Evaluation Model for Modular Children's Wooden Storage Cabinet Design

Yin Zhao * and Yunjia Xu

The design evaluation method of furniture products was explored for modular children's wooden storage cabinets. An evaluation model consisting of the Kano model, hierarchical analysis, and grey relational analysis is proposed. A 25-member panel of experts was involved in the development of the evaluation guidelines and the scoring of the program. The expert group used the KJ method to obtain evaluation guidelines for modular children's wooden furniture that met the requirements of the hierarchical analysis method and screened the functional indicators through 103 validated questionnaires for the Kano model. The evaluation guidelines of modularized children's wooden storage cabinets were thus obtained, which are both comprehensive and targeted. Then, hierarchical analysis and grey relational analysis were combined to select the solution with the highest grey weighted correlation result as the best solution. The feasibility of the grey comprehensive evaluation method, which combines subjective preference and objective empowerment, in the field of furniture was confirmed through the practice of selecting the best of the three modular children's wooden storage cabinet design solutions, and the evaluation preference of the modular children's wooden storage cabinet was uncovered. The design model provides an innovative evaluation tool for children's furniture manufacturers to optimize their sales strategies.

DOI: 10.15376/biores.18.4.7818-7838

Keywords: Design evaluation; Children's modular furniture; Influencing factors; Multilevel evaluation model; Grey system

*Contact information: College of Furnishings and Industrial Design, Nanjing Forestry University, Nanjing, Jiangsu Province, 210037, China; *Corresponding author: zhaoyin@njfu.edu.cn*

INTRODUCTION

In the face of constantly updating market competition, furniture companies need to explore solutions that cater to different furniture audiences. New approaches are needed in order to expand the product audience, improve product life cycles, and gain more willingness to pay from consumers (Yoshimoto 2009; Di *et al.* 2020). While there have been various research paths to evaluate the design of industrial products, a comprehensive approach has not been widely applied in each segment. There is still a lack of design evaluation methods for selecting optimal solutions when standardized manufacturing specifications already exist in the furniture sector (Sheng *et al.* 2012; Xiong *et al.* 2021; Yu *et al.* 2021). Therefore, this study aims to explore the methodology for developing design evaluation guidelines applicable to the furniture field and to expand comprehensive design evaluation methods in the furniture field. Innovative evaluation tools are provided to furniture manufacturers to optimize sales strategies and expand the functional forms of children's furniture.

To develop an effective evaluation model, existing methods must be sorted and summarized. The conventional method for design evaluation is the Analytic Hierarchy Process (AHP) or the Fuzzy Analytical Hierarchy Process (FAHP), which is combined with the Entropy Weight Method (EWM) (Li and Zhan; Oblak *et al*. 2017; Yue *et al*. 2022; Liu *et al*. 2023b). In these furniture evaluation studies, AHP was applied to the design evaluation of restaurant chairs, online furniture purchase behavior, furniture for parent-child interactive games, and custom panel furniture; some studies combined targeted furniture evaluation indicators for a comprehensive evaluation; however, other furniture categories remain to be explored (Li *et al*. 2020; Wang and Pan 2022; Liu *et al*. 2023a; Jin and Li 2023; Yu *et al*. 2023). It can be seen that AHP is one of the most widely used methods when building evaluation guidelines. The combination of AHP, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and grey relational analysis (GRA) can be used to achieve a more scientific multi-criteria decision making for comparing the solution of complex products (Pandian *et al*. 2016; Tian 2017). In the meantime, GRA is a common method that is used in conjunction with FAHP to improve evaluation accuracy (Sun *et al*. 2018; Tan *et al*. 2019; Liu and Zheng 2021; Hu and Zhao 2022). AHP, as a subjective method, determines the weight coefficients of the evaluation indicators on the basis of constructing the evaluation indicators, which are analyzed qualitatively and quantitatively by a group of experts. The grey relational analysis method can obtain the relationship between each program and indicator through the assignment. Combining the two can make up for the shortcomings of a single evaluation model in terms of accuracy and objectivity, and then better complete the comprehensive evaluation and preference of the design program (Yang *et al.* 2011; Wang *et al*. 2015; Fang and Wang 2020; Li 2021; Cheng *et al*. 2023). Typically, design evaluation of product solutions can already be realized using a combination of AHP and GRA when clear and concrete evaluation guidelines are available. However, there has been a lack of research on evaluation criteria for segmented products in the current furniture sector. Therefore, this study aimed to propose a methodology that is applicable to any major furniture category and can be transformed into evaluation guidelines for a specific individual product through the screening of indicators, thereby improving the efficiency of evaluation guideline development. This work takes a cue from design development research methods. The Kano model is the most commonly used method for requirements categorization and screening, and it is often used in the design guidance phase. The combined use of Kano and AHP not only enables the classification of requirements but also the prioritization of design metrics (Neira-Rodado *et al.* 2020; Ming 2021). Therefore, based on the existing generalized evaluation guidelines, the Kano model is used to classify the metrics and thus eliminate indifference and reverse attributes. Retaining the valid demand and combining it with AHP allows access to evaluation guidelines for a specific single product while ensuring the comprehensiveness of the guidelines (Singh *et al.* 2020; Shahriar 2022). In addition, the House of Quality matrix based on Quality Function Deployment (QFD) requirements transformation, combining the Function-Behavior-Structure (FBS) design model and the fuzzy clustering method, and Interactive Genetic Algorithms (IGA) have been used to carry out design evaluations of industrial products, especially modular products that can be flexibly combined (Fujita 2002; Fujita and Yoshida 2004; Lu *et al*. 2012; Zhang *et al*. 2013; Mamaghani and Barzin 2019; Weng 2021). In summary, in order to realize the design evaluation of segmented furniture categories, it is the most suitable research idea at present to form a composite evaluation model with Kano model, hierarchical analysis, and grey relational analysis.

The selection of the case study is very important. It needs to be representative and accurately positioned to provide reference value for design evaluation of other categories of furniture. Therefore, the study case needs to identify the users, materials, main functions, and structural features in order to carry out the establishment of evaluation guidelines. Modular children's wooden storage cabinets were selected for this study and were chosen for four reasons. First, children's furniture is one of the furniture categories with the largest number of styles and the largest number of specifications, and if the evaluation method proposed in this study is applicable to children's furniture, then other furniture types also can be expected to benefit from use of the method. Children's furniture manufacturers are in the stage of evaluating and implementing sustainable innovation strategies in the face of shifting attitudes and purchasing intentions of parents and consumers in the current marketplace (Shahsavar *et al*. 2020; Wang and Wang 2021). Secondly, wood has been found to be parents' first choice in research studies on raw materials for children's furniture. Wood has a soothing and relaxing effect on children, which is beneficial to children's health and behavior (Nyrud and Bringslimark 2010; Kaputa *et al.* 2018; Wan *et al.* 2015; Wei and Madina 2022). It is significant to note that to avoid environmental damage caused by excessive cutting, furniture manufacturers should choose wood that has a short growth cycle or reduce the use of raw materials by increasing the utilization of engineered wood panels (Zhang 2013; Bai *et al*. 2014; Knauf 2015; Yang and Zhu 2021; Luo and Xu 2023). Then, storage cabinets appear in every child's activity scene as one of the most important types of furniture. At the same time, children have a wide range of storage needs for their belongings, and the selection of storage function as a study case has a certain guiding value. Finally, modular configuration is one way to achieve flexibility and growability in children's furniture. Modular furniture, as a dynamic serialized product, is suitable to serve children's spaces to increase flexibility and interest in use (Ye *et al*. 2021).

Design evaluation for furniture is mainly inextricably linked to consumers' purchase decisions, so integrating consumers in design decisions is a wise decision. Parents as buyers of children's furniture and children as users have different priorities. From an enterprise's point of view, it is most appropriate to target the consumer market for children's furniture and set parents as the target users to participate in the design evaluation. However, the development of evaluation criteria should still be child-centered. At the same time, evaluation criteria for furniture often require the intervention of a plurality of experts. Exploring comprehensive evaluation metrics for children's furniture suitable for parental shopping considerations is a prerequisite when conducting design evaluations of modular children's wooden storage cabinets. Parents today no longer focus solely on the basic functions and price of furniture when creating a space for children in their home; they may also consider the educational value and environmental attributes of furniture for children (Andaç and Güzel 2017; Wan *et al.* 2019; Zhu and Wu 2020). In addition, the comfort and growth adaptability of children's furniture are also important evaluation indicators in the current market (Salvador 2019a). Parents' expectations concerning the educational value of children's furniture lie mainly in cognitive guidance and flexibility of use (Dobrowolska *et al.* 2021). Functional expansion and modular configurations with geometrical shapes are considered important design elements in children's furniture to promote children's enthusiasm for use and intellectual development (Pranoto *et al.* 2022). In the product iteration stage, innovation is required not only in functional expansion and morphological changes but also in ergonomic needs such as user body adaptability and size matching (Salvador 2019b; Ye *et al.* 2021). In addition to the existing generic indicators, this study needs to uncover segmented specific indicators for the product characteristics of modular children's wooden storage cabinets.

In summary, the research objective of this study is to explore the way of constructing a scientific and segmented design evaluation criterion for furniture products and a product design evaluation method that is objective and applicable to the furniture field. The research method is a composite evaluation model composed of Kano model, analytic hierarchy process, and grey relational analysis. The research vehicle is a modular children's wooden storage cabinet. Next, the proposed Kano-AHP-GRA method model will be introduced, the feasibility of the method will be verified through practical cases, and design evaluation conclusions related to modular children's wooden storage cabinets will be derived.

DESIGN EVALUATION MODEL FOR MODULAR CHILDREN'S WOODEN STORAGE CABINETS

Based on the consumer trend of rising parental standards when purchasing children's furniture and the research trend of comprehensive design evaluation of modular products driven by enterprise innovation, the research objective of this study involves a modular design for children's furniture. The specific research objective is modular children's wooden storage cabinets. The main method used in this design evaluation model is the grey comprehensive evaluation method, which integrates the hierarchical analysis method and grey relational analysis method. Among them, the Kano model was used to screen sub criteria when determining evaluation criteria.

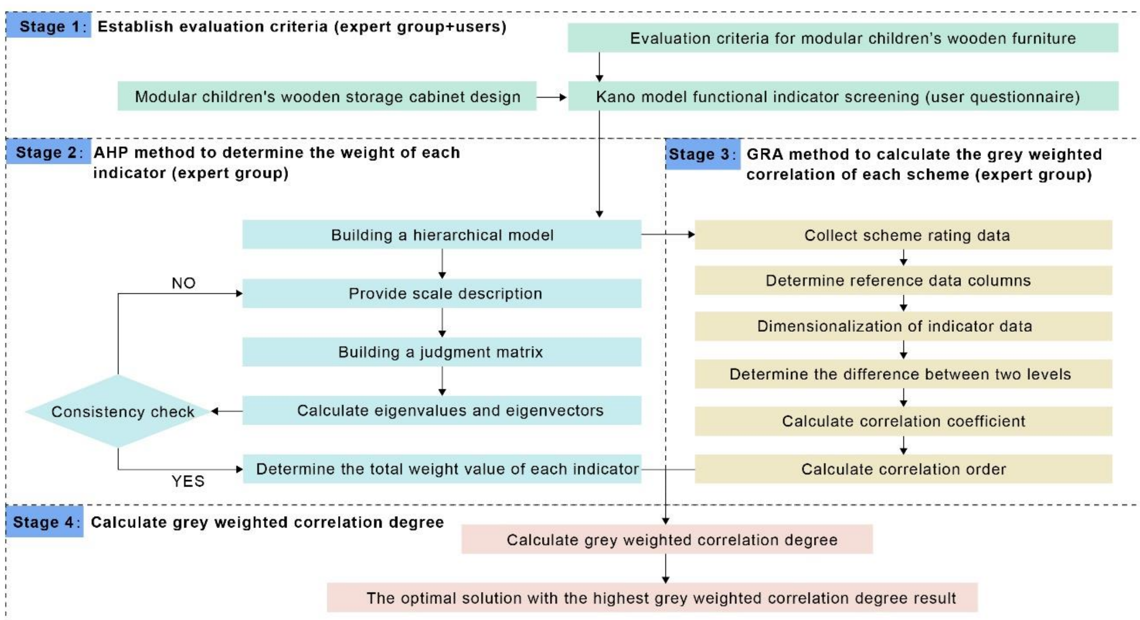

Fig. 1. Flow chart of modular children's wooden storage cabinets design evaluation based on grey comprehensive evaluation method

The process of using the design evaluation model for modular children's wooden furniture based on the grey comprehensive evaluation method is shown in Fig. 1. The first step is to establish design evaluation criteria for modular children's wooden storage cabinets. Given the limited research on modular storage cabinets for children, when establishing evaluation criteria, reference materials were expanded to cover all children's furniture, and then sub-criteria were screened using the Kano model by an expert group. This can ensure both the comprehensiveness of the guidelines and their pertinence. Second, the AHP method was used to assign weights to each evaluation index to improve the scientific nature of the subsequent program evaluation process. Then, the grey relational analysis (GRA) method was used to evaluate each design solution and calculate the correlation sequence. Finally, the solution with the highest result was selected as the optimal solution by calculating the grey weighted correlation.

Establish Evaluation Criteria

Establishing modular children's wooden storage cabinets evaluation guidelines is the foundation for a comprehensive product design, and the objects considered in the evaluation guidelines should include users, consumers, manufacturers, and other groups to obtain the most comprehensive indicators. Children are the direct users of such furniture, and children's feelings of use are the most influential factor in the form and function of the furniture. As consumers of children's furniture, parents primarily consider the safety of the furniture and the modular system, followed by the aesthetics of furniture modeling, and the functional options. Children's furniture manufacturers prioritize the economic value of the enterprise. At the same time, as wooden furniture, the manufacturing process and structural design differences caused by its material properties should also be taken into consideration. Given the limited research on modular children's wooden storage cabinets, there is no standard that can be directly referenced. Therefore, it is necessary to search for relevant information as much as possible from the relevant data of children, parents, and manufacturers mentioned above, and use the Kawakita Jiro (KJ) method for preliminary classification and consolidation.

After obtaining a comprehensive but not modular evaluation criteria for children's storage cabinets, it is necessary to filter and replace existing indicators to improve the accuracy of the evaluation. In particular, function is the main indicator reflecting the differences between furniture categories. The Kano model is recommended to select functionality indicators with educational value. The Kano model can establish a link between the degree of furniture function availability and consumer satisfaction and classify user needs into attractive attribute A, one-dimensional attribute O, must-be attribute M, indifference attribute I, reverse attribute R, and questionable Q. The Kano model's questionnaire (shown in Table 1) is in the form of a five-level scale, and the same need will be asked from both positive and negative aspects. After collecting user questionnaires, user attitudes can be identified according to the Kano model evaluation results classification control table, as shown in Table 2. Analysis by SPSS software can obtain the better-worse coefficients, which are calculated by Eq. 1 and Eq. 2, respectively, for demand.

Table 1. Kano Questionnaire

Kano Question					
Functional form of the question	Like	Must-be	Neutral	Live with	Dislike
Dysfunctional form of the question	Like	Must-be	Neutral	Live with	Dislike

Table 2. Kano Model's Evaluation Table

Requirements		Dysfunctional				
		Like	Must-be	Neutral	Live with	Dislike
Functional	Like	Q	A	A	A	O
	Must-be	R	I	I	I	M
	Neutral	R	I	I	I	M
	Live with	R	I	I	I	M
	Dislike	R	R	R	R	Q
Note: A: attractive; M: must-be; R: reverse; O: one-dimensional; Q: questionable; I: indifference						

$$a_{Better} = (A + O)/(A + O + M + I) \tag{1}$$

$$a_{Worse} = -(O + M)/(A + O + M + I) \tag{2}$$

When using the Kano model to select the functionality indicators, the indifference attribute I, reverse attribute R, and questionable result Q, which are not relevant to rating the specified furniture category, can be eliminated from the existing functionality indicators. Finally, the attractive attribute A, one-dimensional attribute O, and must-be attribute M are retained to constitute the functionality indicators. Together with the other four first-level indicators, these indicators comprise a new and targeted evaluation criteria for modular children's wooden furniture (*i.e.*, the hierarchical structure model of the hierarchical analysis method).

AHP Method to Determine the Weight of Each Indicator

Hierarchical analysis is a hierarchical weighting decision method that can address problems that are difficult to quantitatively analyze completely. Using hierarchical analysis, this study provides indicator weights for the subsequent grey relational analysis and improves the scientific rigor of the program evaluation. The hierarchical analysis method can be divided into five steps. First, a hierarchical structure model, *i.e.*, modular children's wooden storage cabinets, is established. In the established evaluation criterion of modular children's wooden storage cabinets, the first-level indicators at the criterion level are denoted by U_i (i = 1, 2, ..., n), and the second-level indicators at the sub-criterion level are denoted by U_{ij} (i = 1, 2, ..., n; j = 1, 2, ..., m). In the second step, the indicators are scaled and described, and then the importance of any two indicators at the same level is compared and quantified. A nine-point scale is used for comparing importance, and the judgment matrix scale is defined in Table 3. In the third step, after determining the relative importance according to the evaluation scale, the judgment matrix of each level is constructed. In the fourth step, the eigenvalues and eigenvectors are calculated to determine the relative importance of the elements at each level and to conduct the consistency test; the consistency index (*CI*) and the consistency ratio (*CR*) are defined by Eqs. 3 and 4, respectively. Finally, according to the above principles and methods, the group of experts was invited to participate in the collective decision making. Afterwards, the total weight value of each index was determined by arithmetic means. Specifically, after obtaining the relative importance among the elements at the same level, the comprehensive importance of the elements at each level to the overall level was calculated.

Table 3. Judgment Matrix Scales

Scale	Level of Importance
1	*k,q* elements are equally important
3	*k* is slightly more important than *q*
5	*k* is significantly more important than *q*
7	*k* is strongly more important than *q*
9	*k* is definitely more important than *q*
2，4，6，8	Intermediate values
Inverse of scale	If the ratio of the importance of element *k* to element *q* is b_{kq},then the ratio of the importance of element *q* to element *k* is $1/b_{kq}$
*Note: b_{kq} indicates the ratio of the relative importance of indicators *k* and *q* and satisfies $b_{kq} > 0$; $b_{kk} = 1$;$b_{kq}= 1/ b_{qk}$ (k,q = 1,2,…,n). Therefore, the larger b_{kq} is, the higher the importance of indicator *k* relative to indicator *q* is	

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{3}$$

where $\lambda_{\max}$ is the largest eigenvalue of the judgment matrix. Equation 4 is as follows,

$$CR = \frac{\mathrm{CI}}{RI} \tag{4}$$

where the consistency of the judgment matrix is considered acceptable when $CR < 0.10$, otherwise the judgment matrix should be appropriately corrected.

Calculate the Grey Weighted Correlation of Each Scheme

grey relational analysis is a multi-factor statistical analysis method, and the grey correlation can be used to describe the size and order between indicators. The more similar the trend of change among the sample data, the greater the correlation, and *vice versa*. Due to the lack of consideration of the weights given to the evaluation indices for program evaluation using grey relational analysis, the AHP method must be introduced to increase the scientific rigor of the scoring process by way of combining algorithms. When the grey relational analysis method is used, an expert group should be invited to score a single person using a five-point scale method and then take the average of these scores to form a comparison matrix. Meanwhile, to improve the scientific rigor of the scoring process for aesthetic indicators, the intention experiment of emotional semantics for furniture categories can be added before applying the GRA method. The reference chart of users' product perceptual intention scoring can provide the expert group with a basis for scoring the aesthetic indices.

The evaluation criteria for modular children's wooden furniture established according to the AHP method were used to represent the evaluation schemes as S (S = 1, 2, ..., n). The grey-weighted correlation of each scheme was calculated using the GRA method in six steps. The first step is to collect the rating data and form a comparison matrix. In the second step, a reference data column, *i.e.*, an ideal comparison criterion, is determined where the optimal value of each indicator rating value typically constitutes the reference data column, which is denoted by U_0. In the third step, the index data are dimensionless quantized, and the resulting data series matrix is shown in Eq. 5. In the fourth step, the two levels of differences are determined, the absolute differences between the comparison series of each index of the evaluated scheme and the corresponding index of the reference data column are calculated one by one. The maximum and minimum differences are defined by Eqs. 6 and 7, respectively. In the fifth step, the correlation coefficients between each comparison series and the corresponding index of the reference series are calculated using Eq. 8. Finally, the correlation order is calculated, where the correlation coefficients between each index of the comparison series and the corresponding index of the reference series are calculated separately for each comparison series. In the last step, the correlation sequence is calculated, where the mean value of the correlation coefficient between each indicator and the corresponding indicator of the reference series is calculated for each comparison series using Eq. 9. This is represented in Eq. 5,

$$(U1, U2, \ldots, Un) = \begin{bmatrix} U_{11} & U_{21} & \cdots & U_{n1} \\ U_{12} & U_{22} & \cdots & U_{n2} \\ \vdots & \vdots & \ddots & \vdots \\ U_{1m} & U_{2m} & \cdots & U_{nm} \end{bmatrix} \tag{5}$$

where n indicates the number of evaluation programs and m indicates the number of secondary evaluation indicators. Equations 6 through 8 are defined below,

$$\min_{i=1}^{n} \min_{j=1}^{m} \left| U_{0j} - U_{ij} \right| \tag{6}$$

$$\max_{i=1}^{n} \max_{j=1}^{m} \left| U_{0j} - U_{ij} \right| \tag{7}$$

$$S_{ij} = \frac{\min_i \min_j |U_{0j} - U_{ij}| + p \max_i \max_j |U_{0j} - U_{ij}|}{|U_{0j} - U_{ij}| + p \max_i \max_j |U_{0j} - U_{ij}|} \tag{8}$$

where p is the resolution coefficient, $0 < p < 1$, and generally p is taken as 0.5; Eq. 9 is,

$$r_{0i} = \frac{\sum_{j=1}^{m} S_{ij}}{m} \tag{9}$$

where S_{ij} in the formula indicates the correlation between the j^{th} indicator of the i^{th} product and the reference series, and m represents the number of evaluation indicators.

Calculate Grey Weighted Correlation Degree

Grey weighted correlation is calculated for the obtained correlation order r_{0i} using Eq. 10. A certain weight size is calculated for each evaluation index in the evaluation. The calculated grey weighted correlation results are ranked from highest to lowest, and the highest ranked design solution is the optimal solution. In summary, the defined design evaluation for modular children’s wooden storage cabinets can also provide reference indicators for further product iteration based on design solution selection. Equation 10 is given as follows,

$$r'_{0i} = \frac{\sum_{j=1}^{m} \omega_j S_{ij}}{m} \tag{10}$$

where ω_j is the weight of the j^{th} evaluation index; S_{ij} indicates the correlation between the i^{th} index of the j^{th} product and the reference series.

DESIGN EVALUATION CASE

As an important subcategory of children's furniture, storage furniture has multiple product forms and high functional compatibility. Evaluating the design of a storage cabinet is a typical multi-indicator and multi-scheme preference decision problem; therefore, the design evaluation model for modular children's wooden furniture based on the grey comprehensive evaluation method is applicable to evaluating the design of modular storage cabinets for children. In the present study, three modular children's wooden storage cabinet design solutions, denoted S1, S2, and S3, are proposed. These three solutions are all modeled and rendered by the author, and are modular solutions directly proposed based on common design cases. There are five furniture modules in all three design solutions. Figure 2 shows the effects of the three design solutions. The large picture in the upper left corner illustrates the overall effect, and the small pictures on the right and bottom illustrate the individual effects of each module.

S1 has a rounded shape where the modules are single-layer cabinets or double-layer cabinets that are connected in the form of a patchwork and the storage structure contains open storage, drawers, sliding doors, and hanging rods. S2 is inspired by the design of a small car where the modules are single or double cabinets that relate to additional fixtures and the storage structure contains open storage, sliding doors, sliding doors, and hanging rods. S3 is a rotating storage cabinet where the modules are single square cabinets with uniform specifications that are stacked on top of four cabinet feet and the storage structure contains open storage and drawers.

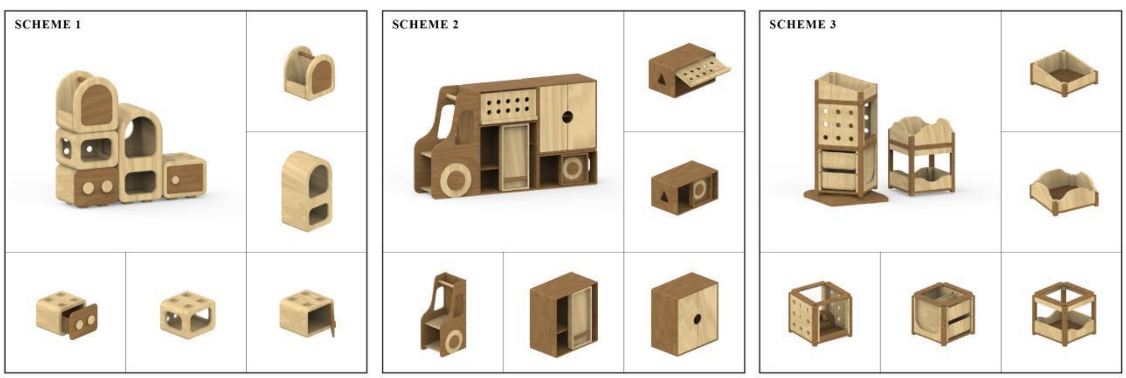

Fig. 2. Modular children's wooden storage cabinet design solutions

Establishment of Evaluation Standards for Modular Children's Wooden Storage Cabinets

Several key terms were obtained by retrieving information on various aspects, such as children's physiology, children's psychological characteristics, modular product characteristics, and economy indicators of furniture companies. The modular system, furniture safety, modeling aesthetics, functional options, and economic value are the research directions. Modular combination design can increase the diversity, flexibility, and standardization of furniture products (Guo and Kang 2020). The convenience of product installation directly determines whether a technician is required and the length of time the individual user needs to install the furniture. Furniture products are not Fast-Moving Goods, and their durability and comfort are also important purchase indicators for consumers (Weiguo 2014; Phuah *et al*. 2022). Safety is not only reflected in materials and structure, but also reasonable clearance and anti-toppling measures to prevent injuries in children (Salvador 2015; Zhang and Li 2022). Aesthetic evaluation of children's furniture often involves adjectives, such as artistic, interesting, and creative, but these terms do not serve as aesthetic indicators because they are influenced by the limitations of the rater. Therefore, a more scientific approach would set morphological curves and stylistic proportions as evaluation indicators; however, they must be paired with a perceptual intentional preference rating scale as a rating reference. Meanwhile, color, as a decisive factor for visual evaluation, is also related to the material matching of wooden furniture, both of which should be included in the aesthetic evaluation index (Tamthintha *et al*. 2018; Jiang *et al*. 2020). Functional indicators are closely related to children's furniture categories, and additional functions of children's furniture in addition to basic functions also merit attention. Montessori education and sensory coordination are concerned with nurturing children's growth, facilitating parent-child interactions, and providing interactive guidance. In addition, growability, inclusive storage, and expandability are common functional requirements for parents when purchasing children's furniture, and modularity is the main way to achieve these three types of functions (Dai and Xu 2019). The most pertinent economy indicators for companies are in manufacturing costs and market prospects, but recycling is also an indicator that cannot be ignored (Weiguo 2014; Phuah *et al*. 2022).

The evaluation criteria of modular children's wooden furniture are a comprehensive set involving multiple levels and factors. A group of experts was invited to categorize the collected information and to supplement and filter the evaluation index elements using the Kawakita Jiro (KJ) method. To address the lack of a rigorous subjective scoring system for modular children's wooden furniture, 25 industry experts, designers, technicians, sales personnel, and expert users were invited to form groups of five persons each. Among them, expert users refer to parents with rich experience in purchasing and using children's furniture. The composition and basic information of the expert group are shown in Table 4.

Table 4. Composition of Expert Group

Expert groups	Summary	Numbers
Industry experts	Experts in children's furniture	5
Designers	modular children's furniture designers	5
Technicians	Experienced practitioners in children's furniture manufacturing	5
Sales personnel	Children's furniture salesperson	5
Expert users	Parents with experience in buying and using children's furniture	5

The expert group extracted and classified the valid information of the collected terms and then obtained a set of basic evaluation and usage guidelines for modular children's wooden furniture. The basic evaluation criteria for modular children's wooden furniture obtained by the KJ method consisted of five first-level criteria: 1) system indicators, 2) safety indicators, 3) aesthetic indicators, 4) functionality indicators, and 5) economy indicators, as shown in Fig. 3. System indicators include standard structure, flexible combination, easy installation, comfort, and durability. Safety indicators include environmental protection materials, warning signs, anti-injury gaps, and reliable connections. Aesthetic indicators include form curve, modeling ratio, color design, and material matching. Functionality indicators include basic attributes, growability, interactive guidance, the Montessori puzzle, parent-child interaction, inclusive storage, expandability, and sensory coordination. Economy indicators include manufacturing cost, market prospect, and recycling.

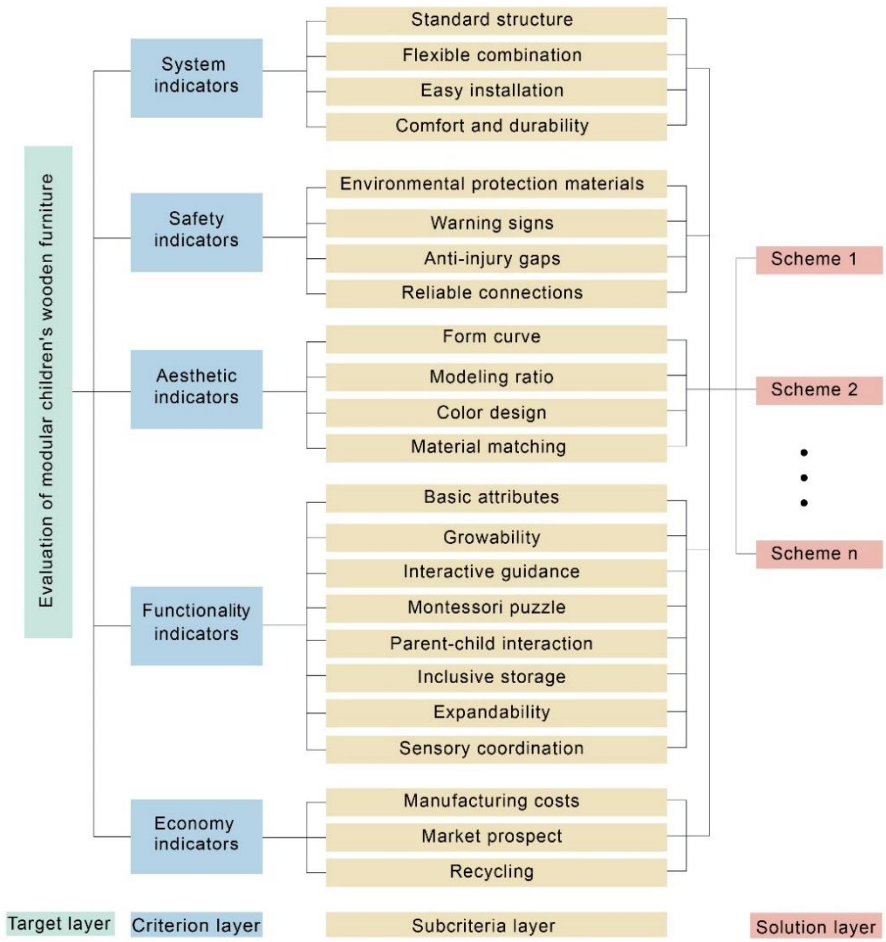

Fig. 3. Evaluation guidelines for modular children's wooden furniture

Through expert group discussion, four recommendations for applying the existing basic evaluation guidelines for modular children's wooden furniture are proposed:

1. This set of evaluation guidelines for modular children's wooden furniture is a basic template that should be customized to the specified furniture characteristics when scoring in specific furniture categories.

2. The evaluation guidelines are applicable to the weight calculations in hierarchical analysis and scoring design solutions.

3. When evaluating modular children's wooden furniture design for different categories, the sub-criteria layer of functionality indicators should be targeted and filtered using the Kano model, and the indicators for basic attributes should be replaced accordingly.

4. Because each rater has a slightly different perception of the aesthetics of the furniture, the perceptual intention should be rated first and then used as the basis evaluating the aesthetic indicators.

Therefore, referring to the first guideline for using the basic evaluation indicators, the evaluation criteria for modular children's wooden storage cabinets must be developed and the Kano model was used to analyze the attributes of the sub-criteria of the functionality indicators in the basic evaluation indicators. The questionnaires were distributed to the target group of parents, and 103 valid questionnaires were collected and analyzed using SPSS software to obtain the better-worse coefficients of eight functionality indicator sub-criteria and their corresponding attributes, which are shown in Table 5. In this process, three indifference attributes (interactive guidance, parent-child interaction, and sensory coordination) were excluded, and the basic attributes of growability, the Montessori puzzle, inclusive storage, and expandability, were used as the sub-criteria of the functionality indicators for modular children's wooden storage cabinets. In line with the third guideline for the use of basic evaluation indicators, the basic attributes are tailored to children's storage.

Table 5. Kano Attributes of Sub-functionality Indicators

Functionality Indicators Subcriteria	M	O	A	I	R	Q	Batter Coefficient	Worse Coefficient	Attribute
Basic attributes	51	34	13	5	0	0	0.46	-0.83	M
Growability	8	43	19	33	0	0	0.60	-0.50	O
Interactive guidance	0	13	34	56	0	0	0.46	-0.13	I
the Montessori puzzle	0	3	59	41	0	0	0.60	-0.03	A
Parent-child interaction	0	5	22	76	0	0	0.26	-0.05	I
Inclusive storage	10	45	13	35	0	0	0.56	-0.53	O
Expandability	2	7	53	41	0	0	0.58	-0.09	A
Sensory coordination	0	0	7	94	2	0	0.07	0.00	I

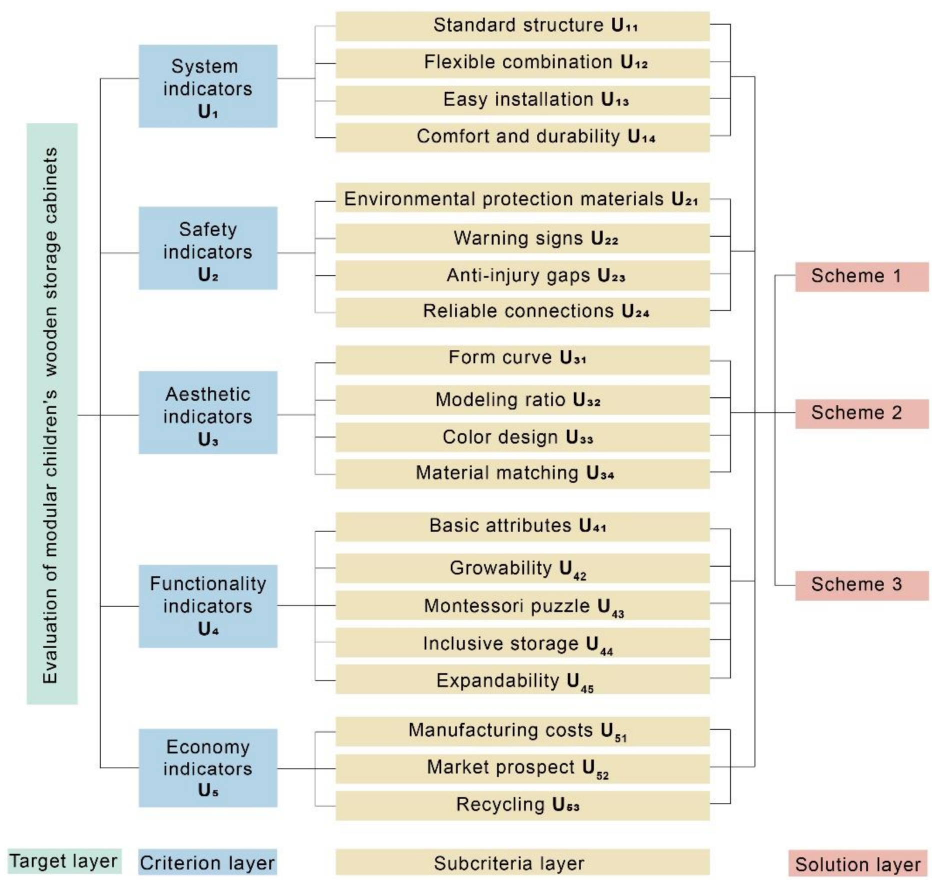

Fig. 4. Evaluation guidelines for modular children's wooden storage cabinets

AHP Method to Determine the Weight of Each Indicator

Based on the Kano model, combined with the requirements of the hierarchical structure model of the AHP method, the first level indicators of the criterion layer were determined as system indicators (U_1), safety indicators (U_2), aesthetic indicators (U_3), and functionality indicators (U_4). Figure 4 lists the evaluation guidelines (*i.e.*, the hierarchical structure model) for modular children's wooden storage cabinets and the overall evaluation system contains five first-level indicators and 20 second-level indicators. The group of experts described in Table 1 used a nine-point scale to make collective decisions on the importance and weight of each evaluation criterion of modular children's wooden storage cabinets. The hierarchical analysis method used to calculate the weights is illustrated in Table 6.

Table 6. Rating Scale for Modular Children's Wooden Storage Cabinets

Criterion Layer		Subcriteria Layer			Total Weight Value	Ranking
Index	Weight	Index	Weight	CR		
U_1	0.1357	U_{11}	0.3620	0.0601 < 0.1	0.0491	7
		U_{12}	0.1386		0.0188	12
		U_{13}	0.0572		0.0078	18
		U_{14}	0.4423		0.0600	5
U_2	0.5135	U_{21}	0.5681	0.0154 < 0.1	0.2917	1
		U_{22}	0.0580		0.0298	10
		U_{23}	0.1420		0.0729	4
		U_{24}	0.2319		0.1191	3
U_3	0.0687	U_{31}	0.2586	0.0349 < 0.1	0.0178	13
		U_{32}	0.5733		0.0394	8
		U_{33}	0.1157		0.0080	17
		U_{34}	0.0524		0.0036	19
U_4	0.2440	U_{41}	0.5288	0.0349 < 0.1	0.1290	2
		U_{42}	0.1298		0.0317	9
		U_{43}	0.0344		0.0084	16
		U_{44}	0.2390		0.0583	6
		U_{45}	0.0680		0.0166	14
U_5	0.0381	U_{51}	0.2790	0.0624 < 0.1	0.0106	15
		U_{52}	0.6491		0.0247	11
		U_{53}	0.0719		0.0027	20

Calculating the Grey Weighted Correlation Degree for Each Scheme Using the GRA Method

Before scoring the program, a perceptual imagery survey was conducted for the aesthetic indicators, in line with the fourth guideline for using the basic evaluation indicators. The seven-point Likert scale was used, and the perceptual imagery questionnaire was distributed to a group of 25 people and another group of 25 general consumers. After 50 valid questionnaires were collected, the mean value of the evaluation results was calculated to obtain the perceptual imagery scores of the aesthetic indicators of modular children's wooden storage cabinets, which are shown in Fig. 5. Among them, the Cronbach's alpha coefficient of questionnaire validity is 0.756 > 0.7, indicating that this questionnaire was valid.

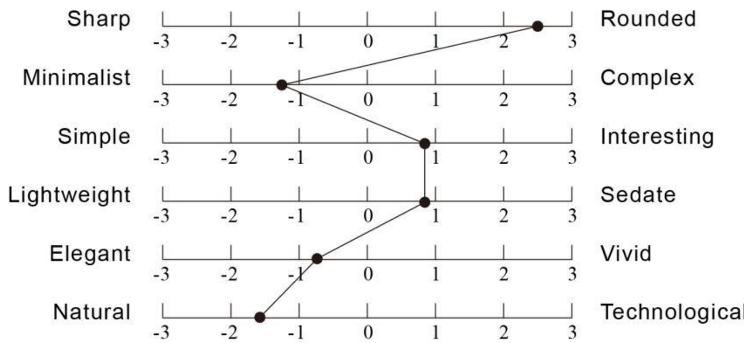

Fig. 5. Aesthetic indicator scoring criteria for modular children's wooden storage cabinets

To score the solutions using the GRA method, it is necessary to have the 25 judges of the panel score each of the 20 evaluation indicators of the three solutions on a five-point Likert scale. For scoring the aesthetic indicators, special attention was given to the imagery vocabulary criteria shown in Fig. 5. Finally, the average of the scores by the panel of judges was used as the final score of each solution to form the comparison matrix U. Given that the optimal value of each index is five, the reference number was determined as $\{U_0\}$ = {5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5}, and the correlation coefficient was determined to take $p = 0.5$ in the calculation. Meanwhile, because the score matrix of this paper is already quantified by dimensionless quantization, there is no need to perform dimensionless quantization again. The grey relational coefficients calculated by Eq. 8 are shown in Table 7, and the grey relational grades calculated by Eq. 9 are shown in Table 8.

$$U=\begin{bmatrix} 2.8 & 3.76 & 3 & 4.44 & 4.44 & 1 & 4 & 4 & 4 & 2.32 & 2.32 & 2.76 & 3.76 & 1.32 & 3 & 3.12 & 1.32 & 2.44 & 1.8 & 2.92 \\ 3 & 3.8 & 3.6 & 4 & 3.76 & 1.32 & 3.44 & 2.32 & 3.68 & 4.68 & 4 & 4.68 & 4.76 & 4.32 & 4.76 & 4.32 & 4.56 & 4.36 & 4.68 & 3.56 \\ 4.68 & 2 & 4 & 2.8 & 4 & 1.24 & 2.44 & 4.24 & 2.24 & 3.68 & 4 & 4 & 3.68 & 3 & 2.44 & 3.52 & 3.24 & 3 & 3.32 & 3.68 \end{bmatrix}$$

Table 7. Results of Grey Relational Coefficient for Each Design Scheme

Evaluation Indicators	Scheme 1	Scheme 2	Scheme 3
U_{11}	0.533	0.560	0.966
U_{12}	0.691	0.700	0.448
U_{13}	0.560	0.659	0.747
U_{14}	0.875	0.747	0.533
U_{21}	0.875	0.691	0.747
U_{22}	0.373	0.394	0.389
U_{23}	0.747	0.629	0.491
U_{24}	0.747	0.479	0.812
U_{31}	0.747	0.675	0.471
U_{32}	0.479	0.966	0.675
U_{33}	0.479	0.747	0.747
U_{34}	0.528	0.966	0.747
U_{41}	0.691	1.000	0.675
U_{42}	0.394	0.836	0.560
U_{43}	0.560	1.000	0.491
U_{44}	0.577	0.836	0.644
U_{45}	0.394	0.918	0.596
$U5_1$	0.491	0.848	0.560
U_{52}	0.431	0.966	0.609
U_{53}	0.549	0.651	0.675

Table 8. Results of Grey Relational Grades for Each Design Scheme

Scheme	Grey Relational Grade	Ranking
Scheme 1	0.586	3
Scheme 2	0.763	1
Scheme 3	0.629	2

Calculate the Grey Weighted Correlation Degree

Combining the comprehensive weights of the indicators in Table 6 and the results of the grey relational coefficients calculation in Table 7, the grey-weighted correlations degrees of the three modular children's wooden storage cabinets were obtained by Eq. 10, which are shown in Table 9. From the ranking shown in Table 9, it can be seen that the order of the design solution preferences was S2 > S1 > S3. Therefore, through the comprehensive design evaluation model of multi-modular furniture proposed in this study, S2 was selected as the best solution.

Table 9. Results of Grey-weighted Correlations Degree for Each Design Scheme

Scheme	Grey-weighted Correlations Degree	Ranking
Scheme 1	0.0354	2
Scheme 2	0.0364	1
Scheme 3	0.0339	3

RESULTS AND DISCUSSION

Through business analysis of consumer trends in children's furniture and current market conditions, this study found that modern parents' consumption preferences in terms of flexibility of use and adaptability to growth were the main factors in their decisions to purchase children's furniture. Modularity was one way to achieve the flexibility and growability in children's furniture. Modular innovation should not only include functional expansion and morphological changes but also consider the ergonomic needs of users. At the same time, modular children's wooden furniture is a dynamic series of products, and a research framework that combines the AHP method index assignment process and the GRA method correlation score can effectively avoid missing indicators and improve the scientific rigor of the score. Ultimately, the evaluation and selection of multiple design solutions was achieved, expanding the functional forms of children's furniture, and optimizing sales strategies.

Industry experts, designers, technicians, sales personnel, and expert users on children's furniture could be invited to filter and summarize the descriptive words related to children's furniture. Because the current generation of parents pays more attention to children's growth, the factors considered in the purchase of children's furniture show a trend of diversified segmentation. At the same time, the demand for functional expansion and morphological innovation triggered by the pursuit of high costs performance has become a hot spot for research. This showed that the system indicators, safety indicators, aesthetic indicators, functionality indicators, and economy indicators of children's furniture will directly affect parents' consumption attitudes and purchase intentions. Among them, the system indicators included standard structure, flexible combination, easy installation, comfort, and durability. Safety indicators include environmental protection materials, warning signs, anti-injury gaps, and reliable connections. Aesthetic indicators include form curve, modeling ratio, color design, and material matching. Functionality indicators include basic attributes, growability, interactive guidance, the Montessori puzzle, parent-child interaction, inclusive storage, expandability, and sensory coordination. Economic indicators include manufacturing costs, market prospects, and recycling. In the evaluation of modular design solutions for children's storage cabinets, the evaluation system contains five primary indicators and 20 secondary indicators. Among the secondary indicators, the one with the largest weight is environmental protection materials, which highlights the importance of materials. Furthermore, it is worth noting that wood is the most popular material in children's furniture. However, the proposed evaluation indicators and their weight scores have only been assessed by a group of experts, which can be considered highly subjective. In subsequent studies, artificial intelligence algorithms should be added to expand the cross-cutting multidisciplinary indicators. Additionally, the sample size for obtaining scores should be increased to improve the objectivity and scientific rigor of the evaluation process of design solutions. Additionally, the design evaluation method proposed in this study has not been practiced in the real market, and the reliability of the method needs to be verified in a larger sample given the relatively small children’s furniture market. In addition, with the increasing emphasis on environmental concerns, recycling of products, environmental impact, resource utilization, and other sustainability factors will be considered in the evaluation index in the future.

CONCLUSIONS

1. This paper proposed an innovative design evaluation model for modular children’s wooden furniture based on the grey comprehensive evaluation method. First, a group of experts constructed a design evaluation criterion template using the Kawakita Jiro (KJ) method and screened functionality indicators in the evaluation criterion template using the Kano model. Comprehensive evaluation criteria were established for a targeted modular children’s wooden storage cabinet set. Then, the analytic hierarchy process (AHP) was used to assign weights to each evaluation index and grey relational analysis (GRA) to evaluate each design solution and calculate the correlation order. Finally, by calculating the grey weighted correlation degree, the optimal scheme was selected. This solution provided a reference for companies in the product iteration stage of manufacturing furniture for children.
2. For evaluating the design of modular storage cabinets for children, three non-differential attributes (interactive guidance, parent-child interaction, and sensory coordination) were excluded from the set of eight functionality indicators. Among the five primary criteria of the modular design evaluation guidelines, the largest weight was safety indicators with a weight of 0.5135, followed by functionality indicators with a weight of 0.2440. System indicators, aesthetic indicators, and economy indicators had lower weight values of 0.1357, 0.0687, and 0.0381, respectively.
3. The modular design evaluation criteria for children's modular storage cabinets had 20 sub-criteria. Among them, the top three items with the larger weight were environmental protection materials, basic attributes, and reliable connections, whose weighted values were 0.2917, 0.1290, and 0.1191, respectively. The last three items

with the lower weight were the Montessori puzzle, color design, and easy installation, with weights of 0.0084, 0.0080, and 0.0078, respectively.

4. In the design evaluation case for the children’s modular storage cabinet, the grey weighted correlation of S1 was 0.0354, the grey weighted correlation of S2 was 0. 0364, and the grey weighted correlation of S3 was 0.0339. Therefore, S2, which had the highest grey weighted correlation, was successfully screened as the optimal option. The feasibility of the innovative design evaluation model proposed in this study was confirmed by the case of children's storage cabinets.

ACKNOWLEDGMENTS

The authors are grateful for the financial support of the Priority Academic Program Development (PAPD) of Jiangsu Province, the Joint Research Program of Nanjing Forestry University, and Jiangsu Co-Innovation Center of Efficient Processing and Utilization of Forest Resources.

REFERENCES CITED

Andaç, T., and Güzel, A. (2017). “Attitudes of families with children towards eco-friendly designed furniture: Kayseri sample,” *BioResources* 12(3), 5942-5952.DOI: 10.15376/biores.12.3.5942-5952

Bai, W. D., J. Xu, and Zhang, J. Z. (2014). “The application of paper materials in children furniture,” *AMR* 945–949, 465-469. DOI: 10.4028/www.scientific.net/AMR.945-949.465

Błaszczak, I., Dobrowolska, E., Mielnik, A., and Lisiecka, E. (2021). “A systemic model of furniture meant for stimulating development of a child based on educational aids from M. Montessori,” *Annals of Warsaw University of Life Sciences-SGGW, Forestry and Wood Technology* 2021(113), 13-19. DOI: 10.5604/01.3001.0015.2327

Cheng, Q., Kang, Y.-B, Yang, C.-B., Zhang, C.-X., and Chen, C.-H. (2023). “A new reliability allocation method for machine tools based on ITrFNs and AHP-GRA,” *Int. J. Adv. Manuf. Technol*. 124, 4019-4032. DOI: 10.1007/s00170-021-08153-5

Dai, L., and Xu, B. (2019). “Research on the furniture design criteria for children’s psychological development in home environment,” in: *Design, User Experience, and Usability. Application Domains: 8th International Conference, DUXU 2019*, Held as Part of the 21st HCI International Conference, HCII 2019, Orlando, FL, USA, Proceedings, Part III 21 (pp. 277-286). DOI: 10.1007/978-3-030-23538-3_21

Di, Q., Zhilei, X., and Pengkun, G. (2020). “Study on module design of residential units in prefabricated boarding schools,” *E3S Web of Conferences* 165(2020), article 04027. DOI: 10.1051/e3sconf/202016504027

Fang, S.-X., and Wang, A.-M. (2020). “Measurement of corporate social responsibility of automobile enterprises based on AHP-GRA model,” *Journal of Intelligent & Fuzzy Systems* 38(6), 6947-6956. DOI: 10.3233/JIFS-17977

Fujita, K. (2002). “Product variety optimization under modular architecture,” *Computer-Aided Design* 34(12), 953-965. DOI: 10.1016/S0010-4485(01)00149-X

Fujita, K., and Yoshida, H. (2004). "Product variety optimization simultaneously designing module combination and module attributes," *Concurrent Engineering* 12(2), 105-118. DOI: 10.1177/1063293X04044758

Guo, L., and Kang, J. C. (2020). "A study on the functional modules and structural design of standardized unit cabinet for mass customization wardrobe," *Korea Institute of Deigns Research Society* 5(1), 9-20. DOI: 10.46248/kidrs.2020.1.9

Hu, D., and X. Zhao. (2022). "Reliability assessment of modular design of pod decision," *JAMDSM*, 16(1), article 0018. DOI: 10.1299/jamdsm.2022jamdsm0018

Jiang, L., Cheung, V., Westland, S., Rhodes, P. A., Shen, L., and Xu, L. (2020). "The impact of color preference on adolescent children's choice of furniture," *Color Research and Application* 45(4), 754-767. DOI: 10.1002/col.22507

Jin, D., and Li, T. (2023). "Research on decorative materials properties used in the production of cabinets based on visual/tactile experience," *Coatings* 13(1), article 178. DOI: 10.3390/coatings13010178

Kaputa, V., Barčić, A. P., Maťová, H., and Motik, D. (2018). "Consumer preferences for wooden furniture in Croatia and Slovakia," *BioResources* 13(3), 6280-6299. DOI: 10.15376/biores.13.3.6280-6299

Knauf, M. (2015). "Understanding the consumer: Multi-modal market research on consumer attitudes in Germany towards lightweight furniture and lightweight materials in furniture design," *European Journal of Wood and Wood Products* 73(2), 259-270. DOI: 10.1007/s00107-014-0866-9

Li, M., and Zhang, J. (2021). "Integrating Kano Model, AHP, and QFD methods for new product development based on text mining, intuitionistic fuzzy sets, and customers satisfaction," *Mathematical Problems in Engineering*, article ID 2349716. DOI: 10.1155/2021/2349716

Li, X.-R., Hou, X.-G., Yang, M., He, J.-X., Wang, Y.-Y., Guo, H.-Y., Li, X.-Y., and Wang, L.-Y. (2021). "The optimal decision-making model of industrial design scheme based on multi-level grey comprehensive evaluation method and its application," *Journal of Graphics* 42(4), 670-679. DOI: 10.11996/JG.j.2095-302X.2021040670

Li, Y., Xia, J., Xu, Y., and Huang, D. (2020). "Research on quality evaluation of customized plank furniture based on the entropy weight-analytical hierarchy process," *Journal of Physics Conference Series* 1584 (1), article ID 012062. DOI: 10.1088/1742-6596/1584/1/012062

Li, Y., and Zhang, X. (2017). "Research on comprehensive decision model based on analytic hierarchy process and entropy method," in: *The 3rd Annual International Conference on Modern Education and Social Science*, Destech Publications, Inc., China, Wuhan, pp. 19-23.

Liu, S., and Zheng, W. (2021). "Priority order recognition method of module redesign for the CNC machine tool product family to improve green performance," *Transactions of the Canadian Society for Mechanical Engineering* 45(4), 513-531. DOI: 10.1139/tcsme-2020-0190

Liu, M., Zhu, X., Chen, Y., and Kong, Q. (2023a). "Evaluation and design of dining room chair based on analytic hierarchy process (AHP) and fuzzy AHP," *BioResources* 18(2), 2574-2588. DOI: 10.15376/biores.18.2.2574-2588

Liu, W., Huang, Y., Sun, Y, and Yu, C. (2023b). "Research on design elements of household medical products for rhinitis based on AHP," *Mathematical Biosciences and Engineering* 20(5), 9003-9017. DOI: 10.3934/mbe.2023395

Lu, C. F., Li, Y., Liu, X. J., and Ren, H. H. (2012). "IGA-based user evaluation driven optimization design of forklift styling," *Applied Mechanics and Materials* 160, 287-291. DOI: 10.4028/www.scientific.net/AMM.160.287

Luo, Y., and Xu, W. (2023). "Optimization of panel furniture plates rework based on intelligent manufacturing," *BioResources* 18(3), 5198-5208. DOI: 10.15376/biores.18.3.5198-5208

Koleini Mamaghani, N., and Barzin, E. (2019). "Application of quality function deployment (QFD) to improve product design quality in school furniture," *Iran University of Science and Technology* 29(2), 277-287. DOI: 10.22068/ijaup.iust.2020.11

Neira-Rodado, D., Ortíz-Barrios, M., de la Hoz-Escorcia, S., Paggetti, C., Noffrini, L., and Fratea, N. (2020). "Smart product design process through the implementation of a fuzzy Kano-AHP-DEMATEL-QFD approach," *Applied Sciences* 10(5), article 1792. DOI: 10.3390/app10051792

Nyrud, A. Q., and Bringslimark, T. (2010). "Is interior wood use psychologically beneficial? A review of psychological responses toward wood," *Wood and Fiber Science* 2010(2), 202-218.

Oblak, L., Pirc Barčić, A., Klarić, K., Kitek Kuzman, M., and Grošelj, P. (2017). "Evaluation of factors in buying decision process of furniture consumers by applying AHP method," *Drvna Industrija* 68(1), 37-43. DOI: 10.5552/drind.2017.1625

Pandian, P., Devanayagam Sundaram, V., and Sivaprakasam, R. (2016). "Development of Fuzzy based intelligent decision model to optimize the blind spots in heavy transport vehicles," *PROMET-Traffic & Transportation* 28(1), 1-10. DOI: 10.7307/ptt.v28i1.1614

Phuah, Z. Y., Ng, P. K., Lim, B. K., Nathan, R. J., Ng, Y. J., and Yeow, J. A. (2022). "The conceptualisation of inventive and repurposable children's furniture," *Forests* 13(12), article 2053. DOI: 10.3390/f13122053

Pranoto, A. A., Tedjokoesoemo, P. E. D., Nilasari, P. F., and Sari, S. M. (2022). "Participatory design to develop Montessori modular furniture for pre-prosperous community learning center," *Journal of Visual Art and Design* 13(2), 156-170. DOI: 10.5614/j.vad.2021.13.2.6

Salvador, C. (2015). "Contributions of ergonomics to an affective sustainability in children's furniture," *Procedia Manufacturing* 3, 6483-6489. DOI: 10.1016/j.promfg.2015.07.931

Salvador, C. (2019a). "Human interaction, emotion and sustainability: Designing wooden children's furniture," *Advances in Ergonomics in Design, Advances in Intelligent Systems and Computing*, F. Rebelo and M. M. Soares (eds.), Springer, Cham, Switzerland, pp. 599–606. DOI: 10.1007/978-3-319-94706-8_63

Salvador, C. (2019b). "Adapting furniture to the child – Ergonomics as a main tool in a design project," *Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018), Advances in Intelligent Systems and Computing*, S. Bagnara, R. Tartaglia, S. Albolino, T. Alexander, and Y. Fujita (eds.), Springer, Cham, Switzerland, pp. 1294-1305. DOI: 10.1007/978-3-319-96071-5_131

Shahriar, M. M., Parvez, M. S., and Talapatra, S. (2022). "Hierarchizing the product characteristics of industrial plain sewing machine for making best purchase decision," *Mathematical Problems in Engineering*, article ID 2578875. DOI: 10.1155/2022/2578875

Shahsavar, T., Kubeš, V., and Baran, D. (2020). "Willingness to pay for eco-friendly furniture based on demographic factors," *Journal of Cleaner Production* 250, article ID 119466. DOI:10.1016/j.jclepro.2019.119466

Sheng, Z. Q., Liu, Y. C., Jin, Y., and Liu, Y. X. (2012). "Mass customization–oriented module combination method," *Advanced Materials Research* 487, 395-400. DOI: 10.4028/www.scientific.net/AMR.487.395

Singh, R., Avikal, S., Rashmi, R., and Ram, M. (2020). "A Kano model, AHP and TOPSIS based approach for selecting the best mobile phone under a fuzzy environment," *International Journal of Quality & Reliability Management* 37(6/7), 837-851. DOI: 10.1108/IJQRM-01-2020-0022

Sun, Y., Yang, H., and Meng F. (2018). "Research on an intelligent behavior evaluation system for unmanned ground vehicles," *Energies* 11(7), article 1764. DOI: 10.3390/en11071764

Tamthintha, P., Palaprom, K., and Nawattanaprasert, K. (2018). "A study on perceptions of preschool Children's furniture design: Pictorial stimuli experiment," *MATEC Web Conference* 204, article ID 01003. DOI:10.1051/matecconf/201820401003

Tan, Y.-S., Chen, H., and Wu, S. (2019). "Evaluation and implementation of environmentally conscious product design by using AHP and grey relational analysis approaches," *Ekoloji* 28(107), 857-864.

Tian, G., Zhang, H., Zhou, M., and Li, Z. (2017). "AHP, grey correlation, and TOPSIS combined approach to green performance evaluation of design alternatives," *IEEE Transactions on Systems, Man, and Cybernetics: Systems* 48(7), 1093-1105. DOI: 10.1109/TSMC.2016.2640179

Wan, M., Chen, J., and Toppinen, A. (2015). "Consumers' environmental perceptions of children's furniture in China," *Forest Products Journal* 65(7–8), 395-405. DOI: 10.13073/FPJ-D-14-00102

Wan, M., Zhang, Y., and Ye, W. (2019). "Consumer willingness-to-pay a price premium for eco-friendly children's furniture in Shanghai and Shenzhen, China," *Forest Products Journal* 68(3), 317-327. DOI: 10.13073/FPJ-D-17-00050

Wang, J., and Pan, Y. (2022). "Design evaluation of parent-child interactive game furniture based on AHP-TOPSIS method," *Journal of the Korea Convergence Society* 13(2), 235-248. DOI: 10.15207/JKCS.2022.13.02.235

Wang, W., and Wang, S. (2021). "Toward parent-child smart clothing: Purchase intention and design elements," *Journal of Engineered Fibers and Fabrics* 16, article ID 155892502199184. DOI: 10.1177/1558925021991843

Wang, W. J., Yu, S. H., Wang, S. X., Chen, J., and Deng, L. (2015). "Multilevel comprehensive evaluation and decision making of ergonomics," *Discrete Dynamics in Nature and Society*, article ID 689203. DOI: 10.1155/2015/689203

Wei, P., and Madina, Z. (2022). "Application of environmentally friendly materials in the design of children's furniture based on fuzzy technology," *Mathematical Problems in Engineering* 2022, article ID 5165699. DOI: 10.1155/2022/5165699

Weiguo, L. (2014). "Discussion on emotional design of preschool children's furniture," in: *2014 2nd International Conference on Advances in Social Science, Humanities, and Management (ASSHM-14)*, Atlantis Press, Amsterdam, Netherlands, pp. 72-74. DOI: 10.2991/asshm-14.2014.22

Weng, L. (2021). "Functional combination-oriented module identification for adaptable-function mechanical product design," *International Journal of Advanced Manufacturing Technology* 116, 523-536. DOI: 10.1007/s00170-021-07344-4

Xiong, X., Lu, G., and Lu, D. (2021). "Research on children's customized furniture design based on group technology," *Applied Sciences* 11(23), article 11371. DOI: 10.3390/app112311371

Yang, D., and Zhu, J. (2021). "Recycling and value-added design of discarded wooden furniture," *BioResources* 16(4), 6954-6964. DOI: 10.15376/biores.16.4.6954-6964

Yang, X. A., Deng, Q., Sun, G. L., and Wang, B. B. (2011). "Research on evaluation and decision-making model of product design scheme based on TFN-AHP-GRA," *Advanced Materials Research* 201–203, 1170-1176. DOI: 10.4028/www.scientific.net/amr.201-203.1170

Ye, J., Li, W., and Yang, C. (2021). "Research on modular design of children's furniture based on scene theory," in: *Human-Computer Interaction. Design and User Experience Case Studies*, Springer, Cham, Switzerland, pp. 153–172. DOI: 10.1007/978-3-030-78468-3_11

Yoshimoto, T. (2009). "Modularization, design optimization, and design rationalization: A case study of electronics products," *Annals of Business Administrative Science* 8, 75-90. DOI: 10.7880/abas.8.75

Yu, C., Liu, W., Fei, Y., Chen, J., and Hu, Z. (2023). "Influencing factors of online furniture purchase behavior based on analytic hierarchy process," *BioResources* 18(2), 2857-2873. DOI: 10.15376/biores.18.2.2857-2873

Yu, N., Wang, J., Hong, L., Tao, B., and Zhang, C. (2021). "Evaluation of the color aesthetics of fine wood based on perceptual cognition," *BioResources* 16(2), 4126-4148. DOI: 10.15376/biores.16.2.4126-4148

Yue, H., Zhu, T.-L., Zhou, Z.-J., and Zhou, T. (2022). "Improvement of evaluation method of elderly family medical product design based on AHP," *Mathematical Problems in Engineering* 2022, article ID 4036030. DOI: 10.1155/2022/4036030

Zhang, C., Wang, P., Sheng, Z., and Liu, Y. (2013). "Research on module selection method in the modular design of CNC machine tool," *Advanced Materials Research* 619, 351-354. DOI: 10.4028/www.scientific.net/AMR.619.351

Zhang, W., and Li, S. (2022). "The integrated development of furniture design and children's characteristics based on artificial intelligence," *Scientific Programming* 2022, article ID 6036160. DOI: 10.1155/2022/6036160

Zhang, X. (2013). "Furniture design based on green ecological environment," *Informatics and Management Science II*, W. Du (ed), Springer, London, UK, pp 283–289.

Zhu, J., and Wu, Q. (2020). "Furniture design based on parent-child interaction experience," *E3S Web Conference* 179, article ID 02098. DOI: 10.1051/e3sconf/202017902098

Article submitted July 18, 2023; Peer review completed: August 5, 2023; Revised version received and accepted: September 19, 2023; Published: October 2, 2023.
DOI: 10.15376/biores.18.4.7818-7838