APPLICATION OF THE ANALYTIC NETWORK PROCESS IN EVALUATING LAMINATED STRAND LUMBER GLULAM COMPOSITES MADE FROM PALM LEAF AXIS AND CEDARWOOD

Majid Azizi
University College of Agriculture and Natural Resources,
University of Tehran
mazizi@ut.ac.ir

Narges Sharif Mousavi
University College of Agriculture and Natural Resources,
University of Tehran
narges.mousavi@ut.ac.ir

Hamid Zare Hossienabadi
University College of Agriculture and Natural Resources,
University of Tehran
hzareah@ut.ac.ir

Mehdi Jonoobi
University College of Agriculture and Natural Resources,
University of Tehran
mehdi.jonoobi@ut.ac.ir

ABSTRACT

The use of lignocellulosic residues in the production of engineered wood products promises a sustainable future. This research aims to compare and evaluate the properties of LSL glulam (laminated strand lumber) made from date palm leaf axis and a composite (a combination of cedarwood and LSL from date palm leaf axis) using two types of adhesives: epoxy glue and polyvinyl acetate. Combined glulam with palm tree residues and epoxy binder generally results in better physical and mechanical properties, making it suitable for construction applications and service conditions. This study presents a sustainable policy for decision-making in choosing the best option for producing combined glulam using the ANP (Analytic Network Process) method. First, 12 intermediate indicators and 92

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important sub-indices were determined and categorized into the following groups: economic, market, environmental, social, cultural, and technology. The effectiveness of all four options was then evaluated. The results showed that the combined glulam (cedarwood, LSL, and epoxy) option had the highest priority. The options of combined glulam (cedarwood, LSL, and polyvinyl acetate), glulam (LSL and epoxy), and glulam (LSL and polyvinyl acetate) ranked second to fourth, respectively. Additionally, the results of the sensitivity analysis indicated that changes in cost have the most significant impact on the choice of options and should be given special attention in future policy decisions. This policy framework aims to promote sustainable practices in the construction industry by encouraging the use of renewable materials like palm leaf axis as a substitute for traditional wood, thereby reducing deforestation.

Keywords: ANP; glulam; palm leaf axis; epoxy; cedarwood; LSL

1. Introduction

Researchers have found that the use of wood and its engineered products, such as glulam, can increase the safety factor of a residential structure in addition to making it lighter (Ceccotti, 2008; Dujic et al. 2010; Rinaldin & Fragiacomo, 2016). Several essential and influential factors, including the lack of wood resources and the creation of severe restrictions on the harvesting of forest trees, as well as the need for beams and wooden segments with larger dimensions in wooden structures, led to researchers using an engineered product such as glulam instead of solid wood in their plans. Glulam is an engineered wood product made of layers of wood bonded together with industrial adhesives. The manufacturing process of this product begins with the selection of high-quality wood which is then split into narrow strips, usually 5.08 to 10.16 cm wide, and then combined with industrial adhesives to form large panels. Then, these panels are cut and shaped to the desired dimensions using CNC (Computer Numerical Control) machines (Issa & Kameid, 2005). The advantage of this product compared to traditional wood is its higher resistance to fire and water, which results in glulam being used as an alternative to metal in many construction applications. The adhesive used in the production of glulam is usually a two-component synthetic resin such as polyurethane or epoxy. Resin is applied to the wooden strips using a spray or roller, and then the beams are pressed together with high pressure to create a strong connection (Hansson & Larsen, 2005). Glulam is an engineered product that has many advantages over traditional wood and is used in many construction industries, including guardrails, bridges, and towers. Due to the high strength of glulam, its use can help reduce costs, time, and workforce requirements in construction projects, and at the same time, it can be beautiful and decorative (Tazarv et al. 2019).

The use of laminated and engineered wooden beams has grown significantly around the world, especially in Europe and America. Published results and statistics show that Austria produced about 1.5 million cubic meters of glulam in 2014 (El-Houjevri et al., 2019). Also, 395,000 cubic meters and 35,000 cubic meters of glulam was produced in America and Canada, respectively in 2016 (El-Houjeyri et al., 2019). Iran is a vast country with only about 7% of the country being covered by forest. According to the official statistics published by FAO (2012), about 7.5 million tons of dates have been harvested in the world from 1.1 million hectares of palm groves. Iran ranks second in production and third in the cultivated area of dates in the world. Based on recent studies conducted in the field of date palm planting and exploitation in Iran, it has been determined that the size of the country's palm groves today is close to 220,000 hectares (more than 2% of the total arable land), and accordingly, 17% of the world's groves belong to Iran (Hajian & Hamidi Esfahani, 2015). The space required for planting a palm tree is 10 meters by 10 meters; therefore, there are about 100 palms in each hectare of a palm-cultivated area. Within the 220,000 hectares of palm-cultivated land in Iran, there are about 20-27 million palm trees (Hajian & Hamidi Esfahani, 2015). On average, each palm tree produces about 34 kilos of waste from pruning, of which about 25% is related to palm residues. Therefore, at least 200,000 tons of lignocellulosic materials that can be used in transformation industries are available. One of the most outstanding engineered wood products is glulam. This product is mainly designed for applications that will be subjected to high loads and stress (Osmannezhad et al., 2014).

Demir (2025) proposed a fuzzy MCDM-based framework for security management in smart cities. The study focused on the assessment of security risks and the selection of appropriate security measures. The results show that the fuzzy-based model significantly increases the accuracy of prioritizing risks and provides a systematic method for selecting the most effective security measures. This study contributes to the literature by presenting an innovative decision-making tool for security management in smart cities. Akbulut (2025) presented the use of MCDM approaches in the insurance sector and provides important information to top management or decision makers of insurance companies on issues such as accurate performance measurement, identification of strengths and weaknesses, optimization of operations, and improvement of strategic decisions. The results obtained from the Grey PSI method indicate that the net profit-to-total equity, net premiums received-to-gross premiums received, and total operating expenses-to-gross premiums received are the three most significant criteria affecting the corporate financial performance of the relevant non-life insurance companies. The application of the grey MARCOS ranking method shows that the assessment and evaluation of corporate financial performance in the insurance sector is of critical importance for sector managers, policyholders, regulatory authorities, policymakers, and other stakeholders, due to the

significant benefits that insurance companies provide at both micro and macroeconomic levels.

Asyraf et al. (2022) stated that due to concerns about the lack of oil resources and the use of synthetic plastics, societies have become interested in the use of natural fibers and bio-polymers in products. Biocomposites of lignocellulosic fibers are considered a sustainable alternative due to their wide availability, reduced carbon emissions, and biodegradability. Palm is known as one of the main crops cultivated in Malaysia and Indonesia and is used as a source of lignocellulosic fibers for biocomposites. Also, the cellulose content of palm fibers (OPFs or Oil Palm Fibers) increases the mechanical properties of composites. Therefore, the use of such lignocellulosic materials, which have no valuable use in the manufacture of composite wood products, especially the use of LSL layered chip wood obtained by connecting them with glue as an intermediate layer in the manufacture of composite glulam, not only ensures optimal utilization but also aligns with sustainable development policies. Incorporating the palm leaf axis in the production of LSL introduces a novel material to the wood industry, which, in addition to being an optimal use of palm tree pruning waste, contributes to the reduction of wood and forest resource consumption. Furthermore, the use of epoxy and polyvinyl acetate adhesives ensures the production of a high-quality final product with improved properties compared to traditional glulam. The innovative aspect of this research lies in utilizing LSL made from the palm leaf stem axis, a material previously undefined with suitable applications and added value. This approach is particularly significant in a country with about 17% of the world's palm trees, addressing the critical shortage of wood and wood resources. These materials represent a sustainable and valuable addition to the production of new, eco-friendly products.

Hypothesis

- Composite glulam based on LSL (Laminated Strand Lumber) made from palm leaf axis and cedarwood has more advantages than full LSL glulam.
- Economic and environmental criteria are more important than other criteria in the construction of composite glulam.

Goals

- This evaluation aims to determine the most sustainable and policy-compliant option using the Analytic Network Process (ANP). The focus will be on optimizing resource utilization and minimizing environmental impact.
- This involves assessing the strengths and weaknesses of these products to develop sustainable production policies and practices. The goal is to ensure that the criteria align with sustainable development goals and industry best practices, promoting the efficient and eco-friendly use of resources.

2. Methodology

This study aims to provide a comparative evaluation of composite glulam based on LSL made from palm leaf axis and cedarwood, as well as full LSL glulam. In the network model, merits are divided into four subsections: benefits, opportunities, costs, and risks. Overall factors influence these merits to obtain weighting values for each. This process follows the principles of the ANP.

The research method in this study is comprised of sub-components of the ANP modeling process, which are as follows: alternatives, strategic criteria or overall factors; criteria of benefits, costs, opportunities, and risks; prioritizing overall factors; prioritizing merits; prioritizing criteria and alternatives; final outcome; sensitivity analysis; and conclusion.

2.1 Analytic Network Process (ANP)

The Analytical Network Process is one of the multi-criteria decision-making methods, which is widely used to solve various problems in the real world due to its consideration of complex and related relationships between decision elements and the ability to apply quantitative and qualitative features simultaneously (Taherdoost & Madanchian, 2023).

The ANP, a generalization of the AHP method for multicriteria decision-making, provides a broader framework for decision-making in complicated environments. The advantage of this theory over the AHP is its ability to extend to the cases of dependence and feedback and generalization of the supermatrix approach. It allows interactions and feedback within clusters (inner dependence) and between clusters (outer dependence). The ANP is a coupling of two parts. The first consists of a 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 supermatrix of limiting influence is computed for each control criterion. Finally, each of these supermatrices is weighted by the priority of its control criterion, and the results are synthesized by adding them to all the control criteria.

The ANP has been applied to a wide variety of decision-making problems, including project management, risk assessment, supplier selection, and product design. The main advantages of the ANP include its ability to handle complex decision problems with multiple criteria, subjective inputs, and interdependent relationships between criteria (Taherdoost & Madanchian, 2023).

A model using the ANP in supplier selection was developed and implemented in an electronic company (Gencer & Gurpinar, 2007). ANP models have also been used for locating facilities strategically (Partovi, 2006), selecting the appropriate energy policy for Turkey (Ulutas, 2005), and for product mix planning in semiconductor fabricators (Chang, et al. 2005).

The ANP can be considered the general form of the AHP (Saaty, 2006) and is more concerned with network structure. In terms of advantages, it allows for dependence and includes independence. It has the ability to prioritize groups or clusters of elements. It can handle interdependence better than the AHP and "can support a complex, networked decision-making with various intangible criteria" (Tsai et al., 2010, 3884). Its major disadvantage, in addition to those associated with the AHP, is that "it ignores the different effects among clusters" (Wang, 2012, 930). The ANP is often utilized in project selection, product planning, green supply chain management, and optimal scheduling problems. Many of these problems have interdependence among criteria that the AHP does not normally handle well. It can also prioritize the groupings involved in project selection and scheduling problems. Taliscali and Ercan (2006) and Alves, Simões, and Neyra (2008) show that the fundamental advantages of the AHP/ANP, in comparison with other MCDM methods, are that it is "user-friendly" and easy to use for topical experts, and its ability to apply qualitative and quantitative factors together in the evaluation. The basic difference between the methods is that the ANP has a network structure that allows the analysis of dependence among elements of the model. This makes the ANP more powerful in situations with complex levels of uncertainty, and allows the analysis to more closely model reality.

2.2 Survey and data collection

In this research, three sample questionnaires were designed and compiled. The goal of the first questionnaire was to determine the weighted value of indicators and sub-indices. Eight people completed the survey, five were wood industry experts and producers, and three were university professors. The second questionnaire was for pairwise comparison of sub-networks and their nodes in terms of solutions and feedback within the networks. Twelve people completed this survey, seven of whom were wood industry experts, three were wood industry producers, and two were wood industry professors, and management. The goal of the third questionnaire was to determine the weighted value of the strategic criteria affecting the design of four macro experts in the field of design and market economy and products of Iran's wood industry. SuperDecisions software was used to analyze the judgments related to the weighting of indicators and alternatives.

2.3 Alternatives

Four potential alternatives for comparative evaluation of composite glulam based on LSL were analyzed:

1) Combined glulam of cedarwood – LSL with epoxy adhesive [Glulam (cedarwood +LSL + epoxy)]
2) All glulam LSL with epoxy adhesive [Glulam (LSL + Epoxy)]
3) Combined glulam of cedarwood - LSL polyvinyl acetate adhesive [Glulam (Cedarwood + LSL + PVA)]
4) Glulam all LSL polyvinyl acetate adhesive [Glulam (LSL + PVA)]

2.4 Strategic criteria as overall factors

The merits of benefits, costs, opportunities, and risks were weighted by four general factors or strategic criteria, categorized into one of the following broad categories (see Figure 1):

- Economic
- Environmental with two subsections:
  - Wood
  - Wastes
- Rules and regulations
- Cultural and social with two subsections:
  - Population growth
  - Education level
- Technology with two subsections:
  - Access to experts
  - Flexibility

After investigations, preliminary studies, review of sources, and interviews with industry managers and experts, a total of 76 sub-criteria and 12 intermediate criteria were identified as control criteria. The research algorithm is shown in Figure 1.

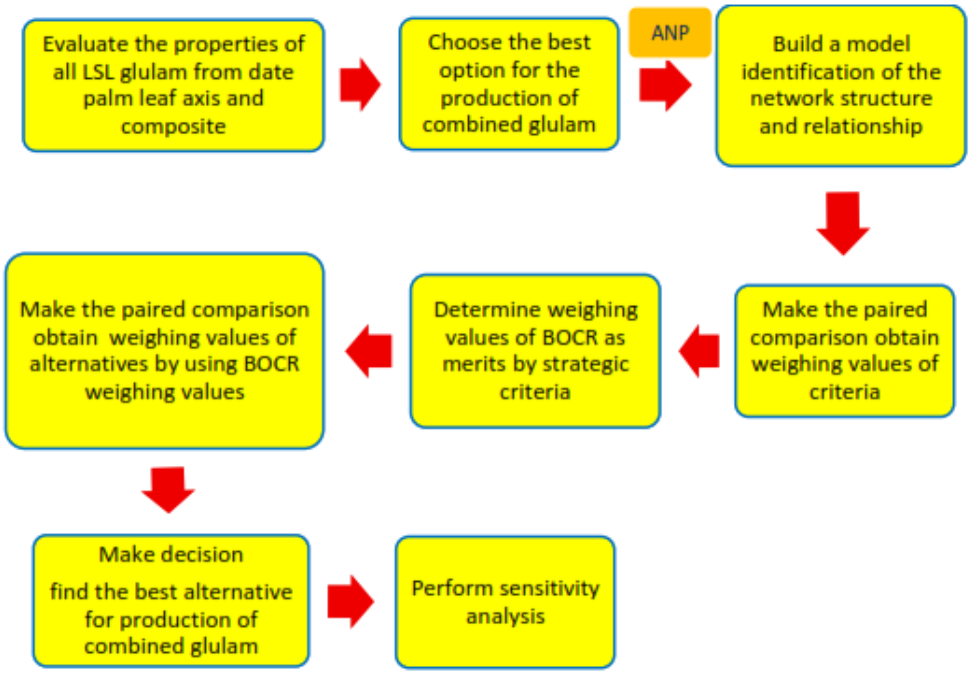

Figure 1 Algorithm of the research

2.5 BOCR (merits) model

In the ANP method, the indicators and criteria that are effective in decision-making were first formulated in the form of the BOCR model (Saaty & Cho, 2001b; Wijnmalen, 2007). Definite and favorable indicators were organized into benefits, possible and favorable indicators were presented as opportunities, definite and unfavorable indicator were organized into costs, and possible and unfavorable indicators were presented as risks. The control criteria were classified under benefits, opportunities, costs, and risks. All of the criteria and sub-criteria with their abbreviations are described in Table 1.

Table 1
Factor table

Main criteria of benefits	**Sub-criteria**	**Abbreviation**
Economic & marketing/ Economic	Job creation	B1
Economic & marketing/ Economic	Prevent environmental pollution	B2
Economic & marketing/ Economic	Being close to raw material production centers	B3

Main criteria of benefits	**Sub-criteria**	**Abbreviation**
Economic & marketing/ Economic	Reducing construction costs	B4
Economic & marketing/ Economic	Use of waste	B5
Economic & marketing/ Economic	Taking advantage of the scientific and technological structures of universities	B6
Economic & marketing/ Economic	Utilizing the capacity of knowledge-based companies	B7
Economic & marketing/ Economic	Financial support and social security	B8
Economic & marketing/ Economic	Reduction of the finished price	B9
Economic & marketing/ Economic	Increase in profits	B10
Economic & marketing/ Economic	Design and implementation of internal marketing	B11
Economic & marketing/investment	Reducing prices and improving the company's competitiveness	B12
Economic & marketing/investment	Access to technologies	B13
Economic & marketing/investment	Higher mechanical resistance	B14
Technology/ Technological	Better application of knowledge and technology transformation into new products	B15
Technology/ Technological	Turning knowledge and technology into a new product	B16
Technology/ Technological	Possibility of research on cheap and local raw materials	B17
Environmental/ Environmental	The possibility of green supply chain management	B18
Environmental/ Environmental	Reducing energy consumption using new methods	B19
Environmental/ Environmental	Principal exploitation of forests	B20
Environmental/ Environmental	Reducing the use of volatile and organic substances	B21

Main criteria of benefits	**Sub-criteria**	**Abbreviation**
Environmental/ Environmental	Reducing carbon production (using less resources - more recycling and reducing waste production)	B22
Economic & marketing / Economic	Purchase of raw materials	C1
Economic & marketing/ Economic	Cost of storage	C2
Economic & marketing / Economic	The cost of transporting raw materials	C3
Economic & marketing / Economic	Cost of chemicals	C4
Economic & marketing / Economic	The cost of collecting raw materials	C5
Economic & marketing / Economic	Productivity	C6
Economic & marketing/ Marketing and sales	Cost of detailed market study	C7
Economic & marketing/ Marketing and sales	New product marketing cost	C8
Economic & marketing/ Marketing and sales	Cost of participating in exhibitions	C9
Economic & marketing/ Marketing and sales	Cost of setting up a store or agency for continuous sales	C10
Economic & marketing / Export	Handing over foreign markets to leading competitors	C11
Economic & marketing / Export	Analytical cost of export target markets	C12
Economic & marketing / Export	Negative competition among domestic exporters	C13
Economic & marketing / Export	Lack of knowledge of export target markets	C14
Economic & marketing / Import	Sharp increase in imports	C15

Main criteria of benefits	**Sub-criteria**	**Abbreviation**
Economic & marketing / Import	Currency withdrawal from the country	C16
Social/ Social	Control/influence on human resources	C17
Supply and production/ Raw material	Increasing the cost of providing raw materials	C18
Supply and production/ Raw material	Sudden stoppage of supply of raw materials	C19
Supply and production/ Raw material	Dependence on the supplier	C20
Supply and production/ Raw material	Decrease in the quality of supply of raw materials	C21
Supply and production/ Raw material	Cost of using non-native raw materials	C22
Supply and production/ R&D	Cost of aggressive strategy (development of a new technological product)	C23
Supply and production/ R&D	Lack of confidence in the degree of usefulness of the product	C24
Environmental/ Environmental	Excessive consumption wood (destruction of forests)	C25
Environmental/ Environmental	Increase in greenhouse gas emissions	C26
Environmental/ Environmental	Accumulation of waste caused by non-recyclability	C27
Economic & marketing/ Economic	Possibility of export	O1
Economic & marketing/ Economic	Investment	O2
Economic & marketing/ Infrastructures	Using the capacity of graduates	O3
Economic & marketing/ Having a competitive advantage	Reducing investment risk	O4

Main criteria of benefits	**Sub-criteria**	**Abbreviation**
Economic & Market/ Having a competitive advantage	Directing valuable investment flows	O5
Economic & marketing/ Having a competitive advantage	Improving the performance of domestic industries	O6
Economic & marketing/ Marketing and sales	High profit margin for the manufactured product	O7
Economic & marketing/ Marketing and sales	Possibility of segmenting the market according to the target markets	O8
Economic & marketing/ Marketing and sales	Helping with an affordable pricing strategy	O9
Economic & marketing/ Export	Earning currency from non-oil exports	O10
Economic & marketing/ Export	Movement in the direction of resistance economy	O11
Economic & marketing/ Export	Presenting awards to new designs	O12
Economic & marketing/ Export	Helping to internalize and externalize the economy for export	O13
Economic & marketing/ Competitiveness	Having a competitive advantage	O14
Economic & marketing/ Competitiveness	Increasing the share of foreign markets	O15
Economic & marketing/ Competitiveness	Having a comparative advantage	O16
Social/ Social	Creating jobs	O17
Social/ Social	Renovation of villages	O18
Social/ Social	Changing and developing the consumption pattern	O19
Environmental/ Environmental	Effective use of energy and available resources	O20
Environmental/ Environmental	Optimizing the use of raw materials	O21

Main criteria of benefits	**Sub-criteria**	**Abbreviation**
Environmental/ Environmental	Possibility of obtaining environmental certificates for the export of palm trees	O22
Environmental/ Environmental	Possibility of returning products to the company for recycling	O23
Environmental/ Environmental	Possibility of natural recycling (biological degradation)	O24
Social/ Social	Lack of acceptance and recognition of the product	R1
Social/ Social	Low product quality	R2
Social/ Social	Competitive strength with alternative products	R3
Social/ Social	Delay in the delivery of raw materials	R4
Social/ Social	Lack of sufficient training and experience for graduates	R5
Social/ Social	Inflexibility of managers	R6
Economics/ Economics	Decrease in sales and increase in storage cost	R7
Economics/ Economics	Reducing the import tariff of goods	R8
Economics/ Economics	Product price increase	R9
Economics/ Economics	Risk of anti-competitive action by large industrial cartels (monopoly poles)	R10
Economics/ Export	Risk of increasing the price of the finished product	R11
Economics/ Export	Lack of liquidity and working capital for glulam production	R12
Economics/ Export	Lack of knowledge of tools and machinery in glulam production	R13
Economics/ Investment	Strong presence of foreign competitors	R14
Economics/ Investment	Possibility of increasing the level of competition	R15
Economics/ Competitiveness	Intense competition among domestic producers	R16
Economics/ Competitiveness	Risk of information rent in the market	R17

Main criteria of benefits	Sub-criteria	Abbreviation
Economics/ Competitiveness	Anti-competitive measures such as imports	R18
Economics/ Competitiveness	Lack of codified rules and regulations regarding competition	R19

The overall structure of the model is shown in Figure 2.

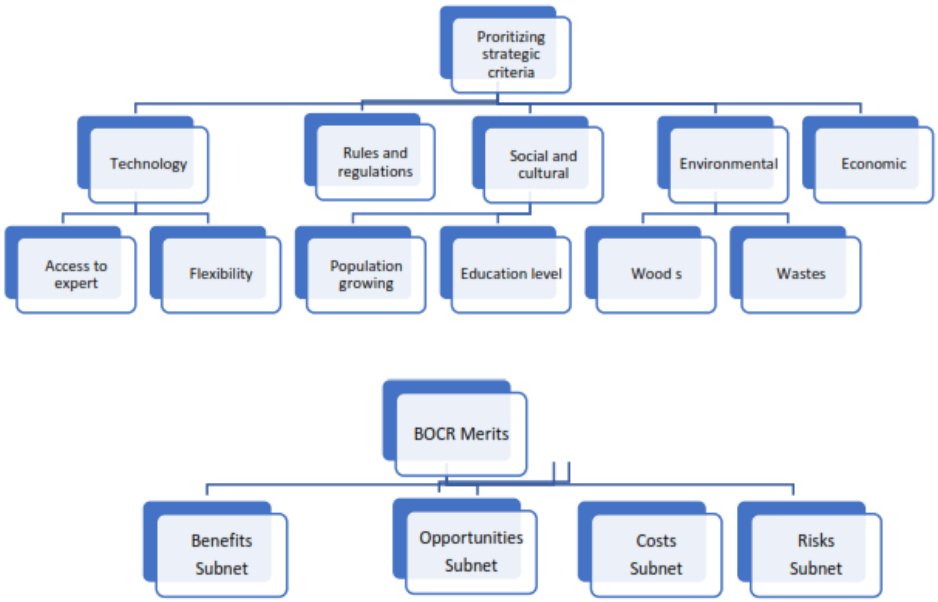

Figure 2 Overall structure of the model

3. Results

3.1 Prioritizing overall factors or strategic criteria

Ratings of overall factors were done by pairwise comparison of the lower-level factors and summing up the main factors at the top level. The results of weighting values of overall factors obtained from the SuperDecisions software are shown in Figure 3.

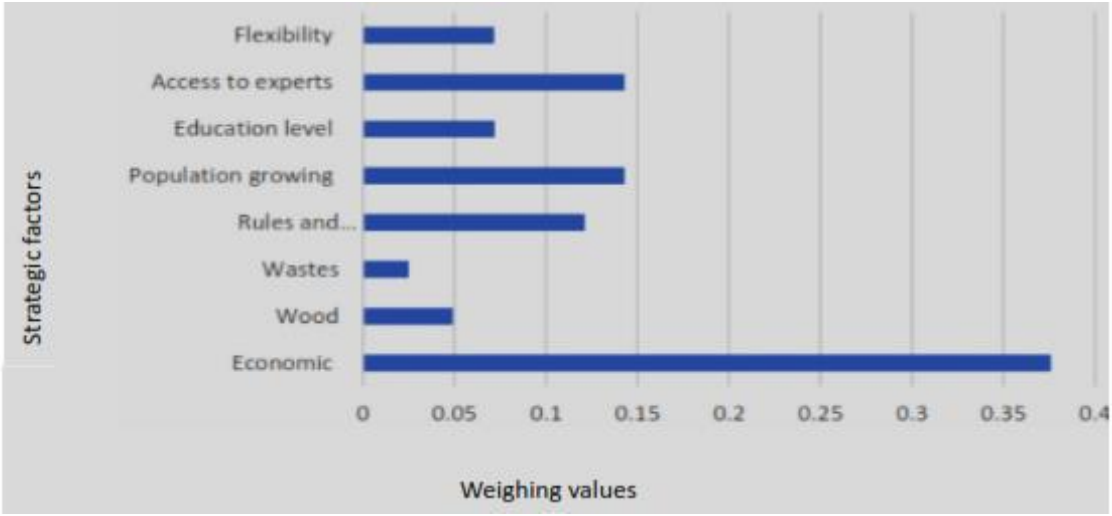

Figure 3 Resulting weight assignments of overall factors

The final weight was obtained from ranking benefits, opportunities, costs, and risks concerning strategic criteria (see Table 2).

Table 2
Result of BOCR weighing value concerning strategic criteria

Merits/Overall factors		**Risks**	**Opportunities**	**Costs**	**Benefits**
Economic (0.376)		Excellent	Average	Excellent	Above average
Environmental (0.074)	Wood (0.049)	Above average	Above average	Average	Average
	Wastes (0.025)	Excellent	Below average	Excellent	Average
Rules and regulations (.121)		Above average	Average	Above average	Average
Cultural and social (0.055)	Population growth (o.143)	Excellent	Average	Excellent	Below average
	Education level (0.0172)	Excellent	Average	Excellent	Average
Technology	Access to experts (0.143)	High	Medium	High	Low
	Flexibility (0.0716)	93-100%	60-69%	70-84%	70-84%

Overall priorities	0.381	0.114	0.351	0.153

Benefits: With a weight of 0.381, this merit is considered the most crucial factor in the research and received the highest rank. The results show that managers or researchers pay the most attention to profitability and productivity in their strategic decisions.

Opportunities: This merit, with a weight of 0.351, ranked second and shows that expert managers pay attention to the analysis of opportunities in the external and internal environment to exploit them.

Costs: With a weight of 0.114, this criterion ranked fourth (last place). The results show that managers pay little attention to issues related to costs in their strategic decisions, and this criterion is the least important.

Risks: With a weight of 0.153, this criterion ranked third. The results show that the recognition and management of risks is also of great importance and that they should be given special attention in strategic decisions.

The focus is on exploiting opportunities and managing risks in a strategic environment to gain higher profits and productivity. Also, cost management has the least attention. The results show that decision-makers strongly seek to maintain and improve the benefits and upgrade the product strategy.

Final weights of strategic criteria

Economic factors with a weight of 0.376 have the most substantial influence on people's decisions regarding the manufacture of glulam from the palm leaf axis (Figure 1). This result shows that managers and employers of the wood and wooden structures industry pay significant attention to economic issues, and this criterion is essential. Factors such as exchange rate, price of raw materials, demand in the market, economic policy, and rate of economic growth are probably critical to them.

3.2 Prioritizing criteria and alternatives

Results of pairwise comparisons between sub-criteria for benefits, costs, opportunities, and risks by the ANP, as well as pairwise comparisons of the criteria and alternatives against each other and by the merits mentioned above, are reported in Table 3. SuperDecisions software was used to apply the ANP. In the BOCR structure, the following formula is used in calculations (Saaty & Cho, 2001b):

(Benefits)*(Opportunities)/(Costs)*(Risks) (1)

Table 3
Synthesized priorities of the criteria, subcriteria, and alternatives

Merits	**Criteria**	**Subcriteria (Abbreviation)**		**Glulam from wood, LSL and epoxy**	**Glulam from LSL and epoxy**	**Glulam from wood, LSL and polyvinyl acetate**	**Glulam from LSL and polyvinyl acetate**
Benefits (0.381)	Economic & marketing (0.536)	Economic (0.401)	B1 (0.214)	0.333	0.166	0.333	0.166
			B2 (0.173)	0.166	0.333	0.166	0.333
			B3 (0.097)	0.166	0.333	0.166	0.333
			B4 (0.41)	0.334	0.167	0.253	0.244
			B5 (0.104)	0.166	0.333	0.166	0.333
		Infrastructure (0.146)	B6 (0.259)	0.395	0.232	0.232	0.14
			B7 (0.327)	0.333	0.166	0.333	0.166
			B8 (0.412)	0.444	0.222	0.222	0.111
			B9 (0.367)	0.111	0.222	0.222	0.444
			B10 (0.394)	0.333	0.166	0.333	0.166
			B11 (0.238)	0.496	0.127	0.29	0.085
		Investment (0.338)	B12 (0.714)	0.301	0.228	0.363	0.106
			B13 (0.285)	0.333	0.166	0.333	0.166
	Technology (.307)	Technological (1.00)	B14 (0.433)	0.54	0.135	0.251	0.072
			B15 (0.263)	0.375	0.125	0.375	0.125
			B16 (0.129)	0.333	0.166	0.333	0.166
			B17 (0.173)	0.111	0.222	0.222	0.444
	Environmental (.156)		B18 (0.27)	0.166	0.333	0.166	0.333
			B19 (0.185)	0.333	0.166	0.333	0.166
			B20 (0.239)	0.333	0.166	0.333	0.166

Merits	**Criteria**	**Subcriteria (Abbreviation)**		**Glulam from wood, LSL and epoxy**	**Glulam from LSL and epoxy**	**Glulam from wood, LSL and polyvinyl acetate**	**Glulam from LSL and polyvinyl acetate**
			B21 (0.173)	0.333	0.166	0.333	0.166
			B22 (0.131)				
Benefits normalized				**.0317**	**0.199**	**0.286**	**0.196**
Opportunities (0.351)	Economic & Marketing (0.26)	Economic (0.264)	O1 (0.333)	0.482	0.156	0.271	0.088
			O2 (0.666)	0.511	0.154	0.255	0.078
		Infrastructure (0.122)	O3 (1.00)	0.196	0.403	0.162	0.236
		Having a competitive advantage (0.224)	O4 (0.351)	0.276	0.102	0.436	0.184
			O5 (0.432)	0.122	0.227	0.227	0.423
			O6 (0.216)	0.438	0.186	0.265	0.109
		Marketing & sales (0.085)	O7 (0.413)	0.256	0.107	0.471	0.164
			O8 (0.167)	0.161	0.341	0.165	0.331
			O9 (0.418)	0.333	0.166	0.333	0.166
		Export (0.165)	O10 (0.429)	0.168	0.367	0.123	0.34
			O11 (0.112)	0.166	0.333	0.166	0.333
			O12 (0.27)	0.155	0.372	0.13	0.341
			O13 (0.187)	0.164	0.379	0.133	0.323
		Competitivenes s (0.139)	O14 (0.4)	0.477	0.153	0.287	0.08
			O15 (0.2)	0.432	0.166	0.304	0.096
			O16 (0.4)	0.434	0.182	0.286	0.096
	Social (0.162)	Social (1.000)	O17 (0.527)	0.33	014	0.33	0.199
			O18 (0.194)	0.471	0.164	0.256	0.107
			O19 (0.277)	0.333	0.166	0.333	0.166
	Environmental (1.00)	Environmental (1.000)	O20 (0.194)	0.158	0.38	0.138	0.321
			O21 (0.194)	0.124	0.41	0.11	0.354

Merits	**Criteria**	**Subcriteria (Abbreviation)**		**Glulam from wood, LSL and epoxy**	**Glulam from LSL and epoxy**	**Glulam from wood, LSL and polyvinyl acetate**	**Glulam from LSL and polyvinyl acetate**
			O22 (0.102)	0.27	0.12	0.418	0.19
			O23 (0.194)	0.343	0.149	0.358	0.149
			O24 (0.194)	0.124	0.41	0.11	0.351
Opportunities normalized				**0.314**	**0.222**	**0.26**	**0.202**
Costs (0.114)	Economic & marketing ((0.467)	Economic (0.226)	C1 (0.093)	0.45	0.179	0.28	0.089
			C2 (0.093)	0.333	0.166	0.333	0.166
			C3 (0.093)	0.166	0.333	0.166	0.333
			C4 (0.415)	0.125	0.509	0.079	0.285
			C5 (0.136)	0.166	0.333	0.166	0.333
			C6 (0.167)	0.08	0.294	0.138	0.486
		Marketing & sales (0.273)	C7 (0.144)	0.16	0.349	0.16	0.329
			C8 (0.453)	0.167	0.385	0.131	0.315
			C9 (0.154)	0.268	0.252	0.232	0.246
			C10 (.247)	0.268	0.288	0.241	0.202
		Export (.301)	C11 (0.352)	0.166	0.333	0.166	0.333
			C12 (0.139)	0.17	0.464	0.109	0.155
			C13 (0.227)	0.201	0.352	0.169	0.276
			C14 (0.280)	0.17	0.322	0.194	0.312
		Import (.309)	C15 (0.719)	0.166	0.333	0.166	0.333
			C16 (0.280)	0.25	0.25	0.25	0.25
	Social (0.16)	Social (1.000)	C17 (0.5)	01.66	0.333	0.166	0.333
	Supply and production (0.277)	Raw material (0.666)	C18 (0.2)	0.438	0.186	0.265	0.109
			C19 (0.2)	0.333	0.166	0.333	0.166

Merits	**Criteria**	**Subcriteria (Abbreviation)**		**Glulam from wood, LSL and epoxy**	**Glulam from LSL and epoxy**	**Glulam from wood, LSL and polyvinyl acetate**	**Glulam from LSL and polyvinyl acetate**
			C20 (0.2)	0.166	0.333	0.166	0.333
			C21 (0.2)	0.093	0.286	0.168	0.451
			C22 (0.2)	0.333	0.166	0.333	0.166
		R & D (0.333)	C23 (0.27)	0.166	0.333	0.166	0.333
			C24 (0.72)	0.09	0.304	0.143	0.458
	Environmental (0.095)	Environmental (1.000)	C25 (0.428)	0.333	0.166	0.333	0.166
			C26 (0.247)	0.166	0.333	0.166	0.333
			C27 (0.323)	0.333	0.166	0.333	0.166
Costs normalized				**0.199**	**0.316**	**0.190**	**0.262**
Risks	Social (0.25)	Social (1.000)	R1 (0.173)	0.166	0.333	0.166	0.333
			R2 (0.229)	0.109	0.265	0.186	0.438
			R3 (0.218)	0.109	0.186	0.265	0.438
			R4 (0.120)	0.169	0.338	0.151	0.34
			R5 (0.109)	0.166	0.333	0.166	0.333
			R6 (0.149)	0.165	0.131	0.161	0.341
	Economic (0.75)	Economics (0.391)	R7 (0.279)	0.166	0.333	0.166	0.333
			R8 (0.307)	0.163	0.278	0.163	0.395
			R9 (0.262)	0.232	0.395	0.14	0.232
			R10 (0.15)	0.158	0.285	0.162	0.394
		Export (0.301)	R11 (0.262)	0.250	0.250	0.250	0.250
			R12 (0.31)	0.250	0.250	0.250	0.250
			R13 (0.195)	0.166	0.333	0.166	0.333
		Investment (0.146)	R14 (0.666)	0.250	0.250	0.250	0.250

Merits	**Criteria**	**Subcriteria (Abbreviation)**		**Glulam from wood, LSL and epoxy**	**Glulam from LSL and epoxy**	**Glulam from wood, LSL and polyvinyl acetate**	**Glulam from LSL and polyvinyl acetate**
			R15 (0.333)	0.265	0.109	0.438	0.186
		Competitiveness (0.161)	R16 (0.264)	0.265	0.109	0.438	0.186
			R17 (0.242)	0.250	0.250	0.250	0.250
			R18 (0.150)	0.166	0.333	0.166	0.333
			R19 (0.165)	0.250	0.250	0.250	0.250
Risks normalized				**0.200**	**0.277**	**0.215**	**0.305**

3.3 Results of control criteria and alternatives under benefits

Table 3 shows the overall weight of the criteria of the benefits network. It shows that the economic criteria, and the market with a weight of 0.536 has gained the highest importance in the interest network. This result shows that economic and market factors are very influential in decision-making regarding the production of mixed glulam.

The reasons for the high priority of economic and market criteria are as follows:

- Direct influence on profitability: economic factors such as profitability rate, target market, competitor status, and pricing have a direct effect. Choosing the right market and pricing can increase profitability.
- Attractiveness for investors: economic attractions can attract investors to the industry. These people may invest in and support development programs.
- Influence on decision-makers: Paying attention to the economy and the market means a deep understanding of demand and supply, as well as the advantages and disadvantages of the market and financial issues. This analysis can be effective in making strategic decisions. Also, the consistency ratio of the comparisons is 0.017, which is smaller than 0.1. This means that the decisions made according to economic and marketing criteria are compatible with technological and environmental issues.

According to Table 3, the first alternative (production of glulam from LSL based on palm leaves and cedarwood with epoxy adhesive) with a weight of 0.317 has a higher priority compared to other alternatives.

The overall structure of the network of economic and market benefits is as follows: the criteria are divided into four main categories, economy, infrastructure, marketing and sales,

and investment (see Table 3). Each main category includes sub-criteria, and nodes with related options. The economic criterion with a weight of 0.40l is presented as the most critical criterion in decision-making. The inconsistency ratio of the comparisons is 0.03, which is less than 0.1, and shows the favorable consistency of the comparisons. This choice as the main criterion is justified because of the influence of the sub-criteria related to it in the production of combined glulam.

This explanation can be justified from the following point of view:

- Impact on job creation: Economic criteria related to employment and the creation of job opportunities are essential in the production of combined glulam. Creating jobs and helping economic development are among the main goals, and this is one of the reasons for the preference for this criterion.
- Reducing construction costs: Factors related to the economy can help improve the production process and reduce construction costs. This reduction can have a direct effect on profitability and cost analysis.
- Use of waste and reduction of environmental pollution: Factors related to the economy can help in the optimal use of resources and reduction of environmental pollution.
- Impact on the development of industry and market: Factors related to the economy can help the development of the industry and market related to combined glulam.

In the economics and marketing network, reducing prices and improving the competitiveness of companies (B12), with a weight of 0.714, is the most crucial selection within the network. The result indicated that the decrease in prices and the increase in competition have a strong influence on the decision-making of companies.

Another logical argument for choosing the economic criterion as the main criterion in deciding the production of glulam is discussed below:

- Reducing costs and increasing profitability: the use of palm leaf axis residues as raw materials and the ability to reduce production costs can increase profitability. Also, the use of cedarwood and epoxy adhesive can help improve the performance of a product, which can increase the selling price and, as a result, create more profit.
- Creating jobs and reducing construction costs: glulam production needs a workforce that can create jobs and help develop the economy. Also, reducing construction costs for buildings and facilities can increase the economic value.
- Support for the optimal use of local resources: the use of palm leaf residues as raw materials shows that we use local resources in the production of our products and support the development of the local economy.

This analysis shows that the economic criterion is consistent with financial goals, employment, and optimal use of local resources, and it was chosen as the primary criterion for this purpose.

3.4 Results of control criteria and alternatives under Opportunities

In this section, the opportunities for the production of different types of glulam are presented. Table 3 shows the overall weight of the control criteria of the opportunities network. Economic and market criteria with a weight of 0.728 have been assigned as a more critical criterion compared to other criteria. This analysis shows that the importance and priority of economic and market criteria are greater than those of other criteria due to the influence of the sub-indices related to them on the factors associated with the production of combined glulam. The inconsistency ratio of the comparisons is the number 0.082, which is less than 0.1, which shows that the comparisons of the criteria are compatible.

The reasons for the importance of economic and market criteria are as follows:

- Influencing production factors: Economic and market criteria directly affect the production of combined glulam. This effect can be seen in the form of increasing production, reducing costs, and improving the quality of products.
- Impact on competitiveness and marketability: Marketability and economic criteria can help develop the market, attract new customers, and increase competitiveness. These matters can lead to an increase in income and profit.
- Impact on decision-makers: Economic and market criteria can influence important decision-makers who are related to the development of the production of combined glulam.
- Impact on economic development: economic and market criteria can help the development of the industry and the market of similar products related to combined glulam. This development can lead to economic growth and an increase in employment.

Table 3 shows that the first alternative, the production of glulam combined from LSL based on palm leaf and cedar wood along with epoxy adhesive with a weight of 0.314, has the highest priority in the opportunities network. The option of glulam combined from LSL based on palm leaf and cedarwood along with epoxy glue has essential opportunities in the field of glulam production. It can lead to the development and improvement of business performance.

The overall structure of the network of economic & market opportunities:

The criterion of investment (O2) in the network of economic opportunities, with a weight of 0.666, is the highest priority and is considered the most crucial decision-making criterion (Table 3). The positive effect is that improving the performance of domestic industries by focusing on the production of combined glulam with cheap and available raw materials (palm residue) can lead to reducing the risk of investment and improving investment in the future. Additionally, aligning with economic policy and sustainability practices can further enhance investment prospects and ensure long-term benefits. The inconsistency ratio is compared with the value of 0.039, which is less than 0.1, which shows that the comparisons of the criteria are compatible with each other.

The use of the capacity of graduates with a weight of 1.00 has obtained the highest weight in the nodes within the criteria network because by producing this type of glulam, the mechanical and structural properties of the product have been improved, and these materials are used to create products with high quality and stability. The production of combined glulam with different materials and new technologies provides the possibility of making more added value. The result can help attract foreign investments and support the region's economic development. Also, the production of products with advanced technologies and new materials provides the possibility for graduates' participation in meaningful and valuable positions in the industry.

The reasons for the importance of the production option of combined glulam from LSL based on palm leaf and cedarwood with epoxy adhesive in the network of opportunities can be explained as follows:

- The use of local materials and opportunities for local agricultural production: The production of glulam using local materials such as cedarwood and remaining palm leaves helps to develop local resources and agriculture in the country. Additionally, incorporating sustainability practices and aligning with local economic policies can further enhance these opportunities. The employment of graduates in this industry can also help improve the local economy.
- The potential of exporting to international markets: the production of this type of glulam with suitable location and physical characteristics can be imported to global markets and can lead to an increase in exports. Aligning this production with export policies can further enhance its success and help people trade with other countries.
- Impact on the development of the resistance economy: increasing production and non-oil exports can strengthen the country's resistance economy. This impact can improve the country's income sources and reduce reliance on oil resources.
- Improving the performance of domestic products: developing products with better mechanical and physical performance can lead to an increase in customers and

promotion of domestic industries. This issue can help the country grow in industry and technology.

- Helping sustainable development: the use of local materials and the development of local resources can help the sustainable development of the region.

3.5 Results of control criteria under Costs

The structure of the cost network and the determination of control criteria are expressed in four economic and market, social, supply and production, and environmental networks. Table 3 shows the weight of control criteria under the cost network. The analysis of the network indicates that the economic and market criterion, with a weight of 0.467, has been introduced as the highest priority in the decision-making process. This criterion is known as the most critical criterion due to the influence of its sub-indices on market factors, as well as the sales and production of glulam in the country. The inconsistency ratio of the comparisons is 0.01, which indicates the consistency of the results obtained from the pairwise comparisons of the criteria of this network.

The weighing values of the options in the cost network are as follows: the result (Table 3) shows that the production of glulam, a combination of LSL based on palm leaves with epoxy adhesive, has higher costs (0.316) than other options, which is not desirable.

The overall structure of the network of economic costs:
The cost network structure is divided into four main criteria: economic, marketing & sales, export and import (see Table 1). The result of the comparison of the main criteria shows import and export criteria with the final weights of 0.309 and 0.301 are more important than the economic and marketing & sales. The production of combined glulam by domestic producers who are not aware of the conditions of export target markets leads to handing over foreign markets to leading competitors. Domestic exporters who have lost their ability to compete and export may only export to weak domestic markets. This issue causes harmful and unstable competition in the economy, which leads to the import of similar products and causes the currency to leave the country. In this situation, companies tend to reduce the quality of products and prices so as not to close down due to recession.

The result of the comparison of the criteria shows that the increased weight of imports with a weight of 0.719 (C 15) has gained the highest priority in the nodes within the criteria; production of glulam from palm leaf LSL with epoxy adhesive has some particular problems and costs that need to be taken into account when choosing this option.

Some of the issues caused by the production of this product are:

- Relatively low resistance: The product has relatively low resistance due to the selection of suitable materials and the accurate production process needed to maximize product quality. This may require more precise quality control and increase production costs.
- High density: High product density can lead to high weight and more difficult shipping, which can increase shipping costs.
- Use of expensive adhesives: Using expensive adhesives such as phenol-formaldehyde and epoxy may increase production costs because these types of adhesives are more costly and consume more.
- Marketing cost: due to the specific features of the product and the high cost of production, marketing and advertising may require the cost of introducing and advertising the product.

The increased import of glulam may lead to a decrease in domestic production capacity because producers may prefer foreign products to domestic ones due to lower production costs and better quality. This can lead to a decrease in production capacity and expertise in the domestic industry. Also, the increase in imports may lead to the weakening of the country's export capacity because if the government is interested in importing more from abroad, it will focus more on production for the domestic market and pay less attention to production for foreign markets.

Production of combined glulam (a combination of LSL based on palm leaves with epoxy adhesive) as the highest priority (0.316) in the costs network can cause problems such as production with higher costs, reduction of product quality, low ability to compete in the markets, and adverse effects on the environment (see Table 3).

3.6 Results of control criteria under risks

Table 3 shows the weights of the control criteria of the risk network. The economic criterion is the most important criterion for making decisions about risks in producing combined glulam due to the influence of most of the indicators and factors under its influence. In addition, the inconsistency ratio is less than 0.1, which shows that the comparisons in criteria and sub-criteria in the risks network are consistent.

Table 3 shows the overall weight of options in the risk network. In this figure, glulam from the palm leaf axis LSL, along with polyvinyl acetate adhesive, with an average weight of 0.305, is the highest priority. Factors such as low product quality, weak competitiveness against foreign products, lack of recognition and rejection, increase in storage cost, and increase in product price are the reasons for the high risk of producing this product.

The overall structure of the sub-network of economic risks:

Table 1 shows that the criteria are divided into four general groups: economy, export, investment, and competitiveness. The strong presence of foreign competitors is the highest priority, with a weight of 0.666 (R14) in the sub-network of economic risks. The strong presence of foreign competitors in the production of glulam can be considered as one of the factors that increase economic risks in this industry which is due to the following reasons:

- Intense competition: the existence of foreign competitors with high power and ability in the production of glulam can lead to competition in international markets. This competition may reduce the prices and profitability of domestic glulam production companies.
- Decrease in export markets: The presence of foreign competitors may decrease the country's export market share. This can lead to a decrease in sales and export income and result in economic decline for the country. Implementing effective export policies can help mitigate these effects and support the country's financial stability.
- Reducing the ability to compete: The presence of foreign competitors with high capabilities may reduce the ability of domestic companies to compete with them.
- Effects of changes in international markets: The presence of foreign competitors has made the country dependent on changes in global markets, which results in sudden changes in demand, prices, and export target markets in the country. Implementing responsive economic policies can help manage these fluctuations and stabilize the domestic market.
- Increase in violation of intellectual property rights: The presence of foreign competitors may lead to an increase in breach of intellectual property rights and illegal copying of technologies and technical knowledge of domestic companies. Strengthening intellectual property policies can help protect domestic innovations and technical expertise.

Concerning the results, decision-makers are worried about the low quality of the product and the adverse effects of various economic factors in the case of the production of glulam from LSL based on palm leaf along with polyvinyl acetate adhesive (see Table 3). This type of glulam is due to its weak physical and mechanical properties compared to other options; the demand will probably be lower, and this will reduce sales and profitability.

3.7 Final results of the alternatives in the model of BOCR

Figure 4 shows glulam made with a combination of palm leaf LSL and cedar wood with epoxy adhesive with a normalized weight of 0.372 has the highest priority in decision-making and has been chosen as the best alternative. Then, the option of making combined

glulam from LSL palm leaf axis and cedar wood with polyvinyl acetate adhesive with a normalized weight of 0.307 is in second place.

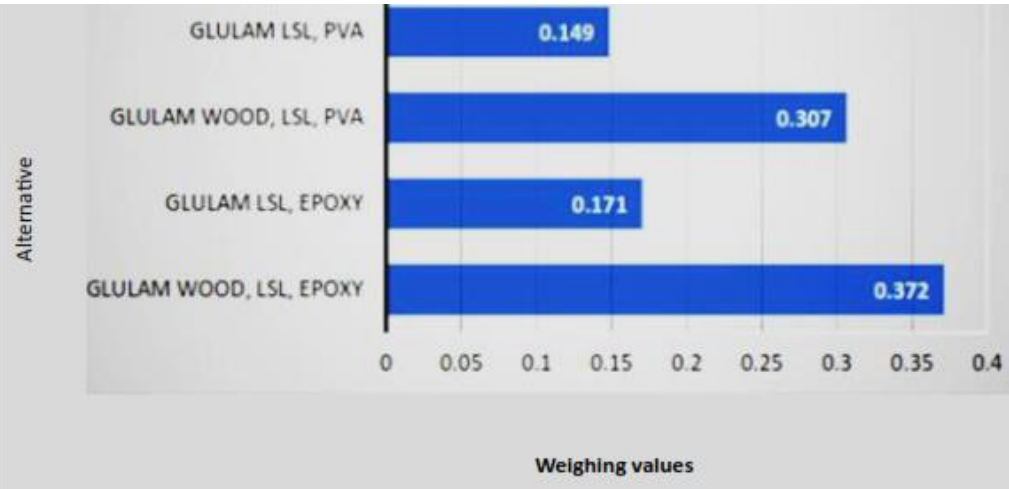

Figure 4 Alternatives priorities of the supermatrix structure

The reasons for choosing the glulam with a combination of palm leaf LSL and cedarwood with epoxy adhesive as the highest priority for the production of glulam can be stated as follows: glulam, with a combination of palm leaf LSL and cedarwood with epoxy adhesive, has the highest priority (0.317) regarding benefits.

- Economic and market criteria: This category includes criteria such as market analysis, demand and supply, variety of products, competitor status, import and export, macroeconomic status, and policy considerations. This option is very effective in attracting the market and meeting economic needs.
- Technology criteria: This includes the ability to use new technology, equipment, and processes, as well as access to technology development. These criteria show that the first option has an improvement and advantage in technology.
- Environmental criteria: These include factors such as the environmental effects of production, product sustainability, consumption of natural resources, and ecological impact. These criteria indicate that the first option pays more attention to environmental and sustainability issues. As a part of the decision-making model, the benefits network has effectively confirmed the first option.

Glulam, with a combination of palm leaf LSL and cedar wood with epoxy adhesive, is the highest priority (0.314) in terms of opportunities.

- Economic and market criteria: This category includes criteria such as market analysis, demand and supply, variety of products, competitor status, import and export, macroeconomic status, etc. These criteria show that the first option is to take advantage of the market and economic opportunities.
- Social criteria: the criteria include the social impact of production, the effects of employment, the improvement of social conditions, etc. Choosing the first option leads to positive social effects.
- Environmental criteria: this category includes criteria such as environmental effects of production, product sustainability, consumption of natural resources, and ecological impact. These criteria show that the first option helps to protect the environment and has positive effects on habitats and natural resources.

Glulam, composed of a combination of palm leaf LSL and cedarwood with epoxy adhesive, ranks third (0.199) in terms of costs. Economic and market criteria under the cost category encompass factors such as production costs, product pricing in the market, market demand and supply, competition, and competitive pricing. The results indicate that this option incurs relatively low costs, making it a viable candidate for future production and development. However, producing glulam from palm leaf axis LSL with epoxy adhesive holds the highest priority concerning economic costs compared to other alternatives. Consequently, this option may not be the most suitable for production.

Glulam, comprising a combination of palm leaf LSL and cedarwood with epoxy adhesive, is assigned the lowest priority (0.200) concerning risks. Within the risk assessment network, economic and social criteria are pivotal. Given the favorable position of this glulam variant concerning economic and social risks, it emerges as a viable alternative for development. From a policy and sustainability perspective, this option demonstrates considerable potential. Conversely, producing glulam from palm leaf axis LSL with polyvinyl acetate adhesive holds the highest priority in terms of risk, rendering it a less favorable alternative for sustainable development.

3.8 Sensitivity analysis

Since there may be different judgments about the comparison of priority rates of benefits, opportunities, costs, and risks or their sub-criteria, a sensitivity analysis of the results should be performed (Saaty, 2001). It can be shown that by increasing or decreasing the weight of one criterion, the ratios of the weights of the other three criteria (concerning each other) remain unchanged, although the sum of their weights changes accordingly (Equation 2). For example, if the weight of benefits increases from 0.381 to 0.5, then the new weights of costs, opportunities, and risks will be 0.092, 0.284, and 0.124, respectively. Although

the sum of these weights is decreased to 0.5, they are proportional to the previous ones, that is, 0.114, 0.351, and 0.153 (see Table 2).

C+O+R=0.618 Total weight of criteria
C/0.618=0.184 (2)
0.184=C^'/((1-0.5))
C^'=0.092
C′: New weight of costs

To perform a sensitivity analysis, we applied the software developed by Saaty (2001a). The results are illustrated in Table 4. After changing the weights of one criterion, the priorities also change, as shown in Table 4.

The main priority is as follows:
WLE [Glulam (Cedarwood +LSL + epoxy)], WLP [Glulam (Cedarwood + LSL + PVA)], LE [Glulam (LSL + Epoxy)], LP [Glulam (LSL + PVA)]

Figures 5-8 show the sensitivity analysis of four merits.

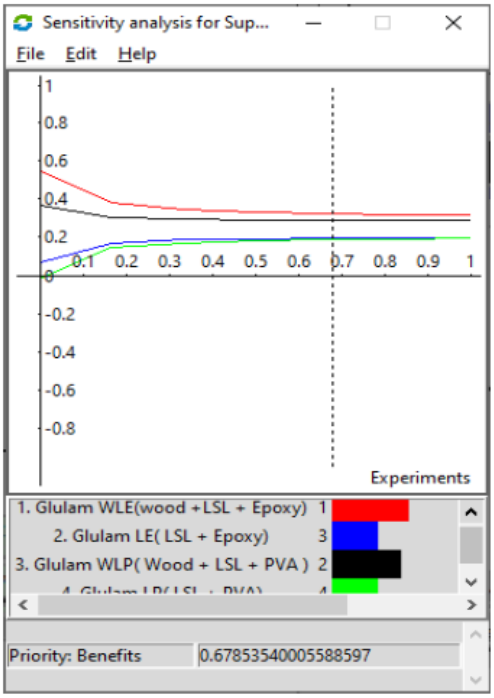

Figure 5 Sensitivity analysis of Benefits

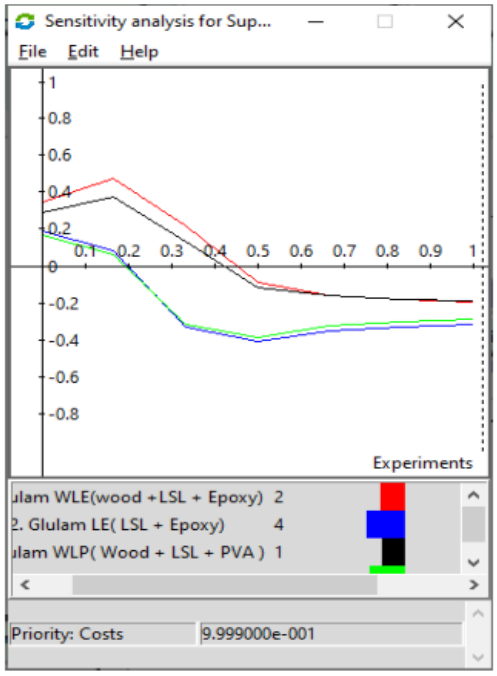

Figure 6 Sensitivity analysis of Cost

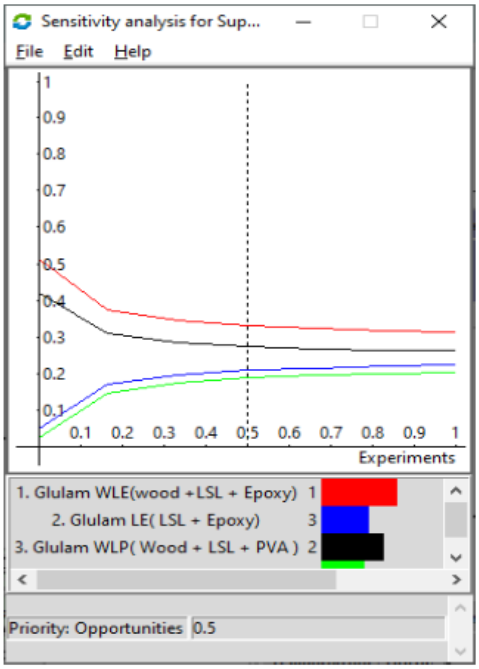

Figure 7 Sensitivity analysis of Opportunities

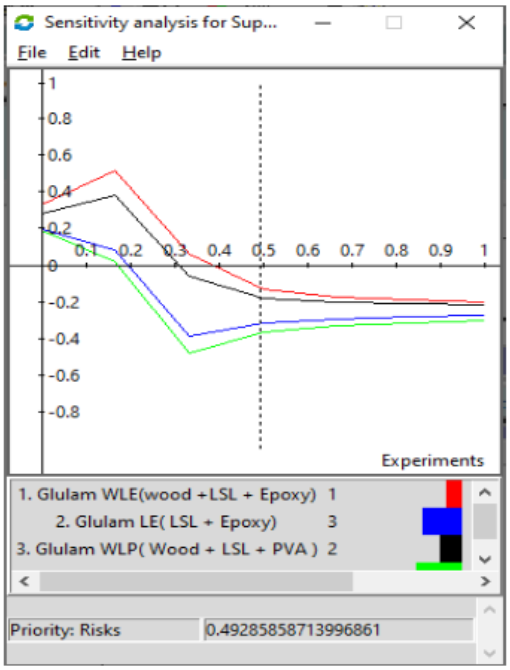

Figure 8 Sensitivity analysis of Risks

Table 4
Results of sensitivity analysis (Basic priority: WLE>WLP>LE>LP)

Merits	**Basic weight**	**Number of changes**	**New weight**	**New priorities**
Benefits	0.381	-	-	-
Costs	0.114	2	.278 .786	WLE>WLP>LP>LE WLP>WLE>LP>LE
Opportunities	0.351	-	-	-
Risks	0.153	-	-	-

Table 4 shows that costs is the most sensitive criteria with changes in priority of the alternatives occurring twice.

4. Discussion

Glued wood technology, commonly known as glulam, is an essential method in the production of wood products. With this technology, the natural defects of wood, such as surface knots, cracks, and points where resin collects, are eliminated. This process increases the strength and reduces changes in the strength of wood. The use of glulam technology improves the efficiency of wood consumption and has positive effects on the environment. This technology leads to greater productivity of existing wood resources, reduces the need to harvest forests, and reduces environmental degradation. Also, due to the lack of wood resources in the world and the need to preserve the environment, this technology is proposed as an effective and sustainable substitute for traditional wood in the construction industry and various other industries. Since this technology helps improve productivity and reduce environmental degradation, it can be considered an innovative and sustainable option for problems related to wood resources. In this research, a suitable substitute called “palm leaf axis” was used instead of pulp wood in the production of glulam. Two types of glulam were created. In the first type, layers of cedarwood and LSL (palm leaf axis) were used, and in the second type, only LSL (palm leaf axis) was used. These two types of glulam are made using two types of adhesives, epoxy and polyvinyl acetate. This research clearly contributes to the development of the glulam production industry, improves its performance, and when deciding on the production of composite glulam, the focus is on the most strategic merit, which is the benefits.

Based on this, economic factors with a weight of 0.38 are the most critical. This result shows that the factors related to the economic situation are considered primary factors and essential variables in decision-making regarding the production of combined glulam. From

the point of view of the country's wood industry managers and employers, criteria such as benefits, opportunities, costs, and risks are crucial and influential in the decisions related to the production of combined glulam. Policy frameworks that promote sustainability play a key role in these decisions. The benefits of combined glulam production in this study are significant. The various benefits of combined glulam production include being more economical, available raw materials, and appropriate strengths such as higher bending and shear strengths have a significant impact on the strategies of decision-making, managers, and employers of the country's wood industries. These results can help the industry make more effective improvements in the production of combined glulam and support its advancement toward sustainable practices.

The final results of the alternatives in the supermatrix structure show that the production of combined glulam with LSL based on palm leaf and cedarwood with epoxy adhesive with a normalized weight of 0. 372 has the highest priority and has been chosen as the best alternative. In the field of economic planning and production of glulam, the combination of LSL based on palm leaf and cedarwood with epoxy adhesive in the country can be effective from several of the following essential points of view:

- Industrial and economic development: Domestic production of combined glulam using local resources and internal capabilities will help the development of the wood and furniture industry in the country. This production can encourage job creation and economic growth and allow local production units to be strong competitors in the domestic and even foreign markets.
- Supplying domestic needs and exports: The production of hybrid glulam products inside the country can help meet the domestic needs of the construction, furniture, and domestic equipment industries, and make the export of these products to international markets is possible. Exports increase the country's foreign currency income.
- Economic independence: the domestic production of combined glulam can help reduce dependence on imports and foreign competitors in the wood and furniture industry.
- Increasing employment: The development of the production of combined glulam products can help create jobs in the country. Providing the production needs of this product leads to the creation of various jobs in the supply chain, including farmers to provide raw materials and workers in a production unit.
- Technological development and higher education: Combined glulam production requires special technical and engineering skills. This issue has caused the development of local technology and increased the capabilities of educational centers.
- Encouraging foreign investment: By creating internal capabilities in the field of combined glulam production, the country can consider incentives that increase foreign investment by emphasizing technology transfer and creating local employment.

- Promotion of added value: The production of combined glulam with high added value can help develop related industries and increase profitability in the production chain. In general, the development of the production of combined glulam products using local resources and domestic capabilities can help improve the country's wood and furniture industry and be effective in advancing the national economic and industrial goals.
- Increase market share: By making this type of combined glulam and changing its design and production, it is always possible to present a product to the market that is up-to-date in terms of design and technology and better than what competitors offer. These competitive advantages can be practical in business development and increasing market share as a leading company.
- Social achievements: The production of combined glulam with the use of palm trees can help build self-confidence and increase self-sufficiency in domestic producers. Empowering farmers and local people to cultivate more palm trees and use their residues can help increase people's income and increase employment in deprived areas. Suppose the production of combined glulam becomes operational. In that case, it will lead to the reconstruction of villages and a transformation in the pattern of consumption of regional resources, ultimately helping to improve the living conditions of people in these areas. The economy will bring many benefits to the country and contribute to sustainable development.
- Environmental achievements: In the environmental field, the positive and undeniable effects of the production of this type of glulam are promising. The use of these green materials instead of wood in the production of glulam has a robust environmental justification as follows:
- Reduction of wood harvesting from forests: By using palm residues as the primary material for glulam production, it is possible to reduce wood harvesting from forests and reduce its harmful effects on the environment.
- Reduction of waste production: Palm leaves are usually left as waste in nature or burned. By collecting and using its residues as a raw material in the production of glulam, it is possible to transform biological waste into a valuable product and reduce the production of waste.
- Supporting the environment and exports: The production of combined glulam with green materials can help create the possibility of obtaining environmental certificates for producers because the production of glulam, a combination of palm residues, can be considered a sustainable and environmentally effective solution in the wood and building materials industry.

According to these results and the confirmation of the research hypotheses, it can be concluded that the use of different materials in combined glulam (the use of LSL based on palm leaves and cedarwood) can improve the properties and the performance of glulam

structures. Also, in a parallel study, it was found that the bending strength and modulus of elasticity of glulam made of LSL and cedarwood with epoxy adhesive is higher than the other three types of glulam (Sharifmousavi, 2023). One study showed that epoxy adhesive performs better than polyvinyl acetate adhesive in making composite products (Custódio, 2009). These findings can assist organizations and decision-makers within the wood and construction industry in devising more effective strategies for glulam production, thereby optimizing resource utilization. Furthermore, the focus on economic and environmental criteria underscores the significant contributions of the wood industry and glulam production to the nation's financial and environmental improvements, highlighting their strategic importance.

5. Conclusion

This research presents a decision-making model for investigating combined glulam production that was developed using the ANP. The method of determining the indicators and sub-indicators and the degree of adoption and effectiveness, encompassed the following four main alternatives: glulam from LSL palm leaf, cedarwood, and epoxy adhesive; glulam from LSL palm leaf and epoxy adhesive; glulam from LSL palm leaf, cedar wood, and polyvinyl acetate adhesive; and glulam from LSL palm leaf and polyvinyl acetate adhesive. Questionnaires derived from the SuperDecisions software were distributed among experts. After evaluating and correcting the inconsistency ratio of the comparisons, the results indicated that the option of Glulam from LSL palm leaf, cedarwood, and epoxy adhesive had the highest priority in the research. The sensitivity analysis of the network of costs revealed that this was the most sensitive criteria, warranting future consideration by experts in their decision-making processes. The findings highlight that glulam produced from LSL palm leaf, cedarwood, and epoxy adhesive emerges as a promising alternative due to its economic and environmental benefits. Integrating policy frameworks that promote sustainability and address deforestation concerns, this combination offers a sustainable solution for applications requiring high strength despite its low density. Implementing such policies is essential to maximize the benefits, as adopting these sustainable materials contributes significantly to mitigating deforestation by utilizing renewable resources and reducing reliance on traditional timber sources. The research underscores the critical importance of these policy frameworks to ensure the long-term viability and environmental responsibility of the wood industry.

REFERENCES

Akbulut O., Y. (2025). Analysis of the corporate financial performance based on Grey PSI and Grey MARCOS model in Turkish insurance sector. *Knowledge and Decision Systems with Applications, 1*(2025), 57-69.

Alves, S.N.L., Simões, S.A.C., & Neyra, B.M.C. (2008). Literature review about ANP method application to the problem of supplier selection. *Brazilian Symposium of Operational Research* September 2-5, João Pessoa, Brazil.

Asyraf, M.R.M., Ishak, M.R., Syamsir, A., Nurazzi, N.M., Sabaruddin, F.A., Shazleen, S.S., Norrrahim, M.N.F., Rafidah, M., Ilyas, R.A., Zakir, M., Abd Rashid, M.Z. & Razman. M.R. (2022). *Journal of Materials Research and Technology*, *17*, 33–65. https://doi.org/10.1016/J.JMRT.2021.12.122.

Ceccotti A. (2008). New technologies for construction of medium-rise buildings in seismic regions: The XLAM case. *Structural Engineering International, 18*(2), 156–165. https://doi.org10.2749/101686608784218680.

Chang, S.H., A.H.I.Lee, and W.L.Pearn. (2005). Analytic network process approach for product mix planning in semiconductor fabricator. *International Journal of Production Economics, 96*(1), 15-36.

Custódio J., Broughton, J. & Cruz, H. (2009). A review of factors influencing the durability of structural bonded timber joints. *International Journal of Adhesives, 29*(2), 173–185. https://doi.org/10.1016/j.ijadhadh.2008.03.002.

Demir G. 2025. Fuzzy Multi-Criteria Decision-Making based security management: Risk assessment and countermeasure selection in smart cities. *Knowledge and Decision Systems with Applications, 1*(2025), 70-91.https://doi.org/10.59543/kadsa.v1i.13701

Dujič B., Štrus, K., Zarnic, R., Ceccotti, A. (2010). *Prediction of dynamic response of a 7-storey massive xlam wooden building tested on a shaking table.* World Conference on Timber Engineering, Trentino, Italy.

El-Houjeyri, I., Thi, V.D., Oudjene, M., Khelifa, M., Rogaume, Y., Sotayo A. & Guan, Z. (2019). Experimental investigations on adhesive-free laminated oak timber beams and timber-to-timber joints assembled using thermo-mechanically compressed wood dowels.

Construction and Building Materials, 222, 288–299. https://doi.org/10.1016/J.CONBUILDMAT.2019.05.163.

Food and Agriculture Organization of the United Nations (2012). https://www. fao.org

Gencer, C. & Gurpinar, D. (2007). Analytic network process in supplier selection: A case study in an electronic firm. *Applied Mathematical Modeling, 31*, 2475-2486. https://doi.org/10.1016/j.apm.2006.10.002

Hajian, S. & Hamidi-Esfahani, Z. (2015). Date palm status and perspective in Iran, date palm genetic resources and utilization. *Asia and Europe, 2*, 19-47. https://doi.org/10.1007/978-94-017-9707-8_2.

Hansson M. & Larsen, H.J. (2005). Recent failures in glulam structures and their causes. *Engineering Failure Analysis, 12*(5), 808–818. https://doi.org/ 10.1016/J.ENGFAILANAL.2004.12.020.

Issa C. A. & Kmeid, Z. (2005). Advanced wood engineering: glulam beams. *Construction and Building Materials, 19*(2), 99–106. https://doi.org/10.1016/J.CONBUILDMAT.2004.05.013

Osmannezhad, S., Faezipour, M. & Ebrahimi, G. (2014). Effects of GFRP on bending strength of glulam made of poplar (Populus deltoids) and beech (Fagus orientalis). *Construction and Building Materials, 51*, 34–39. https://doi.org/10.1016/J.CONBUILDMAT.2013.10.035

Partovi, Y.F. (2006). An analytic model for locating facilities strategically. *Omega, 34*(1), 41-55. https://doi.org/10.1016/j.omega.2004.07.018

Rinaldin G. & Fragiacomo, M. (2016). Non-linear simulation of shaking-table tests on 3- and 7-storey X-lam timber buildings. *Engineering Structures, 113*, 133–148. https://doi.org/10.1016/J.ENGSTRUCT.2016.01.055

Saaty T. (2001a). *Decision on national missile defense program*. 6th International Symposium on the AHP, Bern, Switzerland.

Saaty T. & Cho Y. (2001b). The decision by the US Congress on China's trade status: A multicriteria analysis. *Socio-Economic Planning Sciences, 35*, 243¬252. https://doi.org/10.1016/S0038-0121(01)00016-7

Saaty, T. (2006). Rank from comparisons and from ratings in the analytic hierarchy/network processes. *European Journal of Operational Research, 168*, 557-570.

Sharifmousavi, N. (2023). *Construction and comparative evaluation of LSL-based glulam made from palm leaf and cedar wood using the Analytical Network Process (ANP).* Doctoral Dissertation, University of Tehran.

Taherdoost, H., Madanchian, M.(2023). Analytic Network Process (ANP) method: A comprehensive review of applications, advantages, and limitations. *Journal of Data Science and Intelligent Systems*, 1−7. https://ssrn.com/abstract=4626843

Taliscali, A.K., & Ercan, S. 2006. The Analytic Hierarchy & the Analytic Network Processes in multicriteria decision making: a comparative study. *Journal of Aeronautics and Space Technologies, 2* (4), 55-65.

Tazarv, M., Carnahan, Z., Wehbe, N., (2019). Glulam timber bridges for local roads, *Engineering Structures, 188*, 11–23. https://doi.org/10.1016/J.ENGSTRUCT.2019.03.012.

Tsai, W., Leu, J., Liu, J., Lin, S., and Shaw, M. 2010. A MCDM approach for sourcing strategy mix decision in IT projects. *Expert Systems with Applications, 37*(5): 3870–3886.

Ulutas Berna, H., (2005). Determination of appropriate energy policy for Turkey. *Energy, 30* (2005):1146–1161. https://doi.org/10.1016/j.energy.2004.08.009

Wang, T. 2012. The interactive trade decision-making research: An application of novel hybrid MCDM model. *Economic Modelling, 29*(3): 926–935.

Wijnmalen, D.J.D., 2007. Analysis of benefits, opportunities, costs, and risks (BOCR) with the AHP–ANP: A critical validation, Mathematical and Computer Modeling, *46*(7–8), 892–905. https://doi.org/10.1016/J.MCM.2007.03.020.