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Machine selection for custom manufacturing in small-scale furniture businesses

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Abstract

With the integration of computer-aided design and computer-aided production, furniture industry enterprises seem to have problems such as not being able to fully use their existing production capacities and needing qualified personnel. In this context, the issue of machine selection for small-scale enterprises that make order-type production, based on the principle that a rational investment goes through the selection of the appropriate machine, has been examined. As it is known, unlike traditional machines, operators who will use CNC machines are expected to have basic CNC knowledge, at least enough PLC (Programmable Logic Controller) knowledge to change some settings, and the features of the machine they will use. In addition, the work to be done, the capacity of the enterprise, the desired quality from the product, the compatibility with other machines, the selection of machines that are not suitable for the production style, the presence of machines that cannot be used as they should and are kept in idle position to be evaluated in a different way cause great problems for the enterprise. Considering the intensity in our country, in this research, a small-capacity panel furniture manufacturer that makes order-type production is examined; machine types that stand out for three main processes such as panel sizing, edge banding and hole drilling are included. For this purpose, regardless of whether the panel furniture production is CNC, PLC controlled or conventional for the machine line, the machine type has been selected. In the study, AHP (Analytic Hierarchy Process), which is one of the multi-criteria decision making methods, was used as a method. As a result, suitable machine type or machine type combinations are suggested for small-scale furniture businesses.

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Introduction

It is seen that the woodworking machinery industry has largely completed the developments in woodworking and cutting theory, and continues its development with its integration with new technologies and informatics. In addition, with the integration of computer-aided design and production, furniture industry enterprises are generally

faced with problems such as not being able to fully use their existing production capacities and needing qualified personnel. In this context, based on the principle that a rational investment goes through the selection of the appropriate machine, the issue of machine choosing for small-scale enterprises that make custom production is examined in this study. As it is known, unlike traditional machines, operators who will use CNC machines are expected to have basic CNC knowledge, at least enough PLC (Programmable Logic Controller) knowledge to change some settings, and the features of the machine they will use. However, the selection of machines that are not suitable for the work to be done, the capacity of the enterprise and the way of production, the presence of machines that cannot be used properly and kept in idle position to be evaluated in a different way cause great problems for the enterprise. This study was carried out on a small-capacity company, which is a panel furniture manufacturer, taking into account the density of furniture enterprises in our country, as well as the sectoral weight and production type, which is increasing in preference.

In the research, the selection of the machine type, which can be realized with CNC, PLC control or conventional, was made for the line of panel furniture production. Machine types such as panel sizing, edge tripling and hole drilling are included. This machine, CNC, PLC controlled or conventional production of panel furniture for the line, the machine type has been selected. Designed in this way, it is the design of models that are generally targeted in the design of suitable models of a machine type machine type for small-scale enterprises engaged in type production.

On the other hand, when the literature studies are examined, it is seen that the Turkish Woodworking Machinery sector has achieved a similar development in terms of technology, but is insufficient in terms of product-machine diversity and after-sales service (Investment-Production) support, considering the level of development in the world AIM sector. With this study, it is also aimed to contribute to the elimination of the sector's inadequacies in this area (Sofuoğlu and Kurtoğlu, 2013; Kurtoğlu and Dilik, 2018; 2021; Kuşcuoğlu, 2022).

Machine selection and effective factors in the furniture industry

As stated in the literature studies, in general, many factors are effective in machine selection. The common type of furniture in the furniture industry is panel furniture. Panel furniture is also called cabinet furniture or box furniture. Panel products such as particleboard, fiberboard, plywood, solid panel are used in the production of panel furniture. In the production of panel furniture, mass production type is generally

used and the machines in the machine park are lined up and it is essential that the workpieces do not move backwards as much as possible. On the other hand, the increasing demand diversity with the developing technology increases the weight and importance of order type production in the furniture industry. In this context, the factors affecting the machine selection in general can be summarized as follows (Kobu, 2008; Kurtoğlu and Dilik, 2018; 2021; Sofuoğlu and Kurtoğlu, 2013; Kurtoğlu, 2010; Sofuoğlu, 2001).

1. Production type (series, custom, mixed etc.) and capacity
2. Types of products planned to be produced in the following periods
3. Compatibility of machines with each other in terms of capacity
4. Compatibility of machines with each other in terms of technology
5. Distance between machines, depending on part dimensions
6. Ease of repair, maintenance and use of machines
7. Price of machines
8. Working safety in machines
9. Benefit and cost analysis
10. Machine operator costs

With the developing technology, the rapid impact of both the changes in lifestyle and the trends that develop depending on the lifestyle on machine selection decisions, as in every field, is clearly seen from the literature studies. Today, due to the increase in consumer demands and competition conditions, enterprises engaged in mass production have begun to shape production conditions similar to custom production. This situation has increased the importance of the preparation times of the machines used in the furniture industry and has brought flexibility in production to the fore. In addition, one of the factors to be considered is production capacity. Optimum capacity values (İlhan and Burdurlu, 1993), which are determined depending on technical capacity, economic capacity, maximum capacity, actual capacity and intended production amount, play an important role in machine selection. Considering this situation from the furniture industry perspective, the prominent criteria when choosing a machine are factors such as price, ease of use, capacity, flexibility, processing quality and the area covered by the machine. Since a private enterprise was not focused on within the scope of the research, only the price, ease of use, capacity and flexibility factors were tried to be considered among all the criteria (Kurtoğlu and Dilik, 2021; Kuşcuoğlu, 2022).

Multi-criterative decision-making methods

Decision-making is the determination of the thought and action patterns applied in the necessary conditions and the selection of the most appropriate one in order to reach the desired goal. Having many alternatives in decision making and doubting which option should be chosen causes decision making problem. For this reason, in the solution of the decision-making problem, it is tried to solve the decision-making problem by paying attention to many criteria as stated below. These criteria are:

- what is the purpose,
- set target,
- environmental factors involved,
- state of the decision maker,
- alternatives,
- reaching the result.

It is specified in the form (URL 1).

Many classical or fuzzy logic-based methods are used by researchers in order to solve the problems known as multi-criteria decision making in the literature. These; Analytical Hierarchy Process (AHP), Analytical Network Process (AAS), MAUT, UTA, MACBETH, PROMETHEE, ELECTRE I-II-III, TOPSIS, UTADIS, FlowSort, GAIA and FS-Gaia (Uludağ and Doğan, 2016).

The AHP (Analytical Hierarchy Process) method, which is one of the multi-criteria decision-making methods in the research, was chosen because of its advantages such as providing significant convenience to users in terms of mathematical operations and intelligibility and the possibility of being used alone. In the study, the selection of the machine type, regardless of whether it is CNC, PLC controlled or conventional, is emphasized for panel sizing, edge banding and hole drilling, which are the three most important processes for the machine line of panel furniture manufacturing (URL1; Taş, 2010).

Methods and materials

Material

The research has been prepared on the companies operating in the field of panel furniture manufacturing, which produce in custom and mass production type.

In the study, machine selection is based on panel sizing, edge banding and hole drilling processes, which are known as the stages that are most exposed to bottleneck

formation in furniture production. Different types of machines used in panel sizing, edge banding and hole drilling are handled over different capacities.

Method

In the research, AHP (Analytical Hierarchy Process) method, which is one of the multi-criteria decision-making methods, was applied due to its advantages. For this purpose, the values in the pairwise comparison scoring used in the created matrices and their equivalents are shown in Table 1 (URL 2).

Table 1. Scoring scale table

Importance values	Value vefinitions
1	Equal importance
3	A little more important (less superiority)
5	Quite important (too superior)
7	Very important (very superior)
9	Extremely important (absolute superiority)
2, 4, 6 and 8	Intermediate values (compromise values)

In the study, machine selection application was made for 3 basic production processes (panel sizing, edge banding, hole drilling) for small-scale enterprises that make custom production. For this purpose, the following scenarios were created for each production process and it was tried to reach the appropriate machine selection decisions.

Scenario 1: Custom production, panel sizing, up to 50 sheets.

Scenario 2: Custom production, edge banding, up to 1600 meters.

Scenario 3: Custom production, drilling, up to 600 surfaces.

From small-scale enterprises to large-scale enterprises, there are different capacities for each process, and in the creation of scenarios; Production types, processes and capacities were blended separately and the selection of the appropriate machine was determined based on comparison matrices. As a result, four different comparison criteria were determined as price, capacity, ease of use and flexibility.

For each case, for example; A company that produces to order type, up to 50 wooden boards per day, while making panel sizing machine comparisons, 4 different matrices in total were created for each of the criteria of “Price”, “Space Covered by the Machine”, “Capacity” and “Ease of Use”. At the same time. In order to determine the advantages of the determined criteria among themselves, the criteria matrix application was made.

Results and discussion

In the study, the comparison matrices and results obtained for machine selection for the 3 basic production processes (panel sizing, edge banding, hole drilling) are given below for each scenario.

The normalization matrix for the criteria determined for Scenario 1 (panel sizing process) has emerged as shown in Table 2.

Table 2. Criteria and normalization matrix for scenario 1

Normalization matrix (criteria)	Price	Capasity	Ease of use	Flexibility	Weight (W)	V	V/W
Price	0.0556	0.0556	0.0333	0.0714	0.0540	0.2168	4.0168
Capacity	0.0556	0.0556	0.0333	0.0714	0.0540	0.2168	4.0168
Ease of use	0.3889	0.3889	0.2333	0.2143	0.3063	1.2571	4.1036
Flexibility	0.5000	0.5000	0.7000	0.6429	0.5857	2.4762	4.2276
					1.0000		4.0912
CI	0.030406889						
RI	0.882						
CR	CI/RI = 0.0345						

As seen in Table 2, the "CR" value was found below 0.1. Calculations appear to be consistent.

The decision matrix for scenario 1 was determined as given in Table 3.

Table 3. Decision matrix for scenario 1

Decision matrix (Scenario 1)	Price	Capacity		Ease of use	Flexibility		Criteria		Result
VS	4.2222	4.0151		4.0408	4.0408		4.0168		66.7528
VS+HS	4.1747	4.0395		4.0362	4.0362	X	4.0168	=	66.6214
CNCB	4.0362	4.0802		4.2222	4.1747		4.1036		67.5773
CNCB+HS	4.0408	4.0395		4.1747	4.2222		4.2276		67.4382

VS : Vertical Sizing Machine
VS+HS : Vertical Sizing+Horizontal Circular Saw Machine
CNCB : CNC Wooden Panel Machining Center (ACCEPTED)
CNCB+HS : CNC Wooden Panel Machining Center+ Horizontal Circular Saw Machine

As a result, when the decision matrix of Scenario 1 is examined, it is seen that CNCB (CNC Wood Board Machining Center with Large Table) stands out with a score of 67,5773 (Fig. 1). CNCB+HS (CNC Wooden Panel Machining Center and Horizontal Circular Saw Machine) took the second place.

Fig. 1. CNC Wooden Panel Machining Center (URL 3)

The criteria and normalization matrix determined for Scenario 2 (Edge Banding Process) appeared as given in Table 4.

Table 4. Criteria and normalization matrix for Scenario 2

Normalization Matrix (criteria)	Price	Capacity	Ease of use	Flexibility	Weight (W)	V	V/W
Price	0.1071	0.1875	0.0735	0.1193	0.1219	0.4919	4.0362
Capacity	0.0357	0.0625	0.0441	0.0852	0.0569	0.2299	4.0408
Ease Of Use	0.3214	0.3125	0.2206	0.1989	0.2633	1.0994	4.1747
Flexibility	0.5357	0.4375	0.6618	0.5966	0.5579	2.3555	4.2222
					1.0000		4.1185
CI	0.039488555						
RI	0.882						
CR	CI/RI = 0.0448						

The decision matrix of scenario 2 has emerged as given in Table 5.

Table 5. Decision matrix for Scenario 2

Decision matrix (Scenario 2)	Price	Capacity	Ease of use	Flexibility		Criteria		Result
EB8	4.2222	4.0408	4.0362	4.0362		4.0362		67.2611
EB14	4.1747	4.0362	4.2222	4.2222	X	4.0408	=	68.6123
EB20	4.0362	4.1747	4.1747	4.1747		4.1747		68.2139
EB20U	4.0408	4.2222	4.0408	4.0408		4.2222		67.3008

EB8 : Single-Sided Edge Banding (≤ 8 m/min)
EB14 : Single-Sided Edge Banding (≤ 14 m/min) (ACCEPTED)
EB20 : Single-Sided Edge Banding (≤ 20 m/min)
EB20U : Single-Sided Edge Banding (> 20 m/min)

Fig. 2. Single-sided Edge Banding Machine (URL 4)

For the edge banding process, the result from Table 5 (Figure 2) has been determined as the suitability of the „Single-Sided Edge Banding Machine" with a feed rate of 14 m/min or less.

The criteria and normalization matrix determined for Scenario 3 (Hole Drilling Process) appeared as given in Table 6. Hole density, which is an important parameter in drilling processes (such as what type and how many holes will be drilled on a surface) has not been taken into account. However, depending on the nature of the production, in some cases, holes are drilled not only on one surface but on more than one surface, so the selection of the machine is based on the number of surfaces, not the parts. In the drilling process, which is the last process of order type production, in some cases, since the hole is not drilled on only one surface, it is not the number of pieces but the number of surfaces.

Table 6. Normalization matrix of criteria determined for Scenario 3

Normalization matrix (criteria)	Price	Capacity	Ease of use	Flexibility	Weight (W)	V	V/W
Price	0.1000	0.1000	0.1154	0.0714	0.0967	0.3883	4.0152
Capacity	0.1000	0.1000	0.1154	0.0714	0.0967	0.3883	4.0152
Ease of use	0.5000	0.5000	0.5769	0.6429	0.5549	2.2769	4.1030
Flexibility	0.3000	0.3000	0.1923	0.2143	0.2516	1.0168	4.0408
					1.0000		4.0435
CI	0.01450252						
RI	0.882						
CR	CI/RI=0.0164						

The decision matrix for Scenario 3 was also determined, as shown in Table 7.

Table 7. Decision matrix for Scenario 3

Decision matrix (Scenario 3)	Price	Capacity	Ease of use	Flexibility		Criteria		Result
12V	4.0802	4.0177	4.0177	4.0430		4.0152		65.3356
CNCB	4.0395	4.0781	4.1807	4.2760	X	4.0152	=	67.0251
CNCB+12V	4.0151	4.1807	4.0781	4.3043		4.1030		67.0325
MMD	4.0395	4.0177	4.0177	4.0755		4.0408		65.3034

12V : Drilling machine with 1 horizontal, 2 vertical heads
CNCB : CNC Wooden Panel Machining Center
CNCB+12V : CNC Wooden Panel Machining Center+Drilling Machine. 1 horizontal., 2 Vertical Heads (ACCEPTED)
MMD : Manual Multi Hole Drilling Machine

Fig. 3. CNC Wooden Panel Machining Center and Multi-Hole Drilling Machine with 1 Horizontal and 2 Vertical Heads (URL 1, URL 5)

According to these results in Table 7, the combination of "CNC Wooden Panel Machining Center" and "Multi Hole Drilling Machine with 1 Horizontal, 2 Vertical Heads" (CNCB + 12D) (Fig. 3) emerged as the most suitable machine option for Scenario 3 (hole drilling process).

Conclusions

Among the alternative machine options for the production processes examined in the research, the most suitable machine option was determined as follows.

For Scenario 1 (Panel Sizing Process) for producers with a production capacity of up to 50 plates; Vertical Sizing Machine, Vertical Sizing Machine + Reclining Circular Saw Machine Combination, CNC Wooden Panel Machining Center etc. among the alternative machines, it has been revealed that the most suitable one is the "CNC Wooden Panel Machining Center (CNCB)".

For Scenario 2 (Edge Banding Process) for producers using edge bands up to 1600 meters per day, making custom production; Single-Sided Edgebander (up to 8 m/min), Single-Sided-Edgebander (up to 14 m/min), Single-Sided Edgebander (up to 20 m/min), Single-Sided Edgebander (over 20 m/min) etc. It turned out that the most suitable one among the alternative machines is the "Single-Sided Edge Banding Machine" with a feeding speed of 14 m/min or less, with the code EB14.

In the hole drilling process, depending on the nature of the production, in some cases, since holes are drilled not only on one surface but on more than one surface, the machine is chosen based on the number of surfaces, not the piece. For Scenario 3 (Hole Drilling Process) for working situations with a daily drilling capacity of up to 600 surfaces in custom production; there are machine alternatives such as 1 Horizontal 2 Vertical Head Drilling Machine, CNC Wooden Panel Machining Center, CNC Wooden Panel Machining Center + 1 Horizontal 2 Vertical Head Drilling Machine Combination, Manual Multi Hole Drilling Machine etc. in the study, the combination of "CNC Wooden Panel Machining Center" and "Drilling Machine with 1 Horizontal 2 Vertical Heads" (CNCB + 12 V) turned out to be the most suitable for this purpose.

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