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Analysis of Key Attributes of Wooden Toys via an Interval-Valued Spherical Fuzzy Analytic Hierarchy Process

Analiza ključnih svojstava drvenih igračaka primjenom sfernoga neizrazitog analitičkog hijerarhijskog procesa s intervalnim vrijednostima

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ABSTRACT • *The evaluation of wooden toys is a complicated process and can be overwhelming for decision-makers in the presence of many conflicting criteria. Hence, this study proposes a fuzzy decision-making model to identify and prioritize the key attributes of wooden toys. For this purpose, the interval-valued spherical fuzzy analytic hierarchy process (AHP), which is one of the fuzzy multicriteria decision-making methods, is applied to obtain weight vectors. Firstly, the wooden toy evaluation problem is formulated as a multicriteria decision-making problem. Then five main criteria and twenty subcriteria are defined with the help of experts. The decision-making team carries out the pairwise comparisons of the criteria. As a result, the priority weights are computed and the ranking order of the criteria is revealed. Additionally, the validity of the obtained results is supported by conducting a comparative analysis between other popular fuzzy methods: interval type-2 fuzzy AHP, interval-valued Pythagorean fuzzy AHP, and spherical fuzzy AHP. According to the modeling results, the most important criteria are "absence of small parts and sharp edges", "free of harmful wood preservatives and paints", "workmanship quality", "contribution to psychomotor development", and "contribution to cognitive development". The proposed framework can be adapted to similar decision processes for the evaluation or improvement of toys. Consequently, the findings of this research will help manufacturers, designers, and consumers in making conscious decisions.*

KEYWORDS: *analytic hierarchy process, expert perspective, fuzzy logic, multicriteria decision-making, wooden toy*

SAŽETAK • *Ocjenjivanje drvenih igračaka složen je proces i za donositelje odluka može biti vrlo težak ako postoji mnogo proturječnih kriterija. Stoga je u ovom istraživanju predložen neizraziti model donošenja odluka za prepoznavanje i određivanje ključnih svojstava drvenih igračaka. Pritom je za dobivanje pondera primijenjen sferni neizraziti analitički hijerarhijski proces (AHP), koji je jedna od neizrazitih višekriterijskih metoda odlučivanja. Problem vrednovanja drvene igračke najprije je formuliran kao višestruki problem odlučivanja. Zatim je uz pomoć*

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stručnjaka definirano pet glavnih kriterija i 20 potkriterija. Tim za donošenje odluka proveo je usporedbu kriterija u parovima. Kao rezultat toga izračunani su ponderi prioriteta i definiran redoslijed kriterija. Komparativnom analizom dodatno je provedena provjera rezultata s rezultatima dobivenim drugim dvjema popularnim neizrazitim metodama: intervalnim tip 2 neizrazitim AHP-om i Pitagorinim neizrazitim AHP-om s intervalnim vrijednostima. Prema rezultatima modeliranja, najvažnijim su se pokazali kriteriji „bez sitnih dijelova i oštrih rubova", „bez štetnih premaznih materijala", „kvaliteta izrade", „doprinos psihomotoričkom razvoju" i „doprinos kognitivnom razvoju". Predočeni se okvir može prilagoditi za slične procese odlučivanja u ocjenjivanju i poboljšanju igračaka. Slijedom toga, rezultati ovog istraživanja pomoći će proizvođačima, dizajnerima i korisnicima igračaka u donošenju ispravnih odluka.

KLJUČNE RIJEČI: *analitički hijerarhijski proces, stručna perspektiva, neizrazita logika, višestruko odlučivanje, drvena igračka*

1 INTRODUCTION
1. UVOD

Toys can be defined as products designed for use in learning or playing by children. Symbolic play materials, manipulative toys, art and craft materials, problem-solving toys, and cause-and-effect toys are some of these products. A wide variety of raw materials are used for the manufacture of toys. Wood is one of the most popular raw materials owing to its safety aspects, aesthetic appearance, and durability (Mercan, 2018).

The unique characteristics of wood have considerably contributed to the increase in demand for wooden toys. The purchasing process consists of four main stages: (i) need (problem) recognition, (ii) information retrieval, (iii) alternative evaluation, and (iv) final decision (Oblak *et al*., 2017). Evaluating wooden toys can be a confusing experience because alternatives need to be evaluated against many conflicting criteria. Decision-makers may be subjective and uncertain about their preference levels owing to incomplete information. Hence, selection criteria should be analyzed for the unbiased assessment of alternatives.

Although the need for research on the weighting of toy attributes is acknowledged, the number of studies focusing on this topic is insufficient. According to Fallon and Harris (1989), the most important attributes are safety and teaching new skills. Duracell (2005) has elucidated that costs, product quality, and children's desires possess substantial influences on toy selection decisions. Al Kurdi (2017) has reported that safety, durability, flexibility, and product category affect the decision-making process. Scherer *et al*. (2017) have employed the conjoint analysis technique to analyze the key attributes of bio-based sand toys. According to the researchers, the most important attribute is toy price. Richards *et al*. (2020) have reported that consumers give more importance to the educational qualities of toys. Mai (2021) has detected that the most important factors influencing the selection of green toys are design, material reliability, and the degree of environmental friendliness.

The importance of product selection criteria is not identical in decision-making problems. In order to obtain reliable and informative results, the opinions of different experts should be gathered and modeled through a scientific technique (Singer and Özşahin,

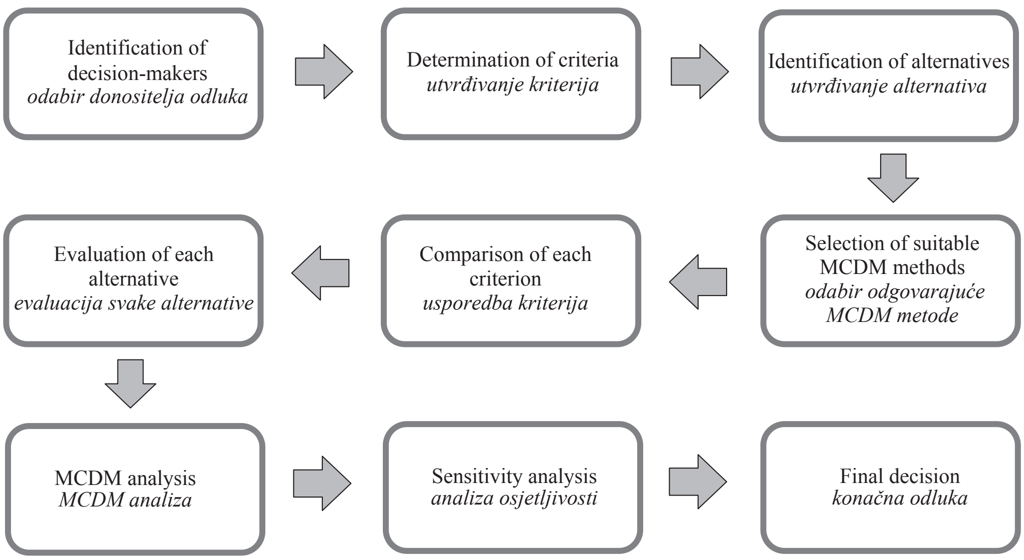

Figure 1 MCDM process
Slika 1. Proces višekriterijskog odlučivanja

2021). One of the most popular scientific techniques is multicriteria decision-making (MCDM). This technique analyzes complex decision situations and processes by various decision support tools. The principal purposes of the MCDM technique are to prioritize multiple conflicting criteria and to choose the best alternative from a candidate set based on comparison matrices. Figure 1 illustrates the main procedure of MCDM models (Kim and Chung, 2013).

There are several weighting methods for MCDM. The analytic hierarchy process (AHP) usually displays more practical and significant properties than the others. The popularity of the AHP method can be attributed to its simplicity, ease of use, flexibility, hierarchical structure, and consistency tests (Alelaiwi, 2019). This method assesses the relative importance of decision elements by employing a 1-9 discrete scale. Pairwise comparison matrices are created and analyzed to obtain weight vectors. When conducting AHP modeling in practice, performance ratings can lead to unrealistic and misleading impressions. Decision-makers cannot assign precise scores to comparison judgments owing to the complexity of decision problems, the subjectivity of some criteria, and the limitation of thinking (Kar, 2015; Shameem *et al*., 2020). The fuzzy set theory can express and treat uncertain situations. Hence, the fuzzy AHP approach is more useful for modeling the vague thoughts of respondents and reasoning the quantitative degree of each decision element (Ashtiani and Abdollahi Azgomi, 2015; Mahjouri *et al*., 2017).

The fuzzy set theory considers approximate reasoning to facilitate decision-making. The relative significance of criteria and the suitability of alternatives are represented via linguistic labels and fuzzy numbers. Fuzzy conclusions are transformed into crisp values to sort or rank decision elements (Balogun *et al*., 2015). The standard fuzzy set assigns one membership point from the interval [0, 1] to each element. In hesitant decision situations, membership degrees can be inadequate in describing the statements of respondents (Wang and Li, 2018). Therefore, different fuzzy theories have been proposed in the literature. The spherical fuzzy set is one of the recent fuzzy extensions addressing the membership, non-membership, and hesitancy degrees of elements. This fuzzy set offers flexibility in generating the priorities of criteria and alternatives under the indefinite environment (Ashraf and Abdullah, 2020; Gül, 2020). Hence, the AHP method has been updated with the spherical fuzzy set to obtain robust results against uncertainties.

The spherical fuzzy AHP method has brought new insights into the solution of many problems such as renewable energy location selection (Kutlu Gündoğdu and Kahraman, 2020), manufacturing system selection (Mathew *et al*., 2020), prioritization of laminate flooring selection criteria (Singer and Özşahin, 2021), Covid-19 crisis management (Demir and Turan, 2021), and sustainable supplier selection (Unal and Temur, 2022). Interval-valued approaches take into account more uncertain information (Srinivas and Singh, 2018; Song *et al*., 2019). Hence, the present study utilizes the interval-valued spherical fuzzy AHP method. Several decision problems such as hospital performance assessment (Kutlu Gündoğdu and Kahraman, 2021), transportation system evaluation (Duleba *et al*., 2021), and financial accounting fraud detection (Hamal and Senvar, 2022) have been solved by this method. The results have demonstrated that the interval-valued spherical fuzzy AHP excellently expresses human preferences.

The consequences of wooden toy selection decisions affect children. Hence, it is necessary to weigh up evaluation factors before making such decisions. To the best of our knowledge, wooden toy selection criteria have not been explored and analyzed in any other study. Therefore, the objectives of the current study are to identify the key attributes of wooden toys, to analyze each attribute from experts' perspectives, and to bridge the knowledge gap by employing the interval-valued spherical fuzzy AHP method. This paper provides different viewpoints because the evaluation of wooden toys is considered a complex MCDM problem and the application of the proposed method is new in the field of wood science.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Interval-valued spherical fuzzy set
2.1. Sferni neizraziti skup s intervalnim vrijednostima

The spherical fuzzy set is an extension of the previous fuzzy sets (Figure 2). This new extension consists of membership, non-membership, and hesitancy functions (Kutlu Gundogdu and Kahraman, 2019). The interval-valued spherical fuzzy set is more effective in coping with uncertainties and gives the advantage to model the opinions of different decision-makers. This fuzzy set is defined by Eq. 1 (Balin, 2020).

$$\tilde{s} = \left\{ x, \left([\mu_{\tilde{s}}^{-}(x), \mu_{\tilde{s}}^{+}(x)], [v_{\tilde{s}}^{-}(x), v_{\tilde{s}}^{+}(x)], [\pi_{\tilde{s}}^{-}(x), \pi_{\tilde{s}}^{+}(x)] \right) \middle| x \in X \right\} \quad (1)$$

$[\mu_{\tilde{s}}^{-}(x), \mu_{\tilde{s}}^{+}(x)]$, $[v_{\tilde{s}}^{-}(x), v_{\tilde{s}}^{+}(x)]$, and $[\pi_{\tilde{s}}^{-}(x), \pi_{\tilde{s}}^{+}(x)]$ are the lower (−) and upper (+) limits of membership, non-membership, and hesitancy, respectively. The squared sum of $\mu_s + (x)$, $v_s + (x)$, and $\pi_s + (x)$ is between 0 and 1. The following equations are used to calculate refusal degrees (Kutlu Gündoğdu and Kahraman, 2021):

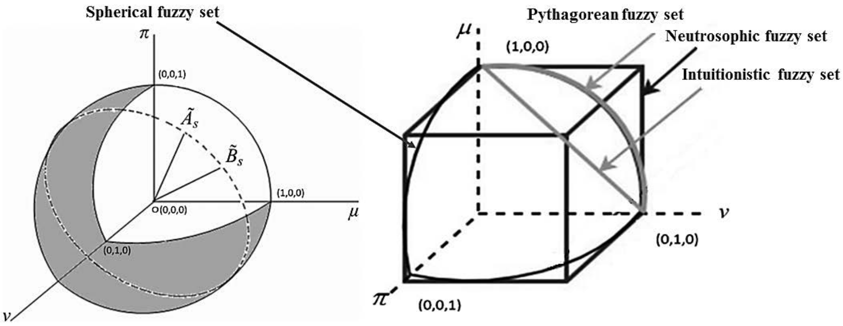

Figure 2 Geometrical interpretation of spherical fuzzy set
Slika 2. Geometrijski prikaz sfernoga neizrazitog skupa

$$\varphi_{\tilde{s}}^{+} = \sqrt{1 - \left(\left(\mu_{\tilde{s}}^{+}(x) \right)^2 + \left(v_{\tilde{s}}^{+}(x) \right)^2 + \left(\pi_{\tilde{s}}^{+}(x) \right)^2 \right)} \quad (2)$$

$$\varphi_{\tilde{s}}^{-} = \sqrt{1 - \left(\left(\mu_{\tilde{s}}^{-}(x) \right)^2 + \left(v_{\tilde{s}}^{-}(x) \right)^2 + \left(\pi_{\tilde{s}}^{-}(x) \right)^2 \right)} \quad (3)$$

The basic algebraic operations on $\tilde{s}_1$ and $\tilde{s}_2$ numbers are elucidated below (Duleba *et al.*, 2021).

$$\tilde{s}_1 \oplus \tilde{s}_2 = \left\{ \begin{array}{c} \left[\begin{array}{c} \left((\mu_1^-)^2 + (\mu_2^-)^2 - (\mu_1^-)^2 (\mu_2^-)^2 \right)^{1/2}, \\ \left((\mu_1^+)^2 + (\mu_2^+)^2 - (\mu_1^+)^2 (\mu_2^+)^2 \right)^{1/2} \end{array} \right], \left[v_1^- v_2^-, v_1^+ v_2^+ \right], \\ \left[\begin{array}{c} \left(\left(1 - (\mu_2^-)^2\right)(\pi_1^-)^2 + \left(1 - (\mu_1^-)^2\right)(\pi_2^-)^2 - (\pi_1^-)^2 (\pi_2^-)^2 \right)^{1/2}, \\ \left(\left(1 - (\mu_2^+)^2\right)(\pi_1^+)^2 + \left(1 - (\mu_1^+)^2\right)(\pi_2^+)^2 - (\pi_1^+)^2 (\pi_2^+)^2 \right)^{1/2} \end{array} \right] \end{array} \right\} \quad (4)$$

$$\tilde{s}_1 \otimes \tilde{s}_2 = \left\{ \begin{array}{c} \left[\mu_1^- \mu_2^-, \mu_1^+ \mu_2^+ \right], \left[\begin{array}{c} \left((v_1^-)^2 + (v_2^-)^2 - (v_1^-)^2 (v_2^-)^2 \right)^{1/2}, \\ \left((v_1^+)^2 + (v_2^+)^2 - (v_1^+)^2 (v_2^+)^2 \right)^{1/2} \end{array} \right], \\ \left[\begin{array}{c} \left(\left(1 - (v_2^-)^2\right)(\pi_1^-)^2 + \left(1 - (v_1^-)^2\right)(\pi_2^-)^2 - (\pi_1^-)^2 (\pi_2^-)^2 \right)^{1/2}, \\ \left(\left(1 - (v_2^+)^2\right)(\pi_1^+)^2 + \left(1 - (v_1^+)^2\right)(\pi_2^+)^2 - (\pi_1^+)^2 (\pi_2^+)^2 \right)^{1/2} \end{array} \right] \end{array} \right\} \quad (5)$$

$$\lambda \cdot \tilde{s} = \left\{ \begin{array}{c} \left[\begin{array}{c} \left(1 - \left(1 - (\mu^-)^2 \right)^{\lambda} \right)^{1/2}, \\ \left(1 - \left(1 - (\mu^+)^2 \right)^{\lambda} \right)^{1/2} \end{array} \right], \left[(v^-)^{\lambda}, (v^+)^{\lambda} \right], \\ \left[\begin{array}{c} \left(\left(1 - (\mu^-)^2 \right)^{\lambda} - \left(1 - (\mu^-)^2 - (\pi^-)^2 \right)^{\lambda} \right)^{1/2}, \\ \left(\left(1 - (\mu^+)^2 \right)^{\lambda} - \left(1 - (\mu^+)^2 - (\pi^+)^2 \right)^{\lambda} \right)^{1/2} \end{array} \right] \end{array} \right\} \quad (6)$$

$$\tilde{s}^{\lambda} = \left\{ \begin{array}{c} \left[(\mu^-)^{\lambda}, (\mu^+)^{\lambda} \right], \left[\begin{array}{c} \left(1 - \left(1 - (v^-)^2 \right)^{\lambda} \right)^{1/2}, \\ \left(1 - \left(1 - (v^+)^2 \right)^{\lambda} \right)^{1/2} \end{array} \right], \\ \left[\begin{array}{c} \left(\left(1 - (v^-)^2 \right)^{\lambda} - \left(1 - (v^-)^2 - (\pi^-)^2 \right)^{\lambda} \right)^{1/2}, \\ \left(\left(1 - (v^+)^2 \right)^{\lambda} - \left(1 - (v^+)^2 - (\pi^+)^2 \right)^{\lambda} \right)^{1/2} \end{array} \right] \end{array} \right\} \quad (7)$$

2.2 Interval-valued spherical fuzzy analytic hierarchy process
2.2. Sferni neizraziti analitički hijerarhijski proces s intervalnim vrijednostima

The AHP method is used to analyze complex decision situations and processes. The procedure of this method starts by structuring any problem in a hierarchal manner. The AHP schema comprises objectives (peak level), criteria (intermediate level), and alternatives (bottom level) (Figure 3) (Singer and Özşahin, 2022).

The elements of the same level are compared by employing a nine-point scale. Decision-makers' judgments are transferred to pairwise comparison matrices. The inconsistency level of each matrix is estimated through consistency indices. Once the performance scores of decision elements are divided by column sums, the row averages of final matrices are taken to obtain weights and priority orders (Ahammed and Azeem, 2013; Özşahin *et al.*, 2019).

The conventional AHP method uses crisp numbers for pairwise comparisons. However, precise scores may be improper or insufficient due to the inevitable uncertainty in the decision-making process. Fuzzy approaches effectively reflect the vagueness of human thinking through a set of possible values (Dožić *et al.*, 2018; Shameem *et al.*, 2020). In this study, the interval-valued spherical fuzzy AHP method is used as a linguistic preference measurement tool. The steps of this method can be expressed as follows (Kutlu Gündoğdu and Kahraman, 2021):

Step 1: Pairwise comparison matrices are created based on the linguistic evaluations of decision-makers using the scale given in Table 1.

$$D = \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & \tilde{a}_{nn} \end{bmatrix} \quad (8)$$

where n refers to the number of criteria and $\tilde{a}_{ij}$ is an interval-valued spherical fuzzy number representing the relative importance between criteria.

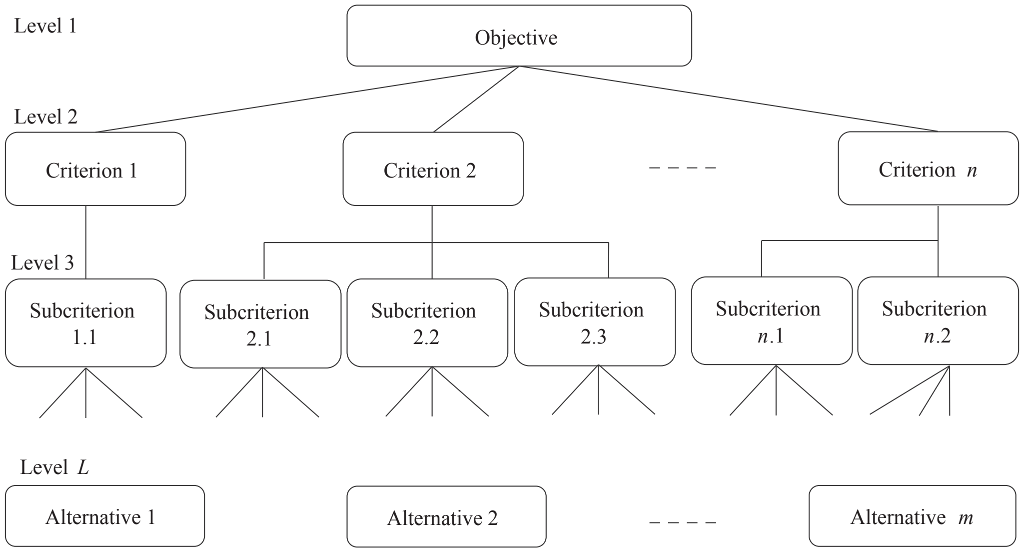

Figure 3 A multilevel decision hierarchy
Slika 3. Hijerarhija višekriterijskog odlučivanja

Table 1 Fuzzy rating scale
Tablica 1. Neizrazita ljestvica ocjenjivanja

Linguistic term *Lingvistički termin*	**Interval-valued spherical fuzzy number** *Sferni neizraziti broj s intervalnim vrijednostima*	**Score index** *Indeks rezultata*
Absolutely more importance (AMI) *apsolutno visoka važnost (AMI)*	([0.85,0.95],[0.10,0.15],[0.05,0.15])	9
Very high importance (VHI) / *vrlo velika važnost (VHI)*	([0.75,0.85],[0.15,0.20],[0.15,0.20])	7
High importance (HI) / *velika važnost (HI)*	([0.65,0.75],[0.20,0.25],[0.20,0.25])	5
Slightly more importance (SMI) / *nešto veća važnost (SMI)*	([0.55,0.65],[0.25,0.30],[0.25,0.30])	3
Equal importance (EI) / *jednaka važnost (EI)*	([0.50,0.55],[0.45,0.55],[0.30,0.40])	1
Slightly low importance (SLI) / *neznatno niža važnost (SLI)*	([0.25,0.30],[0.55,0.65],[0.25,0.30])	1/3
Low importance (LI) / *niska važnost (LI)*	([0.20,0.25],[0.65,0.75],[0.20,0.25])	1/5
Very low importance (VLI) / *vrlo niska važnost (VLI)*	([0.15,0.20],[0.75,0.85],[0.15,0.20])	1/7
Absolutely low importance (ALI) *apsolutno niska važnost (ALI)*	([0.10,0.15],[0.85,0.95],[0.05,0.15])	1/9

Step 2: Score indices are assigned to pairwise comparisons to apply the AHP consistency test. Respondents' judgments are checked using Eq. 9. Consistency ratios under 0.10 indicate that comparison results are acceptable.

$$consistency\,ratio = \frac{\left(\frac{\lambda_{\max} - n}{n-1}\right)}{random\,consistency} \tag{9}$$

Here, $\lambda_{\max}$ is the largest eigenvalue of matrix D and random consistency is the mean consistency index of randomly generated matrices (Stein and Mizzi, 2007). The random consistency values proposed by Saaty (1977) for different values of n can be seen in Table 2.

Step 3: Fuzzy weights are calculated using the following equation:

$$\tilde{w}_i^s = \left\{ \begin{matrix} \left[\begin{matrix} \left(1-\prod_{i=1}^{n}\left(1-(\mu_i^-)^2\right)^{w_i}\right)^{1/2}, \\ \left(1-\prod_{i=1}^{n}\left(1-(\mu_i^+)^2\right)^{w_i}\right)^{1/2} \end{matrix} \right], \left[\prod_{i=1}^{n}(v_i^-)^{w_i}, \prod_{i=1}^{n}(v_i^+)^{w_i}\right], \\ \left[\begin{matrix} \left(\prod_{i=1}^{n}\left(1-(\mu_i^-)^2\right)^{w_i} - \prod_{i=1}^{n}\left(1-(\mu_i^-)^2-(\pi_i^-)^2\right)^{w_i}\right)^{1/2}, \\ \left(\prod_{i=1}^{n}\left(1-(\mu_i^+)^2\right)^{w_i} - \prod_{i=1}^{n}\left(1-(\mu_i^+)^2-(\pi_i^+)^2\right)^{w_i}\right)^{1/2} \end{matrix} \right] \end{matrix} \right\} \tag{10}$$

where $w = 1/n$

Table 2 Random consistency index
Tablica 2. Indeks slučajne konzistencije

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Random consistency value *Indeks slučajne konzistencije*	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Step 4: Fuzzy conclusions are defuzzied according to Eq. 11.

$$S\left(\tilde{w}_i^s\right)=\frac{\left(\mu^-\right)^2+\left(\mu^+\right)^2-\left(v^-\right)^2-\left(v^+\right)^2-\left(\pi^-/2\right)^2-\left(\pi^+/2\right)^2}{2}+1 \quad (11)$$

Step 5: Crisp weights are obtained using Eq. 12.

$$w_i=\frac{S\left(\tilde{w}_i^s\right)}{\sum_{i=1}^{n} S\left(\tilde{w}_i^s\right)} \quad (12)$$

2.3 Decision framework
2.3. Okvir za odlučivanje

In the present study, the key attributes of wooden toys are analyzed by employing an expert knowledge-based decision-making approach. The research methodology comprises three main stages. In the first stage, the most important criteria are identified based on literature research and expert interviews. Then an interval-valued spherical fuzzy AHP-based model is devised to obtain weight vectors. In the last stage, the prioritization procedure is initiated to determine the importance of each criterion. The steps of this study are shown in Figure 4.

The expert team is comprised of practitioners and academicians in Turkey. The experts are selected by considering their experience, knowledge, and published record on the research topic. Several criteria are discovered from the literature (Fallon and Harris, 1989; Duracell, 2005; Al Kurdi, 2017; Scherer *et al.*, 2017; Mercan, 2018; Richards *et al.*, 2020; Mai, 2021). The list of criteria is refined and expanded by the experts. The hierarchy is structured with one objective, five main criteria, and twenty subcriteria. The hierarchical structure of the problem is portrayed in Figure 5. The objective of the decision-making process is elucidated at the top level of the hierarchy, while the main criteria and their subcriteria are listed at the middle and bottom levels, respectively.

The main criteria of the problem are "economic properties", "developmental supports", "quality properties", "safety properties", and "functional properties". The subcriteria of "economic properties" are identified as "affordability", "longevity", "minimum coating requirement", and "product origin". The subcriteria of "developmental supports" are determined as "contribution to cognitive development", "contribution to psychomotor development", "contribution to social-

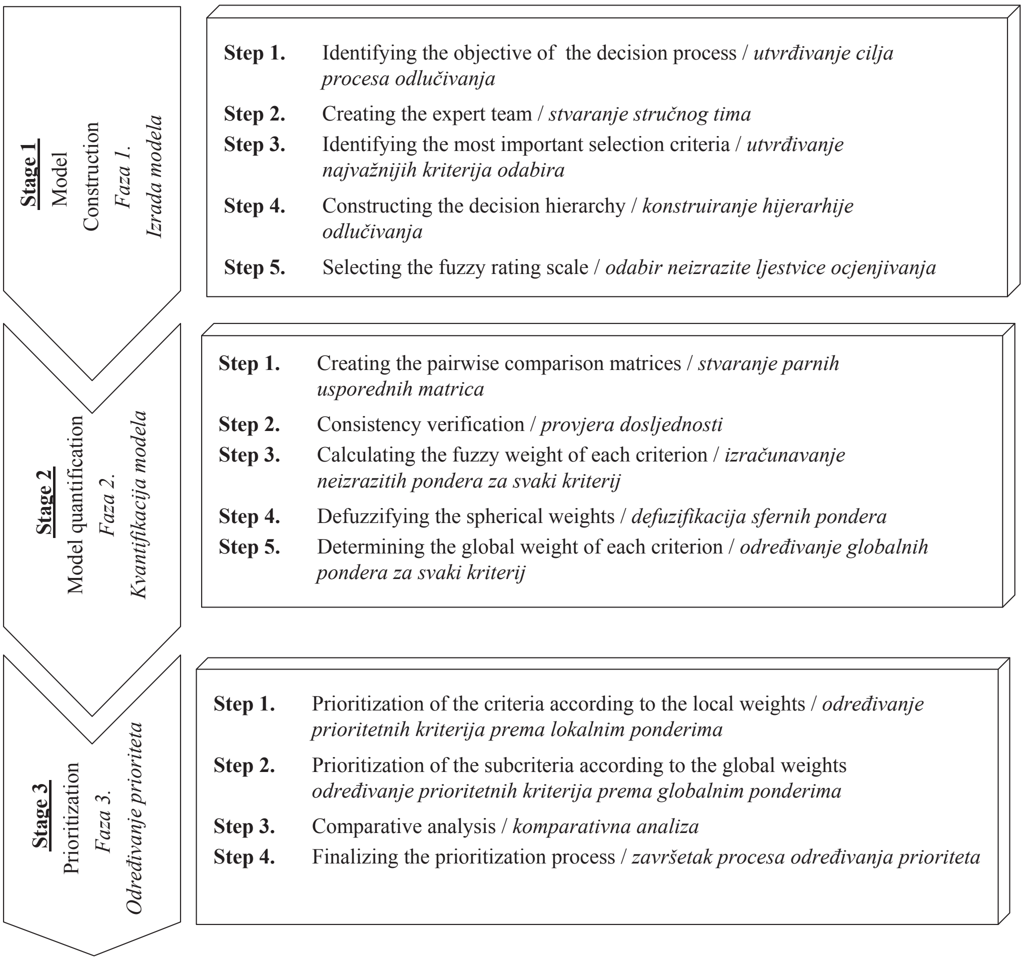

Figure 4 Steps of this study
Slika 4. Koraci u ovom istraživanju

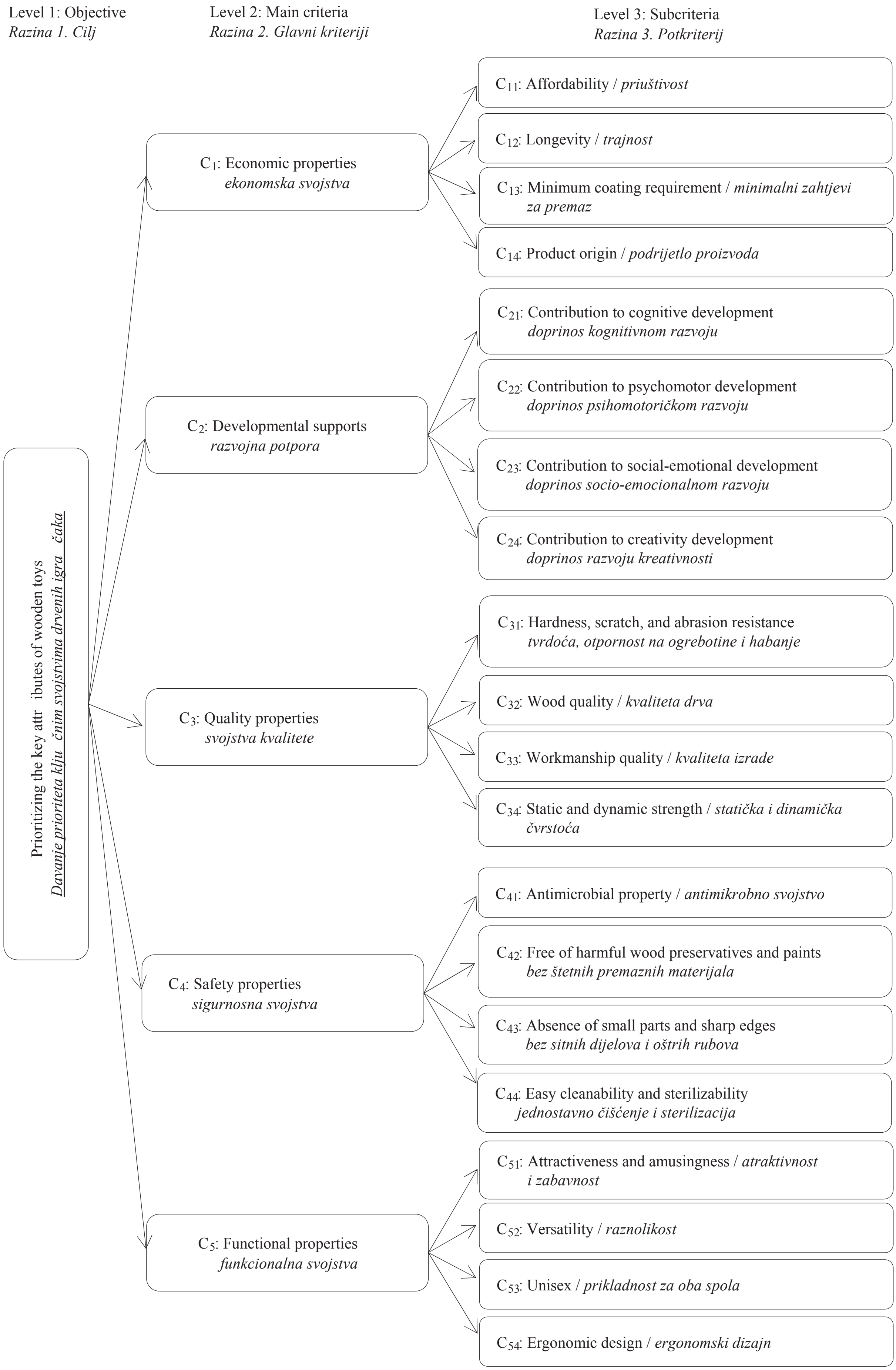

Figure 5 Hierarchical structure of the problem
Slika 5. Hijerarhijska struktura problema

emotional development", and "contribution to creativity development". The subcriteria of "quality properties" are defined as "hardness, scratch, and abrasion resistance", "wood quality", "workmanship quality", and "static and dynamic strength". The subcriteria of "safety properties" are identified as "antimicrobial property", "free of harmful wood preservatives and paints", "absence of small parts and sharp edges", and "easy cleanability and sterilizability". Lastly, the subcriteria of "functional properties" are determined as "attractiveness and amusingness", "versatility", "unisex", and "ergonomic design".

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

The experts are requested to express their preference between every pair of criteria. The fuzzy AHP questionnaires are filled out according to the verbal labels given in Table 1. The consensus-building process is applied to execute collaborative decision-making. The experts' responses are compiled, and then the second round of questionnaires is initiated. After three rounds of opinion consolidation, the experts' final consensus is received. The linguistic preferences are converted to the corresponding interval-valued spherical fuzzy numbers. The main criteria are compared with respect to the objective, while the subcriteria are evaluated against the relevant main criterion. After the pairwise comparison matrices are determined to be consistent, the interval-valued spherical fuzzy AHP is applied to weight the criteria. The matrices used to determine the priorities of the criteria are presented in Tables 3-8.

As an example, the priority calculation of "economic properties" will be elucidated. The fuzzy weight of this criterion is computed as follows:

$$\mu=\begin{bmatrix}\sqrt{1-\left(\left(1-0.50^2\right)^{0.2}\right)\times\left(\left(1-0.20^2\right)^{0.2}\right)\times\left(\left(1-0.25^2\right)^{0.2}\right)\times\left(\left(1-0.15^2\right)^{0.2}\right)\times\left(\left(1-0.25^2\right)^{0.2}\right.}\,,\\ \sqrt{1-\left(\left(1-0.55^2\right)^{0.2}\right)\times\left(\left(1-0.25^2\right)^{0.2}\right)\times\left(\left(1-0.30^2\right)^{0.2}\right)\times\left(\left(1-0.20^2\right)^{0.2}\right)\times\left(\left(1-0.30^2\right)^{0.2}\right.}\end{bmatrix}$$

$$=\left[0.30,0.35\right]$$

$$v=\begin{bmatrix}\left(0.45^{0.2}\times0.65^{0.2}\times0.55^{0.2}\times0.75^{0.2}\times0.55^{0.2}\right),\\ \left(0.55^{0.2}\times0.75^{0.2}\times0.65^{0.2}\times0.85^{0.2}\times0.65^{0.2}\right)\end{bmatrix}=\left[0.58,0.68\right]$$

$$\pi=\begin{bmatrix}\sqrt{\begin{matrix}\left(\left(1-0.50^2\right)^{0.2}\right)\times\left(\left(1-0.20^2\right)^{0.2}\right)\times\left(\left(1-0.25^2\right)^{0.2}\right)\times\left(\left(1-0.15^2\right)^{0.2}\right)\\ \times\left(\left(1-0.25^2\right)^{0.2}\right)-\left(\left(1-0.50^2-0.30^2\right)^{0.2}\right)\times\left(\left(1-0.20^2-0.20^2\right)^{0.2}\right)\times\\ \left(\left(1-0.25^2-0.25^2\right)^{0.2}\right)\times\left(\left(1-0.15^2-0.15^2\right)^{0.2}\right)\times\left(\left(1-0.25^2-0.25^2\right)^{0.2}\right)\end{matrix}}\,,\\ \sqrt{\begin{matrix}\left(\left(1-0.55^2\right)^{0.2}\right)\times\left(\left(1-0.25^2\right)^{0.2}\right)\times\left(\left(1-0.30^2\right)^{0.2}\right)\times\left(\left(1-0.20^2\right)^{0.2}\right)\\ \times\left(\left(1-0.30^2\right)^{0.2}\right)-\left(\left(1-0.55^2-0.40^2\right)^{0.2}\right)\times\left(\left(1-0.25^2-0.25^2\right)^{0.2}\right)\times\\ \left(\left(1-0.30^2-0.30^2\right)^{0.2}\right)\times\left(\left(1-0.20^2-0.20^2\right)^{0.2}\right)\times\left(\left(1-0.30^2-0.30^2\right)^{0.2}\right)\end{matrix}}\end{bmatrix}$$

$$=\left[0.24,0.31\right]$$

Table 3 Comparison matrix for the main criteria
Tablica 3. Matrica usporedbe za glavne kriterije

Criterion / *Kriterij*	C_1	C_2	C_3	C_4	C_5	$\tilde{w}^s$	$S(\tilde{w}^s)$	w
C_1	EI	LI	SLI	VLI	SLI	([0.30, 0.35], [0.58, 0.68], [0.24, 0.31])	0.69	0.132
C_2		EI	EI	SLI	SMI	([0.52, 0.60], [0.35, 0.43], [0.26, 0.33])	1.13	0.218
C_3			EI	LI	SMI	([0.48, 0.56], [0.38, 0.46], [0.27, 0.34])	1.07	0.206
C_4				EI	VHI	([0.66, 0.76], [0.22, 0.28], [0.21, 0.26])	1.43	0.275
C_5					EI	([0.38, 0.45], [0.48, 0.57], [0.25, 0.32])	0.88	0.169

Table 4 Comparison matrix for "economic properties"
Tablica 4. Matrica usporedbe za kategoriju „ekonomska svojstva"

Criterion / *Kriterij*	C_{11}	C_{12}	C_{13}	C_{14}	$\tilde{w}^s$	$S(\tilde{w}^s)$	w
C_{11}	EI	SMI	HI	SLI	([0.52, 0.61], [0.33, 0.40], [0.25, 0.32])	1.16	0.282
C_{12}		EI	SMI	LI	([0.41, 0.48], [0.45, 0.53], [0.26, 0.33])	0.94	0.228
C_{13}			EI	LI	([0.32, 0.37], [0.57, 0.67], [0.25, 0.32])	0.71	0.173
C_{14}				EI	([0.59, 0.69], [0.26, 0.32], [0.24, 0.30])	1.31	0.318

Table 5 Comparison matrix for "developmental supports"
Tablica 5. Matrica usporedbe za kategoriju „razvojna potpora"

Criterion / *Kriterij*	C_{21}	C_{22}	C_{23}	C_{24}	$\tilde{w}^s$	$S(\tilde{w}^s)$	w
C_{21}	EI	SLI	HI	SMI	([0.52, 0.61], [0.33, 0.40], [0.25, 0.32])	1.16	0.283
C_{22}		EI	HI	SMI	([0.57, 0.66], [0.27, 0.33], [0.25, 0.31])	1.27	0.309
C_{23}			EI	SLI	([0.32, 0.37], [0.57, 0.67], [0.25, 0.32])	0.71	0.174
C_{24}				EI	([0.42, 0.49], [0.43, 0.51], [0.27, 0.33])	0.96	0.234

Table 6 Comparison matrix for "quality properties"
Tablica 6. Matrica usporedbe za kategoriju „svojstva kvalitete"

Criterion / *Kriterij*	C_{31}	C_{32}	C_{33}	C_{34}	$\tilde{w}^s$	$S(\tilde{w}^s)$	w
C_{31}	EI	LI	VLI	LI	([0.31, 0.35], [0.61, 0.72], [0.23, 0.30])	0.65	0.154
C_{32}		EI	SLI	SMI	([0.52, 0.61], [0.33, 0.40], [0.25, 0.32])	1.16	0.277
C_{33}			EI	HI	([0.63, 0.73], [0.24, 0.30], [0.22, 0.28])	1.37	0.328
C_{34}				EI	([0.46, 0.53], [0.42, 0.51], [0.24, 0.31])	1.01	0.241

Table 7 Comparison matrix for "safety properties"
Tablica 7. Matrica usporedbe za kategoriju „sigurnosna svojstva"

Criterion / *Kriterij*	C_{41}	C_{42}	C_{43}	C_{44}	$\tilde{w}^s$	$S(\tilde{w}^s)$	w
C_{41}	EI	LI	VLI	EI	([0.38, 0.43], [0.56, 0.66], [0.26, 0.34])	0.77	0.184
C_{42}		EI	SLI	HI	([0.55, 0.64], [0.32, 0.39], [0.24, 0.30])	1.21	0.291
C_{43}			EI	VHI	([0.66, 0.76], [0.22, 0.29], [0.21, 0.27])	1.43	0.342
C_{44}				EI	([0.38, 0.43], [0.56, 0.66], [0.26, 0.34])	0.77	0.184

Table 8 Comparison matrix for "functional properties"
Tablica 8. Matrica usporedbe za kategoriju „funkcionalna svojstva"

Criterion / *Kriterij*	C_{51}	C_{52}	C_{53}	C_{54}	$\tilde{w}^s$	$S(\tilde{w}^s)$	w
C_{51}	EI	SMI	HI	SLI	([0.52, 0.61], [0.33, 0.40], [0.25, 0.32])	1.16	0.285
C_{52}		EI	EI	SLI	([0.40, 0.45], [0.50, 0.60], [0.28, 0.36])	0.85	0.209
C_{53}			EI	LI	([0.39, 0.44], [0.54, 0.64], [0.26, 0.35])	0.79	0.195
C_{54}				EI	([0.57, 0.66], [0.27, 0.33], [0.25, 0.31])	1.27	0.311

The defuzzfied value of ([0.30, 0.35], [0.58, 0.68], [0.24, 0.31]) is obtained as below.

$$S=\frac{(0.30)^2+(0.35)^2-(0.58)^2-(0.68)^2-(0.24/2)^2-(0.31/2)^2}{2}+1=0.69$$

After the normalization operation is applied to the resulting weight vector, the crisp weight of "economic properties" is revealed as 0.132. As can be seen in Figure 6, the sequence of the main criteria is "safety properties" (0.275) > "developmental supports" (0.218) > "quality properties" (0.206) > "functional properties" (0.169) > "economic properties" (0.132). The obtained ranking result indicates that "safety properties" deserves the highest priority in wooden toy selection.

The crisp weights obtained from the pairwise comparison matrix of "economic properties" are presented in Figure 7. The subcriterion "product origin" (0.318) has the highest weight value and is prioritized

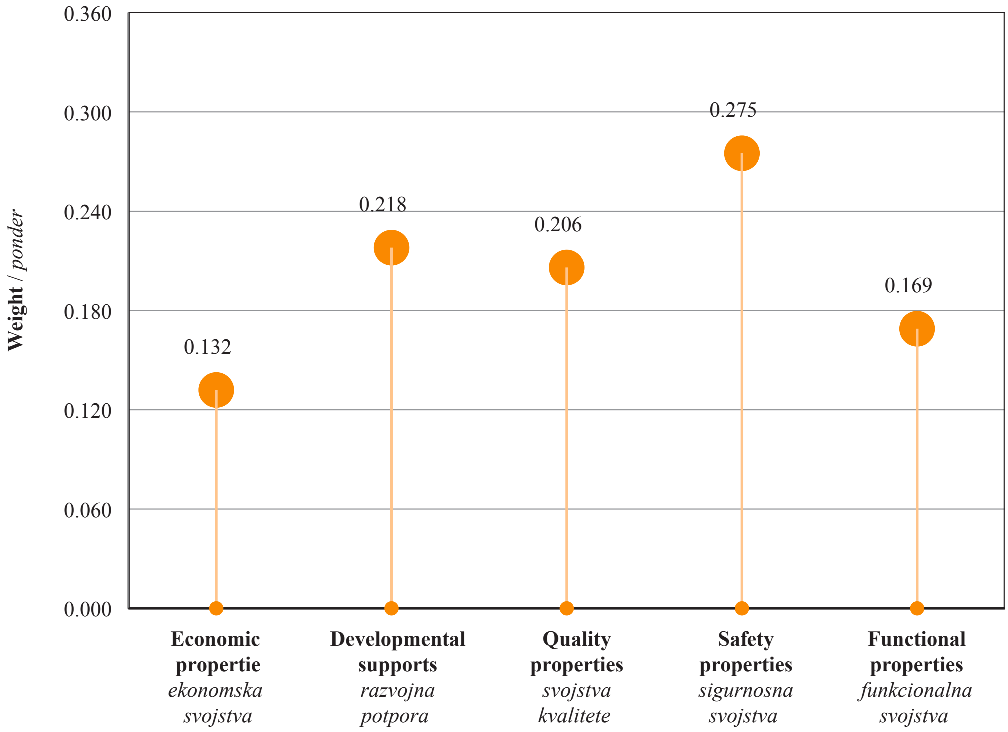

Figure 6 Modeling results for the main criteria
Slika 6. Rezultati modeliranja za glavne kriterije

as the most important one. Many consumers regard this criterion as a sign of product reliability (Kaynak *et al.*, 2000). Hence, consumer perceptions and purchase likelihood are significantly influenced by the origin of toys. The criteria "affordability" (0.282) and "longevity" (0.228) come in second and third, respectively, while "minimum coating requirement" (0.173) emerges as the least important subcriterion.

Figure 8 demonstrates the weight distribution of the subcriteria within the "developmental supports" category. The most important subcriterion of this category is "contribution to psychomotor development"

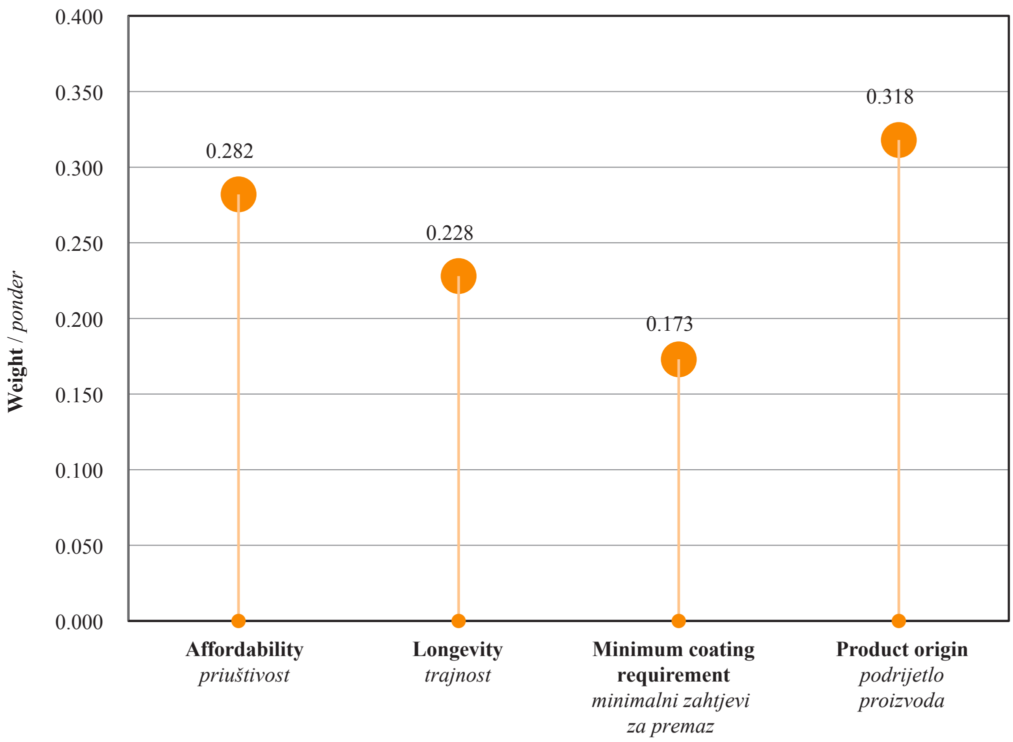

Figure 7 Modeling results for "economic properties"
Slika 7. Rezultati modeliranja za kategoriju „ekonomska svojstva"

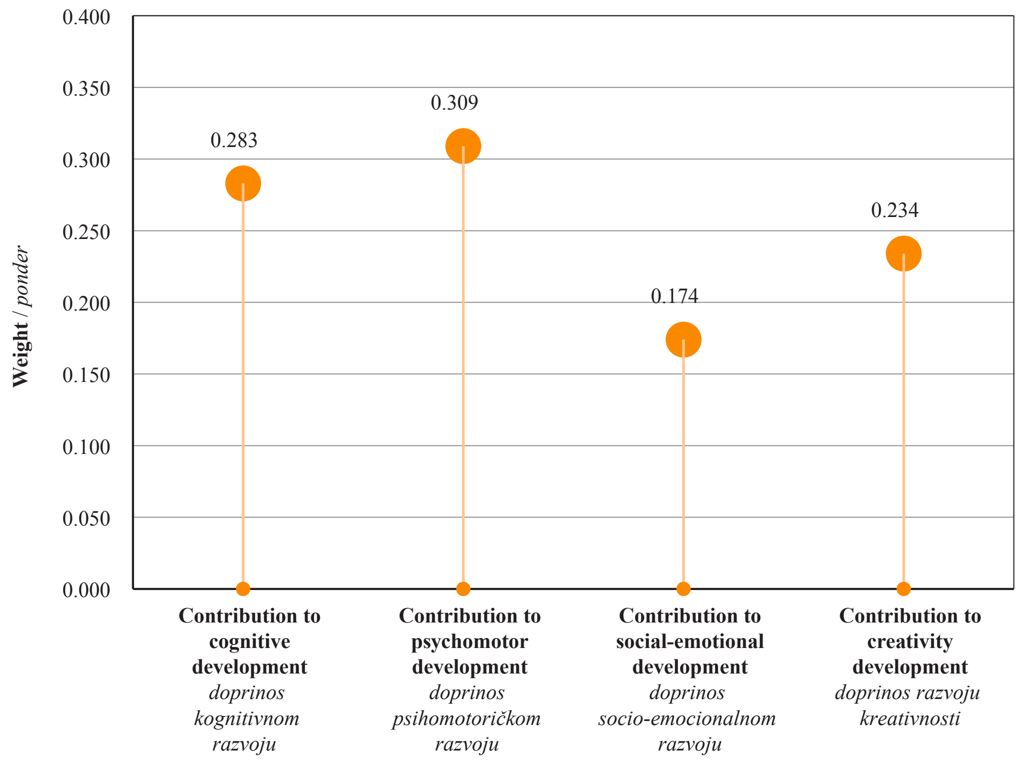

Figure 8 Modeling results for "developmental supports"
Slika 8. Rezultati modeliranja za kategoriju „razvojna potpora"

(0.309). The expert team has highlighted that children playing with wooden toys can learn to control their muscles in the psychomotor aspect and their movements can acquire agility, strength, and speed. The second important subcriterion is "contribution to cognitive development" (0.283). The subcriterion "contribution to creativity development" (0.234) is positioned at the third rank, while "contribution to social-emotional development" (0.174) is at the end of the local priority list.

When the weights in Figure 9 are ranked in descending order, it is observed that "workmanship quality" (0.328) is the most considerable subcriterion within the "quality properties" category. Poor quality can

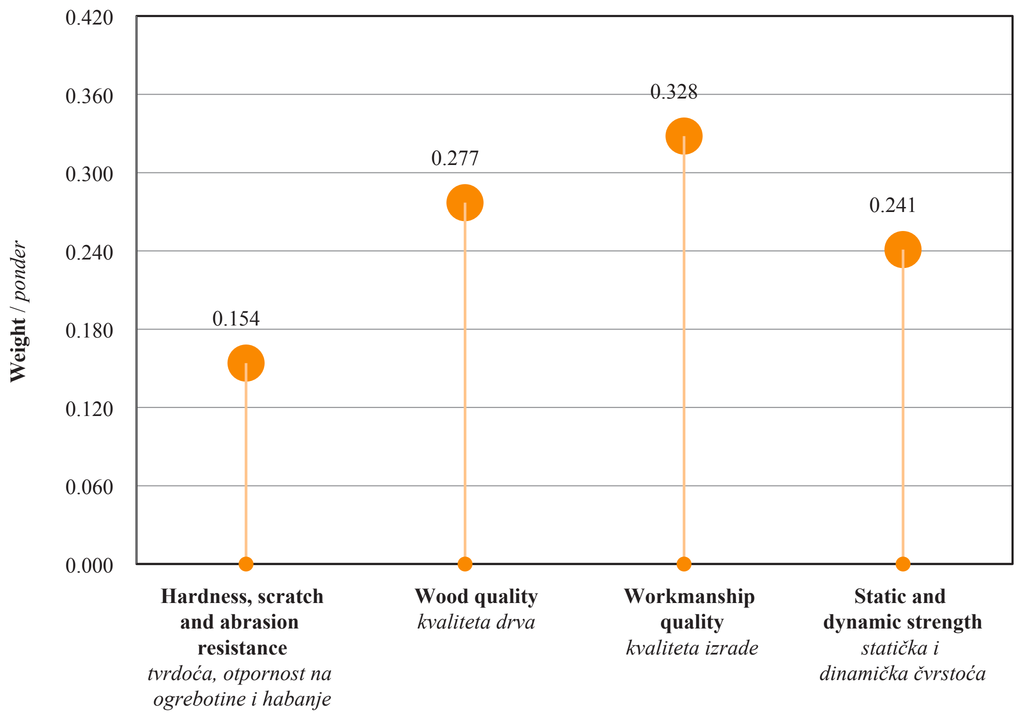

Figure 9 Modeling results for "quality properties"
Slika 9. Rezultati modeliranja za kategoriju „svojstva kvalitete"

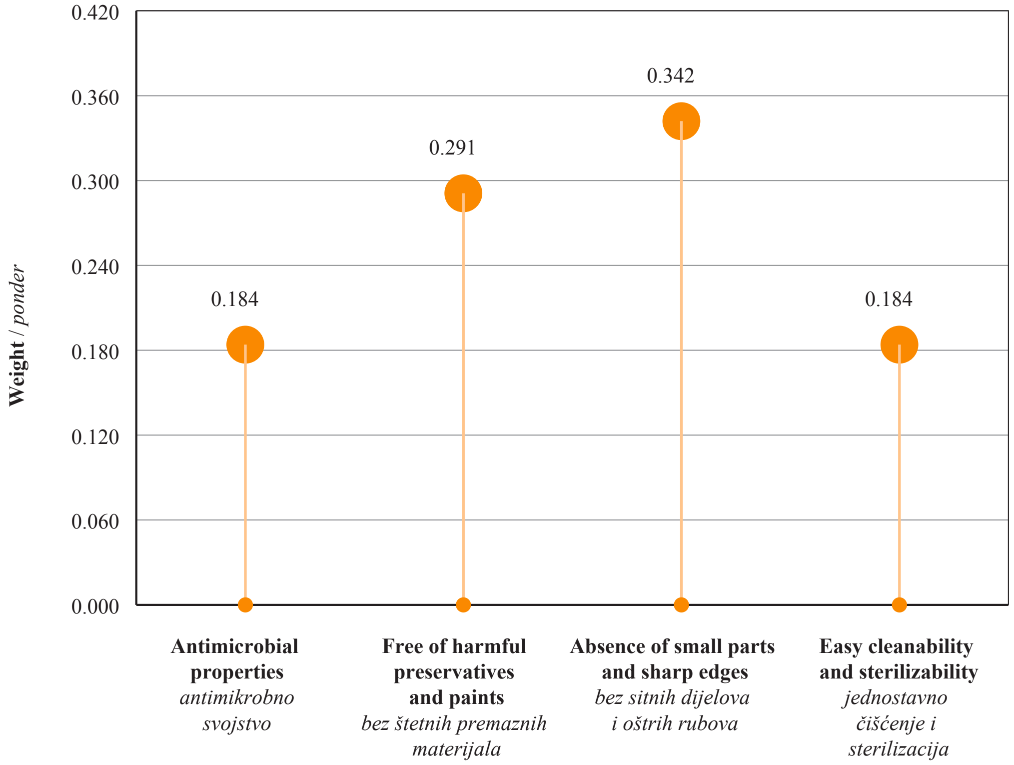

Figure 10 Modeling results for "safety properties"
Slika 10. Rezultati modeliranja za kategoriju „sigurnosna svojstva"

cause permanent or latent product failures and negatively affect the appearance of products (Azemovic *et al*., 2014). The subcriteria "wood quality" (0.277) and "static and dynamic strength" (0.241) obtain the second and third ranks, respectively. The least significant subcriterion appears to be "hardness, scratch, and abrasion resistance" (0.154).

The modeling results for the "safety properties" category are presented in Figure 10. The priority order of the subcriteria of this category is as follows: "ab-

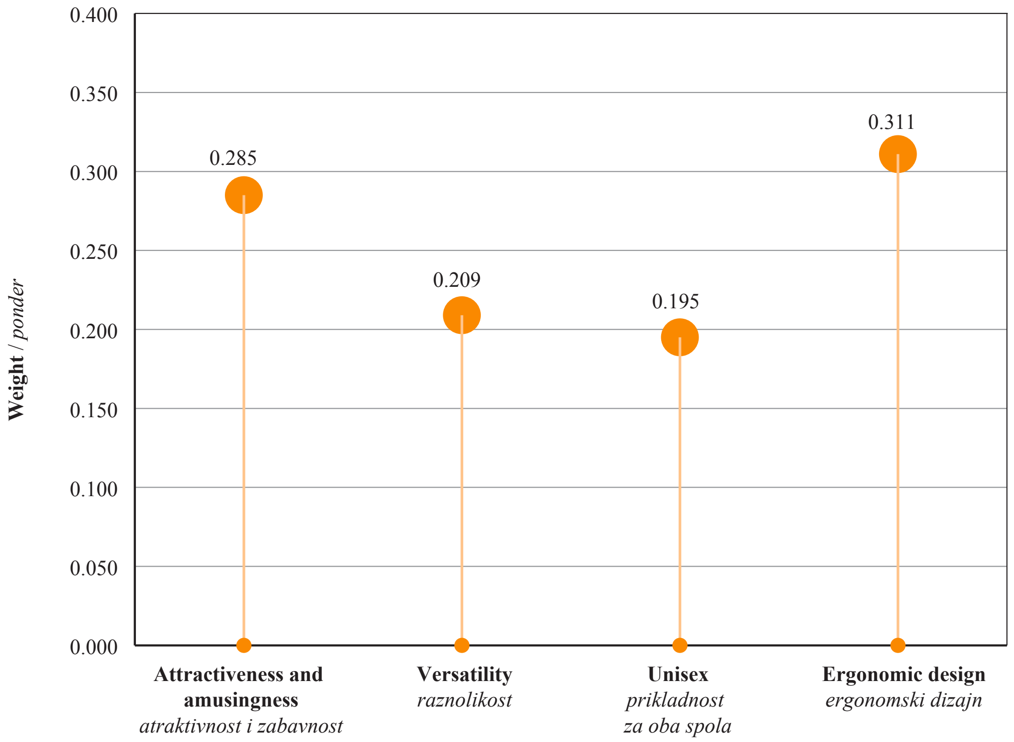

Figure 11 Modeling results for "functional properties"
Slika 11. Rezultati modeliranja za kategoriju „funkcionalna svojstva"

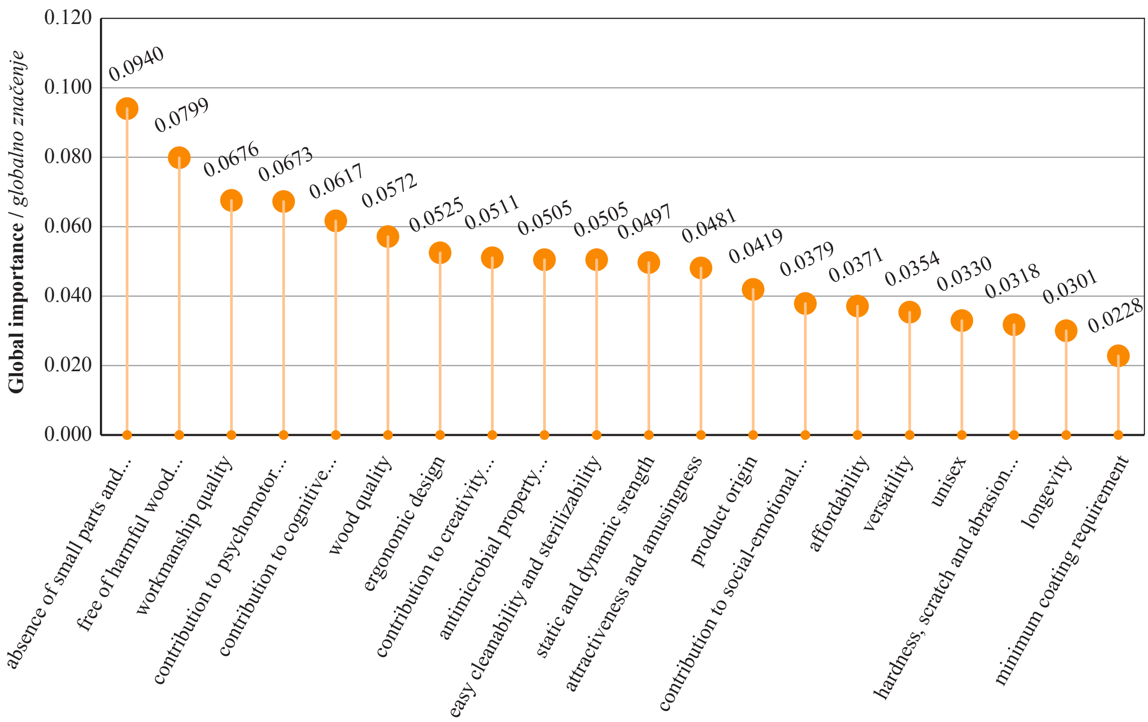

Figure 12 Global importance of subcriteria
Slika 12. Globalno značenje potkriterija

sence of small parts and sharp edges" (0.342) > "free of harmful wood preservatives and paints" (0.291) > "antimicrobial property" (0.184) = "easy cleanability and sterilizability" (0.184). The ranking result means that the experts give more importance to "absence of small parts and sharp edges" than to others. Some toys can be dangerous. Hence, alternatives should be carefully evaluated and then ranked from safest to least safe.

According to Figure 11, "ergonomic design" (0.311) is the most important subcriterion within the "functional properties" category. Good ergonomic design improves product usability and user satisfaction. It ensures that children can utilize toys correctly without causing harm to themselves. The criterion "attractiveness and amusingness" (0.285) has the second-highest weight value, while "versatility" (0.209) is the third-highest weighted subcriterion.

The local weights derived from the comparison matrices are multiplied to reveal the global importance of the subcriteria. Figure 12 demonstrates the global priority for each subcriterion. The top five subcriteria and their global weight are as follows: {absence of small parts and sharp edges, 0.0940}, {free of harmful wood preservatives and paints, 0.0799}, {workmanship quality, 0.0676}, {contribution to psychomotor development, 0.0673}, and {contribution to cognitive development, 0.0617}. Decision-makers should focus primarily on these subcriteria in evaluating different wooden toys.

The reliability and accuracy of decision-making models are generally examined by conducting a comparative analysis. Hence, the data gathered from the experts are tested by three popular fuzzy methods: interval type-2 fuzzy AHP, interval-valued Pythagorean fuzzy AHP, and spherical fuzzy AHP. Figure 13 demonstrates the changes in the global weights of the subcriteria. As can be seen in the figure, "absence of small parts and sharp edges", "free of harmful wood preservatives and paints", "workmanship quality", "contribution to psychomotor development", and "contribution to cognitive development" hold the top five ranks. The weights assigned to the criteria by the methods are not the same; however, the ranking position of the criteria mostly remains the same. The applied methods consider different assumptions and scales. Hence, the differences in the results can be attributed to these factors. The interval-valued spherical fuzzy AHP is a more recent method that considers membership, non-membership, and hesitancy at the same time, and provides a more comprehensive range of membership function definitions. Consequently, the decision framework has strong robustness and feasibility.

The decision-making process associated with choosing wooden toys is complex due to the uncertainty, subjectivity, and conflicting factors. Decision-makers are confronted with many alternatives, which should be evaluated and compared initially. Hence, the identification and prioritization of selection criteria are essential. As pointed out previously, there is no information on the usage of the MCDM technique to specify and analyze the key attributes of wooden toys. Hence, this study provides a novel, comprehensive,

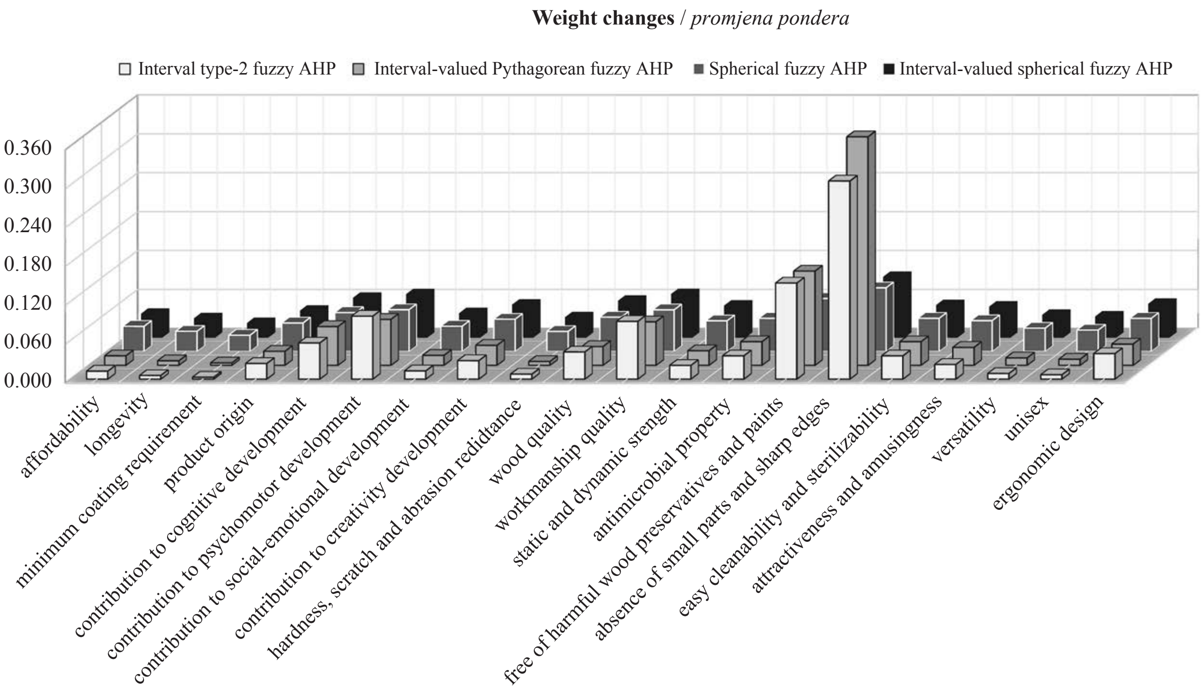

Figure 13 Comparison of different fuzzy AHP outputs
Slika 13. Usporedba različitih neizrazitih izlaznih vrijednosti AHP-a

and valuable guide to assist consumers, designers, and manufacturers in determining the best options.

4 CONCLUSIONS
4. ZAKLJUČAK

This study identifies and prioritizes the key attributes of wooden toys from experts' perspectives. A review of the relevant academic literature and expert interviews are conducted to identify decision criteria. At the end of this process, twenty subcriteria are finalized under five main criteria. A three-level hierarchical model is devised for the prioritization purpose. The required data is gathered from experts who have experience with the research topic. The main criteria and subcriteria used in the study are assigned weights by employing an interval-valued spherical fuzzy AHP approach. According to the modeling results, the most significant main criterion is "safety properties" (27.5 %). The overall priority results demonstrate that "absence of small parts and sharp edges" (9.40 %), "free of harmful wood preservatives and paints" (7.99 %), "workmanship quality" (6.76 %), "contribution to psychomotor development", and "contribution to cognitive development" (6.17%) deserve a higher priority in the decision-making process.

Our research endeavor is different from the previous studies. The originality and value of this paper can be elucidated as follows: (i) identification, classification, and prioritization of the key attributes of wooden toys for the first time; (ii) comprehensive and quantitative analysis of selection criteria; (iii) consideration of uncertainties and hesitations for solving the problem; (iv) examination of the problem from experts' perspectives; (v) first implementation of the interval-valued spherical fuzzy set in the field of wood science. In this research, it is assumed that wooden toy selection criteria are mutually exclusive. Further research may apply the fuzzy cognitive map to examine the interdependency among these criteria. Consumers' preferences can be examined under the fuzzy MCDM environment. The performance of different options can be rated under the criteria to rank them from the best to the worst or to sort them into predefined ordered classes.

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