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DETERMINATION OF WEIGHT FACTORS OF QUALITY INDICES OF PARTICLEBOARDS

Julia Mihajlova[1], Neno Trichkov[2], Tsvetelin Evstatiev[3]
University of Forestry, 10 Kliment Ohridski blvd, 1756 Sofia, Bulgaria
e-mail: [1]jmihajlova@yahoo.com; [2]ntrichkov@yahoo.com; [3]ceevstatiev@abv.bg

ABSTRACT

The quality of each product is a set of a great number of indices and characteristics that define its ability to meet the consumers' requirements.

By means of survey of specialists, the more important indices determining the quality of particleboards were ranked and weight factors for each index were calculated. With these weight factors, the determination of composite quality index of PBs will be possible. The results also give guidelines for improvement of the quality of this type of material.

Key words: quality, indices, expert assessment, ranking, concordance, weight factor, PBs

INTRODUCTION

Particleboards (PBs) are the most used wood-based material in furniture production. Data of European Panel Federation (Annual Report 2011/2012) show that the PBs consumption in 2011 had not yet restored the volumes form before the crisis (Table 1). The import in Romania and Serbia decreased considerably for this 5-year period, with the import from these two countries having increased. The import from Bulgaria in 2011 increased, but the import grew at a higher rate. In Bulgaria and Greece, no new facilities were built, whereas the serious increase of capacity for production of PBs in Romania and Serbia is striking.

The increased production capacity of Romania and Serbia, the unused capacities of the factories in Greece and the striving for increase of the import of these countries will intensify the competition in the region. This could have a negative effect on the Bulgarian manufacturers of boards.

Table 1: Development of PBs market for the period 2007-2011 in thsd. m^3 (Annual Report 2011/2012)

	Consumption		Import		Export		Capacity	
	2007	**2011**	**2007**	**2011**	**2007**	**2011**	**2007**	**2011**
Bulgaria	359	442	95	132	208	170	500	523
Greece	529	220	109	15	65	100	780	750
Romania	1000	852	336	133	250	400	930	2040
Serbia	62*	202*	240	112	18	68	65	370

** production*

Quality is an important factor for the competitiveness of the organisation, for retaining and/or increasing its market share. Quality affects both company's expenses and receipts.

Higher quality means less errors, less defective products, less claims. Although the increase of the level of the quality of the products of a certain company requires efforts and funds, the total effect lies in reduction of expenses per unit of product.

With respect to receipts, the quality is associated with the client's requirements and needs. Higher quality means better product characteristics, higher degree of

client's satisfaction, and this also means higher receipts (Juran and Godfrey 1998).

The permanent relation with the clients gives to the organisation timely information both about the requirements and preferences and about the defects of the products offered. It is shown in the requirements to the quality management systems pursuant to ISO 9001:2008 that "*the organisation must follow the information related to client's perception as to what extent the organisation has satisfied his requirements*".

QUALITY MEASUREMENT AND ASSESSMENT

A number of requirements are set to each product. Quality is dynamic and the consumers' expectations are constantly rising, with new requirements being set. When assessing the quality level and, with this, the degree of meeting the requirements, several main methods are used: differential, comprehensive and mixed (Dyukendzhiev & Yordanov 2008, Mihajlova 2012, Stefanov et al. 2004).

The differential methods consists in calculation and comparison of each index individually with basic ones.

The methods for determination of a summarised, group and integral index belong to the complex methods.

The integral index represents a ratio of the total useful effect to the total expenses for creation and operation (consumption) of the product.

With the method for quality assessment with the complex summarised index, the comparison is of groups of differential indices shown in one complex index. The calculation of this index is by means of determination and use of weight factors.

The division on the indices into groups (technical, economic, etc.) allows determining group complex indices.

The requirements to particleboards used for production of furniture for interior uses in dry environment are given in BDS EN 312 as class P2. Shown for boards 13 – 19 mm thick are: bending strength not less than 13 N/mm², transverse tensile strength not less than 0,35 N/mm², modulus of elasticity 1600 N/mm², surface layer strength not less than 0,8 N/mm². The requirements and methods for testing melamine faced boards (MFBs) are regulated in EN 14322 and EN 14323.

These standards show the physicomechanical and aesthetic properties of boards. Besides them, of importance both to the consumer and the manufacturer are a number of other characteristics (economic, ergonomic, environmental, etc.). The assessment of their importance should be based on information just from the client. Information that is obtained in the everyday communication, by means of conducting sociological or expert surveys.

The aim of the survey is the ranking (arrangement), in terms of importance, of indices on which the quality of particleboards (PBs) depends, determination of weight factors with whose help to determine a complex (aggregate) quality index of PBs and disclosure of problem characteristics that are to be improved.

This is achieved with the conduct of a questionnaire survey by means of preparation and sending of questionnaires via Internet to e-mail addresses of companies offering particleboards and companies manufacturing furniture made of particleboards, processing and analysis of the data obtained.

METHODS

The determination of weight factors is through use of various forms of expert or sociological survey (Hristov 2005, Georgiev et al. 2008, Stoyanov & Krastev 2008) and

application of objective methods for assessment. Such method is the a priori ranking, also used to sift out the significant from insignificant factors (Trichkov 2011). Weight factors are also used in multipurpose optimisation (Vuchkov & Stoyanov 1980) and making compromise decisions.

The methods used to determine the weight factors by specialists' opinions is described in (Vuchkov & Stoyanov 1980, Trichkov 2011).

Specialists, *m* in number, give their opinion of *n* indices, by arranging them by significance from 1 to *n*, with note 1 being for the most significant of them. The calculation of the weight factors is performed if there is agreement of specialists' opinions. This agreement is checked by means of calculation of the concordance (agreement) coefficient by the following formula:

$$W_K = \frac{12.\sum\left(d^2\right)}{m^2.\left(n^3 - n\right) - m.\sum_{j=1}^{m} T_j} \qquad (1)$$

with:

$$\sum\left(d^2\right) = \sum_{i=1}^{n}\sum_{j=1}^{m}\left[a_{ij} - 0.5.m.(n+1)\right]^2 \qquad (2)$$

where a_{ij} is the note given for the *i*-th index by the *j*-th specialist, *n* – number of factors included in the survey, and *m* – number of specialists interviewed.

When any of the specialists gives equal notes to two or more indices, it is necessary that they are recalculated (reranked). The quantity T_j is also calculated (in the cases of related ranks in the notes) by formula (3):

$$T_j = \sum_{r=1}^{k}\left(t_r^3 - t_r\right) \qquad (3)$$

where t_r is the number of coinciding ranks.

The concordance coefficient (W_κ) varies from 0 in case of full lack of agreement in the opinions to +1 in case of full agreement.

The assessment of the significance of the calculated coefficient W_κ is determined by checking the hypotheses: H_0: disagreement in interviewees' opinions, H_1: lack of disagreement in interviewees' opinions, through χ^2-criterion at $n \geq 7$, which is calculated by the following formula:

$$\boldsymbol{\chi^2 = m(n-1).W_K} \qquad (4)$$

The concordance coefficient W_κ is significant if

$$\chi^2 > \chi^2_{table}(\alpha, \nu) \qquad (5)$$

with $\nu = n\text{-}1$ – degree of freedom, $\alpha = 0{,}05$ – significance level.

In case of agreement in the subjective opinions of the specialists, weight factors (W_i) can be calculated by the formula:

$$\boldsymbol{W_i = \frac{V_i}{\sum_{i=1}^{n} V_i}\ ;\quad i = 1, 2, \ldots, n} \qquad (6)$$

where:

$$\boldsymbol{V_i = \frac{\left(m.n - \sum_{i=1}^{m} a_{ij}\right)}{m.(n-1)}}. \qquad (7)$$

For the coefficients thus obtained, the following condition is satisfied

$$\sum_{i=1}^{n} W_i = 1. \qquad (8)$$

RESULTS AND DISCUSSION

The necessary data was obtained by means of a questionnaire survey via Internet among manufacturing companies offering particleboards and companies manufacturing furniture, using laminated particleboards. The questionnaire is presented below. The answers of the specialists from the companies are marked with capital Latin letters (A, B, C..., L).

The notes for the indices are filled in two tables: Table 2 – notes for physicomechanical indices, and Table 3 – notes for indices for selection of a supplier of boards.

QUESTIONNAIRE

Company:.....
Subject of activity:.....
Is the company certified pursuant to ISO 9001 or other management system and what?.....
Position and education (specialisation, specialty) of the specialist:..…….....
After each table you can give opinions, proposals to supplement the survey or other proposals.

I. Assess, in terms of significance, the indices given in Table 2.

The notes are from 1 to 10, with 1 being for the most significant factor, 10 respectively for the most insignificant.

Table 2: Notes for physicomechanical indices

No.	Indices, n_i	Index note given by the specialist, m_j											
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
1	Swelling (Gt), %	8	6	8	6	10	5	5	8	8	9	5	4
2	Transverse tensile strength (τ), N/mm²	7	4	6	7	5	6	2	5	1	4	7	4
3	Modulus of elasticity (Em), N/mm²	10	5	7	4	8	10	10	9	7	7	9	1
4	Water absorption (A), %	9	6	10	9	9	9	9	6	9	10	6	1
5	Resistance to axial removal of screws (σs), N/mm²	2	5	9	1	7	3	4	3	2	2	1	1
6	Dimensional stability (board warping, buckling)	1	5	5	5	2	4	3	2	3	3	3	1
7	Board hardness	3	4	4	10	6	7	6	7	10	5	8	4
8	Bending strength ($\sigma_{bend.}$), N/mm²	6	4	3	8	3	8	8	10	6	6	10	4
9	Surface layer (and laminate) ungluing strength, N/mm²	4	3	2	3	4	2	7	4	4	1	4	1
10	Deviation from board thickness (variation in thickness), mm/m	5	5	1	2	1	1	1	1	5	8	2	1

II. As a representative of a company that offers particleboards, assess the indices given in Table 3 according to your clients' requirements (for furniture manufacturing company: assess the indices according to their significance for selection of a supplier).

The notes are from 1 to 7. Again, 1 is for the most significant criterion, and 7 – for the most insignificant.

Table 3: Assessment of indices according to clients' requirements / according to their significance for selection of a supplier

No.	Indices, n_i	Index note given by the specialist, m_j											
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**

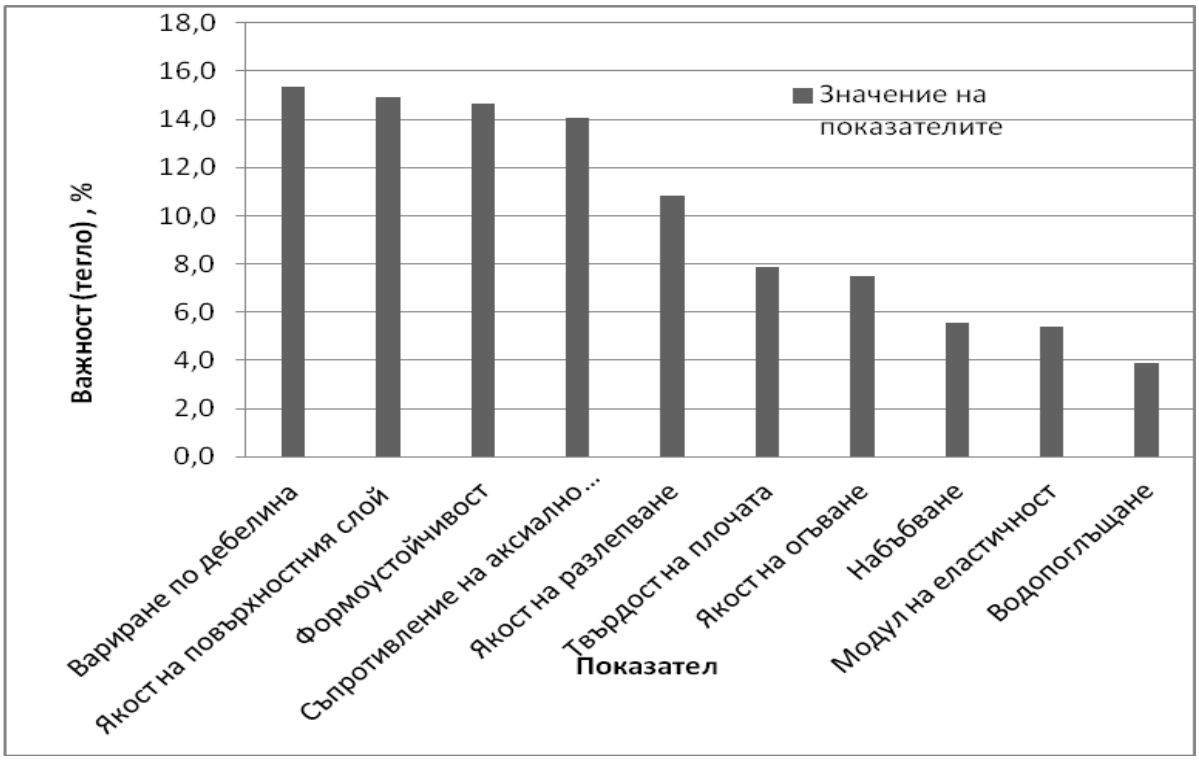
11	Product diversity (size, thicknesses, decorations)	1	1	1	3	1	1	1	1	2	4	1	4
12	Time for obtaining the boards (from order to execution)	7	2	2	4	2	3	3	5	5	5	4	1
13	Possibility for delivery to the client	4	1	6	5	4	2	5	6	6	6	5	1
14	Discounts	6	1	4	2	3	4	2	4	4	3	2	1
15	Reputation of board manufacturer	5	1	3	6	6	7	6	2	1	2	6	5
16	Board price	2	1	5	1	5	6	4	3	3	1	3	4
17	Availability of possibility for order by phone, Internet and Skype	3	1	7	7	7	5	7	7	7	7	7	4
What are the advantages of particleboards?:.....													
What disadvantages and problems in the use of particleboards impress you?:.....													

The questionnaires were sent to 170 e-mail addresses. The filled in and returned questionnaires are 12.

After processing the data (notes for physicomechanical indices) presented in Table 2, the concordance coefficient $W_{\kappa 1} = 0{,}448$, χ^2-criterion $\chi^2 = 49{,}472$, were obtained, at $\alpha = 0.05$ and degree of freedom $v = n-1 = 9$, $\chi^2_{table} = 16{,}919$ was read for χ^2 from the table.

As $\chi^2 > \chi^2_{table}$, the zero hypothesis is rejected, which means that the concordance coefficient W_κ is significant and the data can be used to rank the indices and calculate weight factors.

The division of the indices into two groups is presented in Fig. 1. The first five indices form nearly 70 % of the effect on the quality. The variation in thickness and dimensional stability of boards are due to their wrong storage, and may be also to bad conditioning in the days after their production. The ungluing strength of the surface layer is associated with its wear, something that was noted by the half of the specialists as a disadvantage of the laminated boards.

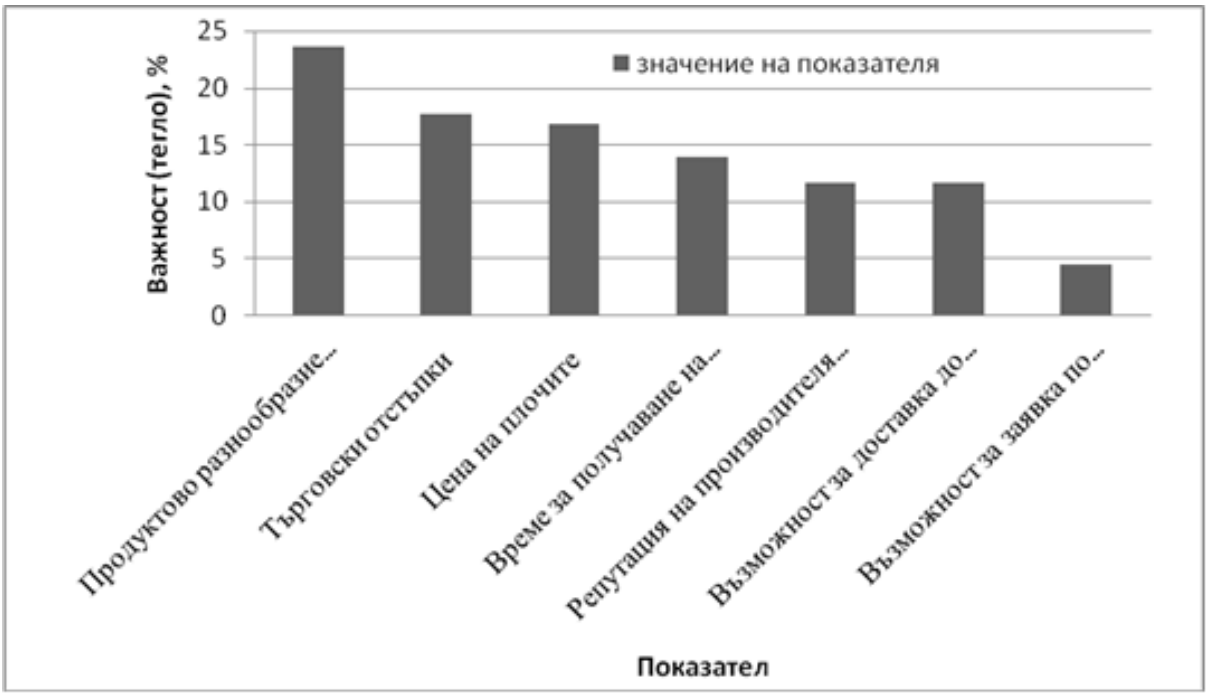


Significance (weight), %; Index value; Variation in thickness; Surface layer strength; Dimensional stability; Resistance to axial...; Ungluing strength; Board hardness; Bending strength; Swelling; Modulus of elasticity; Water absorption; Index.
Figure 1: Ranking of weight factors for assessment of physicomechanical indices

The transverse tensile strength and the resistance to axial removal of screws, although the manufacturers meet the standard requirements, are expressed in board delamination, most often when screwing in screws in its edge. The relatively low note for the bending strength and the modulus of elasticity is probably due to the good level of these indices, achieved by all manufacturers, i.e. they are not a problem. The swelling and water absorption are not of essential importance during use in dry environment.

After processing the data from Table 3, the concordance coefficient $W_{к2} = 0,385$, $\chi^2 = 21,502$, were obtained, at $\alpha = 0,05$ and degree of freedom $v = n-1 = 6$, $\chi^2_{table} = 12,592$ was read for χ^2 from the table.

$\chi^2 > \chi^2_{table}$ and the zero hypothesis is rejected, which means that the concordance coefficient $W_к$ is significant and the data can be used to rank the indices and calculate weight factors.



Significance (weight), %; Index value; Product diversity...; Discounts; Board price; Time for obtaining...; Reputation of board...; Possibility for delivery to...; Possibility for order by...; Index.
Figure 2: Ranking of weight factors for assessment of indices according to clients' requirements / according to their significance for selection of a supplier

The product diversity (Fig. 2) was assessed as the most important index when selecting a board supplier. In the conditions of a crisis, the price of the materials is of great importance and the discounts and board prices are the next indices in terms of significance. Most supplying companies deliver the boards to the client within 24 – 36 h from the order. It is regular practice that the order is placed by phone or e-mail. And therefore, these factors were assessed lower. The manufacturer's reputation yields to board price. Many of the furniture-manufacturing companies work with several suppliers, compensating thus the lack of some decorations with a given distributor, and look for the price most profitable to them.

As advantages of PBs, the interviewees showed: easy processing, price, diversity of colours and decorations. Disadvantages shown are: board coating, loose boards, insufficient moisture resistance, lack of edges (thicknesses, widths) for some decorations.

CONCLUSION

After processing the questionnaires received, the following results were obtained:

- the concordance coefficients were calculated and checked for significance;
- the quality indices were ranked;
- the weight factors of the two groups of indices were determined.

At concordance coefficient $W_{к1} = 0{,}448$, as most significant for the first group of indices (physicomechanical indices) there stood up:

- variation in thickness, with weight factor $W_{10} = 0{,}154$;

- surface layer ungluing strength, with weight factor $W_9 = 0,149$;
- dimensional stability, with weight factor $W_6 = 0,146$;
- resistance to axial removal of screws, with weight factor $W_5 = 0,141$.

For the second group of indices, the concordance coefficient is $W_{к2} = 0,385$, and as most important indices determined were:

- product diversity, with weight factor $W_{11} = 0,236$;
- discounts, with weight factor $W_{14} = 0,177$;
- board price, with weight factor $W_{16} = 0,169$.

The ranking of the groups of indices (physicomechanical and indices for selection of suppliers) reveals the shift of the attention from the bending strength and the modulus of elasticity to the dimensional stability of the boards. This does not mean that they have to be ignored, but at least to retain the level reached by these indices.

The quality of the face surfaces and their wear resistance must be improved. The board manufacturers must more carefully follow the quality of papers for lamination.

The price and product diversity are the main factors in the selection of boards by furniture companies.

The survey results show the effect of individual indices and give guidelines for improvement of the quality of particleboards.

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