Multi-criteria Group Decision Making in the Selection of CNC Woodworking Machinery

Fatma Betul Yeni[1](✉), Mehmet Mustafa Acipayamoglu[2], and Emre Cevikcan[3]

[1] Industrial Engineering Department, Engineering Faculty, Karadeniz Technical University, Trabzon, Turkey
fb.yeni@ktu.edu.tr

[2] Alternatif Makina Sanayi ve Danişmanlik Hizmetleri Ltd. Şti., Istanbul, Turkey
mustafa@altermak.com

[3] Industrial Engineering Department, Management Faculty, Istanbul Technical University, Istanbul, Turkey
cevikcan@itu.edu.tr

Abstract. The machine selection process has been an important issue for companies for many years. The wrong selection of the machine leaves a negative result on the efficiency, precision, flexibility, and sensitive production capacity of the company, and this leads to many problems. In this study, a real case application in a company that serves in the wood industry sector is carried out for the process of CNC woodworking machine selection. First, the main criteria and sub-criteria affecting machine selection are defined. For the decision-making process, 3 senior executives of the company are considered as decision-makers (DM). During the evaluation of alternatives under these criteria, the AHP method, one of the most popular Multi-Criteria Decision Making (MCDM) methods, is used. A sensitivity analysis is also conducted for a different scenario to see the change in the rankings of alternatives.

Keywords: Analytical hierarchy process · Multi-criteria group decision making · CNC machine selection

1 Introduction

The woodworking industry began to develop rapidly in the late 1970s and is still in progress today. Although our country tries to continue the competition with the leading companies in this sector, the dependence on the imported industrial machines is still considered as a problem. Most of the investments in the wood sector are made by imported machines coming from abroad. Considering that the competitiveness of our companies around the world is directly proportional to the quality and cost of the product they produce; it is seen that it is very important to keep operational efficiency at the optimum level. In all these factors, the cost of machinery investment is very critical. If the right choices are made by the companies in the selection of machinery, the resources

F. Calisir and O. Korhan (Eds.): GJCIE 2019, LNMIE, pp. 97–105, 2020.
https://doi.org/10.1007/978-3-030-42416-9_10

will be used optimally in terms of finance, quality, and efficiency. This, in turn, will be effective in competition and will make positive contributions to the country's economy.

The machinery used in wood processing or furniture production, which is the subgroup of the forest products industry, is generally referred to as woodworking machines. Woodworking machines were mostly mechanically controlled up to 25–30 years ago. The wood industry, which has previously used traditional machines, has started to use special software machines by making them computerized as a result of R & D studies. These types of machinery, called CNC (Computer Numeric Control). In the wood industry, the machinery and equipment in the processing of wood and its conversion to furniture vary according to the way and feature of the wood. First of all, the machines used in the process of cutting the wood, which is the raw material of the wood industry, from the forest into logs and then turning it into wood, veneer or derivative materials will be excluded. The process up to here can be called as the forest products industry. In this study, the machines which are used in the process of turning the material taken from the forest to industrial products and reaching to the final consumer in the furniture industry taken into consideration.

By the usage of CNC machines in the furniture industry, the measurement accuracy and standardization are increased, and the cycle time of the product is decreased. Also, the flexibility of the production is increased by the CNC control of some machines. In this study, the selection process of CNC machines used in furniture, auxiliary materials or semi-finished production lines produced from flakeboard or MDF (Medium Density Fiberboard) material, which are called panel manufacturing in the wood industry, are handled. A real case application is carried out in a company for the process of CNC woodworking machine selection by considering the capacity and constraints of the enterprise. After determining the necessary criteria by the experts, the alternative machines are evaluated in terms of these criteria by three decision makers (DMs). In this process, the Factory manager, Production manager, and Sales manager are considered as DMs. Later, the evaluations of the DMs are aggregated, and the best CNC machine is selected using the Analytic Hierarchy Process (AHP), one of the Multi-Criteria Decision Making (MCDM) methods.

The purpose of MCDM methods is to keep the decision-making mechanism under control in cases where the number of alternatives and criterion is high, and to achieve the decision result as easily and quickly as possible. Also, companies using modern decision-making methods pioneer global business relationships and have competitive advantages in managing these relationships. The AHP, one of the most widely used MCDM tools, is the process of developing numerical values to rank each decision alternative according to the degree of meeting the criteria (Saaty and Ergu 2015). The AHP method answers the questions "which one to choose?" or "what is the best?" by choosing the best alternative that meets all the criteria of the decision maker. The implementation of the AHP method is shaped by four basic principles. Decomposition, pairwise comparison, synthesis of priorities, and the final decision based on the mixed composition. These basic principles also constitute the steps of AHP. This method, first introduced by Myres and Alpert in 1968, was improved by Saaty (1977) as a model and used in the solution of decision-making problems. AHP is based on pairwise comparisons through the criteria that affect the decision, and the significance values of the decision points in terms of these criteria, using a predefined comparison scale on a given decision hierarchy. In the literature, there are plenty of studies using AHP in different areas such as selection, evaluation, decision making, etc. Karim and Karmaker (2016) presented an integrated approach of AHP & TOPSIS methods for machine selecting process. This structure involves identifying the weights of the criteria by using AHP and ranking the alternatives by using TOPSIS. Camci (2018) proposed a hesitant fuzzy analytic hierarchy process (HFAHP) model consisting of 4 main criteria and 11 sub-criteria for CNC router selection in woodwork manufacturing. Ozdagoglu et al. (2017) introduced a new machine selection process considering the Fuzzy Analytic Hierarchy Process (AHP) method. The company's machine selection process is also analyzed, given the criteria obtained from the company by comparing the machine vendors. Farhan et al. (2016) developed a model of analytic hierarchy process (AHP), to assist in selecting suitable machine configurations for special purpose machines (SPMs) from available alternatives. This study reduced the time required for designing SPMs.

2 Methodology

The machine selection process has been an important issue for companies for many years because the incorrect selection of the machine leaves a negative result on efficiency, precision, flexibility, and the company's responsive production capacity and cause many problems. The machines used in the production of wooden furniture can be examined in two main groups according to the attribute of furniture production such as machines for the production of solid wood or panel furniture. In both process types, CNC machines are used to process the material. In this study, only CNC machines used in panel furniture production is discussed.

In the decision-making process of CNC woodworking machine, the basic requirements related to the machine are determined first by taking into consideration the whole process. Thus, some of the alternatives are eliminated. Later, the needed features are determined according to the machine's required operations. These features are sorted in order of importance. Among these features, those that are considered indispensable and those who influence the efficiency and work quality of the machine are selected. In a decision-making environment, these selected features are considered as criteria and used to evaluate the alternatives. In this way, it is aimed to select the most suitable machine from a set of alternatives, which is appropriate for at least one purpose or criterion.

2.1 Identifying the Main Criteria and Sub-criteria

Within the scope of this study, firstly, the criteria to be taken into consideration in the selection of CNC surface treatment machine and horizontal sizing machine which is required in a factory that produces panel furniture is defined. The criteria discussed in the selection process of the CNC woodworking machine are grouped into three main headings; Technical factors, Operator-related factors, and Financial factors. Their categorization is shown in Table 1.

Table 1. Criteria took into account to select the best CNC woodworking machine

Main criteria	Sub-criteria
C1: Technical factors	C11: Number of axes
	C12: Stiffness
	C13: Motor power
	C14: Tool change speed
	C15: Control unit performance
	C16: Processing accuracy
	C17: Workspace and height
	C18: Magazine number and capacity
	C19: Machine sled system
C2: Operator-related factors	C21: Easy part connection
	C22: Setting time
	C23: Ease of use of the program
	C24: Easy error detection
	C25: Job security
C3: Financial factors	C31: Cost
	C32: Service
	C33: Payment method
	C34: Maintenance cost

2.2 The Application of AHP Method

After the identification of the criteria, the hierarchy of the problem is constructed in different levels containing the goal, criteria, and sub-criteria. The alternative machine brands are determined as Wekke, Morbildelli, SCM, and EAS by the company. The selection hierarchy for the best CNC woodworking machine is given in Fig. 1.

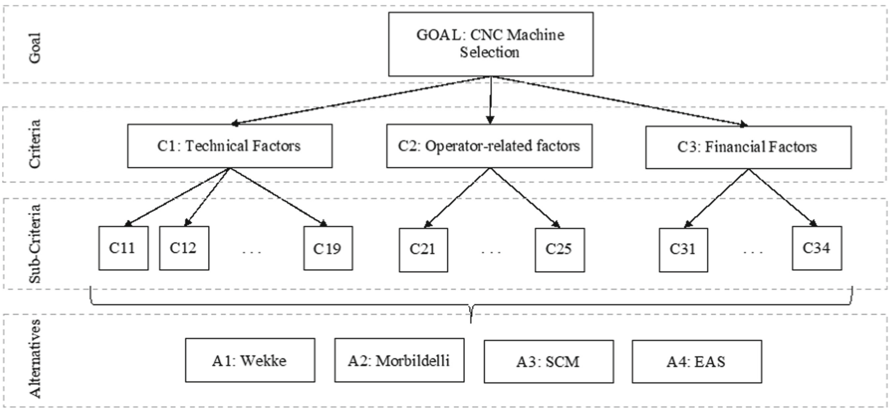

Fig. 1. The selection hierarchy of the best CNC woodworking machine

At this stage, the values to be given about the criteria that will affect the decision at all levels of the hierarchical structure should be converted into a matrix. Since there are 4 different machine alternatives determined by the company, it is necessary to make a pairwise comparison of these alternatives under each sub-criterion. Thus, the relative importance of each item in this structure will be determined. In this evaluation process, Saaty's nine-point scale, shown in Table 2, is used by the DMs. Unlike the other criteria, the number of axes, motor power, working space, magazine number and capacity, and cost criteria does not change according to the machine. Hence, these criteria are weighted by using benefit points instead of pairwise comparison.

Table 2. Saaty's nine-point scale (Saaty 1980)

Level of importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	For compromises between above

3 Results

For the CNC woodworking machine selection process, the 4 alternative types of machinery are evaluated under 3 main criteria, and 18 sub-criteria. The relevant matrices were filled by the DMs for the selection of the most suitable alternative by the AHP method. To make the decision process more accurate, 3 different decision makers, Factory manager, Production manager, and Sales manager, are referred. The comparison matrices generated separately by each DM are aggregated using a geometric mean. The aggregated pairwise comparison matrix of the main criteria in terms of CNC machine selection goal is created, weights of the main criteria are calculated and given in Table 3.

Table 3. The weights of the main criteria in level 1 of AHP

Main criteria	Weight
Technical factors	0,43
Operator-related factors	0,20
Financial factors	0,37

According to this analysis, "Technical factors" is the most important main criterion which affects the CNC woodworking machine selection from DMs' perspective.

Table 4 indicates the evaluation of four alternatives in terms of the nine sub-criteria of "Technical factors." For this main criterion, "C12: Stiffness", "C16: Processing accuracy" and "C19: Machine sled system" are the most important criteria among all.

Table 4. Evaluation of sub-criteria of Technical factors

Technical factors	C11	C12	C13	C14	C15	C16	C17	C18	C19
Weights of sub-criteria	0,03	0,24	0,06	0,02	0,05	0,24	0,07	0,03	0,25
A1: Wekke	0,25	0,575	0,349	0,271	0,62	0,627	0,234	0,353	0,425
A2: Morbidelli	0,25	0,088	0,233	0,506	0,159	0,185	0,281	0,235	0,238
A3: SCM	0,25	0,276	0,233	0,162	0,125	0,094	0,313	0,235	0,239
A4: EAS	0,25	0,061	0,186	0,061	0,097	0,094	0,172	0,176	0,097

Table 5 shows the evaluation of four alternatives in terms of the five sub-criteria of "Operator-related factors." For this main criterion, "C25: Job security" is considered as the most important criteria among all by the DMs'.

Table 5. Evaluation of sub-criteria of Operator-related factors

Operator-related factors	C21	C22	C23	C24	C25
Weights of sub-criteria	0,07	0,23	0,25	0,10	0,36
A1: Wekke	0,591	0,451	0,124	0,192	0,588
A2: Morbidelli	0,172	0,374	0,452	0,183	0,241
A3: SCM	0,157	0,101	0,367	0,346	0,122
A4: EAS	0,08	0,074	0,057	0,279	0,049

The evaluation of four alternatives in terms of the four sub-criteria of "Financial factors" is shown in Table 6. For this main criterion, "C31: Cost" is taken as the most important criteria among all by the DMs'.

Table 6. Evaluation of sub-criteria of Financial factors

Financial factors	C31	C32	C33	C34
Weights of sub-criteria	0,52	0,14	0,23	0,11
A1: Wekke	0,17	0,07	0,05	0,05
A2: Morbidelli	0,22	0,36	0,19	0,14
A3: SCM	0,25	0,48	0,19	0,26
A4: EAS	0,35	0,09	0,57	0,56

Table 7. Ranking the alternatives

Sub-criteria	Criteria weight (Cw)	Sub-criteria weight (Sw)	Cw * Sw	Wekke (A1)	Morbidelli (A2)	SCM (A3)	EAS (A4)
C11	0,43	0,03	0,01	0,25	0,25	0,25	0,25
C12	0,43	0,24	0,10	0,57	0,09	0,28	0,06
C13	0,43	0,06	0,03	0,35	0,23	0,23	0,19
C14	0,43	0,02	0,01	0,27	0,51	0,16	0,06
C15	0,43	0,05	0,02	0,62	0,16	0,12	0,10
C16	0,43	0,24	0,10	0,63	0,18	0,09	0,09
C17	0,43	0,07	0,03	0,23	0,28	0,31	0,17
C18	0,43	0,03	0,01	0,35	0,24	0,24	0,18
C19	0,43	0,25	0,11	0,42	0,24	0,24	0,10
C21	0,20	0,07	0,01	0,59	0,17	0,16	0,08
C22	0,20	0,23	0,05	0,45	0,37	0,10	0,07
C23	0,20	0,25	0,05	0,12	0,45	0,37	0,06
C24	0,20	0,10	0,02	0,19	0,18	0,35	0,28
C25	0,20	0,36	0,07	0,59	0,24	0,12	0,05
C31	0,37	0,52	0,19	0,17	0,22	0,25	0,35
C32	0,37	0,14	0,05	0,07	0,36	0,48	0,09
C33	0,37	0,23	0,08	0,05	0,19	0,19	0,57
C34	0,37	0,11	0,04	0,05	0,14	0,26	0,56
Result				0,335	0,230	0,231	0,203

Finally, the alternatives are ranked using the evaluation values under defined weights of criteria/sub-criteria. As seen in Table 7, Alternative 1: Wekke machine is selected as the best CNC woodworking machine by the rate of 0,335. The ranking of the alternatives is A1 > A3 > A2 > A4.

4 Discussion

In this section, a sensitivity analysis is performed by creating different case scenarios to take into account the different situations related to the machine selection process. On the current situation of the machine to be selected;

- Scenario 1: A more difficult and complex material will be processed. For this reason, it is assumed that the weight of C15 (Control unit performance), C23 (Ease of use of the program) and C18 (magazine number and capacity) criteria increase by 20–25%.
- Scenario 2: Parts with larger dimensions will be processed. For this reason, the weights of C17 (Workspace and height), C12 (Stiffness), and C13 (Motor power) will be increased by 20%.

- Scenario 3: The importance of the C25 (Job security) criteria will be increased by 25%.
- Scenario 4: It is assumed that the importance of C31 (Cost) and C33 (Payment method) criteria increased by 20% due to the sudden fluctuation in foreign exchange prices.
- Scenario 5: It is assumed that the manufacturer producing machinery interrupted the work due to the financial crisis and slowed down its activities. Therefore, the weight of the C32 (Service) and C34 (Maintenance cost) criteria will increase by 20%.

Table 8. Sensitivity analysis for different scenarios

Weight						
Sub-criteria	Current state	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
C11	0,013	0,013	0,013	0,013	0,013	0,013
C12	0,104	0,104	0,125	0,104	0,104	0,104
C13	0,028	0,028	0,033	0,028	0,028	0,028
C14	0,01	0,01	0,01	0,01	0,01	0,01
C15	0,021	0,026	0,021	0,021	0,021	0,021
C16	0,104	0,097	0,071	0,104	0,104	0,104
C17	0,032	0,032	0,038	0,032	0,032	0,032
C18	0,011	0,013	0,011	0,011	0,011	0,011
C19	0,105	0,105	0,105	0,105	0,105	0,105
C21	0,013	0,013	0,013	0,013	0,013	0,013
C22	0,046	0,046	0,046	0,046	0,046	0,046
C23	0,051	0,061	0,051	0,033	0,051	0,051
C24	0,021	0,011	0,021	0,021	0,021	0,021
C25	0,073	0,073	0,073	0,091	0,073	0,073
C31	0,192	0,192	0,192	0,192	0,231	0,174
C32	0,051	0,051	0,051	0,051	0,024	0,062
C33	0,084	0,084	0,084	0,084	0,101	0,084
C34	0,04	0,04	0,04	0,04	0,012	0,048
Results						
A1: Wekke	0,335	0,334	0,33	0,344	0,339	0,333
A2: Morbidelli	0,23	0,233	0,229	0,226	0,228	0,231
A3: SCM	0,231	0,232	0,237	0,227	0,224	0,234
A4: EAS	0,203	0,201	0,204	0,203	0,208	0,203
Ranking						
A1: Wekke	1	1	1	1	1	1
A2: Morbidelli	3	2	3	3	2	3
A3: SCM	2	3	2	2	3	2
A4: EAS	4	4	4	4	4	4

As a result of the sensitivity analysis performed under different scenarios, it is observed that there is not any significant change in the order of ranking of the alternatives. As seen in Table 8, WEKKE brand machine is the best choice while EAS brand machine is the last one. There is only some replacement between MORBIDELLI and SCM machines according to the scenarios.

5 Conclusion

Turkey is an efficient location in terms of raw materials and potential customers. Accordingly, the furniture sector also follows a developing path in our country. This situation causes the manufacturers of furniture machines in the world to show great interest to our country. This means an increase in machine alternatives. As the alternatives increases, the selection process becomes difficult or different elements come to the fore, and wrong machine purchases or faulty investments are in question. In this context, using analytical methods in the selection of machine is an indispensable necessity for selecting the most suitable machine for the capacity and expectations of the enterprise. The direct impact of production on this issue will also have significant impacts on employee motivation.

In this study, CNC woodworking machine selection process to be performed in a company serving in the wood industry sector is handled. The main criteria and sub-criteria affecting machine selection are defined. During the evaluation of alternatives under these criteria, the AHP method, which is one of the multi-criteria decision making (MCDM) methods, is used. As a decision-maker (DM) in this decision-making process, 3 people working as senior executives are selected.

In the implementation of the AHP method, the criteria are firstly defined, and a hierarchy of criteria is established. The most suitable machine is selected using pairwise comparison matrices and normalization technique. Then, a sensitivity analysis is conducted by creating scenarios with different situations. Thus, changes in the ranking of alternative machines under different conditions are monitored.

References

Camci A, Temur GT, Beskese A (2018) CNC router selection for SMEs in woodwork manufacturing using hesitant fuzzy AHP method. J Enterp Inf Manag 31(4):529–549

Farhan UH, Tolouei-Rad M, Osseiran A (2016) Use of AHP in decision-making for machine tool configurations. J Manuf Technol Manag 27(6):874–888

Karim R, Karmaker CL (2016) Machine selection by AHP and TOPSIS methods. Am J Ind Eng 4(1):7–13. https://doi.org/10.12691/ajie-4-1-2

Özdağoğlu A, Bahar S, Yakut E (2017) Machine selection with fuzzy AHP in a dairy factory. J Manag Econ 24(2):295

Saaty TL (1977) A scaling method for priorities in hierarchical structures. J Math Psychol 15:234–281

Saaty TL (1980) The analytical hierarchical process. Wiley, New York

Saaty TL, Ergu D (2015) When is a decision-making method trustworthy? Criteria for evaluating multi-criteria decision making methods. Int J Inf Technol Decis Making 14:1171–1187