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Selection of Alternative Filling Material in The Bed Production with AHP and ELECTRE Methods

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ABSTRACT

Bed production has an important market in the furniture sector. In spite of the fact that sponge is generally preferred as filler in the production process of beds, increasing prices in recent years and the preference of new materials with the development of alternative filling materials have increased. Recently it is seen other than sponge, the granule, wadding, and STW are also used as filling material in bed production. From the management point of view, the choice of filler is an important decision problem that depends on the situation of the business and many objective and subjective criteria must be taken into consideration. It is appropriate to examine such a problem with the Analytical Hierarchy Method (AHP) and the ELECTRE method, which have the ability to make quantitative evaluations and synthesize factor weights from subjective judgments. The criteria for selection of the filler material and the extent to which the criterion will affect the evaluation are important decision points. The opinions of experts in bed production were consulted to determine the criteria to be used in the evaluation. The obtained results show that four basic criteria must be taken into consideration in the selection of filler material. In this study, AHP was used for determining the criteria weights, and ELECTRE methods were used for the selection of the best filling material. The results showed that wadding is the optimum filler material for bed production.

1. Introduction

In today's world businesses are realizing their production within a specific plan and program in order to increase their income by using resources efficiently. Businesses consider many important criteria when producing the products they manufacture. Among these criteria, the selection of the most appropriate raw material is an important factor. Businesses consider many factors related to raw materials at the point where they prefer the best raw material. The majority of businesses are primarily aiming at lower costs, using raw materials that provide sufficient conditions for the product. At the same time, however, not to reduce the quality perception of the process, special care should be taken into consideration.

In the filling process of the production of the bed, it’s started to be used materials that are more convenient and mass-producible rather than that require more time and hand skills nowadays. These materials could provide the opportunity to make better quality, comfortable, and useful beds that save time and labor [1].

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Alternative filling materials and some specifications that can be used in bed production are mentioned below.

- Synthetic rubber (sponge) is one of the most commonly used materials and is obtained by the synthesis of petroleum derived chemicals and does not contain natural latex but exhibits behavior close to natural rubber in terms of its mechanical properties. Although sponge is highly preferred, it has certain advantages and disadvantages in selection factors. Sponge has a wide availability but on the other hand in terms of price, it is the filling material having the highest price according to the other raw materials. The ease of payment is also low.
- Granule. In addition to insulation in the construction sector, it is also used in the furniture industry. In terms of price, higher than wadding and STW. Because it is made from recycled sponge, there is volatile substance odor for a certain period of time due to the adhesives used in its construction, but it is orthopedic. Procurement and payment convenience are not available.
- STW is a new product in the market. It has a very wide usage potential. It has almost equal performance with its alternatives in quality. It is hygienic as well as orthopedic. The price is higher than the wadding. Procurement and payment is easy.
- Wadding is the lowest priced material among all and widely used in bedding, furniture, carpet and floor covering, apparel, home textiles and decorative production. It also performs the lowest quality. Procurement and payment is easy.

In this study, a new model is proposed in which the Analytical Hierarchy Method (AHP) and the ELECTRE methods are integrated in order to determine the alternative filling material to be used in bed production. As a result of the interviews with the sector and related actors in the first phase of the study, the criteria to be considered in selecting alternative filler materials have been determined. In the second stage, weight points were assigned to the criteria determined by the AHP method based on the opinions of the related persons and experts of the sector. At the end of the work, alternate filling materials were ranked according to preference levels using the method of ELECTRE.

The study consists of 4 parts other than the introduction section. The first part is the literature review section. In the second and third sections, AHP and ELECTRE methods are explained, respectively. In the fourth section, an actual data set is used for the application of the proposed model and the evaluation of the obtained results discussed.

2. Literature Review

AHP, one of the MCDM methods, has been applied to many decision-making processes that require selection among multiple alternatives under the influence of multiple criteria. Production management, financial sector, selection of software programs, technology selection, location selection, staff selection, supplier selection, strategy determination, performance evaluation, and item selection (automobile, home, furniture, mobile phone, etc.) are some of the wide variety of applications used. Some recent studies found in the literature are as follows.

Colak [2] propose the construction of solar power plant using Geographical Information Systems (GIS) technology. Within AHP framework, solar energy potential, roads, energy transmission lines, transformer centers, slope, aspect, location of dams and rivers, natural gas pipelines, fault lines, land cover, and residential areas are taken into consideration [2]. Using multi-criteria methods in order to select the route variant, the most favorable for the environment according to European Union's environmental policy, used AHP with modifications [3]. Dey et al. [4] use AHP to overcome the potential bias when dealing with the heterogeneous degree of expertise in group decision-making. The example of a warehouse location selection in a supply chain is used to demonstrate the usefulness of the proposed method [4]. Castillo et al. [5] conducted a study for developing a personnel promotion strategy for each level of the organization by identifying specific criteria. The complexity and the subjectivity of these criteria made clear by the use of MCDM approach particularly AHP method [5]. Applying AHP and geographic information system, Dahri and Abida [6] helped to characterize of flood hazard in Tunisia, which is considered as an important step for flood management in the region.

There are many studies done with AHP in the literature. In the early years when AHP was introduced, AHP was used alone. Later on especially for the last 20 years, regarding the increasing complexity of the knowledge, more sophisticated methods have been proposed to improve AHP. That is, AHP has been used together with the combination of other MCDM methods to deal with new complex decision-making problems [7]. In this regard, AHP has been used with some of the other MCDM methods such as ANP, MAUT, MAVT, PROMETHEE, TOPSIS, DEAHP, QFD, SWOT analysis, sensitivity analysis, and ELECTRE [8]. Of these methods, sufficient numbers of studies have also been done using AHP with the ELECTRE method.

Botak et al. [9] used AHP and ELECTRE II methods to select the best tools for turning. Eight alternative tools in their study were sorted considering the criteria of the characteristics of the lathe, the power required for cutting, the geometry of the tools, the technological characteristics, and the processing parameters. The weighting criteria were estimated using the two-benchmark scale [9].

Aldabbas et al. [10] sought a solution to the problem of location selection of the fire brigade, which would be established if the three local firefighters at different locations in the Friborg canton were combined at a single center, using the AHP and the ELECTRE I and ELECTRE II methods together. Five separate scenarios in which 61 criteria were taken into consideration were assessed [10].

Khatrouch et al. [11] suggested a decision-making model in the healthcare system that would be helpful in selecting the most appropriate team. In the proposed model, the AHP method was applied to determine the weights of each measure in the decision model. The ELECTRE I method was used to obtain the best set meeting most of the decision-making preferences and the effectiveness of the model was tested on real data collected from Bour Habib Bourguiba's Hospital in Tunisia [11].

Shahhoseini and Yousefinejad [12] sought to solve the problem of ATM location using fuzzy AHP and fuzzy ELECTRE III with MCDM approach. Taking into consideration the similar studies in other countries, the criteria were selected based on the points of view of experts and managers of the branches of Şahr Bank's in Tehran. These are competitors (0.202), security (0.120) transportation and traffic (0.112), population density in the coverage area (0.065), land prices (0.199), proximity to other facilities, public services and city center (0.189), remote traceability (0.180), and rules/regulations (0.039) [12].

When the literature reviewed, no studies were found to determine the alternative filler material to be used in bed production using AHP and ELECTRE methods together. Thus it is envisaged that this study will make an important contribution to the literature. Every step of this study was carried out by taking the opinions of experienced people who have been producing and managing for many years in furniture and bed sector. In this context, it is considered that the determination of the evaluation criteria will be also an important contribution to the literature.

3. The Analytical Hierarchy Process

The concept of AHP was developed by Professor Thomas L. Saaty in the 1970s and is a decision-making method used to solve complex problems with multiple criteria. The most important feature of the AHP is that the decision maker can incorporate both objective and subjective considerations into the decision process. In other words, AHP is a method in which knowledge, experience, individuals' thoughts, and predictions are evaluated logically.

AHP is a method with a very wide application area. For this reason, it is effectively preferred in many decision problems [13-15] such as a large number of successful AHP implementations in marketing, finance, education, public policy, economics, medicine, and sports can be found in the literature. In addition, AHP is used in several studies with methods of operations research such as dynamic programming, integer programming, and target programming.

Stage 1. Decomposition. The first step of the AHP, decomposition, is a process of decomposing into sub-problems in a hierarchical way that allows a decision problem to be more easily understood and evaluated. At the top of the hierarchy is the final target of the decision maker. In the lower levels of the hierarchy, the criteria to be considered for achieving this goal are listed. As the hierarchy goes downwards, the clarity of the criteria becomes even more pronounced. Alternatives are at the bottom of the hierarchy. The degree of hierarchy in the establishment of the decision hierarchy depends on the complexity of the problem and the degree of detail [17].

When groupings are made, should be ensured that

- The elements on the same level are independent of each other,
- Elements at every level are affected only by the level elements below them,
- Each element is only affecting a top level element that it is connected,
- Include a maximum of 7 ∓ 2 elements at each level.

Stage 2. Comparative judgments. The second basic step of the AHP is comparative judgments. Pairwise comparison means that two factors/criteria are compared with each other. If the level of the hierarchy contains n elements to be compared, then total *(n*(n-1)/2)* pairwise comparison is required. These comparisons are organized in matrices. As shown in *Table 1*, a matrix is created by performing pairwise comparisons of the different criteria. The term *Wi/Wj* in the matrix, represents how much criteria *i* is more important than criteria *j* to achieve the goal.

Table 1. *Creating a pairwise comparison matrix for criteria.*

	Criterion 1	**Criterion 2…**	**... Criterion n**
Criterion 1	*W1/W1*	*W1/W2…*	*W1/Wn*
Criterion 2	*W2/W1*	*W2/W2…*	*W2/Wn*
.	.	.	.
.	.	.	.
Criterion n	*Wn/W1*	*Wn/W2…*	*Wn/Wn*

The decision maker uses the 1-9 point preference scale shown in *Table 2* when creating a pairwise comparison judgment, in other words, when the decision maker is asked how important the A criterion is in relation to the B criterion. The effectiveness of this scale has been determined as a result of theoretical comparisons made with applications in different fields and other scales [18].

Table 2. *Scale used in analytic hierarchy process.*

Level of Importance	Definition	Remarks
1	*Equal importance*	*Two activities are equally contributing*
3	*One is more important than the other (moderate level)*	*Experience and judgement makes one activity preferred to another (moderately)*
5	*(strong level)*	*(strongly)*
7	*(very strong level)*	*(very strongly)*
9	*(extremely strong level)*	*(extremely strongly)*
2, 4, 6, 8	*Values in between*	

Saaty [16] suggests that face-to-face surveys should be conducted directly with the people involved in the use of the AHP and take their views on bilateral comparatives [16]. Even if the person or persons concerned are not experts in the subject, they should be at least familiar with the subject.

Stage 3. Calculation of the priority. In the next step after the pairwise comparison matrices are developed, calculation of the priority of each compared element is started. This part of the AHP is called "synthesis". The synthesis step involves calculating and normalizing the largest eigenvalue and the corresponding eigenvector for that eigenvalue. Computer programs such as Expert Choices are designed to determine the priority vector. Computer programs use the method of taking the very high forces of the pairwise comparison matrix and dividing the sum of each row of the obtained matrix by the sum of the elements of that matrix. However, in cases where these programs cannot be used, a number of mathematical techniques can be used to determine the priority vector [16].

Stage 4. Consistency. An important issue for the quality of the final decision is the consistency of judgments formulated by the decision maker during the pairwise comparison process. In the consistency test, the objective is not only to have consistency like “if A is more important than B and if B is more important than C then A is more important than C” but also “if A is twice as important as B and B is 4 times as important as C then A is 8 times as important as C” type consistency. The A-C pairwise comparison result, which will briefly appear as a natural result of pairwise comparisons between A-B and B-C, should be consistent with the A-C pairwise comparison result indicated in the question above. This harmony must be provided for all other pairwise comparisons.

Consistency is accepted as a prerequisite for rational thinking. But in practice it is almost impossible to be completely consistent. Learning new information is only possible with some degree of inconsistency. The AHP does not demand perfect consistency. It allows discrepancy, but at every trial it provides a measure of inconsistency. A consistency ratio proposed by Saaty is used to determine the consistency of pairwise comparison judgments [16]. In order for a comparison matrix to be consistent, the largest eigenvalue (λ_{max}) must be equal to the matrix size (n). The most common method used to calculate the consistency rate involves the following steps.

- To calculate the relative importance of the criterion, the geometric mean of each row is calculated and the "W_i" column vector is constructed.
- By normalizing the generated column vector, the relative significance vector "W_i" is calculated.
- Each line in the matrix is multiplied by the relative significance vector to obtain the V_2 column vector.

- The vector V_3 is then calculated by dividing each element of this vector by the corresponding element in its relative significance vector.
- The arithmetic mean of the V_3 column vector gives λ_{max}, which is the largest eigenvalue.
- The final step is to find the consistency indicator and the consistency ratio. These values are calculated with.

Consistency Indicator $CI = \frac{\lambda_{max} - n}{n - 1}$ (n = number of alternatives compared).

Consistency Ratio $CR = \frac{CI}{RI}$ (*RI* = Randomness Indicator Value). Randomness indicators developed for the 1-15 length matrices by Saaty are shown in *Table 3* [19].

Table 3. *Randomness indicators.*

n	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
Randomness Indicator	*0*	*0*	*0.58*	*0.9*	*1.12*	*1.24*	*1.32*	*1.41*	*1.45*	*1.49*	*1.51*	*1.48*	*1.56*	*1.57*	*1.59*

4. ElECTRE Method

The main purpose of the ELECTRE method is to make pairwise comparisons between alternatives for each criterion. Among the successive comparisons of the alternatives' preferential superiority relation, the concordance index is defined as the number of evidence supporting the result that "the A_J alternative is superior to the A_K alternative" or "more important", and the discordance index which is the opposite of the compatibility index. The method is especially suitable for decision problems involving several criteria but many alternatives superior [20].

The application steps of the ELECTRE method are shown below.

Stage 1. Creating the decision matrix (A). The decision matrix (*A*), in which the evaluation criteria in the columns and the alternatives in the rows, is created.

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ a_{m1} & a_{m2} & . & a_{mn} \end{bmatrix}.$$

Stage 2. Creating the standard decision matrix (X). The decision matrix *A* is transformed into a standard decision matrix structure by normalization. Different normalization formulas are used in cost and benefit criteria.

Normalization for the benefit criteria is

$$x_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{n} a_{ij}^2}} \quad i = 1, \cdots, m \;\; j = 1, \cdots, n. \tag{1}$$

Normalization for the cost criteria is

$$x_{ij} = \frac{\frac{1}{a_{ij}}}{\sqrt{\sum_{i=1}^{m} \left(\frac{1}{a_{ij}}\right)^2}} \quad i = 1, \cdots, m \;\; j = 1, \cdots, n. \tag{2}$$

The Standard Decision Matrix (X) generated by the formulas is shown as follows:

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ x_{m1} & x_{m2} & \cdot & x_{mn} \end{bmatrix}.$$

Stage 3. Creating a weighted normalized decision matrix (Y). The standardized matrix is then multiplied by the W_J values to obtain a weighted normalized matrix (Y). The display of the matrix is as follows:

$$y_{ij} = \begin{bmatrix} w_1 x_{11} & w_2 x_{12} & \cdots & w_n x_{1n} \\ w_1 x_{11} & w_2 x_{22} & \cdots & w_n x_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ w_1 x_{m1} & w_2 x_{m2} & \cdot & w_n x_{mn} \end{bmatrix} y_{ij} = w_j x_{ij} \quad i = 1, \cdots, m \qquad j = 1, \cdots, n.$$

$$\left(\sum_{i=1}^{n} w_j = 1\right). \tag{3}$$

Here W_j is the weight of the j^{th} criterion [20].

<u>*Stage 4. Determination of concordance and discordance sets.*</u> The criteria for each of the pairwise comparison are divided into two separate groups. When the alternatives which are solution-to-be to the problem are not "best" according to all the criteria, they are asked to be "better" according to the majority of these criteria and pairwise comparisons are made [21].

In the ELECTRE method, each concordance set (C_{kl}) corresponds to a set of discordance set (D_{kl}). In other words, there are as many discordance sets as the number of concordance sets. The discordance set elements consist of j values that do not belong to the corresponding concordance set.

The concordance set C_{kl} of two alternatives A_k and A_l where $k \geq 1$ and $l \geq 1$, is defined as the set of all criteria for which A_k is preferred to A_l. It is shown as follows:

$$C_{kl} = \{j, \mid y_{kj} \geq y_{lj}\}, \text{ for } j = 1, 2, 3, ..., N. \tag{4}$$

The complementary set is named as the discordance set and it is described as [20]:

$$D_{kl} = \{j, \mid y_{kj} < y_{lj}\}, \text{ for } j = 1, 2, 3, ..., N. \tag{5}$$

Stage 5. Creating matrices of concordance *(C) and d*iscordance *(D).* Concordance sets are used to generate the concordance matrix (C). The C matrix does not have a value for k=1. The elements of this matrix are calculated by the following formula:

$$c_{kl} = \sum_{j \in c_{kl}} w_j . \tag{6}$$

Here, the C_{kl} concordance index shows how confident it is as a result of the pairwise comparison. For example, if C_{12} = {1,4} then the value of the C_{12} element of the C matrix will be $C_{12} = w_1 + w_4$. The representation of the matrix C is as follows:

$$C = \begin{bmatrix} - & c_{12} & \cdots & c_{1n} \\ c_{21} & - & \cdots & c_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ c_{m1} & c_{m2} & . & - \end{bmatrix}.$$

The elements of the discordance matrix (D) are calculated using the following formula:

$$d_{kl} = \frac{\sum\left(\left|y_{kj_{j \in D_{kl}}} - y_{lj}\right|\right)}{\sum\left(\left|y_{kj_j} - y_{lj}\right|\right)}. \tag{7}$$

The matrix D does not take a value for k = 1, and the representation of the matrix D is as follows:

$$D = \begin{bmatrix} - & d_{12} & \cdots & d_{1n} \\ d_{21} & - & \cdots & d_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ d_{m1} & d_{m2} & \cdots & - \end{bmatrix}.$$

Stage 6. Performing the comparison of excellence. Once the matrices of concordance and discordance have been calculated, their elements are checked in a certain way, and inappropriate alternatives are eliminated.

The dominance of the A_k alternative to A_l is determined by how large the C_{kl} is in the concordance matrix and how small the D_{kl} is in the discordance index.

First, the averages of the C and D values ($\bar{C}$ and $\bar{D}$) are calculated.

If $C_{kl} \geq \bar{C}$ and $D_{kl} \leq \bar{D}$ then alternative A_k is preferred to alternative A_l.

The alternatives selected by the method of ELECTRE form a core (*K*). The core (*K*) is formed according to the following conditions [21]:

- A decision point (alternative) in K is not more dominant than another decision point in *K* (alternate).
- A decision point (alternative) outside *K* is behind at least one point in *K* in the preference order.

Step 7. Calculation of Net Concordance and Discordance Indices. If there are more than one alternative in the core, how to make the selection is determined by calculating the net concordance and discordance indices. Having these indexes provides which alternative is more dominant than the other.

The net concordance index value is the largest, and the net discordance index is the smallest alternative solution set. The C_P's are sorted from large to small, and the D_P's are sorted from small to large. Net concordance and discordance indices are constructed as in *Eq. (8)*.

$$C_p = \sum_{k=1_{k\neq p}}^{m} C_{pk} - \sum_{k=1_{k\neq p}}^{m} C_{kp}. \qquad (8)$$
$$D_p = \sum_{k=1_{k\neq p}}^{m} D_{pk} - \sum_{k=1_{k\neq p}}^{m} D_{kp}.$$

The final ranking is then obtained by selecting the largest "*C*" and the smallest "*D*" [21].

5. Application

To give the best decision in terms of the profitability and efficiency for the enterprise when choosing the raw materials, it is very important to determine the most suitable alternative which can realize the best among the many alternatives. In this study, a model has been constructed to help decision makers make raw material preference decisions more accurate, faster, more flexible, and cheaper. For this purpose, AHP and ELECTRE methods of MCDM techniques are used in the alternative filling material selection process in bed production enterprises.

In this study, the factors for filler selection were examined in 4 groups. The most basic criteria for filler are determined as:

- Price.
- Product quality.
- Ease of payment.
- Ease of procurement.

Once it is clear by which criteria the filler material will be measured, it is necessary to determine the weight of each criterion in the total point. For this purpose, the pairwise comparison matrix shown in *Table 4* has been established for four main criteria defined as price, quality, ease of payment, and ease of procurement.

Table 4. *The pairwise comparison matrix.*

	Ease of Procurement	**Ease of Payment**	**Product Quality**	**Price**
Ease of Procurement	*1*	*2*	*4*	*0.33*
Ease of Payment	*0.5*	*1*	*3*	*0.25*
Product Quality	*0.25*	*0.33*	*1*	*0.2*
Price	*3*	*4*	*5*	*1*

According to the above table, the "ease of procurement" criterion was evaluated to be twice as important as the "ease of payment" criterion. On the other hand, the "ease of payment" criterion is said to be 0.5 times more important than the criteria for "ease of procurement".

The criteria weights, calculated using the pairwise comparisons matrix in *Table 4*, are as in *Table 5*. The consistency ratio calculated for the pairwise comparisons matrix is 0.04 indicating that the pairwise comparisons matrix is consistent.

Table 5. *Criteria weights.*

Criteria	**Level of Importance**
Ease of Procurement	*0.243*
Ease of Payment	*0.129*
Quality	*0.07*
Price	*0.538*

Now that we have set the criterion weights, we have now chosen the best filler material. Recently it is seen that sponge, granule, wadding, and STW are used more as filling material in bed production. The decision matrix containing the values of the fillers according to the criteria is shown in *Table 6*.

Table 6. *Decision matrix.*

	Ease of Procurement	Price (TL/Kg)	Quality	Ease of Payment
Sponge	*6*	*500*	*7*	*10*
Granule	*3*	*300*	*6*	*3*
STW	*5*	*200*	*4*	*8*
Wadding	*4*	*100*	*3*	*5*
Criterion Weights	*0.243*	*0.538*	*0.07*	*0.129*

A market research was conducted to determine the values in the decision matrix and information was obtained from the manufacturers. The values for the three criteria other than the price were determined by the subjective evaluations of the bed manufacturers. For example, bed makers were asked to evaluate the products from 1 to 10 according to their ease of procurement. 1 represents the lowest, while 10 represents the highest ease of procurement. The producers stated that sponge, which has 6 points, can be procured 2 times easier than granule, which gets 3 points. Values for the other two criteria were obtained in a similar way.

For normalization of this decision matrix, benefit criteria was applied for all values except price. The obtained normalized matrix is shown in *Table 7*.

Table 7. *Normalized decisions matrix.*

	Ease of Procurement	Price	Quality	Ease of Payment
Sponge	*0.6469966392*	*0.1601281538*	*0,8962581600*	*0.7106690545*
Granule	*0.3234983196*	*0.3202563076*	*0,7682212800*	*0.2132007164*
STW	*0.5391638660*	*0.4803844614*	*0,5121475200*	*0.5685352436*
Wadding	*0.4313310928*	*0.8006407690*	*0,3841106400*	*0.3553345273*

Then the weighted normalization decision matrix is obtained by multiplying the weights of each normalization criterion in the next step. The results obtained are shown in *Table 8.*

Table 8. *Weighted normalized decisions matrix.*

	Ease of Procurement (1)	Price (2)	Quality (3)	Ease of Payment (4)
Sponge (S)	*0.1572201833*	*0.0861489467*	*0,0627380710*	*0.0916763080*
Granule (G)	*0.0786100917*	*0.1722978935*	*0,0537754900*	*0.0275028924*
STW (W)	*0.1310168194*	*0.2584468402*	*0,0358503260*	*0.0733410464*
Wadding (T)	*0.1048134556*	*0.4307447337*	*0,0268877450*	*0.0458381540*

At this stage, sets of concordance and discordance are defined. The set of concordance is expressed by the letter C and the set of discordance by the letter D. Each alternative was compared with each other by each criterion on the weighted normalized decision matrix. The results are shown in *Table 9*.

Table 9. *Concordance and discordance sets.*

C(S,G)	*1, 3, 4*	*D(S,G)*	*2*
C(S,W)	*1,3,4*	*D(S,W)*	*2*
C(S,T)	*1, 3, 4*	*D(S,T)*	*2*
C(G,S)	*2*	*D(G,S)*	*1, 3, 4*
C(G,W)	*3*	*D(G,W)*	*1,2,4*
C(G,T)	*3*	*D(G,T)*	*1,2,4*
C(W,S)	*2*	*D(W,S)*	*1, 3, 4*
C(W,G)	*1,2,4*	*D(W,G)*	*3*
C(W,T)	*1,3,4*	*D(W,T)*	*2*
C(T,S)	*2*	*D(T,S)*	*1, 3, 4*
C(T,G)	*1,2,4*	*D(T,G)*	*3*
C(T,W)	*2*	*D(T,W)*	*1, 3, 4*

In order to generate the matrices of concordance and discordance, the weight values of the criteria indicated by the individual numbers for each value of the concordance sets from the sets in *Table 9* are summed and the total weights of the sets for the concordance sets are found. The results obtained are shown in *Table 10*.

Table 10. *Matrix of concordance and discordance.*

Comparison	**Concordance**	**Concordance Index**	**Discordance**	**Discordance Index**
C(S,G)	*1,3,4*	*0,442*	*2*	*0,567717746*
C(S,W)	*1,3,4*	*0,442*	*2*	*2,412244814*
C(S,T)	*1,3,4*	*0,442*	*2*	*2,569784519*
C(G,S)	*2*	*0,538*	*1,3,4*	*1,761438686*
C(G,W)	*3*	*0,07*	*1,2,4*	*12,77156812*
C(G,T)	*3*	*0,07*	*1,2,4*	*11,2685339*
C(W,S)	*2*	*0,538*	*1,3,4*	*0,414551622*
C(W,G)	*1,2,4*	*0,910*	*3*	*0,097211302*
C(W,T)	*1,3,4*	*0,442*	*2*	*3,208153203*
C(T,S)	*2*	*0,538*	*1,3,4*	*0,389137686*
C(T,G)	*1,2,4*	*0,910*	*3*	*0,088742689*
C(T,W)	*2*	*0,538*	*1,3,4*	*0,010797708*
	TOTAL:	*5,880*		*35,64862468*
	AVERAGE:	*0,490*		*2,970719*

The aggregate dominance matrix was created by selecting the rows that resulted in "yes" for both C and D values shown in *Table 11*.

According to the results from the *Table 11*, a nucleus was formed as shown in *Fig. 1*.

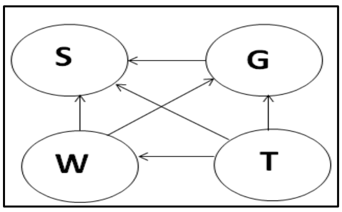

Fig. 1. *Nucleus.*

Table 11. *Aggregate dominance matrix.*

Comparison	$C_{(kl)}$	$C_{(kl)} \geq C_{mean}$	Discordance Index	$D_{(kl)} \leq D_{mean}$	Result
C(S,G)	*0.442*	*NO*	*0,567717746*	*YES*	
C(S,W)	*0.442*	*NO*	*2,412244814*	*YES*	
C(S,T)	*0.442*	*NO*	*2,569784519*	*YES*	
C(G,S)	*0.538*	*YES*	*1,761438686*	*YES*	*G to S*
C(G,W)	*0.07*	*NO*	*12,77156812*	*NO*	
C(G,T)	*0.07*	*NO*	*11,2685339*	*NO*	
C(W,S)	*0.538*	*YES*	*0,414551622*	*YES*	*W to S*
C(W,G)	*0.910*	*YES*	*0,097211302*	*YES*	*W to G*
C(W,T)	*0.442*	*NO*	*3,208153203*	*NO*	
C(T,S)	*0.538*	*YES*	*0,389137686*	*YES*	*T to S*
C(T,G)	*0.910*	*YES*	*0,088742689*	*YES*	*T to G*
C(T,W)	*0.538*	*YES*	*0,010797708*	*YES*	*T to W*

As it can be seen in *Fig. 1* Wadding (*T*) is the best alternative. The net concordance and discordance indices of the raw materials were established according to the formulas in *Eqs. (4)- (7)*. The obtained values are shown in *Table 12*.

Table 12. *Net concordance and discordance values.*

	C	D
Sponge	*-0.288*	*2,9846*
Granule	*-1.584*	*25,0478*
STW	*0,840*	*-11,4746*
Wadding	*1.032*	*-16,5577*

From these values, Wadding (*T*) with the largest value of *C* and the smallest value of *D* is selected as the best filler material. Wadding is followed by STW and Granule, respectively.

6. Conclusion and Recommendations

In the production process of the bed, the materials which make saving of time and workmanship and enable the better quality, are used. Filling material plays an important role in bed production. With the development of technology, various alternatives have been formed at the point of filling materials. In this study, alternate filling materials which can be used in the bed production sector have been evaluated using AHP and ELECTRE methods. It has been determined by taking the opinions of experts and experienced bed makers in the 4 criteria to be used in the implementation process. The obtained model is solved with AHP and ELECTRE methods. As a result of the analyses the wadding is the best among alternative filling materials in bed production. Wadding is followed by STW and Granule filling materials, respectively. It is assumed that the high price of sponge is the result of the last order of preference. Although there are many studies using AHP and ELECTRE in the literature, there are not enough studies in alternative raw material selection in bed production and furniture sector. In this context, it is considered that the determination of the evaluation criteria will be an important contribution to the literature.

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