ITC 3/51
Information Technology and Control
Vol. 51 / No. 3 / 2022
pp. 467-484
DOI 10.5755/j01.itc.51.3.30525

Browser Selection for Android Smartphones Using Novel Fuzzy Hybrid Multi Criteria Decision Making Technique

Received 2022/01/18 | Accepted after revision 2022/07/06

http://dx.doi.org/10.5755/j01.itc.51.3.30525

**HOW TO CITE:** Arunagiri, R., Pandian, P., Krishnasamy, V., Sivaprakasam, R. (2022). Browser Selection for Android Smartphones Using Novel Fuzzy Hybrid Multi Criteria Decision Making Technique. *Information Technology and Control*, 51(3), 467-484. http://dx.doi.org/10.5755/j01.itc.51.3.30525

# Browser Selection for Android Smartphones Using Novel Fuzzy Hybrid Multi Criteria Decision Making Technique

**Ramathilagam Arunagiri, Pitchipoo Pandian, Valarmathi Krishnasamy**
P.S.R Engineering College, Sivakasi – 626140, Tamil Nadu, India;
e-mails: thilla2012@gmail.com; drpitchipoo@gmail.com, valarmathi@psr.edu.in

**Rajakarunakaran Sivaprakasam**
Ramco Institute of Technology, Rajapalayam – 626117, Tamil Nadu, India;
e-mail: srajakarunakaran@yahoo.com

**Corresponding author:** thilla2012@gmail.com

IT and Telecommunication sector has grown massively over the past few decades. Mobile phones that were initially developed for making calls and now become an essential item and are just not restricted to calling. They have dominated most of the gadgets like computers, cameras, etc. Regularly people come across an extensive number of enhanced and better-quality features being built-in with them. A variety of mobile phones with different shapes and sizes are manufactured within a wide range of budgets. This is the key motivation behind an exponential growth in the number of users and the arrival of new manufacturers in the field. Along with this growth, there is a fast growth of mobile application software providers also. Apart from calling, many consumers use smartphones for browsing the internet. This puts users into a dilemma to select a better browser for their smartphone to fulfill their requirements. With this aim, an attempt is made in this paper for the evaluation and selection of a better browser. To achieve this, a hybrid Multi Criteria Decision Making (MCDM) approach is proposed by combining Analytical Hierarchy Process (AHP), COPRAS (Complex Proportional Assessment of alternatives) technique and Fuzzy Analytical Hierarchy Process (FAHP).

**KEYWORDS:** Browser Selection, Multi Criteria Decision Making, AHP, COPRAS, FAHP.

## 1. Introduction

There are speedy and noteworthy developments in communication and information technologies in the recent 20 years. In parallel with these developments, the usage of mobile phones has increased exponentially in a short span. In earlier days, mobile phones were used only for making calls as an alternative to telephones and telegram. After the launch of smartphones, nowadays they can be used as a replacement for many gadgets like digital cameras, computers, and used for many applications using mobile application software. Thus, the importance of smartphones has been increased [2]. Smartphones are enhancing the experience of mobile internet users to access the internet from anywhere. The software providers have introduced continuously a number of new mobile applications with many features. People who are using smartphones have difficulties in selecting the better mobile browser application among the numerous browsers available. Therefore, mobile browser application selection has become a complex multi-criterion decision-making (MCDM) problem. Several criteria such as the number of downloads, the number of reviews given by the users, user rating, latest upgradation available, memory requirement to load no page and five pages, date/year of launch, disc space needed, time to open a new tap, and the URL loading time are influencing the selection of browser [12, 18]. Actually, the decision making on software evaluation and selection is a very complex, expensive and time consuming issue in an organization [10].

Several techniques were used by several researchers. Grey Relational Analysis (GRA) is an effective tool to deal with limited data in quantitative form only [24]. Even though AHP is able to handle problems with qualitative and quantitative criteria in the same decision framework, it is not suitable to address the problem with uncertainty [11]. PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) method [1], MAIRCA (Multi Attributive Ideal-Real Comparative Analysis) methodology [6], VIKOR (VIekriterijumsko KOmpromisno Rangiranje) approach [26], EDAS (Evaluation Based on Distance from Average Solution) technique [27], ELECTRE (Elimination ET Choix Traduisant La Realite) method [36], MARCOS (Measurement of Alternatives and Ranking According to the Compromise Solution) Method [40] and MABAC (Multi-Attributive Border Approximation Area Comparison) technique [43] are able to use the criteria in their own units and can be easily programmable. However, they are not suitable to evaluate vague and uncertain data. To overcome the drawbacks of these models, in this research work FAHP integrated COPRAS methodology is proposed. The Best-Worst Method (BWM) [23] considerably increases the overall consistency, this technique has few disadvantages such as more computational time and not suitable to solve the vagueness in human opinions and uncertainty in the information related to the criteria. In the Full Consistency Method (FUCOM) model [28], there is a subjective influence of the decision maker on the final values of the weight of the criteria. This particularly refers to the personal preferences of the decision makers. FUCOM has shown significantly fewer variations in the obtained values of the weight coefficients. It leads to confusion. Level-Based Weight Assessment (LBWA) model [46] allows for the calculation of weight coefficients with a minimum number of criteria in pairwise comparison only. Hence FAHP was chosen to determine the criteria weights.

## 2. Related Works

Sen et al. [37] presented a thorough review of literature on software selection focused on ERP (Enterprise Resource Planning) application and the classification of ERP software selection methodologies during the period 1982–2007. Additionally, the classification of the selected approaches based on functional perspective is also presented. The review results are summarized and were intended as a source for software selection problems. Tsai et al. [41] have surveyed the selection of ERP software packages and its supplier in Taiwan industries. The survey was performed in 5,000 largest corporations between 2003 and 2006. The dominating criteria for the selection of ERP software were identified and listed. In addition, the selection criteria for the ERP supplier were also discussed. Shee et al. [38] have developed a decision model to appraise the information service providers located in Taiwan using AHP and fuzzy integral approaches. Accounting software selection based on the perceptions of 43 accounting software dealers and 57 accounting software customers was presented by Ivancevich et al. [20]. The strategic areas of agreement and disagreement between those groups were also identified. The evaluation of the software was done based on the agreement factors and disagreement factors using different weightage. The key areas where dealers and customers contrast in their insights were addressed to bridge the gap between their requirements.

Neutrosophic AHP, an improved AHP was used to prioritize the factors influencing third party logistics (3PL) service providers [21]. A typical case study was also demonstrated by using the proposed model. Farshidi et al. [15] have developed a decision support system for selecting the best appropriate database technology. It was proved that the insight of selection process has been increased through case studies and the experts confirmed the same. The selection process was modelled as an MCDM problem with the following stages such as identification of the objective, selection of the factors and alternatives, choosing the weighing method, solution through MCDM method and final decision making. The solution is obtained by the total cost of ownership (TCO) method. Hanafizadeh and Ravasan [19] have proposed a model for selecting an IT outsourcing strategy for e-banking channels. 23 factors were identified and analyzed. Finally, 17 were chosen as influencing factors for outsourcing decisions in e-banking using Fuzzy integrated TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method.

Çalişkan et al. [10] have presented a decision model for a chemical industry. The model was utilized to evaluate the software used to detect the explosion, fire and toxic emission of hazardous chemicals. Initially, through a well-defined questionnaire, the views of Environmental Health and Safety (EHS) experts were collected based on the Likert scale. Then AHP was introduced to analyze the collected data and the weights of the criteria were determined. The final ranks of the software were obtained by using PROMETHEE method. Cricelli et al. [13] introduced a four-step technique to help the decision makers to select the CRM software package. To address the conflicting objective AHP with its fuzzy adaptation was recommended. The outcome of the article was validated in a small scale industry in Italy.

Czekster et al. [14] have selected ERP software using AHP. The evaluation criteria such as procurement and maintenance costs, ERP reputation and positions, level of after sales support, deployment involvement, ERP's feature set, usability, efficiency, consistency, and maintainability were considered. Fumagalli et al. [17] have developed an MCDM model to select suitable simulation software for small and mid-size enterprises (SMEs). AHP was proposed since many criteria influenced the decision. Cai et al. [8] derived a model to forecast the software defects using hybrid cuckoo search and support vector machine (SVM) technique. The results are compared with eight prediction models available in the literature. The evaluation was done based on several influencing factors such as development interfaces, graphics interfaces, multi-media data support, data file support, cost effectiveness and vendor support. Pandey and Litoriya [30] have provided a process selection structure for the selection of software that is compatible with mobile, web and /or desktop. This problem was modelled as MCDM problem and solved using AHP. This proposed model was validated through 20 software projects. Khan et al. [22] classified the challenging factors used in the software selection process faced by vendors. These classifications were made on the data collected through an organized literature survey and the use of AHP. 18 factors were identified through the literature survey and categorized into five classes namely capability, delivery, reliability, management, and distinction. Puzovic et al. [34] presented a hybrid multi-criteria decision-making (MCDM) model for the selection of Product Lifecycle Management (PLM) software. This hybrid MCDM was developed by integrating FAHP and PROMETHEE. The FAHP was applied to address the problem of the ambiguity of decision-makers' decisions and the PROMETHEE method was applied to evaluate the software. Integrated FAHP and Grey Relational Analysis was recommended to solve multi attribute decision problem [42]. Bakır and Atalık [7] evaluated e-service quality in the airline industry using integrated FAHP and Fuzzy MARCOS approach. FAHP was used to prioritize the e-service quality criteria. The case study was conducted using Turkey airline passengers. DEMATEL (Decision making trial and evaluation laboratory) method and FAHP were jointly used by Çakır and Pekkaya [9] to select a better laptop using a case study.

AHP was used to develop the emergency medical service (EMS) system [4], assess the risk [16], select Simulation software [17], ERP Software [25], multimedia authorizing systems (MAS) [30], advanced planning and scheduling (APS) software [31] and prepaid mobile Internet plans [39]. Zavadskas et al. [45] introduced the COPRAS technique to solve MCDM problem with conflict objectives. Blind spots in heavy transport vehicles were optimized using COPRAS method [32-33].

From the literature review, it is concluded that no researchers addressed the selection of mobile browser for android smartphones. To address this problem, in this work a hybrid decision model is developed for the selection of mobile browser for smartphones.

## 3. Research Methodology

The objective of this paper is to propose a hybrid MCDM methodology for the selection of a better mobile internet browser for the smartphone. This objective is attained in three sub-objectives as follows:

- To identify the influencing criteria.
- To determine the weightage of the criteria.
- To find the rank of the browser.

To accomplish the objective of this research, a hybrid MCDM model was proposed by integrating COPRAS and FAHP. In this research twelve mobile browser application software such as Mozilla Firefox (80.1.3), Google Chrome Beta (86.0.4240.30), Opera (59.1.2926.54067), Edge (45.07.4.5059), Dolphin (12.2.3), Naked (1.0.135), Mercury (7.25.0), Flynx (2.1.2), Puffin (8.3.1.41624), Ghostery (69.0.1), Brave Browser (1.12.113) and Samsung browser (12.1.2.5) that are compatible with Android OS are considered for evaluation. Due to commercial ethics, the browsers are named as B1, B2, .... & B12. For the evaluation of these alternatives, 14 criteria are considered after the consultation with the domain experts. Some of them are quantitative (number of downloads, number of reviews given by the users, user rating, memory requirement to load no page and five pages, disc space needed, time to open new tap, the URL loading time, net worth of the organization and years of experience in the field) and others (latest upgradation available, date/year of launch, reputation of the provider and additional features provided) are qualitative. Out of these 14, few criteria which are having least influence have been neglected after conducting selection of influencing criteria using AHP, and the study is carried out by the remaining 10 criteria. These qualitative criteria are quantified using integer ranking based on the optimal requirement (i.e. For latest upgradation available – recent date / year is given higher preference ranking and for date/year of launch – earlier date / year is given higher preference ranking).

The research outline of the proposed model is shown in Figure 1. All the needed data for this work were collected and the solution is obtained in three modules as follows:

- Identification of influencing criteria using AHP.
- Determination of the weights of the criteria using FAHP.
- Determination of the better browser using COPRAS.

### 3.1. AHP

AHP is one of the most successful methods for decision making through the ranking of criteria and selection of alternatives based on expert's judgement [35]. In this study, AHP is used to select the influencing criteria from the available data. First, the criteria used in this study are collected through several sources such as vendor, play store and online database. These criteria were ranked by using AHP and the bottom most criteria are eliminated from the study since they have least importance on the final decision.

The first step of the AHP is the construction of criteria matrix / pair wise comparison matrix / original matrix using nine-point scale [35] which is presented in Table 1. Equation (1) is used to create the criteria matrix.

$$X_{att} = [a_{ij}];\ 1 \le i, j \le m, \tag{1}$$

where, '$a_{ij}$' is the relative importance when comparing $i^{th}$ and $j^{th}$ criteria and 'm' is the number of criteria.

Next the preprocessing / normalizing of the criteria matrix is done by using Equation (2).

$$N_{ij} = \frac{a_{ij}}{T_j}, \tag{2}$$

where $a_{ij}$ is the cell value of $i^{th}$ row and $j^{th}$ column in the criteria matrix; $1 \le i, j \le m$ and $T_j = \sum_{i=1}^{m} a_{ij}$.

**Figure 1**
Research Methodology

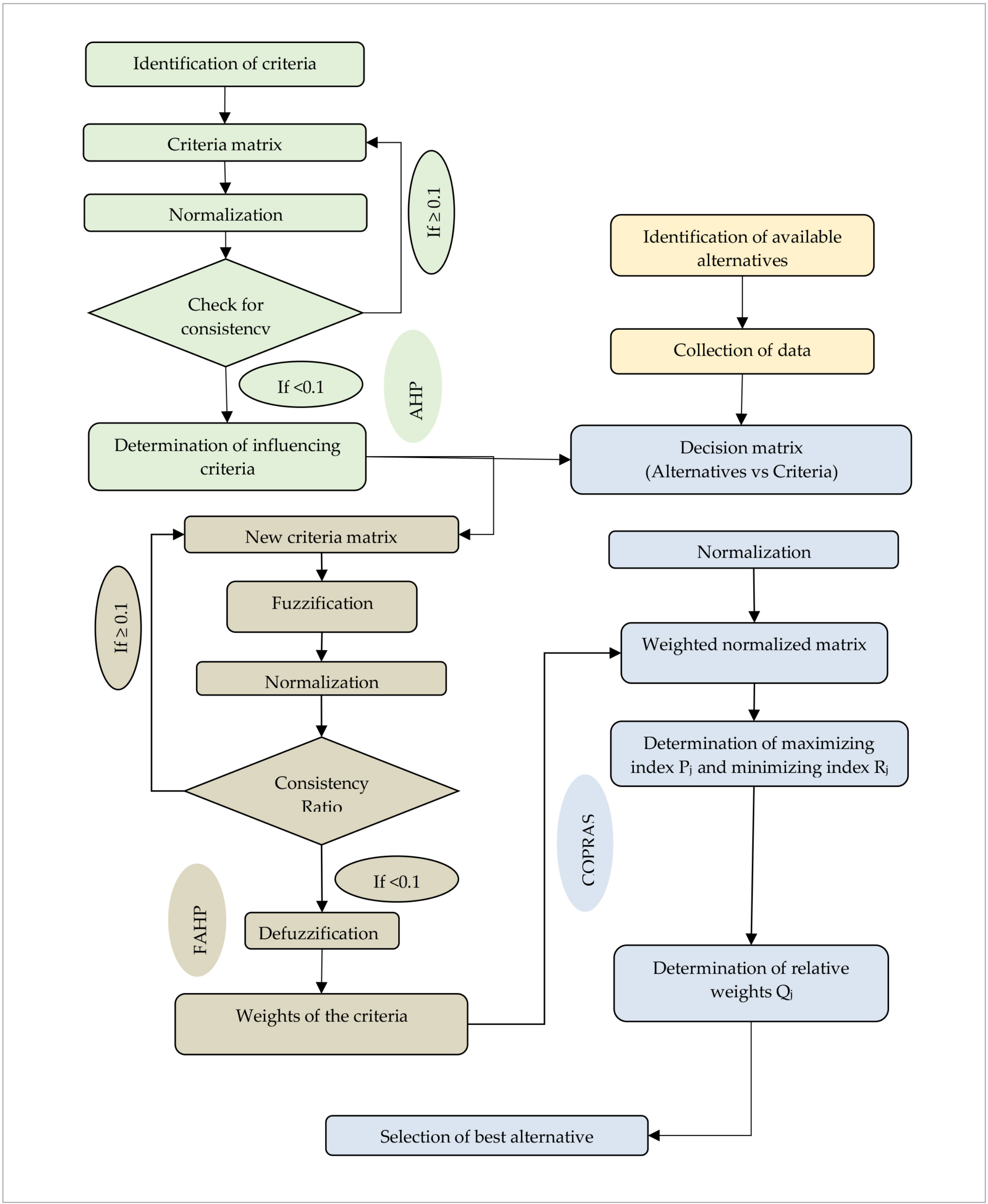


**Table 1**
Nine-point scale and equivalent Triangular Fuzzy Number (TFN)

| Verbal judgment or preference between criteria | Scale [35] | TFN [3] |
|---|---|---|
| Extreme | 9 | 9,9,9 |
| Very strong to extreme | 8 | 7,8,9 |
| Very strong | 7 | 6,7,8 |
| Strong to very strong | 6 | 5,6,7 |
| Strong | 5 | 4,5,6 |
| Moderate to strong | 4 | 3,4,5 |
| Moderate | 3 | 2,3,4 |
| Equal to moderate | 2 | 1,2,3 |
| Equal | 1 | 1,1,1 |

The criteria weights are determined by the row average of the respective criteria. Since the criteria matrix is created based on the expert's judgment, the consistency of the developed criteria matrix should be validated. Equation (3) is used to validate the consistency of the model through the Consistency Ratio (CR).

$$CR = {CI}/{RI}. \quad (3)$$

where 'CI' is Consistency Index which is determined using Equation (8) and 'RI' is random indices for criteria size 'm' which is selected from Table 2.

If the CR is < 0.10, then the criteria matrix can be accepted otherwise the criteria matrix should be restructured.

$$CI = \frac{(\lambda_{\max} - m)}{(m-1)}, \quad (4)$$

where $\lambda$ is the Eigen value.

**Table 2**
Random Indices

| *m* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *RI* | 0 | 0 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 | 1.51 | 1.53 | 1.56 | 1.57 |

## 3.2. FAHP

FAHP is an integrated technique where the AHP is integrated with the concept of fuzzy concept [44]. Fuzzy is used in a situation where the data is available in vague form. In the real world, many data are available in vague form only and those data available are both in qualitative (immeasurable) and quantitative (measurable) form. To overcome this problem, the fuzzy is integrated with AHP to determine the weights of the criteria.

The evaluation criteria obtained through AHP are compared based on the judgement of the decision maker, and the fuzzy criteria matrix was formed using equivalent TFN which is shown in Table 1. The fuzzy number is denoted by Equation (5).

$$F = \{x, \mu F(x), x \in R\}, \quad (5)$$

where $F$ = fuzzy set; $x$ = fuzzy number; R = $-\infty \le x \le \infty$ and $\mu F(x)$ = continuous mapping from R in the interval [0, 1].

A TFN articulates the comparative strength of every pair of elements in the similar order and designated as TFN (M).

TFN (M) = (l, m, u), where $l \le m \le u$ in which 'l', 'm' and 'u' are the lowest, mean and largest feasible values in a fuzzy event. The triangular membership function of 'M' fuzzy number is defined as shown in Equation (6).

$$\mu_A(x) = f(x) = \begin{cases} 0 & x < l \\ (x-l)/(m-l) & l \le x \le m \\ (u-x)/(u-m) & m \le x \le u \\ 0 & x > u \end{cases}. \quad (6)$$

Similar to AHP, Equation (1) is used to generate the fuzzy criteria matrix also. Next the preprocessing / normalizing of fuzzy criteria matrix is done by using Equation (4). The weights (Wi)were determined by defuzzification procedure in which fuzzy numbers are transformed to crisp (single-valued quantity) values [Equation (7)]. For the defuzzification, several methods are found in the literature. In this work, the center of gravity (COG) based defuzzification method has been chosen based on its simplicity and efficiency [5].

$$W_i = \frac{\sum_{i-1}^{k} D_p^i * O^i}{\sum_{i=1}^{k} D_p^i}, \tag{7}$$

where $k$ = rule number, $O^i$ = the class created by rule i (0, 1, .... $L$–1); $L$ = the number of classes.

$$D_p^i = \prod_{i=1}^{n} m_{li}, \tag{8}$$

where $m_{li}$ = membership grade of feature l in the fuzzy regions that inhabits the $i^{th}$ rule and $n$ = number of inputs;

The consistency of the fuzzy model is checked similar to AHP through the Consistency Ratio (CR). If the CR is not less than 0.10 then the criteria matrix is reformulated as mentioned in Figure 1.

### 3.3. COPRAS Method

COPRAS (Complex Proportional Assessment of alternatives) is a simple and effective MCDM technique used to solve problems with conflict objectives [45]. The procedure comprises of the following steps:

- **Decision matrix (Alternatives vs attributes) (X)**. The COPRAS procedure starts with the identification of criteria and the available alternatives. The criteria are identified by AHP method. They are selected from various sources and documented in the form of a matrix (Alternatives vs criteria) which is called decision matrix (X) as shown in Equation (9).

$$X = \begin{bmatrix} x_{11} & x_{12} & \ldots\ldots & x_{1m} \\ x_{21} & x_{22} & \ldots\ldots & x_{2m} \\ \vdots & & & \\ x_{n1} & x_{n2} & \ldots\ldots & x_{nm} \end{bmatrix}, \tag{9}$$

where $n$ = number of alternatives; $m$ = number of criteria

- **Normalized matrix ($\bar{X}$).** The raw data collected are not in uniform scale / range. To bring them into uniform scale the raw data are normalized. In this paper, the normalization is done by using Equation (10) to generate a normalized matrix.

$$\overline{X} = \begin{bmatrix} \bar{x}_{11} & \bar{x}_{12} & \ldots\ldots & \bar{x}_{1m} \\ \bar{x}_{21} & \bar{x}_{22} & \ldots\ldots & \bar{x}_{2m} \\ \vdots & & & \\ \bar{x}_{n1} & \bar{x}_{n2} & \ldots\ldots & \bar{x}_{nm} \end{bmatrix} \tag{10}$$

where $\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}$; $i = 1, 2, ...n$; and $j = 1, 2, \ldots m$.

- **Weight of the criteria (Wj).** The major part of the final decision in MCDM problems is the determination of weights of criteria. In general, the criteria are not having the same weights. Several methods are used by the researchers to determine the weights of the criteria. In this method, FAHP is used to determine the weights.
- **Weighted normalized matrix($\hat{X}$).** The weights of the criteria which were computed through FAHP are multiplied with the respective criteria of all alternatives as shown in Equation (11) to formulate the weighted normalized matrix.

$$\widehat{X} = \begin{bmatrix} \hat{x}_{11} & \hat{x}_{12} & \ldots\ldots & \hat{x}_{1m} \\ \hat{x}_{21} & \hat{x}_{22} & \ldots\ldots & \hat{x}_{2m} \\ \vdots & & & \\ \hat{x}_{n1} & \hat{x}_{n2} & \ldots\ldots & \hat{x}_{nm} \end{bmatrix}, \tag{11}$$

where $\hat{x}_{ij} = \bar{x}_{ij} * W_i$

- **Maximizing index (Pj) and minimizing index (Rj).** The maximizing index (Pj) and minimizing index (Rj) are determined based on the qualitative nature of the expected outcome of the criteria. That means, maximizing index (Pj) is calculated for the criteria with the maximum value as optimal value and minimizing index (Rj) is computed for the criteria with the minimum value as optimal value using Equations (12)-(13), respectively.

$$P_j = \sum_{i=1}^{k} \hat{x}_{ij} \tag{12}$$

$$R_j = \sum_{i=k+1}^{m} \hat{x}_{ij} , \tag{13}$$

where $k$ = number of criteria where the maximum value is the expected outcome.

- **Relative weights (Qj) and ranking of each alternative.** Finally, the relative weights of all the alternatives will be determined by using Equation (14) and the ranking is done based on the descending order of $Q_j$. The alternative with the highest relative weights (ie. Ranked as 1) is selected as the best alternative.

$$Q_j = P_j + \frac{\sum_{j=1}^{n} R_j}{R_j \sum_{j=1}^{n} \frac{1}{R_j}} . \tag{14}$$

# 4. Discussion on Selection of Mobile Browser

## 4.1. Identification of Influencing Criteria Using AHP

In this study 12 Android OS-based mobile browser application software such as B1, B2, .... & B12 are evaluated in three stages. For the evaluation of these alternatives, 14 criteria such as reputation of the provider (C1), the net worth of the organization (C2), number of downloads (C3), number of reviews given by the users (C4), user rating (C5), latest upgradation available (C6), memory requirement to load no page (C7), time to open new tap (C8), the URL loading time (C9), years of experience in the field (C10), additional features provided (C11), memory requirement to load five pages (C12), date/year of launch (C13) and disc space needed (C14) are chosen. Among these 14 criteria, 10 highly influencing criteria are selected using AHP.

**Table 3**

Criteria Matrix

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | 1.000 | 2.000 | 0.250 | 0.250 | 0.333 | 0.333 | 0.200 | 0.143 | 0.167 | 0.333 | 1.000 | 0.167 | 0.500 | 0.111 |
| C2 | 0.500 | 1.000 | 0.200 | 0.200 | 0.250 | 0.250 | 0.200 | 0.200 | 0.333 | 0.500 | 0.500 | 0.200 | 0.200 | 0.111 |
| C3 | 4.000 | 5.000 | 1.000 | 1.000 | 2.000 | 3.000 | 1.000 | 0.333 | 0.333 | 4.000 | 4.000 | 0.500 | 1.000 | 0.250 |
| C4 | 4.000 | 5.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.500 | 0.333 | 0.333 | 4.000 | 3.000 | 0.500 | 1.000 | 0.250 |
| C5 | 3.003 | 4.000 | 0.500 | 1.000 | 1.000 | 1.000 | 0.333 | 0.250 | 0.333 | 3.000 | 2.000 | 0.333 | 1.000 | 0.111 |
| C6 | 3.003 | 4.000 | 0.333 | 1.000 | 1.000 | 1.000 | 0.333 | 0.250 | 0.250 | 2.000 | 1.000 | 0.333 | 1.000 | 0.111 |
| C7 | 5.000 | 5.000 | 1.000 | 2.000 | 3.003 | 3.003 | 1.000 | 0.333 | 0.333 | 3.000 | 2.000 | 0.500 | 2.000 | 0.333 |
| C8 | 6.993 | 5.000 | 3.003 | 3.003 | 4.000 | 4.000 | 3.003 | 1.000 | 1.000 | 6.000 | 4.000 | 2.000 | 2.000 | 0.500 |
| C9 | 5.988 | 3.003 | 3.003 | 3.003 | 3.003 | 4.000 | 3.003 | 1.000 | 1.000 | 5.000 | 6.000 | 2.000 | 2.000 | 0.333 |
| C10 | 3.003 | 2.000 | 0.250 | 0.250 | 0.333 | 0.500 | 0.333 | 0.167 | 0.200 | 1.000 | 4.000 | 0.200 | 0.200 | 0.111 |
| C11 | 1.000 | 2.000 | 0.250 | 0.333 | 0.500 | 1.000 | 0.500 | 0.250 | 0.167 | 0.250 | 1.000 | 0.250 | 0.500 | 2.000 |
| C12 | 5.988 | 5.000 | 2.000 | 2.000 | 3.003 | 3.003 | 2.000 | 0.500 | 0.500 | 5.000 | 4.000 | 1.000 | 3.000 | 0.333 |
| C13 | 2.000 | 5.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.500 | 0.500 | 0.500 | 5.000 | 2.000 | 0.333 | 1.000 | 5.000 |
| C14 | 9.009 | 9.009 | 4.000 | 4.000 | 9.009 | 9.009 | 3.003 | 2.000 | 3.003 | 9.009 | 0.500 | 3.003 | 0.200 | 1.000 |

**Table 4**
Normalized Matrix

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | Weights | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | 0.018 | 0.035 | 0.014 | 0.012 | 0.011 | 0.010 | 0.013 | 0.020 | 0.020 | 0.007 | 0.029 | 0.015 | 0.032 | 0.011 | 0.018 | 13 |
| C2 | 0.009 | 0.018 | 0.011 | 0.010 | 0.008 | 0.008 | 0.013 | 0.028 | 0.039 | 0.010 | 0.014 | 0.018 | 0.013 | 0.011 | 0.015 | 14 |
| C3 | 0.073 | 0.088 | 0.056 | 0.050 | 0.068 | 0.093 | 0.063 | 0.046 | 0.039 | 0.083 | 0.114 | 0.044 | 0.064 | 0.024 | 0.065 | 7 |
| C4 | 0.073 | 0.088 | 0.056 | 0.050 | 0.034 | 0.031 | 0.031 | 0.046 | 0.039 | 0.083 | 0.086 | 0.044 | 0.064 | 0.024 | 0.054 | 8 |
| C5 | 0.055 | 0.070 | 0.028 | 0.050 | 0.034 | 0.031 | 0.021 | 0.034 | 0.039 | 0.062 | 0.057 | 0.029 | 0.064 | 0.011 | 0.042 | 9 |
| C6 | 0.055 | 0.070 | 0.019 | 0.050 | 0.034 | 0.031 | 0.021 | 0.034 | 0.030 | 0.042 | 0.029 | 0.029 | 0.064 | 0.011 | 0.040 | 10 |
| C7 | 0.092 | 0.088 | 0.056 | 0.100 | 0.102 | 0.094 | 0.063 | 0.046 | 0.039 | 0.062 | 0.057 | 0.044 | 0.128 | 0.032 | 0.072 | 6 |
| C8 | 0.128 | 0.088 | 0.169 | 0.150 | 0.136 | 0.125 | 0.189 | 0.138 | 0.118 | 0.125 | 0.114 | 0.177 | 0.128 | 0.047 | 0.131 | 2 |
| C9 | 0.110 | 0.053 | 0.169 | 0.150 | 0.102 | 0.125 | 0.189 | 0.138 | 0.118 | 0.104 | 0.171 | 0.177 | 0.128 | 0.032 | 0.126 | 3 |
| C10 | 0.055 | 0.035 | 0.014 | 0.012 | 0.011 | 0.016 | 0.021 | 0.023 | 0.024 | 0.021 | 0.114 | 0.018 | 0.013 | 0.011 | 0.028 | 12 |
| C11 | 0.018 | 0.035 | 0.014 | 0.017 | 0.017 | 0.031 | 0.031 | 0.034 | 0.020 | 0.005 | 0.029 | 0.022 | 0.032 | 0.190 | 0.035 | 11 |
| C12 | 0.110 | 0.088 | 0.112 | 0.100 | 0.102 | 0.094 | 0.126 | 0.069 | 0.059 | 0.104 | 0.114 | 0.088 | 0.192 | 0.032 | 0.099 | 4 |
| C13 | 0.037 | 0.088 | 0.056 | 0.050 | 0.034 | 0.031 | 0.031 | 0.069 | 0.059 | 0.104 | 0.057 | 0.029 | 0.064 | 0.474 | 0.085 | 5 |
| C14 | 0.165 | 0.158 | 0.225 | 0.200 | 0.306 | 0.281 | 0.189 | 0.276 | 0.355 | 0.187 | 0.014 | 0.265 | 0.013 | 0.095 | 0.195 | 1 |

**Figure 2**
Selection of Influencing Criteria

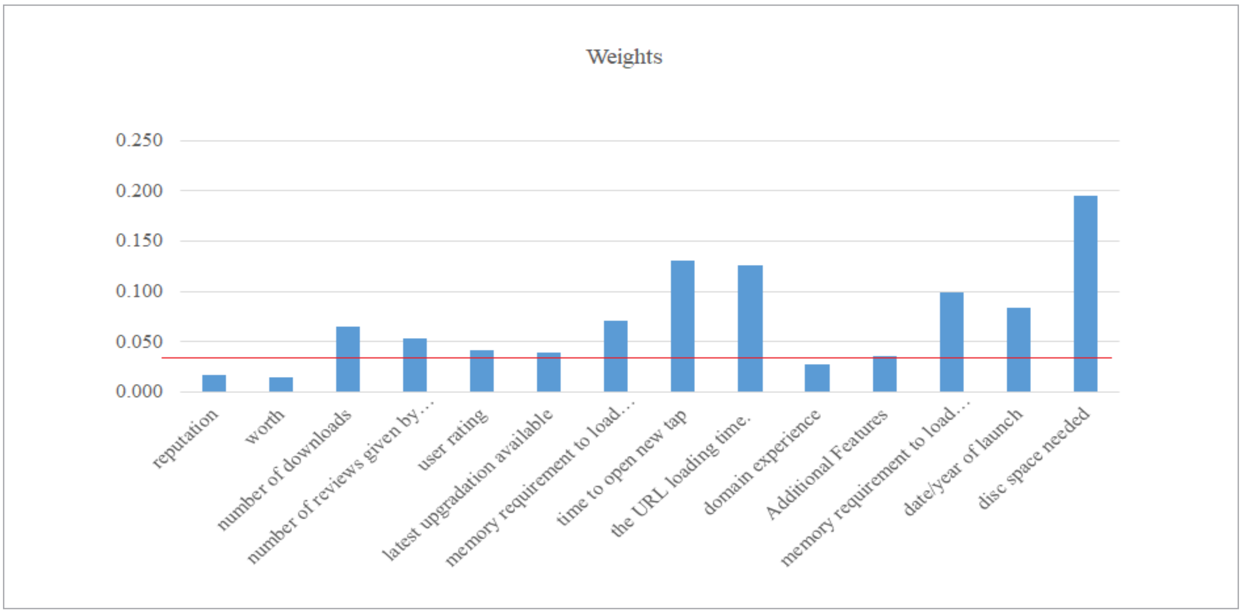


**Table 5**
Fuzzy Criteria Matrix

| | C3 | | | C4 | | | C5 | | | C6 | | | C7 | | | C8 | | | C9 | | | C12 | | | C13 | | | C14 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C3 | 1.000 | 1.000 | 1.000 | 1.000 | 2.000 | 3.000 | 2.000 | 3.000 | 4.000 | 3.000 | 4.000 | 5.000 | 1.000 | 0.500 | 0.333 | 0.250 | 0.200 | 0.167 | 0.333 | 0.250 | 0.200 | 0.500 | 0.333 | 0.250 | 4.000 | 5.000 | 6.000 | 0.200 | 0.167 | 0.143 |
| C4 | 1.000 | 0.500 | 0.333 | 1.000 | 1.000 | 1.000 | 1.000 | 2.000 | 3.000 | 2.000 | 3.000 | 4.000 | 0.500 | 0.333 | 0.250 | 0.200 | 0.167 | 0.143 | 0.250 | 0.200 | 0.167 | 0.333 | 0.250 | 0.200 | 3.000 | 4.000 | 5.000 | 0.167 | 0.143 | 0.125 |
| C5 | 0.500 | 0.333 | 0.250 | 1.000 | 0.500 | 0.333 | 1.000 | 1.000 | 1.000 | 1.000 | 2.000 | 3.000 | 0.333 | 0.250 | 0.200 | 0.167 | 0.143 | 0.125 | 0.200 | 0.167 | 0.143 | 0.250 | 0.200 | 0.167 | 2.000 | 3.000 | 4.000 | 0.143 | 0.125 | 0.111 |
| C6 | 0.333 | 0.250 | 0.200 | 0.500 | 0.333 | 0.250 | 1.000 | 0.500 | 0.333 | 1.000 | 1.000 | 1.000 | 0.250 | 0.200 | 0.167 | 0.143 | 0.125 | 0.111 | 0.167 | 0.143 | 0.125 | 0.200 | 0.167 | 0.143 | 1.000 | 2.000 | 3.000 | 0.111 | 0.111 | 0.111 |
| C7 | 1.000 | 2.000 | 3.003 | 2.000 | 3.003 | 4.000 | 3.003 | 4.000 | 5.000 | 4.000 | 5.000 | 5.988 | 1.000 | 1.000 | 1.000 | 0.333 | 0.250 | 0.200 | 0.500 | 0.333 | 0.250 | 1.000 | 0.500 | 0.333 | 5.000 | 6.000 | 7.000 | 0.250 | 0.200 | 0.167 |
| C8 | 4.000 | 5.000 | 5.988 | 5.000 | 5.988 | 6.993 | 5.988 | 6.993 | 8.000 | 6.993 | 8.000 | 9.009 | 3.003 | 4.000 | 5.000 | 1.000 | 1.000 | 1.000 | 1.000 | 2.000 | 3.000 | 2.000 | 3.000 | 4.000 | 9.000 | 9.000 | 9.000 | 1.000 | 0.500 | 0.333 |
| C9 | 3.003 | 4.000 | 5.000 | 4.000 | 5.000 | 5.988 | 5.000 | 5.988 | 6.993 | 5.988 | 6.993 | 8.000 | 2.000 | 3.003 | 4.000 | 1.000 | 0.500 | 0.333 | 1.000 | 1.000 | 1.000 | 1.000 | 2.000 | 3.000 | 7.000 | 8.000 | 9.000 | 0.500 | 0.333 | 0.250 |
| C12 | 2.000 | 3.003 | 4.000 | 3.003 | 4.000 | 5.000 | 4.000 | 5.000 | 5.988 | 5.000 | 5.988 | 6.993 | 1.000 | 2.000 | 3.003 | 0.500 | 0.333 | 0.250 | 1.000 | 0.500 | 0.333 | 1.000 | 1.000 | 1.000 | 6.000 | 7.000 | 8.000 | 0.200 | 0.167 | 0.143 |
| C13 | 0.250 | 0.200 | 0.167 | 0.333 | 0.250 | 0.200 | 0.500 | 0.333 | 0.250 | 1.000 | 0.500 | 0.333 | 0.200 | 0.167 | 0.143 | 0.111 | 0.111 | 0.111 | 0.143 | 0.125 | 0.111 | 0.167 | 0.143 | 0.125 | 1.000 | 1.000 | 1.000 | 0.111 | 0.111 | 0.111 |
| C14 | 5.000 | 5.988 | 6.993 | 5.988 | 6.993 | 8.000 | 6.993 | 8.000 | 9.009 | 9.009 | 9.009 | 9.009 | 4.000 | 5.000 | 5.988 | 1.000 | 2.000 | 3.003 | 2.000 | 3.003 | 4.000 | 5.000 | 5.988 | 6.993 | 9.009 | 9.009 | 9.009 | 1.000 | 1.000 | 1.000 |

**Table 6**
Fuzzy Normalized Matrix

| | C3 | | | C4 | | | C5 | | | C6 | | | C7 | | | C8 | | | C9 | | | C12 | | | C13 | | | C14 | | | W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C3 | 0.055 | 0.045 | 0.037 | 0.042 | 0.069 | 0.086 | 0.066 | 0.081 | 0.092 | 0.077 | 0.088 | 0.096 | 0.075 | 0.030 | 0.017 | 0.053 | 0.041 | 0.031 | 0.051 | 0.032 | 0.021 | 0.044 | 0.025 | 0.015 | 0.085 | 0.093 | 0.098 | 0.054 | 0.058 | 0.057 | 0.057 |
| C4 | 0.055 | 0.022 | 0.012 | 0.042 | 0.034 | 0.029 | 0.033 | 0.054 | 0.069 | 0.051 | 0.066 | 0.076 | 0.038 | 0.020 | 0.012 | 0.043 | 0.035 | 0.026 | 0.038 | 0.026 | 0.018 | 0.029 | 0.018 | 0.012 | 0.064 | 0.074 | 0.082 | 0.045 | 0.050 | 0.050 | 0.041 |
| C5 | 0.028 | 0.015 | 0.009 | 0.042 | 0.017 | 0.010 | 0.033 | 0.027 | 0.023 | 0.026 | 0.044 | 0.057 | 0.025 | 0.015 | 0.010 | 0.036 | 0.030 | 0.023 | 0.030 | 0.022 | 0.015 | 0.022 | 0.015 | 0.010 | 0.043 | 0.056 | 0.066 | 0.039 | 0.044 | 0.045 | 0.029 |
| C6 | 0.018 | 0.011 | 0.007 | 0.021 | 0.011 | 0.007 | 0.033 | 0.014 | 0.008 | 0.026 | 0.022 | 0.019 | 0.019 | 0.012 | 0.008 | 0.030 | 0.026 | 0.020 | 0.025 | 0.019 | 0.013 | 0.017 | 0.012 | 0.009 | 0.021 | 0.037 | 0.049 | 0.030 | 0.039 | 0.045 | 0.021 |
| C7 | 0.055 | 0.090 | 0.111 | 0.084 | 0.103 | 0.115 | 0.099 | 0.109 | 0.115 | 0.103 | 0.110 | 0.114 | 0.075 | 0.061 | 0.050 | 0.071 | 0.052 | 0.037 | 0.076 | 0.043 | 0.027 | 0.087 | 0.037 | 0.021 | 0.106 | 0.111 | 0.115 | 0.068 | 0.070 | 0.067 | 0.079 |
| C8 | 0.221 | 0.224 | 0.222 | 0.210 | 0.206 | 0.201 | 0.196 | 0.190 | 0.184 | 0.179 | 0.176 | 0.172 | 0.226 | 0.243 | 0.249 | 0.213 | 0.207 | 0.184 | 0.152 | 0.259 | 0.322 | 0.175 | 0.221 | 0.247 | 0.191 | 0.167 | 0.148 | 0.272 | 0.175 | 0.134 | 0.205 |
| C9 | 0.166 | 0.180 | 0.186 | 0.168 | 0.172 | 0.172 | 0.164 | 0.163 | 0.160 | 0.154 | 0.154 | 0.153 | 0.151 | 0.183 | 0.199 | 0.213 | 0.104 | 0.061 | 0.152 | 0.130 | 0.107 | 0.087 | 0.147 | 0.185 | 0.149 | 0.148 | 0.148 | 0.136 | 0.117 | 0.100 | 0.150 |
| C12 | 0.111 | 0.135 | 0.149 | 0.126 | 0.138 | 0.144 | 0.131 | 0.136 | 0.137 | 0.128 | 0.132 | 0.134 | 0.075 | 0.122 | 0.150 | 0.106 | 0.069 | 0.046 | 0.152 | 0.065 | 0.036 | 0.087 | 0.074 | 0.062 | 0.128 | 0.130 | 0.131 | 0.054 | 0.058 | 0.057 | 0.107 |
| C13 | 0.014 | 0.009 | 0.006 | 0.014 | 0.009 | 0.006 | 0.016 | 0.009 | 0.006 | 0.026 | 0.011 | 0.006 | 0.015 | 0.010 | 0.007 | 0.024 | 0.023 | 0.020 | 0.022 | 0.016 | 0.012 | 0.015 | 0.011 | 0.008 | 0.021 | 0.019 | 0.016 | 0.030 | 0.039 | 0.045 | 0.016 |
| C14 | 0.276 | 0.269 | 0.260 | 0.251 | 0.241 | 0.230 | 0.229 | 0.217 | 0.207 | 0.231 | 0.198 | 0.172 | 0.301 | 0.304 | 0.298 | 0.213 | 0.414 | 0.552 | 0.303 | 0.389 | 0.429 | 0.437 | 0.441 | 0.431 | 0.192 | 0.167 | 0.148 | 0.272 | 0.350 | 0.401 | 0.294 |

Tables 3-4 reveal the identification of influencing criteria from the available.

The consistency of the criteria matrix is found by using Equation (3) and in this paper, the CR is found as 0.0974 which is less than 0.1. Hence this is acceptable. The weight of each criterion is computed by the row average in the normalized matrix (Table 4). The least four criteria are eliminated from the study and finally, C3, C4, C5, C6, C7, C8, C9, C12, C13 & C14 are selected to continue the study further.

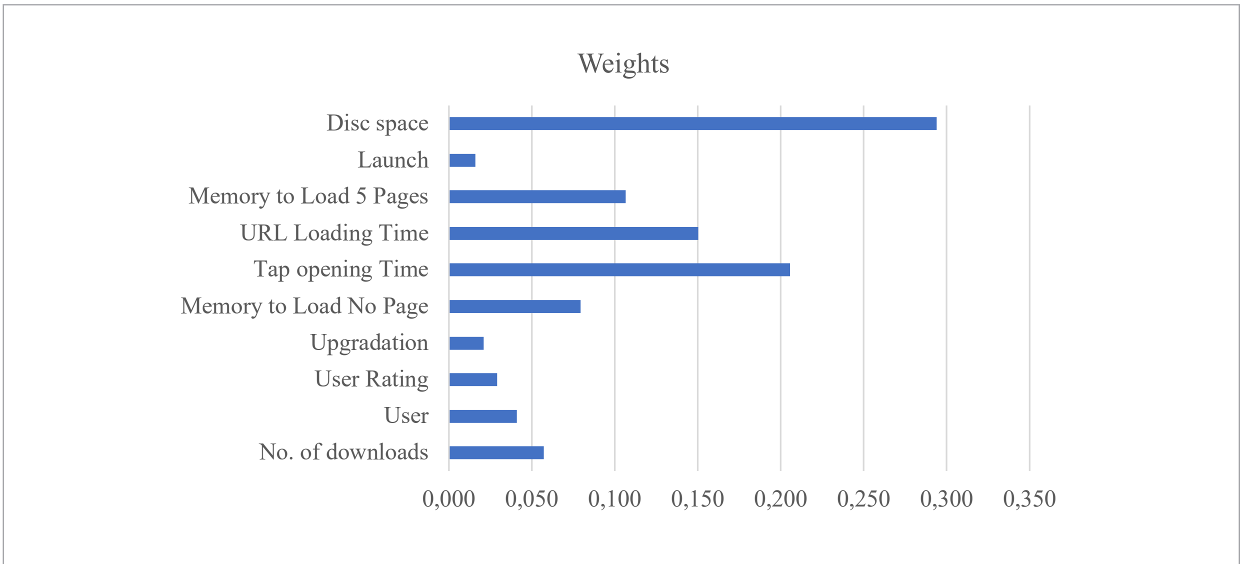
### 4.2. Determination of the Weights of the Criteria Using FAHP

Next FAHP is employed to compute the weights of the 10 criteria which are considered in this study. Similar to AHP, first the ten criteria are compared with each other based on their relative importance criteria matrix is formulated using Equation (1). These crisp values are converted into TFN using Table 1 to formulate fuzzy criteria matrix (Table 5). The fuzzy normalized matrix is formulated by using Equation (2) and the criteria weights are computed using Equation (7) which is also presented in Table 6 and shown in Figure 3. To validate the pair wise comparison, the consistency ratio is calculated using Equation (3) and found as 0.0851. Since the value of CR is < 0.1, the solution is validated.

### 4.3. Determination of the Better Browser Using COPRAS

The collected data (Alternatives and Criteria) are presented in Table 7 (decision matrix). Using Equation (10), the normalized matrix (Table 8) is determined. Equation (11) is used to generate the weighted normalized decision matrix (Table 9). Then the maximizing index (Pj) and minimizing index (Rj) are determined using Equation (12) and Equation (13). Finally, by using Equation (14) the relative weights of the criteria (Qj) for all the alternatives are calculated.

**Figure 3**
Weights of Influencing Criteria




From the relative weights of the criteria, the COPRAS grades are determined by dividing the corresponding Qj by max Qj and presented in Table 10 and Figure 4. The alternative with the highest COPRAS grade is concluded as the best alternative. From Table 10, B2 is selected as the best browser.

**Table 7**
Data Matrix

| | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C12 | C13 | C14 |
|---|---|---|---|---|---|---|---|---|---|---|
| B1 | 100000000 | 3576335 | 3.9 | 8 | 88 | 20 | 0.7 | 360 | 3 | 63.76 |
| B2 | 100000000 | 307595 | 4.3 | 1 | 63 | 7 | 0.4 | 135 | 5 | 34.39 |
| B3 | 100000000 | 377828 | 4.5 | 7 | 99 | 10 | 1.2 | 139 | 2 | 42.12 |
| B4 | 10000000 | 224123 | 4.5 | 1 | 64 | 7 | 0.6 | 186 | 12 | 77.7 |
| B5 | 50000000 | 2532588 | 4.1 | 5 | 45 | 12 | 1.1 | 294 | 1 | 23.03 |
| B6 | 100000 | 8936 | 4.3 | 2 | 59 | 11 | 1.6 | 324 | 10 | 0.1 |
| B7 | 10000 | 67 | 2.4 | 5 | 91 | 8 | 1.2 | 382 | 11 | 31.31 |
| B8 | 500000 | 46270 | 4.2 | 3 | 90 | 12 | 0.8 | 658 | 6 | 2.93 |
| B9 | 50000000 | 755890 | 3.7 | 6 | 94 | 12 | 1.1 | 446 | 4 | 22.19 |
| B10 | 1000000 | 16080 | 3.6 | 4 | 63 | 11 | 0.7 | 293 | 7 | 58.07 |
| B11 | 10000000 | 204474 | 4.3 | 8 | 59 | 10 | 0.7 | 248 | 9 | 49.99 |
| B12 | 1000000000 | 2322943 | 4.5 | 1 | 57 | 13 | 1 | 324 | 8 | 46.78 |

**Table 8**
Normalized Data Matrix

| | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C12 | C13 | C14 |
|---|---|---|---|---|---|---|---|---|---|---|
| B1 | 0.070 | 0.345 | 0.081 | 0.157 | 0.101 | 0.150 | 0.063 | 0.095 | 0.038 | 0.141 |
| B2 | 0.070 | 0.030 | 0.089 | 0.020 | 0.072 | 0.053 | 0.036 | 0.036 | 0.064 | 0.076 |
| B3 | 0.070 | 0.036 | 0.093 | 0.137 | 0.114 | 0.075 | 0.108 | 0.037 | 0.026 | 0.093 |
| B4 | 0.007 | 0.022 | 0.093 | 0.020 | 0.073 | 0.053 | 0.054 | 0.049 | 0.154 | 0.172 |
| B5 | 0.035 | 0.244 | 0.085 | 0.098 | 0.052 | 0.090 | 0.099 | 0.078 | 0.013 | 0.051 |
| B6 | 0.000 | 0.001 | 0.089 | 0.039 | 0.068 | 0.083 | 0.144 | 0.086 | 0.128 | 0.000 |
| B7 | 0.000 | 0.000 | 0.050 | 0.098 | 0.104 | 0.060 | 0.108 | 0.101 | 0.141 | 0.069 |
| B8 | 0.000 | 0.004 | 0.087 | 0.059 | 0.103 | 0.090 | 0.072 | 0.174 | 0.077 | 0.006 |
| B9 | 0.035 | 0.073 | 0.077 | 0.118 | 0.108 | 0.090 | 0.099 | 0.118 | 0.051 | 0.049 |
| B10 | 0.001 | 0.002 | 0.075 | 0.078 | 0.072 | 0.083 | 0.063 | 0.077 | 0.090 | 0.128 |
| B11 | 0.007 | 0.020 | 0.089 | 0.157 | 0.068 | 0.075 | 0.063 | 0.065 | 0.115 | 0.111 |
| B12 | 0.703 | 0.224 | 0.093 | 0.020 | 0.065 | 0.098 | 0.090 | 0.086 | 0.103 | 0.103 |

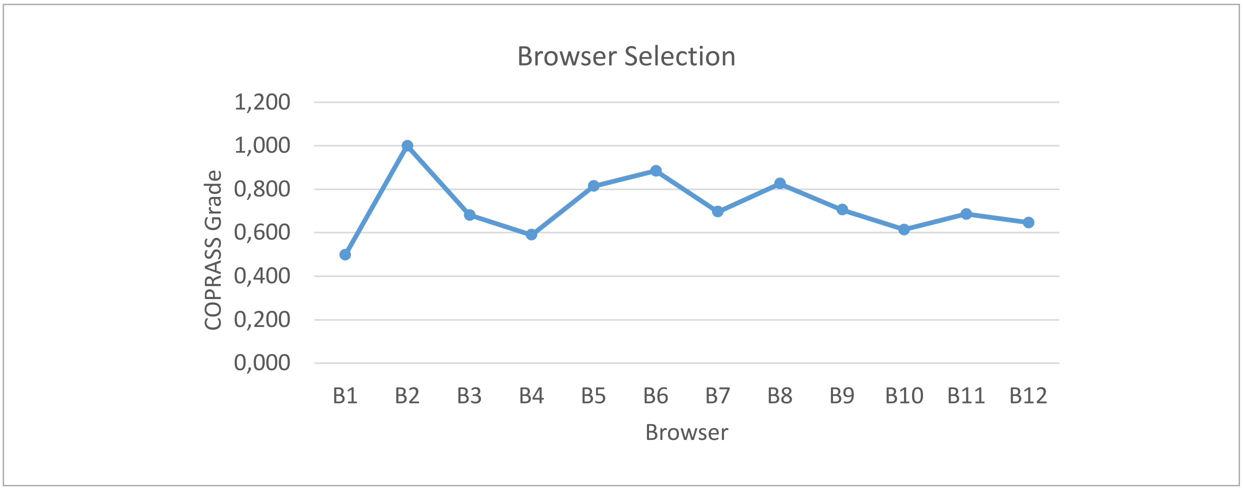
**Table 9**
Weighted Normalized Matrix

| | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C12 | C13 | C14 |
|---|---|---|---|---|---|---|---|---|---|---|
| B1 | 0.004 | 0.014 | 0.002 | 0.003 | 0.008 | 0.031 | 0.009 | 0.010 | 0.001 | 0.041 |
| B2 | 0.004 | 0.001 | 0.003 | 0.000 | 0.006 | 0.011 | 0.005 | 0.004 | 0.001 | 0.022 |
| B3 | 0.004 | 0.001 | 0.003 | 0.003 | 0.009 | 0.015 | 0.016 | 0.004 | 0.000 | 0.027 |
| B4 | 0.000 | 0.001 | 0.003 | 0.000 | 0.006 | 0.011 | 0.008 | 0.005 | 0.002 | 0.051 |
| B5 | 0.002 | 0.010 | 0.002 | 0.002 | 0.004 | 0.019 | 0.015 | 0.008 | 0.000 | 0.015 |
| B6 | 0.000 | 0.000 | 0.003 | 0.001 | 0.005 | 0.017 | 0.022 | 0.009 | 0.002 | 0.000 |
| B7 | 0.000 | 0.000 | 0.001 | 0.002 | 0.008 | 0.012 | 0.016 | 0.011 | 0.002 | 0.020 |
| B8 | 0.000 | 0.000 | 0.003 | 0.001 | 0.008 | 0.019 | 0.011 | 0.019 | 0.001 | 0.002 |
| B9 | 0.002 | 0.003 | 0.002 | 0.002 | 0.009 | 0.019 | 0.015 | 0.013 | 0.001 | 0.014 |
| B10 | 0.000 | 0.000 | 0.002 | 0.002 | 0.006 | 0.017 | 0.009 | 0.008 | 0.001 | 0.038 |
| B11 | 0.000 | 0.001 | 0.003 | 0.003 | 0.005 | 0.015 | 0.009 | 0.007 | 0.002 | 0.032 |
| B12 | 0.040 | 0.009 | 0.003 | 0.000 | 0.005 | 0.020 | 0.014 | 0.009 | 0.002 | 0.030 |

**Table 10**
COPRAS Grade

| | Pj | Rj | 1/Rj | Qj | COPRAS Grade | Rank |
|---|---|---|---|---|---|---|
| B1 | 0.024 | 0.101 | 9.943 | 0.050 | 0.497 | 12 |
| B2 | 0.008 | 0.049 | 20.347 | 0.100 | 1.000 | 1 |
| B3 | 0.011 | 0.072 | 13.812 | 0.068 | 0.681 | 8 |
| B4 | 0.004 | 0.083 | 12.051 | 0.059 | 0.590 | 11 |
| B5 | 0.017 | 0.061 | 16.401 | 0.081 | 0.814 | 4 |
| B6 | 0.003 | 0.055 | 18.096 | 0.088 | 0.884 | 2 |
| B7 | 0.004 | 0.070 | 14.234 | 0.070 | 0.696 | 6 |
| B8 | 0.004 | 0.059 | 16.886 | 0.083 | 0.826 | 3 |
| B9 | 0.010 | 0.070 | 14.330 | 0.070 | 0.705 | 5 |
| B10 | 0.004 | 0.080 | 12.556 | 0.061 | 0.614 | 10 |
| B11 | 0.007 | 0.072 | 13.962 | 0.068 | 0.685 | 7 |
| B12 | 0.052 | 0.080 | 12.503 | 0.065 | 0.646 | 9 |

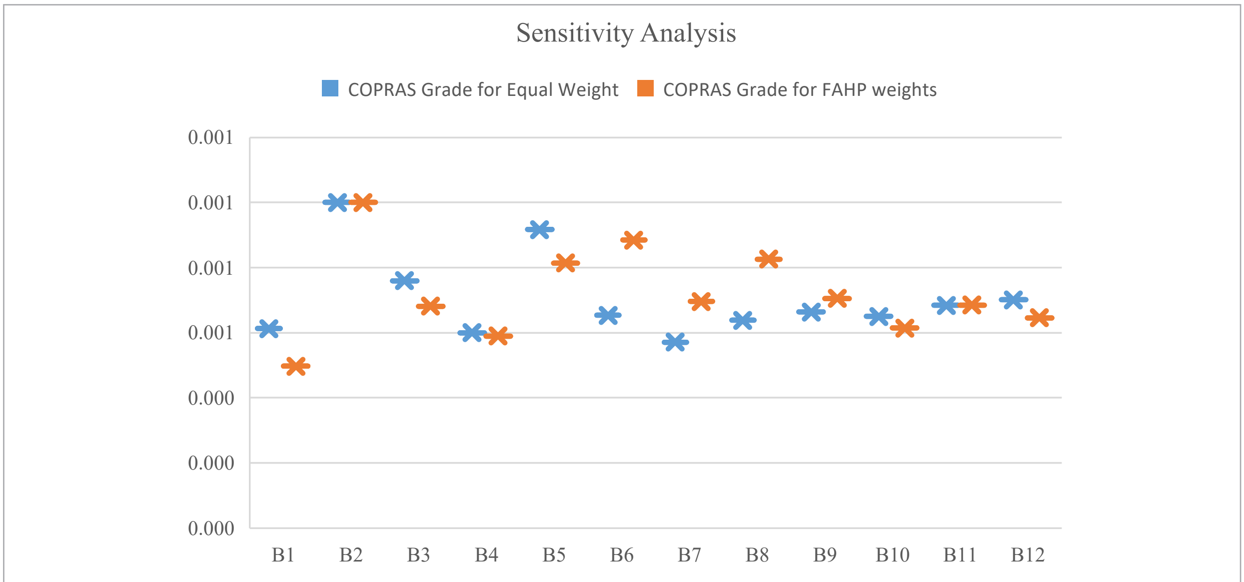
**Figure 4**
COPRAS Grade




## 4.4. Sensitivity Analysis

In the case of MCDM problems, the sensitivity analysis has to be performed in order to confirm the consistency of the model. The consistency of AHP and FAHP models was checked by Equation (3) and found that is less than 0.1. To check the consistency of COPRAS model, this paper examines sensitivity analysis by the changes in weight of criteria and its influence on the stability of solution [29]. Results of COPRAS model depend on the weight of the criteria. The objective of sensitivity analysis is to determine how the changes of criteria weights lead to changes in alternative rakings. The sensitivity of the COPRAS model is presented in Figure 5. Figure 5 proves that the model is consistent and the B2 is the optimal browser.

**Figure 5**
Sensitivity of COPRAS Model



## 5. Conclusion

In this study, the selection of browser for the smartphone was modelled as MCDM problem and to solve a hybrid MCDM model was presented with a case study. The novelty of this paper is the integration of AHP, Fuzzy and COPRAS to assist the decision maker (consumer) to select the browser for their smartphones. The decision was made in three modules such as selection of influencing criteria using AHP, determination of weights of influencing criteria by FAHP and selection of better browser by COPRAS. The outcomes of this study indicated that few of the criteria namely the reputation of the provider, the net worth of the organization, years of experience in the field and additional features provided were not having a reasonable impact on the decision making. At the same time, the criteria like disc space needed, time to open a new tap, the URL loading time, memory requirement to load five pages and date/year of launch have more influence on the final decision. The remaining criteria (number of downloads, number of reviews given by the users, user rating, latest upgradation available and memory requirement to load no page) have moderate influence on the final decision. A case study was also presented to prove the effectiveness of the developed model. By using the developed hybrid model, browser B2 is ranked as 1 followed by browser B6. The developed model is capable of handling both qualitative and quantitative criteria with conflict objectives. This MCDM model can be easily integrated with the knowledge base of a decision support system. In the future, a decision support system can be developed for the same kind of decision making problems.

## References

1. Abdullah, L., Chan, W., Afshari, A. Application of PROMETHEE Method for Green Supplier Selection: A Comparative Result Based on Preference Functions. Journal of Industrial Engineering International, 2019, 15, 271-285. https://doi.org/10.1007/s40092-018-0289-z
2. Aggarwal, A., Choudhary, C., Mehrotra, D. Evaluation of Smartphones in Indian Market Using EDAS. Procedia Computer Science, 2018, 132, 236-243. https://doi.org/10.1016/j.procs.2018.05.193
3. Alias, M. A., Hashim, S. Z. M., Samsudin, S. Using Fuzzy Analytic Hierarchy Process for Southern Johor River Ranking. International Journal of Advanced Soft Computing Applications, 2009, 1(1), 62-76.
4. Alosta, A., Elmansuri, O., Badi, I. Resolving a Location Selection Problem by Means of an Integrated AHP-RAFSI Approach. Reports in Mechanical Engineering, 2021, 2(1), 135-142. https://doi.org/10.31181/rme200102135a
5. Arman, H., Vencheh, A. H., Arman, A., Moslehi, A. Revisiting the Approximated Weight Extraction Methods in Fuzzy Analytic Hierarchy Process. International Journal of Intelligent Systems, 2021, 36(4), 1644-1667. https://doi.org/10.1002/int.22355
6. Baczkiewicz, A., Kizielewicz, B., Shekhovtsov, A., Watróbski, J., Sałabun, W. Methodical Aspects of MCDM Based E-Commerce Recommender System. Journal of Theoretical and Applied Electronic Commerce Research, 2021, 16, 2192-2229. https://doi.org/10.3390/jtaer16060122
7. Bakır, M., Atalık, Ö. Application of Fuzzy AHP and Fuzzy MARCOS Approach for the Evaluation of E-Service Quality in the Airline Industry. Decision Making: Applications in Management and Engineering, 2021, 4(1), 127-152. https://doi.org/10.31181/dmame2104127b
8. Cai, X., Niu, Y., Geng, S., Zhang, J., Cui, Z., Li, J., Chen, J. An Under-Sampled Software Defect Prediction Method Based on Hybrid Multi-Objective Cuckoo Search. Concurrency and Computation: Practice and Experience, 2020, 32(5), e5478. https://doi.org/10.1002/cpe.5478
9. Çakır, S. F., Pekkaya, M. Determination of Interaction Between Criteria and the Criteria Priorities in Laptop Selection Problem, International Journal of Fuzzy Systems, 2020, 22, 1177-1190. https://doi.org/10.1007/s40815-020-00857-2
10. Çalişkan, E., Aksaka, E., Çetinyokuş, S., Çetinyokuş, T. Hybrid Use of Likert Scale-based AHP and PROMETHEE Methods for Hazard Analysis and Consequence Modeling (HACM) Software Selection. International Journal of Information Technology and Decision Making, 2019, 18(5), 1689-1715. https://doi.org/10.1142/S0219622019500330
11. Canco, I., Kruja, D., Iancu, T. AHP, A Reliable Method for Quality Decision Making: A Case Study in Business.

Sustainability, 2021, 13, 13932. https://doi.org/10.3390/su132413932

12. Cervantes, E. 'Need for Speed - What's the Fastest Android Browser? https://lifehacker.com/browser-speed-tests-chrome-24-firefox-18-internet-ex-5976082 (Accessed 04 September 2020)
13. Cricelli, L., Famulari, F. M., Greco, M., Grimaldi, M. Searching for the One: Customer Relationship Management Software Selection. Journal of Multi-Criteria Decision Analysis, 2020, 27 (3-4), 173-188. https://doi.org/10.1002/mcda.1687
14. Czekster, R. M., Webber, T., Jandrey, A. H., Marcon, C. A. M. Selection of Enterprise Resource Planning Software Using Analytic Hierarchy Process. Enterprise Information Systems, 2019, 13(6), 895-915. https://doi.org/10.1080/17517575.2019.1606285
15. Farshidi, S., Jansen, S., Jong, R. D., Brinkkemper, S. A Decision Support System for Software Technology Selection. Journal of Decision Systems, 2018, 27, 98-110. https://doi.org/10.1080/12460125.2018.1464821
16. Fattahi, R., Moghaddam, R. T., Khalilzadeh, M., Pour, N. S., Soltani, R. A Novel FMEA Model Based on Fuzzy Multiple-Criteria Decision-Making Methods for Risk Assessment. Journal of Enterprise Information Management, 2020, 33(5), 881-904. https://doi.org/10.1108/JEIM-09-2019-0282
17. Fumagalli, L., Polenghi, A., Negri, E., Roda, I. Framework for Simulation Software Selection. Journal of Simulation, 2019, 13(4), 286-303. https://doi.org/10.1080/17477778.2019.1598782
18. Gordon, W. Browser Speed Tests: Chrome 24, Firefox 18, Internet Explorer 10, and Opera 12.12. https://lifehacker.com/browser-speed-tests-chrome-24-firefox-18-internet-ex-5976082. Accessed on September 04, 2020.
19. Hanafizadeh, P., Ravasan, A. Z. A Model for Selecting IT Outsourcing Strategy: The Case of E-banking Channels. Journal of Global Information Technology and Management, 2018, 21(2), 111-138. https://doi.org/10.1080/1097198X.2018.1462070
20. Ivancevich, S. H., Ivancevich, D. M., Elikai, F. Accounting Software Selection and Satisfaction: A Comparative Analysis of Vendor and User Perceptions. Reviews of Business Information Systems, 2007, 11(3), 43-52. https://doi.org/10.19030/rbis.v11i3.4415
21. Karamaşa, C., Demir, E., Memiş, S., Korucuk, S. Weighting the Factors Affectıng Logıstıcs Outsourcıng. Decision Making: Applications in Management and Engineering, 2021, 4(1), 19-32. https://doi.org/10.31181/dmame2104019k
22. Khan, A. W., Hussain, I., Zamir, M. Analytic Hierarchy Process-Based Prioritization Framework for Vendor's Reliability Challenges in Global Software Development. Journal of Software: Evolution and Process, 2021, 33(2), e2310; https://doi.org/10.1002/smr.2310
23. Majumder, P., Valentina, E. B., Paul, A., Baidya, D. Application of Improved Fuzzy Best Worst Analytic Hierarchy Process on Renewable Energy. PeerJ Computer Science, 2021, 7, e453. https://doi.org/10.7717/peerj-cs.453
24. Malek, A., Ebrahimnejad, S., Moghaddam, R. T. An Improved Hybrid Grey Relational Analysis Approach for Green Resilient Supply Chain Network Assessment. Sustainability, 2017, 9, 1433. https://doi.org/10.3390/su9081433
25. Malindzakova, M., Puskas, D. The AHP Method Implementation for ERP Software Selection with Regard to the Data Protection Criteria. TEM Journal, 2018, 7(3), 607-611. https://doi.org/10.18421/TEM73-17
26. Mardani, A., Zavadskas, E. K., Kannan, G., Senin, A. A., Jusoh, A. VIKOR Technique: A Systematic Review of the State of the Art Literature on Methodologies and Applications, Sustainability, 2016, 8, 37. https://doi.org/10.3390/su8010037
27. Mehdi, K. G., Maghsoud, A., Zavadskas, E. K., Zenonas, T., Jurgita, A. Stochastic EDAS Method for Multi-Criteria Decision-Making with Normally Distributed Data. Journal of Intelligent & Fuzzy Systems, 2017, 33, 1627-1638. https://doi.org/10.3233/JIFS-17184
28. Pamucar, D., Stevic, Z., Sremac, S. A New Model for Determining Weight Coefficients of Criteria in MCDM Models: Full Consistency Method (FUCOM). Symmetry, 2018, 10, 393. https://doi.org/10.3390/sym10090393
29. Pamučar, D. S., Božanić, D., Ranđelović, A. Multi-Criteria Decision Making: An Example of Sensitivity Analysis. Serbian Journal of Management, 2017, 12(1), 1-27. https://doi.org/10.5937/sjm12-9464
30. Pandey, P., Litoriya, R. Software Process Selection System Based on Multicriteria Decision Making. Journal of Software: Evolution and Process, 2021, 33(2), e2305. https://doi.org/10.1002/smr.2305
31. Piengang, F. C. N., Beauregard, Y., Kenné, J. P. An APS Software Selection Methodology Integrating Experts and Decisions-maker's Opinions on Selection Criteria: A Case Study. Cogent Engineering, 2019, 6(1). https://doi.org/10.1080/23311916.2019.1594509
32. Pitchipoo, P., Vincent, D. S., Rajakarunakaran, S. COPRAS Decision Model to Optimize Blind Spot in Heavy Vehicles: A Comparative Perspective. Procedia Engi-

neering, 2014, 97, 1049-1059. https://doi.org/10.1016/j.proeng.2014.12.383

33. Pitchipoo, P., Vincent, D. S., Rajakarunakaran, S. Development of Fuzzy Based Intelligent Decision Model to Optimize the Blind Spots in Heavy Transport Vehicles. Promet: Traffic &Transportation, 2016, 28(1), 1-10. https://doi.org/10.7307/ptt.v28i1.1614

34. Puzovic, S., Vasovic, J. V., Radojicic, M., Paunovic, V. An Integrated MCDM Approach to PLM Software Selection. Acta Polytechnica Hungarica, 2019, 16(4), 45-65. https://doi.org/10.12700/APH.16.4.2019.4.3

35. Saaty, T. L. How to Make a Decision: The Analytic Hierarchy Process. European Journal of Operations Research, 1990, 48 (1), 9-26. https://doi.org/10.1016/0377-2217(90)90057-I

36. Sabaei, D., John, E., Rajkumar, R. A Review of Multi-Criteria Decision Making Methods for Enhanced Maintenance Delivery. Procedia CIRP, 2015, 37, 30-35. https://doi.org/10.1016/j.procir.2015.08.086

37. Şen, C. G., Baraçli, H., Şen S. A Literature Review and Classification of Enterprise Software Selection Approaches. International Journal of Information Technology and Decision Making, 2009, 8 (2), 217-238. https://doi.org/10.1142/S0219622009003351

38. Shee, D. Y., Tzeng, G. W., Tang, T. I. AHP, Fuzzy Measure and Fuzzy Integral Approaches for the Appraisal of Information Service Providers in Taiwan. Journal of Global Information Technology and Management, 2003, 6 (1), 8-30. https://doi.org/10.1080/1097198X.2003.10856341

39. Sohrabi, A., Pishvaee, M.S., Hafezalkotob, A., Bamdad, S. A Multi-Attribute Model to Optimize the PRICE and composition of Prepaid Mobile Internet Plans. Journal of Enterprise Information Management, 2020, 33(5), 1257-1291. https://doi.org/10.1108/JEIM-09-2019-0279

40. Stankovic, M., Stevic, Z., Dillip Kumar, D., Subotic, M., Pamucar, D. A New Fuzzy MARCOS Method for Road Traffic Risk Analysis. Mathematics, 2020, 8, 457. https://doi.org/10.3390/math8030457

41. Tsai, W. H., Lee, P. L., Chen, S. P., Hsu, W., Lin T. W. A Study of the Selection Criteria for Enterprise Resource Planning Systems. International Journal Business Systems Research, 2009, 3(4), 456-480. https://doi.org/10.1504/IJBSR.2009.027200

42. Ullah, W., Ibrar, M., Khan, A., Khan, M. Multiple Attribute Decision Making Problem Using GRA Method with Incomplete Weight Information Based on Picture Hesitant Fuzzy Setting. International Journal of Intelligent Systems, 2021, 36(2), 866-889. https://doi.org/10.1002/int.22324

43. Wang, J., Wei, G., Wei, C., Wei, Y. MABAC Method for Multiple Attribute Group Decision Making Under q-rung Orthopair Fuzzy Environment. Defence Technology, 2020, 16(1), 208-216. https://doi.org/10.1016/j.dt.2019.06.019

44. Zadeh, L. A. Fuzzy Sets. Information Control, 1965, 8, 338-353. https://doi.org/10.1016/S0019-9958(65)90241-X

45. Zavadskas, E. K., Kaklauskas, A., Turskis, Z., Tamošaitiene, J. Selection of the Effective Dwelling House Walls by Applying Attributes Values Determined at Intervals. Journal of Civil Engineering and Management, 2008, 14(2), 85-93. https://doi.org/10.3846/1392-3730.2008.14.3