Analytic Network Process as an Approach to Prioritize Wood Raw Material for Wood and Paper Factories

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ABSTRACT

Aim Increasing the wood demands at the global level and reducing supply resources for wood industries is one of the most challenges for industrial managers. Considering the limitations of wood production resources, it is necessary to specify the wooden raw material resources by logical plans. In this study, for the first time, network analysis was used to prioritize wood supply alternatives in the Iranian wood industries.

Materials & Methods In this study, we used Analytic Network Process (ANP) to Priority of Supplying Wood Material in Wood Factories. In the Mazandaran Wood and Paper factory, the wood materials are supplied through four methods: forest, ligniculture (wood farming), wood importation, and purchase wood from local markets. In order to conduct this research, the questionnaires were prepared and distributed among 23 specialist experts. After completing the questionnaires and organizing the model in the super decision software (version 1.6) (Analytic Network Process), the inputs and prioritization of the alternatives were done.

Findings The most important resources for supplying wood raw materials in Mazandaran Wood and Paper Factory includes wood harvested from the forest, ligniculture, wood importation, and wood supplies from local markets. The results indicated that among the four alternatives for wood supplying, ligniculture (1.000), wood importation (0.885), forests (0.695), and supplying wood from local markets (0.419) were prioritized as the best alternatives, respectively.

Conclusion Considering the new policies of forest organization, the best approach for wood supplying are ligniculture with fast-growing tree species and wood importation.

Keywords Wood industries, Imports, Analytic Network Process (ANP), Ligniculture, Forest

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Introduction

Growing demand for wood has exerted greater pressure on primary old-growth forests in the world [1]. Therefore, many countries are considering secondary timber resources such as forest plantations [2]. Reducing and eliminating wood harvesting from the forest caused wood industry factories to face the problem of supplying raw materials. Some factories with a nominal capacity of 6 million m³ are working, and many new units are under construction [3]. Sources of wood raw material are very limited and not compatible with wood production sources. Therefore, some factories work with a very small nominal capacity, and the other factories are closed due to competitive pressures. Recently, considering the new policies of Iran's Forests and Pasture Organization about wood harvesting ban from forests, the rate of wood harvesting is very limited. Wood and paper factories face countless challenges after approximately half a century after their establishment, and raw material supply is one of the most important of them [4]. Therefore wood supply chain has been considered for many factory managers. In a competitive market, the producers are not looking for the best suppliers to place them on top of their agendas and decisions after selecting the best markets [5]. Approaches such as wood importation and ligniculture (wood farming) have been mentioned as the best solutions [6, 7].

In Mazandaran Wood and Paper Industries (MWPI), wood is supplied from forests, ligniculture (wood farming), wood importation, and the purchase of wood from local markets. Each of these alternatives is facing some problems and obstacles.

Iranian Northern forests are located south of the Caspian sea with about 1.9 million hectares [8, 9]. Mazandaran Wood and Paper factory have 150,000 hectares of these forests as forestry plans in the Mazandaran province. According to the regulations of booklets for forestry plans under the supervision of Iran's Forest and Pastures Organization [10], this factory exploits broken trees in the regulations of booklets. The average annual harvest rate in forestry plans is less than 0.5m³ha⁻¹, which provides about 10% of the factory wood requirements.

The second source of wood supply in MWPI includes ligniculture (wood farming), which reduces the pressure on forests. Supplying part of the wooden requirements via wood farming creates conditions for employment of several farmers to prevent their immigration to cities, develops the green spaces, protects water resources, and prevents various types of erosion [11]. Mazandaran wood and paper factories started to extend ligniculture by presenting technical services to farmers to supply raw wood materials.

The third alternative is wood important. According to the existing conditions, the importation of various wooden materials is inevitable [10]. However, the import of wood in Iran is faced with many restrictions by the Plant Preservation Organization. . In some cases, wood imports from Russia and Brazil in this factory.

Some of the wooden raw materials are purchased from local markets, including garden woods, poplar plantations, and buying wood material from other operators of forestry plans.

To evaluate and solve wood supply problems in Iran's wood and paper industries, challenges must be fundamentally identified. In this study, the Analytic Network Process (ANP) was applied to analyze decisions to solve multi-criteria issues to select suppliers. Analytic Network Process (ANP) is one of the most complex multi-criteria decision-making methods [10, 12]. The ANP is a generalization of the Analytic Hierarchy Process (AHP). In this model, the hierarchical structure is upgraded to a network that allows interactions between elements of the hierarchy, including criteria, sub-criteria, and alternatives. In other words, in one network, the feedback and interactions between and among the clusters are possible [13]. The application of ANP regarding the supply chain and the economic activities began many years ago [14, 15], and the impact of this method to resolve complex management problems has been proven by many researchers [16, 17].

This process is a new theory in which a hierarchical structure has been replaced by a network structure. This quality makes it possible to examine the dependencies and feedbacks between criteria and sub-criteria [3]. Setting long-term goals and considering appropriate strategies as the priorities are the main elements for goal achievement [18]. One of the most important programs of any production unit is the preparation of raw materials. There are some qualitative and quantitative factors with complex relationships that affect the processes related to the supply chain of raw materials of wood factories, so it is necessary to

analyze these complex relationships between the criteria and sub-criteria in order to prioritize the appropriate alternatives for supplying wood material at the final stage.

The main objective of this study is to decide on the best option to supply the raw wood material required by the Mazandaran Wood and Paper factory. This issue is currently one of the most important challenges for the wood industries in Iran. We hypothesized that ligniculture is the best alternative to supply the wood materials needed in this industry.

Materials and Methods
Materials
Mazandaran Wood and Paper factory are one of the largest paper factories in middle Asia. The nominal capacity of the factory is 175000 tons (including 90000 tons of newsprint and printing paper, 85000 tons of fluting medium) and the wood required for the production lines is 400000m³ (MWPI website).
Analytic Network Process
Some MCDM methods such as Hierarchical models (e.g., the AHP) face certain limitations when decision problems' complexity and interactions among criteria and sub-criteria are not implicitly covered. Various methods are proposed to examine the interaction and dependence among elements. Real-life decision-making problems are consist of some criteria. Decision-makers developed various methods to overcome these problems [9]. ANP is one of the most widely-used methods that have been developed by Thomas L. Saaty. The ANP model can be organized by practical or theoretical perspectives [5]. ANP is one of the most complex multi-criteria decision-making methods that consider the most data about decision-making problems than other multi-criteria decision-making (MCDM) methods. ANP makes it possible to model dependencies and feedback in a problem's network structure [10].

The Analytic Network Process considers other aspects of the decision-making issue, which is impossible in other methods [17]. In this study, the Analytic Network Process (ANP) has been used such a multi-criteria decision-making technique. ANP is better than AHP because it contains interactions, interdependences, and feedback among elements at the different levels [3]. It allows interactions and feedback within clusters (internal dependence) and between clusters (external dependence) [19]. On the other

hand, in the ANP, the importance of the criteria influences the importance of alternatives, but the importance of alternatives affects the criteria [20].

In this model, one criterion is related to other criteria when at least one of its sub-criteria affects one criterion of the other criteria or is affected by one of the other criteria. The component of a model can act as a source of the effect; in other words, they act effectively and are considered the destination of the effect or are effective on themselves [21].

The first step in programming and designing suitable tools for the present study is similar to determining the target group. In this factory, four alternatives were specified for wood supply: forests, wood supply from local markets, ligniculture (wood farming), and wood importation. For each indicator, a decision matrix was assembled (Extremely Preferred: 9 points; Very Strongly Preferred: 7 points; Strongly Preferred: 5 points; Moderately Preferred: 3 points; Equally Preferred: 1 point; and the preferences between the mentioned intervals pointed 2, 4, 6, and 8), and the elements were compared using the fundamental scale.

Model construction and transformation of the problem to a network structure
Construction of a network model requires familiarity with the problem, definition of criteria and sub-criteria, and establishing relationships and interactions. Solving the problem depends on the model maker's art largely, and the formation of this structure does not follow any specific principles.

Hence, solving any kind of problem has its complications [14]. The network decision-making model depends on one-way reactions and the interactions between the criteria and sub-criteria. In Analytic Network Process, one element of the mode affects another element on the other ones and even itself. In other words, the problem is no longer linear, and it manifests itself in a non-linear or network context [12].

Determination of criteria and sub-criteria and their pairwise comparisons
The created network structure in the present study includes several criteria and the desired alternatives. Four main criteria were specified; economic, social, environmental, and international relationships. Several sub-criteria were considered for each criterion. Four alternatives were selected to supply wood materials, including forests, wood purchase

from local markets, ligniculture, and wood importation. In order to perform this research using experts' opinions, questionnaires were prepared and distributed among 23 experts. The rate of importance and dependency between the clusters and alternatives were determined in each questionnaire. After calculating the performance of all alternatives, priority values obtained from each of the districts have been converted into an assignment table integrated with the model.

Pair comparisons between criteria and the related sub-criteria

After relationships between criteria are revealed, the face-to-face interview form is generally created in the software program to measure the pairwise comparisons between criteria. The study group answered the form (23 experts, engineers, Ph.D. in the wood market, wood supply, wood farming, paper making, R&D, and forest in the factory). Pairwise comparisons are formed in Super Decision [9]. Pairwise comparisons are completed for each criterion and cluster by experts; then, they are entered into the Super Decision software program (version. 1.6). Decision-makers to compare elements or clusters must decide in pairs, and in addition, the bilateral dependencies among the elements of a cluster should also be compared in pairs. The effect of each element on the other element can be presented by an eigenvector.

After completing pairwise comparisons, the inconsistency value of each pairwise comparison is calculated [22]. The inconsistent values of all pairwise comparisons used in this study have been checked; they are under 0.1.

In this stage, the internal importance vector is calculated, which indicates the importance of element or clusters, which are obtained by the equation (1):

$$Aw = \lambda_{\max} w$$

A: The matrix of criteria pairwise comparisons

W: Eigenvector

λ max: The highest special numerical value

The most important point in the ANP model is controlling their compatibilities. This important point is especially significant in decisions at Macro-level [23].

Calculation of supermatrix and selection of the super alternative

The importance of influences is estimated by the eigenvalue method based on pairwise comparisons between the indicators. All the models (indicators and alternatives) are compared within and between clusters towards the goal (selecting the optimal prioritization supplying wooden material in Mazandaran wood and paper factory).

Formation of the supermatrix in the ANP model is done in 3 stages. First, the calculated weights for all the pairwise comparisons are entered into the "supermatrix with no weight". In the next stage, the supermatrix is calculated with the weight. Then, the values of the weighted matrix are normalized. In the final stage, the super limit matrix is calculated [21]. ANP is used in a network structure with feedback loops (Feedback Network).

The merits

The entire ANP model consists of a two-level decision-making network (Strategic criteria and Merit). The top-level structure has four merits Benefit, Opportunities, Costs, and Risks [24]. The BOCR subnets were composed of their respective clusters and elements. The network model aims to select the best wood supply for the MWPI factory through group decision-making. Saaty developed a special form of the Analytic Network Process to meet these requirements. A multiple-layer model consisting of subnets for benefits (B), opportunities (O), costs (C), and risks (R) networks will be introduced to find the best alternative of each category [8, 19].

We use the priorities of BOCR to weigh and synthesize the overall weights of the alternatives obtained from the four merit structures (Figure 1). In this process, we must use the reciprocals of the synthesized final priorities of the alternatives under costs and risks obtaining high priorities for the least costly and least risky alternatives [13].

Sensitivity Analysis

In this study, sensitivity analysis is performed to all weights to assess the stability of the alternative rankings for the temporary facility layout problem. The sensitivity analysis of the criteria can determine the most sensitive criteria with weight changes and assist the decision-makers in finding out the optimal alternative [25].

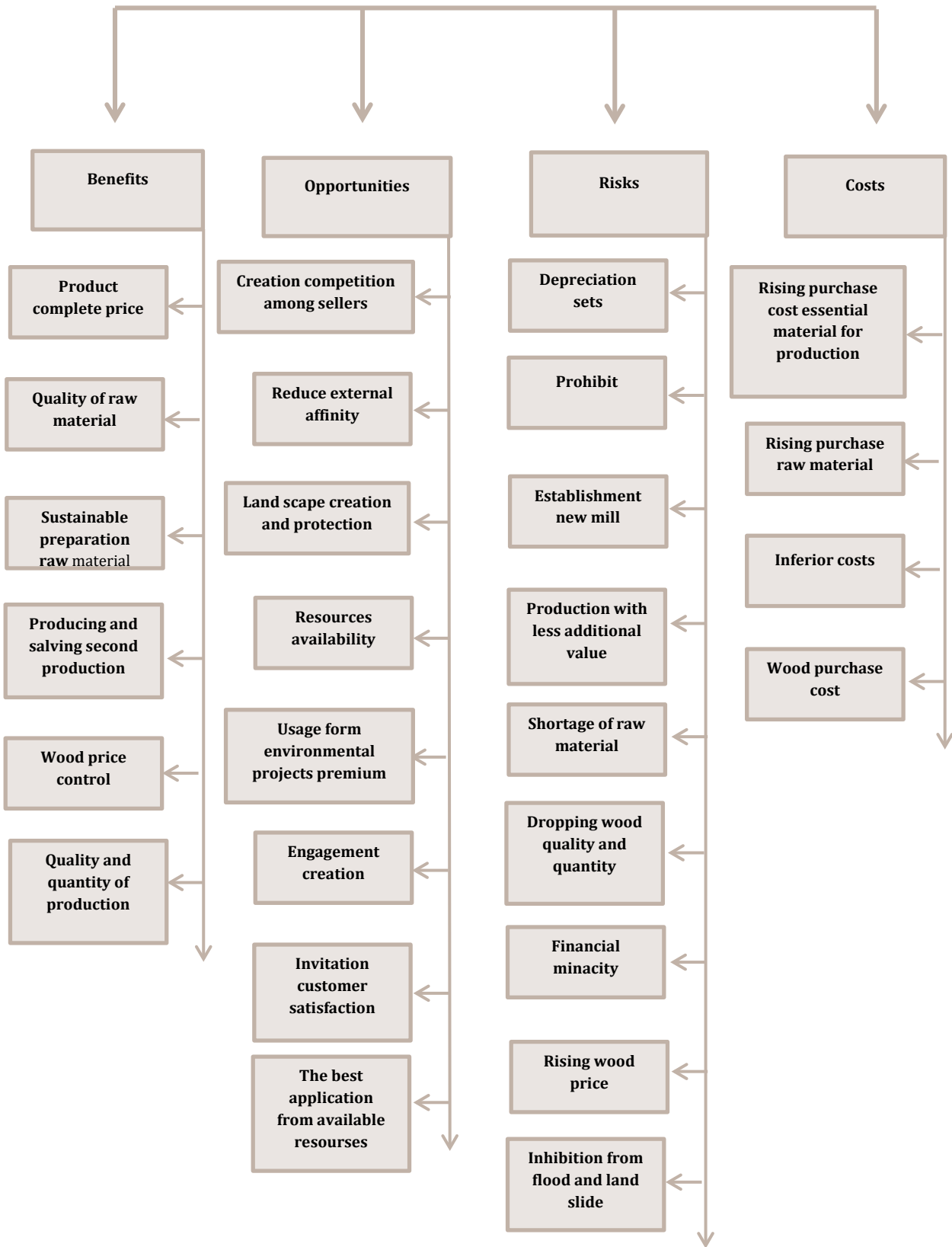**Prioritization of supplying wooden raw materials in Mazandaran wood and paper factory**

Figure 1) BOCR structure in the ANP model for supplying raw materials in MWPI

Findings

The pairwise comparison of criteria is important because the super weighted matrix is calculated by the product of the supermatrix values with no weight and the similar values of the criteria's comparison matrix. The results of the limit supermatrix after standardization were utilized for prioritizing the alternatives concerning the supply of the factory wood raw materials. The social and environmental criteria were more important than the economical and international relationships criteria (Table 1). Considering the final weight of the alternatives, which form the ANP model: ligniculture (wood farming), importation of wood, supply of wood from forests, and purchase of wood from local markets were prioritized for supplying MWPI's wood materials (Table 2).

Sensitivity Analysis

Sensitivity analysis examines how much the weight of the criteria can change (decrease or increase) without changing the ranking of the alternatives. By finding the range of changes in the weight of the criteria, we can determine which weight changes in which criteria can have a greater impact on changing the results, or in other words, the sensitivity of the ranking to the weight of which criteria is lower or more. Based on this, the criteria can be ranked from the lowest sensitivity to the highest sensitivity. Since there may be different evaluations on the comparison of priority rates of benefits, opportunities, costs, and risks or their sub-criteria, sensitivity analysis is used to achieve stability and compatibility [12]. Regarding the

BOCR hierarchy findings, we will find that the ratios of other criteria do not change [19]. In this model, considering the opportunities, risk, cost, and benefit, the best alternative is ligniculture (wood farming). Supplying wood from forest, wood importation, and supplying wood from local markets were the next priorities, respectively (Figures 2 and 3).

Table 1) The criteria and sub-criteria concerning the priority of supplying wooden raw materials for MWPI and their scores

Criteria & Sub-criteria	Score
Economical	0.0160
The possibility of optimum utilization of the available resources	0.0231
Regional economic growth	0.0950
Prevention of outflow from the country	0.1180
Social	0.0980
Engagement	0.1667
Independence in supplying wood material	0.0256
People and NGO resistances	0.1161
Environmental	0.0600
Negative environmental consequences	0.1705
Utilization of environmental projects benefits, trade of Carbon and Clean Development Mechanism	0.0086
Water pollution and effluents	0.0636
International relationships	0.0005
Impact of sanctions	0.0360
Monetary and currency policies	0.0124

Table 2) Prioritization of alternatives for supply of wood materials

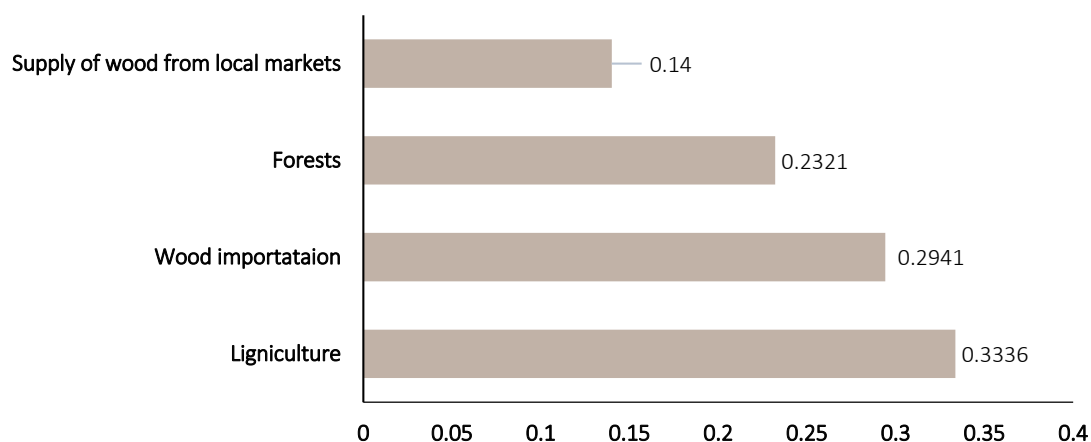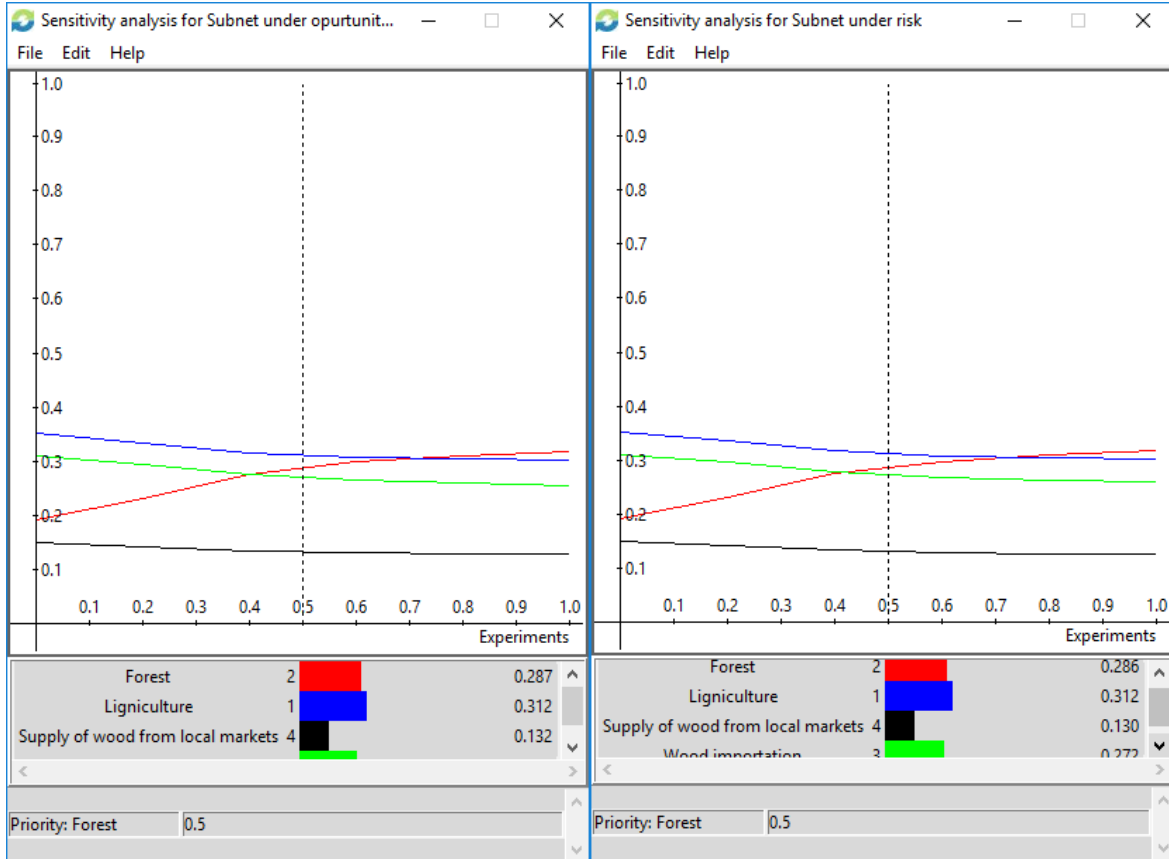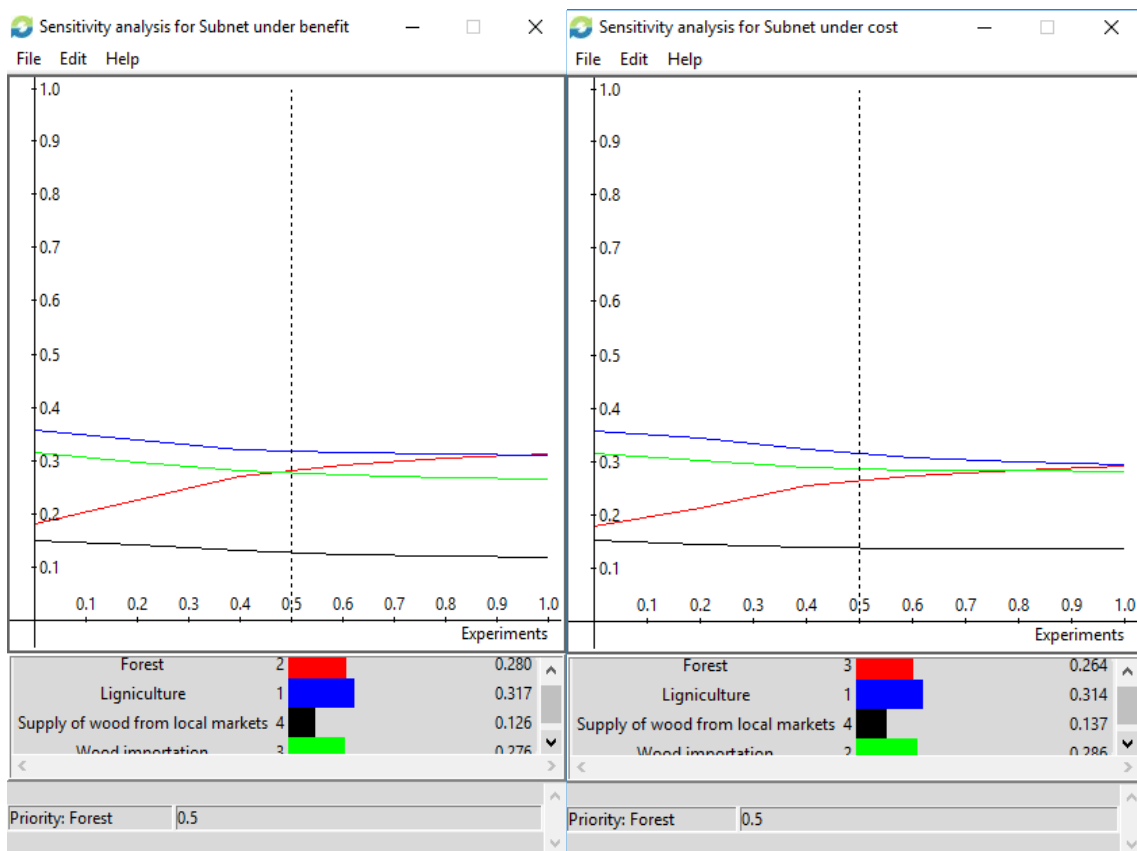| Alternatives	Ideal	Normal
Ligniculture (wood farming)	1	0.3336
Wood importation	0.885	0.2941
Forests	0.6956	0.2321
Supply of wood from local markets	0.4198	0.1400

Figure 2) Final normal values of alternatives

Figure 3) Sensitivity analysis for opportunity (a), risk (b), benefit (c), cost (d)

Discussion

Although many techniques have been utilized to select suppliers (i.e., hierarchical analysis, linear programming, statistical methods), in the present study, we used the ANP method considering its capabilities as the analysis tools for selecting the suppliers [21]. All elements (criteria and alternatives) of the model are compared within and between clusters towards the goal (selecting the optimal prioritization supplying wood Material to the factories). The determining criteria for the present study include economic, social, environmental, and international relationships criteria.

Until 2017, the most important source of wood supply in Iran's wood industries was wood harvesting from the forests of northern Iran [6], which are undoubtedly limit; hence factory managers are forced to apply other approaches for supplying the required wood materials. Considering the limitations of wood resources for production, it is essential to specify the consumption lines of Iran's wood produced by detailed and logical programs. Many things may affect the wood supply, especially wood imports and exports, which are not predictable and depend on conditions such as socioeconomic conditions [2]. Therefore, to help the wood factories, resources of wood production should be examined, and the existing obstacles should be removed through logical plans and programs [11].

The problem in supplying the required woods and raw materials for this industry is such that this industry has faced the danger of recession and making no profits resulting from the shortage of workload (due to not having sufficient wood quantities) and has created employment some problems and limitations for employment in the section. Furthermore, importing this considerable volume of woods and raw materials is also experiencing many issues and obstacles such as currency resources, limitations of importation ports, pests, and diseases, plus quantitative limitations program for ligniculture (wood farming) [11].

In this study, Network Analysis was utilized, considering its capabilities to analyze the selection of wood suppliers. The Analytic Network Process considers other aspects of decision-making that are not feasible in other methods; hence, the decision-making process is performed by the best possible methods [19]. The main objective of the present study includes the presentation of a useful insight by utilization of Analytic Network Process for assessing the issues related to the selection of wood suppliers. These issues are complicated, which might create many quantitative and qualitative concerns. Inside the country, the supply of the required raw materials must be assessed due to the resource limitations, and the best options must be selected for supplying the wood for paper production considering their accessibilities. The raw materials supplied and become accessible through the above method have a substantial role in establishing supply chain methods [26]. By applying the group decision-making-based techniques (such as ANP), it is possible to introduce a new approach for making proper decisions, as in addition to consider various criteria, in these methods, the knowledge and skill of people are utilized well.

The final synthesis results showed that ligniculture (wood farming) was the best choice among four alternatives: forests, wood importation, and purchase of wood from local markets were placed in the next priorities.

Conclusion

The most significant wood raw materials in Wood factories include the wood materials obtained from the northern forests, ligniculture, wood importation, and purchase wood from local markets. Analysis of questionnaires considering the new programs in Forests and Rangelands Organization showed that the best approach is to provide the basic material of the same industries as ligniculture (wood farming) with fast-growing tree species and wood importation.

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