Mobilya ve Ahşap Malzeme Araştırmaları Dergisi
Furniture and Wooden Material Research Journal
Research Article-Araştırma makalesi 2019 - 2(1), 1-10

Classification of product quality with multiple criteria decision making: an example of furniture industry

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Abstract

When the critical success factors for a company operating in the furniture sector are weighted and their scores are analyzed; the most critical factor is determined as of quality, and a selected product group is considered in line with this factor. The study aims to classify the final product concerning quality in the selected product group. Observation of parameters affecting the separation of the selected product as first and second quality; The main steps of the study are the determination of the reasons of the products separated as second quality and classification of these reasons according to their importance levels by taking into account the after-sales service and customer complaints. In order to determine the importance levels of the products identified as second quality, Analytical Hierarchy Process (AHP) method which is one of the multi-criteria decision-making techniques has been used. Then, which type of error is encountered most in the second quality products, how to determine the root cause of these errors, how the faulty products can contribute positively to the business, what needs to be done to minimize the margin of error and thus the efficient use of raw materials can be maintained. Results provide that the firms operating in the field of furniture will guide the work done in order to provide maximum satisfaction to the customer/operation.

Keywords: Furniture sector, Quality, Analytical Hierarchy Process

Ürün kalitesinin çok kriterli karar verme ile sınıflandırılması: mobilya işletmesi örneği

Öz

Bu çalışma kapsamında mobilya sektöründe faaliyet gösteren bir işletme için belirlenen kritik başarı faktörlerinin ağırlıklandırılarak skorlarına bakıldığında; en yüksek skora sahip olan 'kalite' faktörünün en kritik faktör olarak belirlenmesi ile birlikte bu faktör doğrultusunda işletme faaliyetinin seçilen bir ürün grubu ele alınmaktadır. Çalışmada, seçilen ürün grubundaki nihai ürünün kalite açısından sınıflandırılması amaçlanmıştır. Seçilen ürünün birinci ve ikinci kalite olarak ayrılmasına etki eden parametrelerin gözlem yoluyla incelenmesi; ikinci kalite olarak ayrılan ürünlerin sebeplerinin belirlenmesi ve bu sebeplerin satış sonrası hizmeti ile müşteri şikâyetleri göz önünde bulundurularak önem seviyelerine göre sınıflandırılması çalışmanın temel adımlarını oluşturmaktadır. İkinci kalite olarak belirlenen ürünlerin sebeplerinin önem seviyeleri belirlenirken çok kriterli karar verme tekniklerinden Analitik Hiyerarşi Prosesi (AHP) yöntemi kullanılmıştır. İkinci kalite ürünlerde hangi tip hata ile en çok karşılaşıldığı, bu hataların kök nedeninin nasıl tespit edileceği, hatalı ürünlerin işletmeye pozitif yönde nasıl katkı sağlayabileceği, hata paylarının minimuma indirilmesi için neler yapılması gerektiği ve böylelikle hammadde kullanımının nasıl verimli bir şekilde sürdürülebileceği çalışmanın sonunda tartışılmıştır. Böylelikle elde edilen sonuçlar ile mobilya alanında faaliyet gösteren firmaların müşteri /işletme memnuniyetini maksimum seviyede sağlamak amacıyla yapılan çalışmalara yön vermesi öngörülmektedir.

Anahtar kelimeler: Mobilya sektörü; Kalite; Analitik Hiyerarşi Prosesi

Article history: Received:21.01.2019, Accepted:20.04.2019, Published: 28.06.2019, *Corresponding Author: moturakci@adanabtu.edu.tr

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Citation: Oturakçı M., Benli C., (2019), Classification of product quality with multiple criteria decision making: an example of furniture industry, *Furniture and Wooden Material Research Journal, 2 (1), 1-10*

1 Introduction

A firm is essential to ensure sustainability of itself as it has an advantage the competitiveness in the competitive environment in that it can continue its existence. Today, in order to have the most significant advantage in a competitive environment, it is beneficial to maximize customer satisfaction. Customer expectations are of crucial importance concerning customer satisfaction. Customer expectations are also increasing with the expectation that quality will increase with the developing technology. Because of this situation, the emphasis on quality and quality studies are also increasing. In the quality studies within a firm, it is analyzed the feedbacks from the customers after sales.

The evaluation from these results is quite significant in terms of the productivity of studies. Positive results that are satisfied in customer evaluations should be analyzed. More efficient results are obtained when it is examined by dividing it into the roots of the resulting faults. In addition to classifying causes, it is crucial to classify products to analyze which types of errors are occurring.

When undertaking the production of the organization is actualized, they try to keep the mistakes of the enterprises at the minimum level. In some cases, final products are only partially disrupted due to some problems when they arrive at the final quality control stage, or they are identified as second quality and eliminated from the sales with less profit or cost. Since products that pass through certain stages of production must not conform to the specifications specified as quality parameters, they should be allocated to quality groups, in general, is the route being followed by the firm.

There are some studies about quality classification in the literature; Chang et al. (1997) have described a cork stopper quality classification system using morphological filtering and contour extraction and following (CEF) as the feature extraction method, and a fuzzy-neural network as a classifier. Wan et al. (2002) examine the performance of an automatic inspection system for rice quality classification. Kaya et al. (2005) have reviewed artificial neural network applications for quality control problems. Tello et al. (2018) have provided to attain more performance and to categorize to a model of a defect by quality classifying, in the firm that is purposed to produce the faultless wafer. Ngendangenzwa (2018) have provided one step forward to the automation of paint quality control in order to decrease the costs and increase both the production efficiency and product quality. Kozlov et al. (2018) presented a new fault classification model and an integrated approach to fault diagnosis which involves the combination of ideas of Neuro-fuzzy Networks (NF), Dynamic Bayesian Networks (DBN) and Particle Filtering (PF) algorithm on a single platform.

The quality classification has been used in various sectors. By this study, the causes of the quality issues of the most active group of the product are investigated by classifying in itself, these drawbacks are categorized and the reduction of the quality faults to the minimum is purposed.

In accordance with the aim of this study, the first critical success factors of the furniture sector have been defined and prioritized by using Weighted Ranking Analysis (WRA) with two different perspectives. Then, main and sub-causes of observations have been defined in order to distinguish the causes of being a 1st and 2nd level product. After determination, causes have been prioritized by using Analytical Hierarchy Method (AHP) and recommendations with a detailed action plan for the company and for the furniture sector have been presented in order to minimize the quantity of the 2nd level products.

2 Material and Methods

2.1 Material

This work was carried out in a medium-sized furniture company located in the Adana Organized Industrial Zone. The product groups produced in the firm are a panel, laminated MDF, panel door, profile models and furniture components. Production planning activities in this company, decisions about how and when to produce the products are generally determined according to the customer order. In the order of the customer's order, the production plan of the products to be produced is being prepared. When the activities of the firm are examined, and the production is carried out in 2 facilities within the enterprise, the product group which produces and sells the most is the panel. Among the panel types, UHG (Ultra High Gloss) Panel has been determined to be the most produced product. The UHG Panel is reviewed throughout this study.

2.2 Methods

2.2.1 Weighted Ranking Analysis (WRA)

Critical success factors are variables that can significantly affect the general competitive positions of companies in a given sector. WRA is a method to rank success factors by weighting these variables (Wheelen and Hunger, 2011).

These steps are followed for WRA :

i. Determination of factors affecting success,
ii. Based on the possible effects of the factors on the operation, weighting by considering the following ranking scale as 0-1 (0 = not important, 1 = most important)

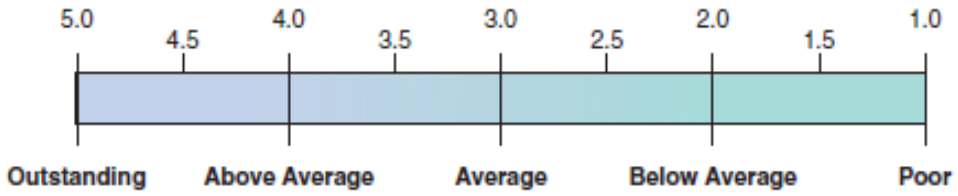

Figure 1. WRA scale Wheelen and Hunger (2011)

iii. Each factor is rated according to the activity of the operator,
iv. Obtaining a weighted score by multiplying each factor by its weight and score,
v. For every factor, the highest score indicates the most critical factor.

2.2.2 Analytical Hierarchy Process (AHP)

AHP method is developed by Thomas Saaty as a multi-criteria decision method (Saaty, 1980). AHP is one of the most widely used methods among multi criteria decision making approaches. In AHP, first, problem definition is made clear. Then, aim, main and sub-criteria are determined to create interactions between criteria and alternatives to build a formulation for a hierarchical structure. Binary comparisons are made by taking a reference to a scale which is presented in Table 1 (Saaty, 1980).

Table 1. AHP Comparison Table (Saaty, 1980)

Importance of Intensity	**Description**
1	Equal importance
3	Moderate importance of one over another
5	Strong importance of one over another
7	Very strong importance of one over another
9	The extreme importance of one over another
2, 4, 6, 8	Intermediate values
Reciprocals	Reciprocals for inverse comparison

For each formed matrix, consistency ratio needs to be calculated which is defined by Saaty as consistency index/random index while the random index is based on the number of criteria (n) and consistency index is formulated by deducting n from the largest eigenvalue of a matrix (λ_{max}) and divided by n-1. Consistency ratio is supposed to be less or equal to 0.10. AHP integrates all individual judgments for the final weights according to the geometric rule of Saaty (1989). According to the final weights, alternatives become ready for reciprocal interpretations. The complexity of AHP algorithms' calculation can be solved by many programs such as Super decision or Expert Choice. Calculations are made in MS Excel for this study.

3 Results and Discussion

3.1. WRA Results

In order to determine the direction of the study, two different evaluations and weighted ranking analysis were applied to obtain a more accurate result. WRA analysis has been applied in order to determine whether product quality is the most important criteria for the company or not. First WRA results include expert opinions while the second one derived from customer satisfaction survey which has been kept by the company from the sales activities.

Both WRA includes the same critical success factors such as product quality; market share; product variety; customer satisfaction and innovation. Results are provided in Table 2 and 3 respectively.

Table 2. Weighted Ranking Analysis -1

Critical Success Factors	**Weights**	**Rating**	**Weighted Score**
Product Quality	0.25	4	1
Market Share	0.18	2	0.36
Product Range	0.16	4	0.64
Customer Satisfaction	0.25	3	0.75
Innovation	0.16	3	0.48
Total	1		

Table 3. Weighted Ranking Analysis-2

Critical Success Factors	**Weights**	**Rating**	**Weighted Score**
Product Quality	0.3	4	1.2
Delivery Time	0.25	4	1
Product Range	0.2	4	0.8
Price	0.25	4	1
Total	1		

Table 2 and 3 presents that "Product quality" is the most vital critical success factor in order to become successful for the company and customers. When the company activities are evaluated in terms of product quality, it needs to concentrate on delivering better quality products and minimizing the quantity of 2nd quality products. Hence, the density of production and the sales ratios were scrutinized to determine which products are sold most and which products are produced the most. It was observed that "Panel" is sold the most and "UHG Panel" is sold the most among panels and illustrated in Figure 2 and 3 respectively. Hence it was decided to continue with "Product Quality of UHG Panels" in the study.

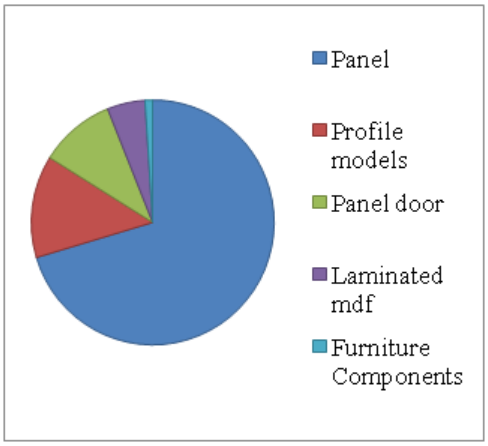

Figure 2. Production intensity and sales rates for all products

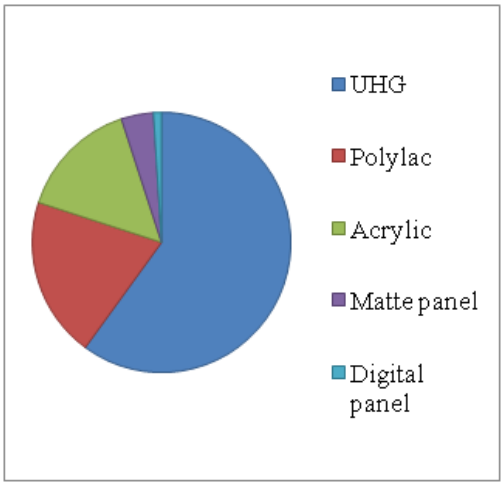

Figure 3. Production intensity and sales rates for panel

In the light of these results, the UHG panel was examined in more detail. All production processes, planning, material flows and raw material components of this product, which was produced in two different tests, were examined on the product tree. When the bill of material of the UHG panel is scrutinized to in Figure 4, it is seen that one UHG panel comes out of folio, laminated MDF, melamine paper and glue.

The raw materials of the UHG panel show variations in itself and UHG panels of different colors and sizes are produced. These variations are differing from according to customer requests. UHG panels can consist of the folio that is various color, and raw MDF that is various sizes. Other components are standard. Folio types are classified into 5 different groups as group 1, group 2, group 3, group 4 and group 5 based on color. While a group folio is represented plain colors, the other groups are named under different groups with their patterns or luminosity. When looking at customer demands and sales ratios, the most used folio in production is group1. 4 kinds of thickness exist like 8 mm, 10 mm, 16 mm and 18 mm, although there is no difference in the length &width of the raw MDF.

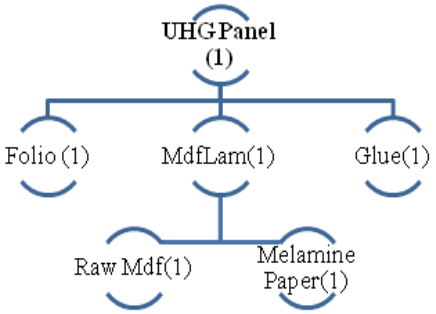

Figure 4. Bill of material of UHG panel

Classified 1st and 2nd level of quality products are observed in consequence of examining the process of UHG panel that was scrutinized through own bill of material during the faults are occurred in the manufacturing process. Production steps of UHG panel have been carefully observed in order to find out causes for distinguishing 2nd level quality products. Main and sub-causes of being 2nd level quality of UHG panels have been identified and presented in Table 4.

Table 4. Classification of causes of 2nd l quality

Causes of 2nd Level quality	**Sub-causes of 2nd Level Quality**
Due to Machine	· Lamination machine · Transmission line · Power Failure/Outage
Due to Labor	· Shifting center of folio · Fault of the operator · Work-load
Due to Raw Material	· Pimple · Folio spot · Bubble · Dregs of glue · Fault of MDF
Due to Production	· Pimple · Bubble · Spot · Dregs of glue · Fault of MDF
Due to Shipment	

3.1. AHP Findings

The main criteria of the second cause of quality and the sub-criteria of each main criterion were compared in the AHP and the weights were calculated to determine the importance of ratings. First, the AHP method is applied to the main criteria of a machine; labor; raw material; production and shipment. Then, sub-criteria are prioritized under their main criteria.

The weights calculated for each criterion indicate the degree and order of importance of that criterion. In aggregate, the criterion with the highest weight is manufacturing-induced defects. The criterion with the highest weight among manufacturing-related faults is a pimple. The other sub-criteria, which are not based on production but have high weight, transmission line, folio center shift and pimple (source of raw material). The AHP results, including all the main criteria and sub-criteria and the weight of each criterion, are shown in the hierarchical structure in Figure 5 below to be seen from a more analytical perspective.

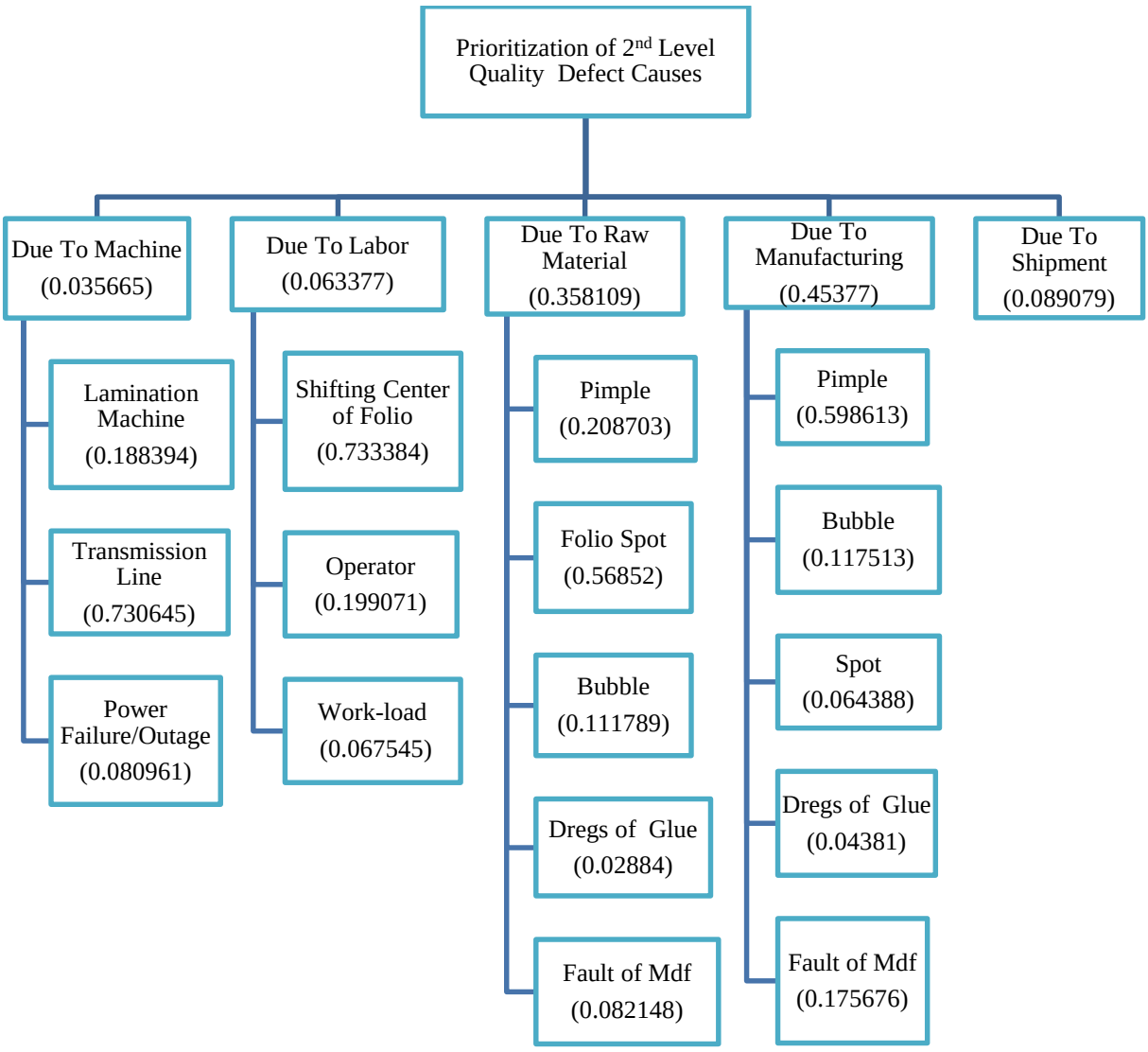

Figure 5. Prioritization of 2nd Level Quality Defect Causes

4 Conclusions and Recommendations

This study aims to prioritize the causes of being 2nd level quality of a selected product and create an action plan to minimize those causes. In this study, causes of being 2nd level quality of UHG panels have been analyzed and prioritized with the help of WRA and AHP methods. In the study, first, two different WRA are applied in order to find out the importance of "product quality" for the company and its customers. Then, main and sub-causes of a selected product, UHG Panel, are determined and prioritized with the AHP method. As a result, manufacturing-oriented problems are defined as the most important cause of being 2nd level quality and pimple problem of panels have been pointed out as the most important sub-cause. Action plan and recommendations to minimize the quantity of 2nd level panels have been presented at below. The action plan is aimed to reduce the number of 2nd level quality products and the loss that may occur and to increase customer satisfaction with increasing the quantity of 1st level quality products. Action plan should be implemented as follows:

- A pimple (due to manufacturing): Melamine-coated MDF, cleaning from melamine breaks and dust before glue application and folio coating; Clearing the transmission line at specific time intervals; Rollers that is with sticking should be changed regularly.
- Folio Spot: As the raw material is related to, it should be negotiated on the cleaning of the production area with the supplier; if the problem persists, negotiating with the purchasing department for supplier change.
- A pimple (due to raw material): As the raw material is related to, it should be negotiated on the cleaning of the production area with the supplier; if the problem persists, negotiating with the purchasing department for supplier change.
- Shifting center of folio: Training of employees to raise awareness of quality.
- Transmission Line: Being careful when entering machine references on the computer screen

When looking at the results of AHP, the mistakes with the most weight are production-induced mistakes. The fault with the most weight after the fault originating from the production is raw material-related defects. When the solution proposal is introduced, the most weighted-mistakes are focused on the AHP. The most significant cause of production-related mistakes is due to the fact that the production line and area are not clean. In the case of raw material defects, the supplier shall be requested to take action by discussing the unsuitability of the raw material sent. At the same time, it is faster to submit the action because the quality element sent to the supplier has the chance to observe the production area of the raw materials coming to the company. In addition to these, as a result of the researches, the company applies discounts in the same way without making a distinction in the sales of the second-level products. So the selling prices are the same. However, the taken stock of it, every second-level defect is not equivalent and therefore the same price makes it a less profitable company. An improvement is recommended on the sales prices of the 2nd level products that the company has fallen or the company has suffered damage. The lower the available surface area, the lower the price. When the surface mistakes are tackled as both the comments can be made more truthful and customer complaints are preponderated;

- According to the observations, the sales price of the 2nd level quality product which will be formed by folio center shifting should be less than the sales price of the 2nd level quality product which is the defect of a pimple (raw material & production). Because the percentage of usability of a plate with a folio center shift is smaller than a pimpled plate.

- The sales price of the 2nd level quality product with a pimple due to raw material should be higher than the sales price of a pimple due to manufacturing 2nd level quality product. This is because when the region where a pimple originating from production is opened, it finds particles in that region. A pimple that these particles form is larger than the raw material-related pimple and therefore the availability rate is lower.
- The selling price of the 2nd level quality product, which is the bubble (raw material & production), should not be much different from the selling price of the 2nd level quality product pimple (raw material & production)) but it should be less. The cause is that the bubble defect is filled with air differently than a pimple. This event can also be caused by the stowing successive of the products over time, causing the hollow. It can reduce the usability of the surface.
- The selling price of a pimple and bubble products should be higher than the price of dregs of glue defects. Because the size of the defect in the dregs of glue is bigger and more visible.
- The sales price of the folio spot defect should not be much different from the sales price of the pimple defects that is a raw material-based defect, but it should be less. Because the folio spot defect can be evident in all products, the product of pimple defect that is raw material origin is more likely to camouflage in patterned groups.

Acknowledgement

This work is supported by the Scientific Research Project Fund of Adana Alparslan Türkeş Bilim ve Teknoloji Üniversitesi under the project number 18103021.

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