mentioned merits, as reported in Table 4.

As Table 4 shows Gilan province has the highest priority in terms of criteria of benefits and opportunities and Ghazvin province has the highest priority in terms of costs and risks. However, we integrate the weights of the merits of benefits, costs, opportunities and risks and the weights of choices against the above mentioned merits (Table 5).

ANALYSIS

As Table 5 shows Gilan with the highest priority is the most suitable place to establish plywood and veneer units. Considering the favorable criteria in decision-making, i.e., benefits and opportunities, Gilan has the highest priority and then Mazandaran The third, fourth and fifth priorities are West Azarbayjan, Kordestan and Ghazvin,, respectively. As shown in Table 2, opportunities and benefits are more important in the

decision compared with costs and risks, because they have higher weight: Opportunities = 0.351, Benefits = 0.337.

In fact, with regard to benefits, Gilan is absolutely preferred over the other choices because of natural resources and infrastructure. It has rich resources of raw materials. Gilan is also preferred under opportunities because of community development and expansion of the industry.

In other words, establishing plywood and veneer units in this region will bring more development, because of existing raw materials and background of the industry. Mazandaran is the second choice after Gilan, in terms of benefits. It has rich resources of raw materials and several wood industry units.

As far as the merit of cost is concerned, the choice of Gilan is of the highest desirability for the decision makers and investors over the other choices in terms of raw material costs, with regard to existence of forest area and accessibility to wood resources. Regarding the sub-criteria of risks, Gilan has the absolute priority for the decision makers and investors in terms of financial support and reliability of supply. In other words, if the plywood and veneer units are established, the choice of Gilan shall be of more desirable in terms of financial support and reliability of supply . Mazandaran has similar conditions, regarding costs sub-criteria.

Among the sub-criteria of costs, the choice of Mazandaran of again results in the low priority over the other choices in terms of sub-criterion of purchase of raw material. In another word if the plywood and veneer units are operated, the choice of Mazandaran shall be of the highest desirability for the decision makers and investors over the other choices in terms of the purchase of raw materials. Regarding the sub-criteria related to risks, the choice of Mazandaran has less priority in terms reliability of supply, in compare with Gilan. In other words if the plywood and veneer units are established, Mazandaran shall be of less desirable in terms of supply of raw material and this is due to the existence of several wood industry plants in Mazandaran and demand of wood raw material is high.

To achieve stability and compatibility of the analysis, we apply sensitivity analysis (Saaty, 2001b). By increasing or decreasing one of the criteria, we will find that the ratios of other criteria do not change. For example if the benefit weights increases from 0.346 to 0.5 the sum of other criteria will be equal to 0.5 and the proportion between them will remain consistent and the new weights of other criteria be as follows: Opportunities: 0.271, Costs: 0.094, Risks: 0.135. However, the study shows by increasing or decreasing the weights of benefits and opportunities, costs and risks there will no change in the establishments of priority for the BOCR conclusions.

CONCLUSIONS

In this study, we applied the ANP and BOCR structure to determine the best location to establish plywood and veneer plants. Out of thirty provinces, first we selected five with rich raw materials and suitable infrastructure. Then, after analysis Gilan province scored the highest. Later, we will find the most suitable site within Gilan province to locate the plant.

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