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Interactive Internet-based Tool Proposal for the WASPAS method: a contribution for decision-making process

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Abstract

This paper presents the findings of the waspasWEB Project, which endeavors to furnish decision makers with a readily accessible mechanism for employing the "Weighted Aggregated Sum Product Assessment (WASPAS)" method. The project's societal contribution encompasses the development of a user-friendly, publicly accessible internet tool, as well as a package released on the Comprehensive R Archive Network (CRAN) to cater to the R language user community. The WASPAS method represents a relatively novel approach that has garnered recognition in both scholarly literature and the commercial domain. The utilization of Operations Research methodologies is crucial in justifying decisions, and this endeavor strives to advance the adoption of such methodologies by offering managers, researchers, and the general public an intuitive and easily approachable multicriteria decision-making tool.

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Keywords: CRAN; Decision Theory; Operations Research; R Language; Shiny

1. Introduction

The field of Multi-Criteria Decision Making (MCDM) is rapidly expanding, with various methods and implementations being developed [1]. The work highlights the importance of Operations Research (OR) in decision-making, which has become more complex due to technological advancements and increased uncertainty. In complementary way, as exposed in [2–6], organizations use decision-making procedures that consider multiple criteria and data sources to identify and manage operational risks.

The OR, as science, provides the structuring, understanding, and analysis of scenarios to solve complex problems in a wide set of areas of human action [7–11]. One of the highlights of the models present in the OR is related to the models not being restricted to the implementation of a given equation but instead based on transcribed algorithms of axiomatic structures based on logical and mathematical processes [12–14].

In this environment, the Multi-criteria Decision Methods (MCDM) can be understood as support techniques to the decision-making agent [15], this being an individual, group of individuals, or organization, for decision-making on

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complex problems, selecting, evaluating or ordering alternatives through different points of view and within pre-established criteria [16]. MCDA is essential in clarifying non-dominant alternatives evaluated under multiple criteria, presenting tradeoff relations with each other [17–22]. For decision-making process, the OR becomes a fundamental element in the advisory mechanism for stakeholders [23, 24]. In a reasoned manner, the use of MCDM enables an expanded analysis of the problems in different scenarios, such as [25–34].

This study proposes a solution to the challenges posed by Multi-Criteria Decision Making (MCDM) problems, employing a range of optimization techniques such as AHP, ANP, PROMETHEE, THOR, SAPEVO, TOPSIS, and WASPAS, among others. While the chosen method, WASPAS, may have limited available literature, it exhibits promising potential for both academic research and practical applications in the market. The practical efficacy of the aggregate method is demonstrated by Chakraborty and Zavadskas [35] through its application as an effective MCDM tool to address eight decision-making problems in industrial manufacturing processes. Additionally, the study [36], validate the applicability of WASPAS by optimizing the solution to five common real-time manufacturing problems. The method's applicability extends to all multicriteria decision processes. For instance, in the realm of healthcare, Darko and Liang [37] employ WASPAS to prioritize patient care in the Ghanaian health system. In a distinct context, a study conducted in India [38], utilizes WASPAS to propose an integrated weighting approach for essential factors affecting client satisfaction with the care experience. The study employed real data collected from the largest health service provider in Calcutta and addressed the demands arising from the sector's economic growth and increased competition in the private healthcare domain in the region.

Soares de Assis et al. [39], present an application of the proposed approach in a complex decision-making problem faced by the State Military Police in Rio de Janeiro, regarding the optimal acquisition of a helicopter. The study highlights the various constraints involved, such as cost, operational versatility, and safety criteria, and demonstrates the rigorous application of the proposed method, serving as a valuable resource for validation of the developed systems.

In this scenario, the study aims to provide tangible products to the community by offering a publicly accessible mechanism on the internet that empowers decision-makers to utilize the WASPAS method as a supporting mechanism. The mechanism is user-friendly and intuitive, and abstracts the computational intricacies involved in the calculation algorithms from the user, thereby eliminating the need for programming or mathematical expertise.

2. Materials and Methods

The article discusses the WASPAS method, which is a multi-criteria decision-making system used to address complex decision-making processes involving extensive sets of alternatives and criteria. The method combines the Weighted Sum Model (WSM) and Weighted Product Model (WPM) methods to yield higher accuracy [40]. The article also highlights that the WSM and WPM methods are only applicable to quantitative data and provides caution against employing qualitative data.

The underlying steps of WASPAS, namely WSM and WPM, share initial procedures. The first step involves constructing the Decision Matrix, as MCDM problems are defined by sets of m alternatives and n criteria. Consequently, an m-by-n matrix is created, containing known values of the n criteria for each of the m alternatives, as illustrated in equation (1).

$$X = \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1n} \\ X_{21} & X_{22} & \dots & X_{2n} \\ \dots & \dots & \dots & \dots \\ X_{m1} & X_{m2} & \dots & X_{mn} \end{bmatrix} \tag{1}$$

The second step of the WASPAS method involves normalizing the values in the decision matrix to overcome the issue of highly disparate criteria. Different normalization formulas are used for monotonic cost or benefit criteria, depending on whether higher or lower values are preferred.

For benefit criteria, the normalization process involves dividing the value of each alternative by the maximum value of the set of values for that specific criterion. The performance values of each alternative with respect to each criterion are normalized, such that each value is divided by the maximum value of that criterion across all alternatives. This is done for each monotonic benefit criterion and is represented by equation (2).

$$\overline{X}_{ij} = \frac{x_{ij}}{max_i(x_{ij})} \tag{2}$$

For monotonic cost criteria, the vector of performance values associated with the specific criterion is normalized by dividing each value obtained for the criterion by the smallest value within the set of values. In this case, the normalization of the alternatives' performance values with respect to the criterion involves applying a function to the vector of values X_{ij} for the j^{th} criterion. This function divides the minimum value of the criterion's value vector by the value of the i^{th} alternative. The formula for this normalization process is represented below:

$$\overline{X}_{ij} \frac{min_i(x_{ij})}{x_{ij}} \tag{3}$$

The WSM and WPM methods differ in determining the best alternatives based on the weighting function, while both assign weights to criteria based on their relative importance determined by the decision maker. The goal of MCDM methods is to produce a ranked list of alternatives that represents their relative importance. In the WSM method, the relative importance value for each alternative is obtained by summing the normalized values of the set of criteria assigned to that alternative, denoted by IR_i and W_j respectively, see equation (4):

$$IR_i = \sum_{j=1}^{n} \bar{X_{\iota J}}\, W_j \tag{4}$$

In the WPM method, normalized values of the criteria are raised to the power of the weight assigned to the relative importance of the j^{th} criterion, as shown in the weights vector, represented by equation (5):

$$IR_i = \prod_{j=1}^{n} \left(\bar{X_{\iota J}}\right)^{W_j} \tag{5}$$

The WASPAS method combines the relative importance of the WSM and WPM methods by introducing a lambda parameter between 0 and 1. This parameter is used to determine the Total Relative Importance by combining the weighted relative importance of WSM and WPM. The total relative importance is calculated as the sum of lambda multiplied by the relative importance from the WSM method, and the complement of lambda multiplied by the relative importance from the WPM method. The lambda value determines the emphasis placed on the WSM and WPM relative importance, with a value of 1 emphasizing WSM and a value of 0 emphasizing WPM.

$$IRT_i = \lambda \times IR_i(WSM) + (1 - \lambda) \times IR_i(WPM) \tag{6}$$

By substituting the weighted sum (WSM) and weighted product (WPM) formulas, we arrive at equation (7), which is commonly encountered in relevant technical literature:

$$IRT_i = \lambda \times \sum_{j=1}^{n} \bar{X_{\iota J}}\, W_j + (1 - \lambda) \prod_{j=1}^{n} \left(\bar{X_{\iota J}}\right)^{W_j}, \lambda_i \in [0,1] \tag{7}$$

3. Computational Tool Proposal

The R language [41] serves as the foundation for all the development in this work. R is an open-source language that was created in 1993 for statistical analysis, data mining, machine learning, and database exploration. It benefits from numerous packages available through the CRAN repository and is recognized as one of the most popular languages for statistical analysis, statistical graphing, and data science projects.

This study heavily relied on RStudio IDE, which is free and compatible with multiple operating systems [42]. RStudio was developed by Posit Software PBC, a prominent organization in the R community that offers valuable resources. Posit Software PBC is a Public Benefit Corporation (PBC) with B-Corp certification, meaning it prioritizes both profit and societal well-being. The study also utilized posit.cloud, an online environment similar to RStudio IDE but with usage limitations. Users must create an account to access their designated work area [43].

The internet-based service developed in this study is hosted on shinyapps.io, which offers a free membership plan with limitations on app hosting and availability. Publishing the application involves utilizing the available functionalities within IDEs, which offer a streamlined publishing option specifically designed for Shiny applications. The application can be run in a browser or within the IDE's runtime viewer, which also provides the capability to command the publication of the application on the internet-based [44].

Significant benefits come with building a software package, such as componentization, code reuse, context isolation, and standardized design, leading to improved code readability and an engaged community. The implementation of this project was in the R language, and the package was promoted through CRAN, a vast repository of R packages supported by a global network of FTP servers or mirrors [45]. CRAN undergoes a rigorous certification process for all packages to ensure compliance with strict standards, and contributors must adhere to the repository's policies for package submission. The development process of the package followed a prototyping approach, which included requirements analysis, package structure design, code implementation, documentation, package submission to CRAN, feedback addressing, and continuous package improvement [46]. Communication was ad hoc, based on the availability of the advisor and student and the CBT project's needs, and activities overlapped and proceeded in parallel.

The primary focus of this work was to obtain practical results and apply the authors' knowledge in the development of tangible products. Although the contributions may be modest, they serve as a valuable resource for the community. The website created during this work serves as a useful tool for professionals in the field of Operations Research and individuals seeking to make informed decisions based on reliable mathematical models without the need for complex calculations or software implementations.

4. Case Study

After validating the algorithm implemented by comparing all the results obtained (partial and final) by the work [39], several other exercises were applied. We will report one of them. The most important thing is that the public tool derived from this work can be used for any MCDM study based on the methods presented here (WSM, WPM, and WASPAS), which can be accessed through the link: *flaviob.shinyapps.io/waspasWeb*.

For this case study, we used the mentioned website using a step-by-step guide that serves as a guide for any further study that uses the tool.

- Step 1: Download the database template and edit it using the application of your choice. The spreadsheet will be the one shown in figure 1, but without any colors. The colors are only for didactic purposes;
- Step 2: Download a public database available on kaggle.com with various models of cell phones presenting technical specifications and prices in dollars;
- Step 3: Analysis and preparation of data from the csv file obtained in the previous step. This step consisted of removing non-numeric specifications and other unnecessary columns for the purpose of the MCDM process;
- Step 4: Assign weights to the criteria and define, for each one, whether it is a cost or benefit criterion;
- Step 5: Import the data, and the result of the upload is then displayed as shown in figure 2;
- Step 6: Visualize the data and submit it to the WASPAS algorithm;
- Step 7: Apply the dynamic lambda to observe the ranking change;
- Step 8: Optionally, change the criteria weight values in the original dataset and return to step 4.

F	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Cost
W	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
C	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9	Criterion 10
Alternative 1	1	2	3	4	5	6	7	8	9	10
Alternative 2	2	3	4	5	6	7	8	9	10	11
Alternative 3	3	4	5	6	7	8	9	10	11	12
Alternative 4	4	123	6	7	8	9	10	11	12	13
Alternative 5	5	6	7	8	9	10	11	12	13	14
Alternative 6	6	7	8	9	10	11	12	13	14	15
Alternative 7	7	8	9	10	11	12	13	14	15	16
Alternative 8	8	9	10	11	12	13	14	15	16	17
Alternative 9	9	10	11	12	13	14	15	16	17	18
Alternative 10	10	11	12	13	14	15	16	17	18	19

Fig. 1. Database Structure, available on the website.

Uploaded file: Cell_Phones.xlsx

Size: 88430 bytes

Type: application/vnd.openxmlformats-officedocument.spreadsheetml.sheet

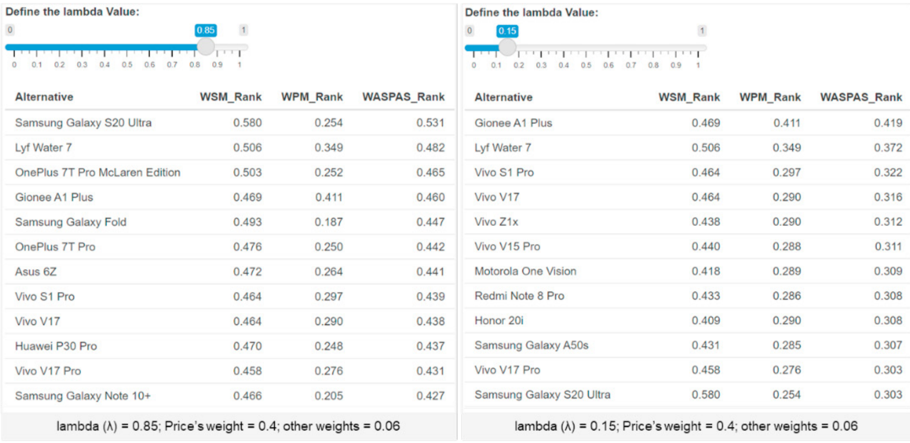
Number of Criteria: 11

Number of Alternatives: 1359

Fig. 2. A dataset with 1359 cell phones with 11 criteria successfully uploaded.

The chosen dataset has the following list of criteria: Battery capacity, Screen size, Resolution x, Resolution y, Processor, RAM, Internal storage, Rear camera, Front camera, Number of SIMs, and Price. The decision maker is required to assign weights to each criterion in such a manner that the summation of weights is equal to 1 or 100%. Since there are eleven criteria and the main one is the Price, some exercises of criteria importance powering can be easily done. For example, a weight of 0.2 or 20% can be assigned to the Price criterion, and the remaining 10 criteria can be equally divided into a weight of 0.08 or 8% each. Similarly, if a weight of 50% is assigned to the Price criterion, the other 10 criteria will have a weight of 0.05 or 5%, to fit the sum of 100%. Alternatively, specific weight values can be assigned for each criterion, provided that the sum of the weights equals 1.

To illustrate the functionality of the tool using a dynamic Lambda application, a value of 0.85 is assigned to Lambda, giving significantly more weight to the WSM method in the overall WASPAS ranking. Conversely, a Lambda value of 0.15 is assigned to invert this weight to the WPM method. In the initial processing, price is given an overvalued weight of 40% while other criteria are neglected. Figure 3 exposes the results.



Alternative	WSM_Rank	WPM_Rank	WASPAS_Rank
Samsung Galaxy S20 Ultra	0.580	0.254	0.531
Lyf Water 7	0.506	0.349	0.482
OnePlus 7T Pro McLaren Edition	0.503	0.252	0.465
Gionee A1 Plus	0.469	0.411	0.460
Samsung Galaxy Fold	0.493	0.187	0.447
OnePlus 7T Pro	0.476	0.250	0.442
Asus 6Z	0.472	0.264	0.441
Vivo S1 Pro	0.464	0.297	0.439
Vivo V17	0.464	0.290	0.438
Huawei P30 Pro	0.470	0.248	0.437
Vivo V17 Pro	0.458	0.276	0.431
Samsung Galaxy Note 10+	0.466	0.205	0.427

lambda (λ) = 0.85; Price's weight = 0.4; other weights = 0.06

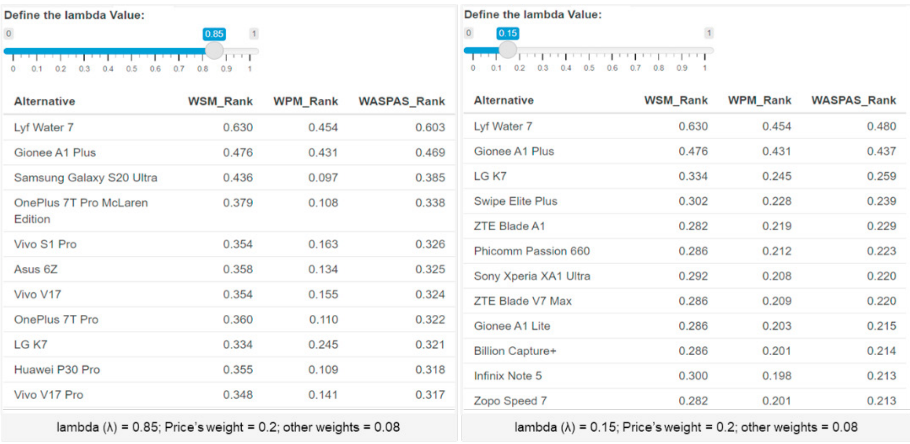
Alternative	WSM_Rank	WPM_Rank	WASPAS_Rank
Gionee A1 Plus	0.469	0.411	0.419
Lyf Water 7	0.506	0.349	0.372
Vivo S1 Pro	0.464	0.297	0.322
Vivo V17	0.464	0.290	0.316
Vivo Z1x	0.438	0.290	0.312
Vivo V15 Pro	0.440	0.288	0.311
Motorola One Vision	0.418	0.289	0.309
Redmi Note 8 Pro	0.433	0.286	0.308
Honor 20i	0.409	0.290	0.308
Samsung Galaxy A50s	0.431	0.285	0.307
Vivo V17 Pro	0.458	0.276	0.303
Samsung Galaxy S20 Ultra	0.580	0.254	0.303

lambda (λ) = 0.15; Price's weight = 0.4; other weights = 0.06

Fig. 3. Sensitivity analysis in the changing of lambda

The slider component allows the dynamic application of the lambda value and the immediate visualization of the sensitivity of each of the underlying methods (WSM and WPM) to the dataset under study.

Second processing: slightly decreasing the price weight to 20%, and equally distributing the other 80% to the other 10 criteria. As in the previous exercise, lambda values of 0.85 are applied, applying more weight in the WSM method, and then the lambda is changed to 0.15, favoring the WPM method. Figure 4 presents the new results.



Alternative	WSM_Rank	WPM_Rank	WASPAS_Rank
Lyf Water 7	0.630	0.454	0.603
Gionee A1 Plus	0.476	0.431	0.469
Samsung Galaxy S20 Ultra	0.436	0.097	0.385
OnePlus 7T Pro McLaren Edition	0.379	0.108	0.338
Vivo S1 Pro	0.354	0.163	0.326
Asus 6Z	0.358	0.134	0.325
Vivo V17	0.354	0.155	0.324
OnePlus 7T Pro	0.360	0.110	0.322
LG K7	0.334	0.245	0.321
Huawei P30 Pro	0.355	0.109	0.318
Vivo V17 Pro	0.348	0.141	0.317

lambda (λ) = 0.85; Price's weight = 0.2; other weights = 0.08

Alternative	WSM_Rank	WPM_Rank	WASPAS_Rank
Lyf Water 7	0.630	0.454	0.480
Gionee A1 Plus	0.476	0.431	0.437
LG K7	0.334	0.245	0.259
Swipe Elite Plus	0.302	0.228	0.239
ZTE Blade A1	0.282	0.219	0.229
Phicomm Passion 660	0.286	0.212	0.223
Sony Xperia XA1 Ultra	0.292	0.208	0.220
ZTE Blade V7 Max	0.286	0.209	0.220
Gionee A1 Lite	0.286	0.203	0.215
Billion Capture+	0.286	0.201	0.214
Infinix Note 5	0.300	0.198	0.213
Zopo Speed 7	0.282	0.201	0.213

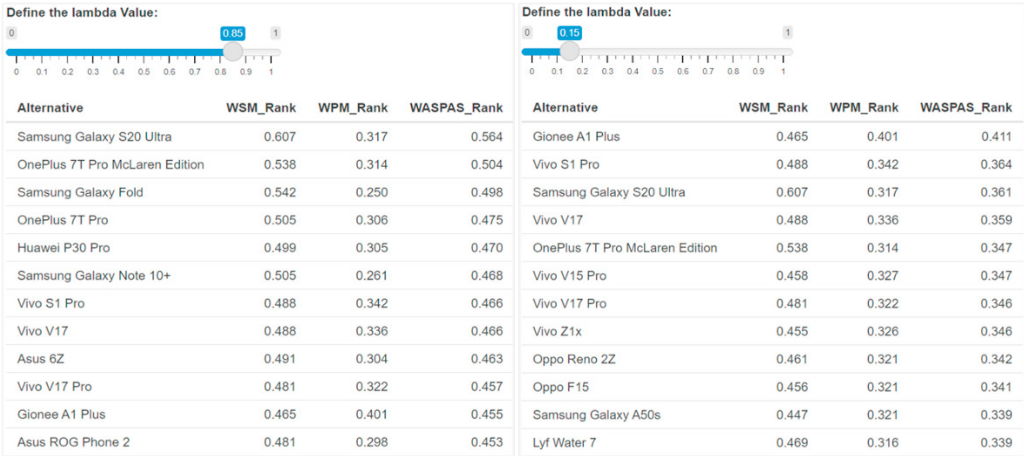
lambda (λ) = 0.15; Price's weight = 0.2; other weights = 0.08

Fig. 4. Sensitivity analysis in the changing of lambda and weights

These first two exercises demonstrate the ease of use of the waspasWEB tool. Now let's apply a more "human" weighting to the criteria, since the technical specifications generally have different relative importance among themselves and the weight of the *Price* criterion may, in fact, not have the oversized importance that we used previously (in many cases, the price is less important than other performance criteria). The weighted set of criteria is shown in table 1, and the results of the third exercise are shown in figure 5.

Table 1. Weighting criteria that would likely make more sense to a decision maker.

Criteria	Weight	Criteria	Weight
Battery capacity (mAh)	0.10	Number of SIMs	0.05
Screen size (inches)	0.10	Internal storage (GB)	0.10
Resolution x	0.075	RAM (MB)	0.10
Resolution y	0.075	Rear camera	0.075
Processor	0.10	Front camera	0.075
Price	0.15		


Define the lambda Value: 0.85

Alternative	WSM_Rank	WPM_Rank	WASPAS_Rank
Samsung Galaxy S20 Ultra	0.607	0.317	0.564
OnePlus 7T Pro McLaren Edition	0.538	0.314	0.504
Samsung Galaxy Fold	0.542	0.250	0.498
OnePlus 7T Pro	0.505	0.306	0.475
Huawei P30 Pro	0.499	0.305	0.470
Samsung Galaxy Note 10+	0.505	0.261	0.468
Vivo S1 Pro	0.488	0.342	0.466
Vivo V17	0.488	0.336	0.466
Asus 6Z	0.491	0.304	0.463
Vivo V17 Pro	0.481	0.322	0.457
Gionee A1 Plus	0.465	0.401	0.455
Asus ROG Phone 2	0.481	0.298	0.453

Define the lambda Value: 0.15

Alternative	WSM_Rank	WPM_Rank	WASPAS_Rank
Gionee A1 Plus	0.465	0.401	0.411
Vivo S1 Pro	0.488	0.342	0.364
Samsung Galaxy S20 Ultra	0.607	0.317	0.361
Vivo V17	0.488	0.336	0.359
OnePlus 7T Pro McLaren Edition	0.538	0.314	0.347
Vivo V15 Pro	0.458	0.327	0.347
Vivo V17 Pro	0.481	0.322	0.346
Vivo Z1x	0.455	0.326	0.346
Oppo Reno 2Z	0.461	0.321	0.342
Oppo F15	0.456	0.321	0.341
Samsung Galaxy A50s	0.447	0.321	0.339
Lyf Water 7	0.469	0.316	0.339

Fig. 5. Sensitivity analysis setting direct weights, with higher importance to WSM ranking and WPM ranking, respectively

The waspasWEB also offers a radar graph view, in which the lambda value is also dynamically applied and immediate visualization of the WASPAS (green), WSM (black) and WPM (red) ranking lines is obtained. The Radar charts, also known as spider web chart or Kiviat diagram are shown in figure 6.

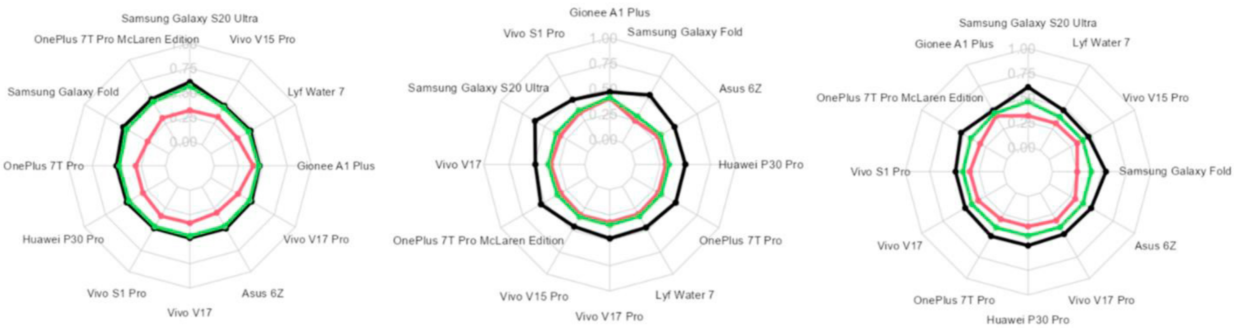


Fig. 6. Kiviat diagram exposition of results

As presented, the proposed computational model works as aid in the implementation of WASPAS methodology, performing the aggregation of numerical preferences through numerical and graphical resources, helping I the clarity of results transparently. The numerical example used in this study works just as aid in the understanding of the interactivity of the internet-based platform, being possible the implementation different case studies with different levels of complexity, in operational, tactical, and strategical environments.

Regarding the source-code complexity perspective, all the necessity of computational programming is transcribed into an internet-based platform, where there is no necessity of coding by the user, as is presented in some computational models [47], being just necessary the alignment of the problematic situation to the WASPAS methodology and basic knowledge to interactive computational platforms, where on the website, is possible to understand all software functionalities through a manual guide to support the users.

5. Conclusion

The present study was based on presenting a computational interactive web model as support in decision-making process through the implementation of WASPAS method, built under the multi-criteria decision support approach.

The WASPAS method is a flexible approach and can be adapted to different types of problems and scenarios. However, it is important to remember that it depends on the accuracy of the weights and values assigned to the criteria and alternatives, which can be difficult to obtain in some situations. Furthermore, the WASPAS methodology can be mathematically demanding for problems with many alternatives or criteria, being necessary the computation support.

The computation proposed framework, presents an interactive approach concerning for the user, enabling the implementation of the mathematical model along with the performance of a sensitivity analysis in the changing of the weights and thresholds of the methodology. As a form of future studies, we search for the integration of a module for open formats exportation of the provided calculations and its results, along with the charts exportation by vectorial graphics, with a high quality of images. Also, we consider the implementation of the model in other case studies framed in the specifications of the method, providing not only the resolution of these but also the identification of improvement points for greater robustness in the method and computational model.

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