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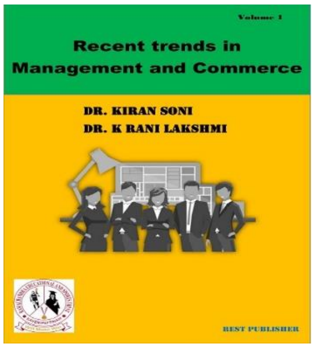

A Study on The Evaluation of Mobile Phones Using the TOPSIS method

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Abstract: *Mobile gadgets are widely used since they have expanded our world and given us new opportunities. Comparing modern mobile devices to Personalized Computers (PCs) from ten years ago reveals that they are more potent. Mobile devices are appealing to users because they are more portable than PCs. Additionally, the fact that they are smaller than personal computers contributes significantly to their growing appeal. Research significance: Online shopping and service websites are particularly affected by the necessity to upgrade service standards and innovate to maintain or increase profit levels in a fiercely competitive industry. The introduction of client enhancements that will aid their judgement process in selecting the products they buy is a crucial component in the successful accomplishment of this goal. Methodology: During this paper, the performance of the chosen mobile phones is assessed using the "technique for order of preference by similarity to ideal solution (TOPSIS)". The "equal weights method (EWM)" assigns several criteria particularly weights of relevance. Result: The rank of alternatives using the TOPSIS method for "Samsung Galaxy S23 Ultra 5G is first, Apple iPhone 14 Pro Max is fifth, Google Pixel 7 Pro 5G is third, OnePlus 11 is fourth and Samsung Galaxy Z Fold 4 5G is second". Conclusion: The result of the analysis shows that the best smartphone among the given mobiles is the "Samsung Galaxy S23 Ultra 5G with 256 GB internal memory, 12 GB RAM, 5000mAH battery capacity, the weight of 233 grams and approximate price of ₹125000".*

Keywords: *Smartphones, Internal memory (GB), RAM (GB), Battery capacity (mAh) Approximate price (in rupees) and MCDM.*

1. INTRODUCTION

An entirely new generation of information interchange has begun as a result of the extensive use of mobile devices as opposed to personal computers. While the shipment of smartphones is rising, personal computer purchase trends have started to decline. Additionally, customers' attention has been drawn to mobile devices due to their growing power and portability features [1]. Portable devices are appealing to users because they are more portable than PCs. Additionally, the fact that they are smaller than personal computers contributes significantly to their growing appeal. Additionally, users' interest is growing in "Rich Mobile Applications (RMA)", like Google Maps, which offer a rich user experience and high levels of interactivity. However, such popularity comes with significant security and privacy risks as well as several other criminal practices. The user is unaware of the harmful activity, which is carried out silently or at odd hours [2,3]. The quantity of PCs is declining while the shipments of handheld phones are rising, according to a comparison between PCs and mobile, ultramobile, tablet, and mobile phone devices. In research on mobile phone usage, there was more Internet traffic related to mobile devices [4]. The purchase of handsets like "Personal Digital Assistants" has been prompted by the present trend toward an extremely manoeuvrable workforce (PDAs). Small physical size, constrained computational power and battery capacity, and the capability of data exchange with a more powerful notebook or desktop pc are characteristics of handheld devices. Additionally, they support interfaces that are mobile-friendly, such as touch screens and microphones in place of keyboards [5]. For both local and remote wireless communication systems, one or more wireless ports, such as "infrared (e.g., IrDA) or radio (e.g., Bluetooth, WiFi, GSM/GPRS)", are typically built-in. The majority of portable devices may be set up to send and receive an email as well as access the web. Although these gadgets have their drawbacks, they provide productivity capabilities in a small package at a reasonable price, and they are swiftly gaining ubiquity in today's business world [6]. Mobile phone hardware has advanced exponentially as a result of its extensive use for communication and information transfer. Innovative functionalities and applications are constantly being introduced to mobile phones to enable them to perform a wide range of new functions in order to satisfy consumers' information needs. Due to these changes, the mobile phone, which is fundamentally a communication tool, now offers features that go beyond the limitations of traditional speech conversation between two people [7,8]. Far above voice, mobile phones satisfy users' needs by offering: (1) interaction services that enable information to be transferred in the form of "text, graphics, and voice", (2) wireless Internet access like "browsing and e-mail", and (3) interactive media and multimedia applications like "colour screens, movies, cameras, games, and music". Detail assessments must be performed in order to fully comprehend the demands and desires of mobile phone users because these aspects are essential to providing universal availability to information and to encouraging the establishment of social communities among its customers [9,10]. He anticipated that products created to satisfy "customer requirements (CRs) and needs" wouldn't be enough to guarantee producers the lion's share of the market. In order for businesses to thrive and expand in "free market economies", they must constantly create new items that can address market needs. The primary focus of businesses in the industries based on full competitiveness is now generating items employing new contemporary research efforts or producing entirely new products [11,12]. In this study "Samsung Galaxy S23 Ultra 5G, Apple iPhone 14 Pro Max, Google Pixel 7 Pro 5G, OnePlus 11 and Samsung Galaxy Z Fold 4 5G" are evaluated with specifications "Internal memory (GB), RAM (GB), Battery (mAh), Weight (gram) and Approximate price (in rupees)" to selection best mobile phone.

2. MATERIALS AND METHODS

The examination method "TOPSIS" is widely used to assess MCDM difficulties. It can be used for a variety of practical tasks, such as determining the financial viability of an industry, comparing economic results, and investing in cutting-edge manufacturing techniques. But there are also some limitations [13]. Unfortunately, the "TOPSIS method" does contain several significant flaws. The likelihood for the incidence known as "rank reversal" is one of the difficulties that TOPSIS brings. When a choice is added to or removed from the decision-making dilemma, the "order of preference for the alternatives" changes [14]. When a solution is added to or removed from, a "Total rank reversal" happens when priorities are completely reversed and the options that were once thought to be the best are now the worst. In "MCDM" a variety of options must be examined and evaluated based on a number of variables. Allowing the decision-maker to select from a range of possibilities is the aim of MCDM. Therefore, practical situations frequently entail multiple competing criteria, and it is unlikely that any single solution can satisfy all of the criteria simultaneously. Therefore, depending on the decision objectives, the solution is a balanced choice. The choice that is "the Negative Ideal Solution (NIS) and most similar to the Positive Ideal Solution (PIS)" will produce the best results, according to TOPSIS' guiding concept. The closeness metric is used to determine the final score [17,18].

Step 1: The decision matrix X, which displays "how various options perform concerning certain criteria", is created.

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

Step 2: Weights for the criteria are expressed as

$$w_j = [w_1 \cdots w_n], \quad where, \sum_{j=1}^{n} (w_1 \cdots w_n) = 1 \quad (2)$$

Step 3: The matrix x_{ij}'s normalized values are computed as

$$n_{ij} = \frac{x_{ij}}{\sqrt[2]{\sum_{i=1}^{m} x_{ij}^2}} \quad (3)$$

"Weighted normalized matrix N_{ij}" is calculated by the following formula

$$N_{ij} = w_j \times n_{ij} \quad (4)$$

Step 4: To begin, let's establish the "ideal best and ideal worst values": Here, we need to decide if the influence is "+" or "-. " If a column has a "+" impact, its greatest value is the "ideal best value for that column," and if it has a "-" influence, its poorest number is the "ideal worst value."

Step 5: Now we need to find "the difference between each response from the ideal best",

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (N_{ij} - A_j^+)^2} \quad for\ i \in [1, m]\ and\ \ j \in [1, n] \quad (5)$$

Step 6: Now we need to find "the difference between each response from the ideal worst",

$$S_i^- = \sqrt{\sum_{j=1}^{n} (N_{ij} - A_j^-)^2} \quad for\ i \in [1, m]\ and\ \ j \in [1, n] \quad (6)$$

Step 7: Now we need to find "the Closeness coefficient of i_{th} alternative"

$$CC_i = \frac{S_i^-}{S_i^+ + S_i^-} \quad where, 0 \le CC_i \le 1, i \in [1, m] \quad (7)$$

The number of "The Closeness Coefficient" shows how much better the options are in relation. A "significantly worse alternative" is indicated by a smaller, CCi. and a "substantially better alternative" by a larger, CCi.

In this study “Samsung Galaxy S23 Ultra 5G, Apple iPhone 14 Pro Max, Google Pixel 7 Pro 5G, OnePlus 11 and Samsung Galaxy Z Fold 4 5G” are evaluated with specifications “Internal memory (GB), RAM (GB), Battery (mAh), Weight (gram) and Approximate price (in rupees)” to selection best mobile phone. Internal memory (GB): Main storage, which is typically 16, 32, or 64GB in size, is the industry installed storage capacity where the OS, pre-loaded applications, and other system software are installed. If your phone only has 16GB of internal storage and no extension slot, this is the maximum amount of storage you will ever have because the user cannot change the total quantity of internal storage. Also keep in mind that the system software will have eaten up part of this [19]. RAM (GB): "RAM" is the area of the phone where the working system (OS) and any apps or data that is now open are stored. In contrast, phone memory is used to keep files, programmes, images, and movies that are essential for the device to function [20]. Battery capability (AH) is calculated as the sum of the currents pulled from the battery when it is able to power the load up to the point at which the voltage of each cell drops below a predetermined level. Longer run times are typically associated with higher mAh values for much the same battery cell. This does not hold true when contrasting various battery kinds. This implies that judging a battery's capacity alone may not be sufficient to determine how long your electrical gadget will operate [21]. Weight (gramme): The majority of smartphones today weigh between 130 grammes and 200 grammes, with screen sizes ranging from just over 5 inches to slightly over 6 inches. The largest smartphones, like the Samsung Galaxy Note 8, weigh 200 grammes. Price range (in rupees): Gross prices is the sum of a product's price and any applicable sales tax or other expenses [22].

3. ANALYSIS AND DISCUSSION

TABLE 1. Smart phones specifications

Mobile Phones	Internal memory	RAM	Battery	Weight	Approx. price
Samsung Galaxy S23 Ultra 5G	256	12	5000	233	125000
Apple iPhone 14 Pro Max	128	6	4323	240	128000
Google Pixel 7 Pro 5G	128	12	5000	212	72490
OnePlus 11	128	8	5000	205	57000
Samsung Galaxy Z Fold 4 5G	256	12	4400	263	127700

Table 1 shows the Smart phones specifications. Internal memory (GB), RAM (GB), Battery (mAh), Weight (gram) and Approximate price (in rupees) are used to evaluate the selected mobile phones.

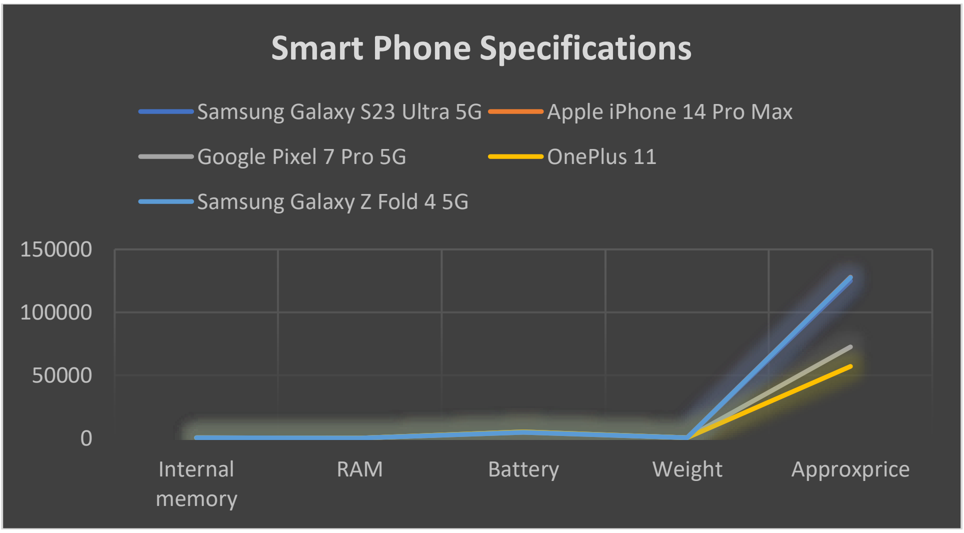

FIGURE 1. Smart phones specifications

Figure 1 shows a graphical view of Smart phones specifications. Internal memory (GB), RAM (GB), Battery (mAh), Weight (gram) and Approximate price (in rupees) are used to evaluate the selected mobile phones.

TABLE 2. Normalized Data

0.6030	0.5203	0.4703	0.4501	0.5244
0.3015	0.2601	0.4066	0.4636	0.5370
0.3015	0.5203	0.4703	0.4095	0.3041
0.3015	0.3468	0.4703	0.3960	0.2391
0.6030	0.5203	0.4138	0.5080	0.5357

The normalized matrix of the Ratings of the performance of the selection of the six-sigma project is displayed in Table 2 above. This matrix was produced using equation three.

TABLE 3. Weight

0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2

The preferred weight for the evaluation parameters is shown in Table 3. In this case, weights are equally distributed among " Internal memory (GB), RAM (GB), Battery (mAh), Weight (gram) and Approximate price (in rupees)". The sum of weights distributed equals one.

TABLE 4. Weighted normalized decision matrix

0.1206	0.1041	0.0941	0.0900	0.1049
0.0603	0.0520	0.0813	0.0927	0.1074
0.0603	0.1041	0.0941	0.0819	0.0608
0.0603	0.0694	0.0941	0.0792	0.0478
0.1206	0.1041	0.0828	0.1016	0.1071

Table 4 shows the weighted normalized matrix of the decision matrix and it is calculated by table 2 and table 3 using equation 4.

TABLE 5. Positive Matrix

0.1206	0.1041	0.0941	0.0792	0.0478
0.1206	0.1041	0.0941	0.0792	0.0478
0.1206	0.1041	0.0941	0.0792	0.0478
0.1206	0.1041	0.0941	0.0792	0.0478
0.1206	0.1041	0.0941	0.0792	0.0478

Table 5 shows the positive matrix calculated by using table 4. The ideal best for a column is the maximum value of that column in table 4.

TABLE 6. Negative matrix

0.0603	0.0520	0.0813	0.1016	0.1074
0.0603	0.0520	0.0813	0.1016	0.1074
0.0603	0.0520	0.0813	0.1016	0.1074
0.0603	0.0520	0.0813	0.1016	0.1074
0.0603	0.0520	0.0813	0.1016	0.1074

Table 6 shows the negative matrix calculated by using table 4. The Ideal best for a column is the minimum value in that column in table 4.

TABLE 7. SI Plus and Si negative

Mobile Phones	SI Plus	Si Negative
Samsung Galaxy S23 Ultra 5G	0.0581	0.0815
Apple iPhone 14 Pro Max	0.1012	0.0089
Google Pixel 7 Pro 5G	0.0617	0.0737
OnePlus 11	0.0696	0.0672
Samsung Galaxy Z Fold 4 5G	0.0644	0.0797

Table 7 shows the "Si plus and Si negative values". The difference between each response from the "ideal best (S_i^+)" is found utilizing equation 5 and the difference between each response from the "ideal worst (S_i^-)" is found utilizing equation 6.

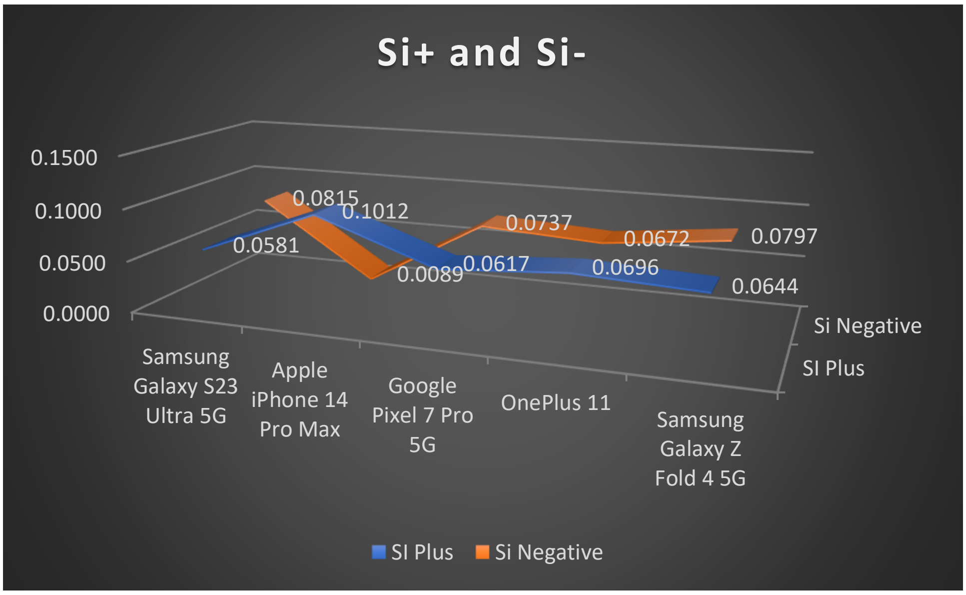

FIGURE 2. SI Plus and Si negative

The figure illustrates the "Si plus and Si negative values" from the analysis. The difference between each response from the "ideal best (S_i^+)" is found utilizing equation 5 and the difference between each response from the "ideal worst (S_i^-)" is found utilizing equation 6.

TABLE 8. Closeness coefficient

Mobile Phones	Ci
Samsung Galaxy S23 Ultra 5G	0.5840
Apple iPhone 14 Pro Max	0.0807
Google Pixel 7 Pro 5G	0.5440
OnePlus 11	0.4913
Samsung Galaxy Z Fold 4 5G	0.5529

Table 8 demonstrates the value of CCi. It is calculated by using equation 7. Here Closeness coefficient value for Samsung Galaxy S23 Ultra 5G is 0.5840, Apple iPhone 14 Pro Max is 0.0807, Google Pixel 7 Pro 5G is 0.5440, OnePlus 11 is 0.4913 and Samsung Galaxy Z Fold 4 5G is 0.5529.

TABLE 9. Rank

Mobile Phones	Rank
Samsung Galaxy S23 Ultra 5G	1
Apple iPhone 14 Pro Max	5
Google Pixel 7 Pro 5G	3
OnePlus 11	4
Samsung Galaxy Z Fold 4 5G	2

Table 9 shows the analysis of the selection of given mobile phones. Here rank of Samsung Galaxy S23 Ultra 5G is first, Apple iPhone 14 Pro Max is fifth, Google Pixel 7 Pro 5G is third, OnePlus 11 is fourth and Samsung Galaxy Z Fold 4 5G is second.

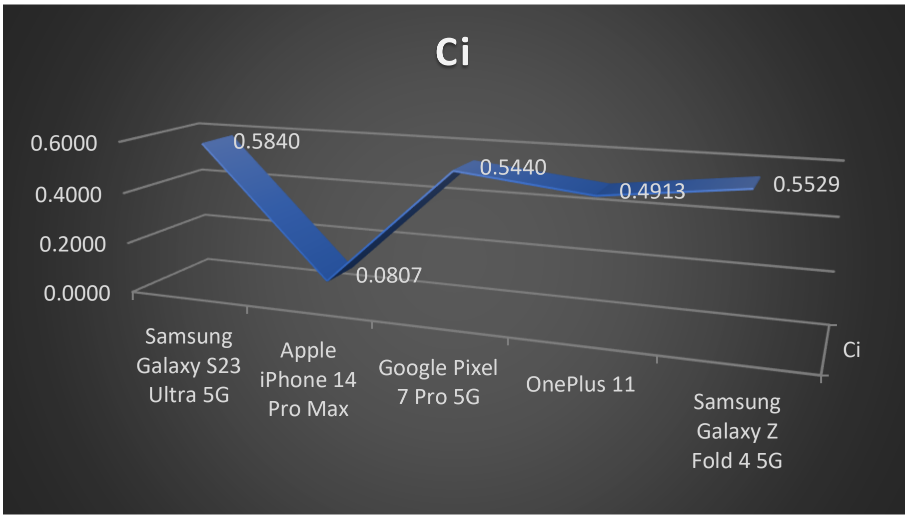

FIGURE 3. Closeness Coefficient (CCi)

Figure 3 illustrates the graphical representation of CCi. It is calculated by using equation 7. Here Closeness coefficient value for Samsung Galaxy S23 Ultra 5G is 0.5840, Apple iPhone 14 Pro Max is 0.0807, Google Pixel 7 Pro 5G is 0.5440, OnePlus 11 is 0.4913 and Samsung Galaxy Z Fold 4 5G is 0.5529.

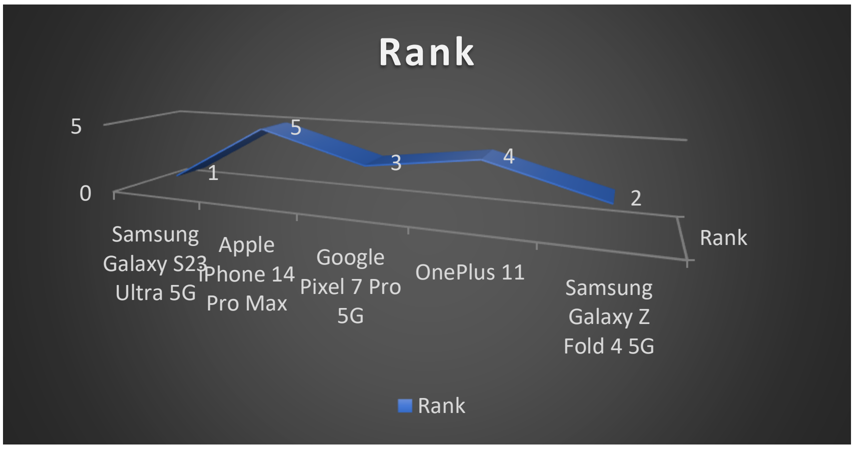

FIGURE 4. Rank

Figure 4 illustrates the ranking of Ui from Table 9. Here rank of alternatives using the TOPSIS method for Samsung Galaxy S23 Ultra 5G is first, Apple iPhone 14 Pro Max is fifth, Google Pixel 7 Pro 5G is third, OnePlus 11 is fourth and Samsung Galaxy Z Fold 4 5G is second. Result of the analysis shows that best smart phone among given mobiles is Samsung Galaxy S23 Ultra 5G with 256 GB internal memory, 12 GB RAM, 5000mAH battery capacity, weight of 233 gram and approximate price of ₹125000.

4. CONCLUSION

Mobile phones are crucial research tools due to their extensive use, the variety of information access methods they offer to their users, and their major influence on users' daily lives. Mobile communication technology, such as wireless Internet, mobile phones, MP3 players, and GPS navigation systems, has undergone a protracted process of innovation that is continually changing and updating according to shifting consumer needs and preferences. The cell phone is considered to be "the most radiative household appliance ever invented" when compared to other modern mobile communication technologies. In the history of contemporary technology, the equipment has one of the quickest rates of home adoption. The product's cutting-edge features are what matter most when students are choosing mobile phones. This may be connected to the fact that, especially among young people, mobile phones are increasingly commonly considered as fashion accessories. Therefore, when it comes to consumer preference for smart phones, "innovation in feature and design" is at the forefront. The rank of alternatives using the TOPSIS method for Samsung Galaxy S23 Ultra 5G is first, Apple iPhone 14 Pro Max is fifth, Google Pixel 7 Pro 5G is third, OnePlus 11 is fourth and Samsung Galaxy Z Fold 4 5G is second. Result of the analysis shows that best smart phone among given mobiles is Samsung Galaxy S23 Ultra 5G with 256 GB internal memory, 12 GB RAM, 5000mAH battery capacity, weight of 233 gram and approximate price of ₹125000.

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