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# Fuzzy Importance Performance with Information Entropy Analysis -An Integrated Approach to Optimize Resource Allocation in Mobile Banking.

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## Abstract

The study proposes Fuzzy Importance Performance with Information Entropy Analysis (FIPIEA), an integrated framework to measure service quality and improve resource allocation in mobile banking by identifying the most critical parameters for the bank's customers and making recommendations to managers about the best use of resources to enhance customer satisfaction. The planned framework attempts to eliminate ambiguity by replacing IPA with a fuzzy approach by introducing info(n.) and fuzzy logic. We verified the framework by administering a 23-item survey tool to bank customers. The survey data was processed through the use of the impact study method, fuzzy logic and info(n) entropy. The processed data identified six key dimensions of m-banking service quality: functional benefit, information quality, structural assurance, trust, system quality, and service quality, which include 19 integral attributes. The study revealed that through the use of FIPIEA, market analysts can effectively identify the factors that should be maintained or improved.

**Keywords:** Entropy, Fuzzy, FIPIEA, Optimize, Resource allocation.

## 1. Introduction

In the last two decades, the fast development of technological breakthroughs, changing customer behavior, and the creation of new items and services have drastically altered the landscape of businesses **(** Geebren, Jabbar, Ming Luo. (2021), Baptista & Oliveira, 2016; Malaquias & Hwang, 2016). To continue in such turbulent times, many organizations, including banking, had to make an effort to change the way they operate. (Donth &Gustafson, 2020). The business models of the multi-channel banking industry (such as internet and mobile banking) have undergone significant changes. (De Leon, 2019). Due to this transition, customers have started using mobile banking for routine financial transactions and account functions. (Kizgin, & Patil, 2019; Sampaio, Ladeira, & Santini, 2017). According to Statista's 2022 study, there are about 16 billion mobile devices in use worldwide and the figure is expected to rise to 18.22 billion by 2025. Additionally, the rapid use of Mobile in not-so-developed countries, is allowing customers to alter their mode of transaction from offline to online (Nguyen & Khoa, 2019d). Moreover, in developing countries, people continue to have concerns about service delivery and satisfaction in relation to m- m-banking. (Kizgin, & Patil, 2019) As a result, providing superior services has become increasingly important. (Chen et al 2011). In this context, examining the most important parameters linked to customer satisfaction is of vital importance for allied businesses (Khan et al.,2020).

In this research, a new method is devised which combines importance-performance with Impact and entropy analysis for measuring service quality in m- banking. The framework attempts to remove bias in decision making by removing the deficiencies of the traditional "Importance Performance Analysis" (IPA) matrix. ("Martilla and James,1977"). Because of this inaccuracy and to to lessen the ambiguity caused by the fuzzy nature of subjective human judgements, the new integrated "fuzzy" approach has been used.

### Studies on mobile banking services quality

Mobile banking helps clients to carry out various banking operations remotely in the most speedy and convenient manner. (Shankar & Datta, 2018) . The activities that can be carried out include instantaneous money transfer, examining accounts, and other banking services (Tam & Oliveira, 2016b; Zhou, 2012**).** The concept of mobile banking has been studied by many scholars. (e.g. Hwang 2018.). Many attempts have been made by researchers in the past to investigate mobile banking using various theoretical and numerical approaches. Shareef et al., 2018) The numerical approach focused on exploring various aspects like understanding differences among countries (Hwang, 2019); and impediments to the adoption of m-banking (Chaouali & Souiden, 2019) . Most of these studies are focused on understanding the attitude towards mobile banking.(Richter, 2018 ). However, when it comes to service quality and resource allocation (here forth SQ and RA), previous studies have not sufficiently addressed this area. (Komulainen & Saraniemi, 2019). Thus, in this paper an attempt is made to explore customer satisfaction in mobile banking (MB) through optimal resource allocation by using FIPIEA approach by combining fuzzy theory and information entropy.

## 2. Theoretical Framework

Importance Performance Analysis (IPA) is used for assessing a client's needs by examining the most important service/ product attributes. (James and Martilla, 1977). IPA has been utilized for a long time to comprehend consumer desires**. I**t has been widely used in various studies such as airlines (Atalay 2019), travel (Guizzardi & Stacchini, 2017),education (Chen & Chen, 2012), public transportation (Freitas 2013), and banking (Yeo 2003). IPA classifies features of the product or services into four equal parts . Prior to this, the determination of the score of the feature's performance and score of the feature's importance divide each one of the two dimensions into two levels. (Figure). The vertical axis reflects the "importance" and horizontal -axis shows the "performance". Until now various methods like scale-centred ("Tonge & Moore, 2007") and data-centered method (Ramakrishnan & Usha, 2016) have been used to split the grid. However, in the present study, the mean of features importance and features performance" and "Impact importance and attribute performance" are employed to split the grid.

Quadrant I ("Concentrate here") The characteristics /features in this grid needs to be focussed with highest efficiency. These attributes are of utmost importance to customers.

Quadrant II ("Keep Up the Good Work"). It is advisable to maintain the current tactics for the characteristics contained in the second quadrant.

Quadrant III ("Low Priority"). The characteristics lying in the third part are not of much significance from the client's point of view.

Quadrant IV ("Possible Overkill"). The managers place too much emphasis on the characteristics in this grid. Rather , they should devote more resources to characteristics lying in the Grid I

Some studies on refining the IPA model have been conducted . Primarily these studies focus on various categories like determination of numerous ways to split the quadrant by altering scale on X and Yaxis (Tong and Moore 2007) and by using data-centric approach ( cobanogluw, 2008) and by analysing the competitors performances (Albayrak, 2015; Guizzardi & Stacchini, 2017 ). In this background, the current study involves calculation of the impact importance of attributes by using information entropy and mean performance of attributes for placement of crosshairs.

Although IPA is a useful method, it has certain shortcomings like erroneous assumptions of causal and proportional relationship between performance and importance (Geng 2013 ), an inadequate assessment of attribute performance (Matzler et al., 2004). Some other shortcomings are incapacity to define the thresholds of IPA quadrants ( Sever, 2015). In order to overcome these shortcomings, a novel approach for calculating impact values was used. Impact takes into consideration the opinion of customers for resource allocation. The FIPIEA developed by calculating impact values using fuzzy logic and entropy is an improvement over the IPA and FIPA approach (Lin, Z. and Vlachos, I. (2018). The FIPIEA method provides a more reliable and valid approach for correcting the deficiencies of data. Additionally, it makes it possible for managers to consider more viewpoints to deliver the highest level of satisfaction by reallocating resources to other important areas. (Lin, Z and Vlachos, I. 2018)

The FIPIEA approach by taking into consideration impact factor, enables managers to allocate resources in a judicious manner. Managers would allocate resources inadvertently if the impact factor was not taken into account. The impact factor reveals the direction and strength of the qualities' influence on assigning resources (Lin and Viachos, 2017). Therefore, in this paper, the FIPIEA approach is used to make optimal distribution of resources.

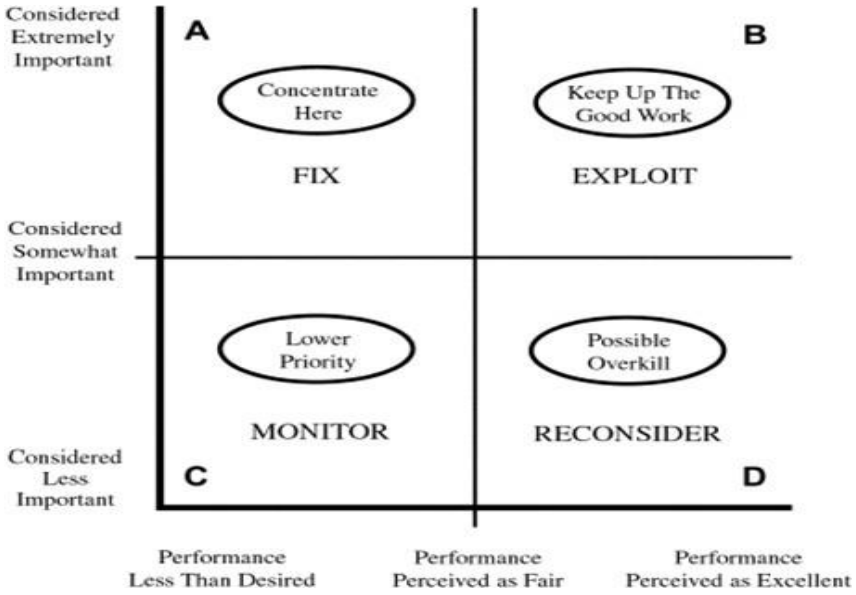


Fig 1 "Importance-performance analysis" (IPA) ("Martilla and James, 1977")

## 3. Fuzzy set theory and Information Entropy:

Fuzzy theory deals with issues involving vagueness. Zadeh expressed fuzzy groups as, "sets with boundaries that are not precise". Inclusion in a fuzzy set is a question of degree instead of acceptance or rejection. Fuzzy logic ensures sophisticated calculations by converting dialectal strategies into commands ("Sumathi, & Deepa, 2007"). Fuzzy theory has been employed by researchers in diverse fields to assess service quality (Chon et al., 2008; Wang, 2004). The responses to the questionnaire were based on assessments like "poor", good and average results in uncertain and imprecise information. (Benizer et al 2007) With the use of fuzzy theory, Zadeh (1965) was able to resolve this issue. Fuzzy theory handles the vagueness and impreciseness of the information. Given that the scale used a 5-point scale (1=strongly disagree, 5=strongly agree) , which is expressed in terms of Triang Fuzzy Numbers (TFN). In this, the belongingness level of a TFN has been denoted by Eq.(1 ) where $a_1, < a_2 < a_3$ .The higher and lower limits are $a_3$ and $a_1$ respectively and intermediate limit $a_2$ refers to the maximum value.

$$\mu_{A\,(x)}= \begin{cases} 0 & x < a_1 \\ x - a_1/a_2 - a_1 & a_1 \le x \le a_3 \\ a_3 - x/a_3 - a_2 & a_2 \le x \le a_3 \\ 0 & x > a_3 \end{cases} \quad (1)$$

To remove bias and ambiguity in decision-making, the present study makes use of info.(n) entropy to analyze the data. Hence in social sciences, this approach is of great relevance. ( Nijkamp,1977). Entropy is used as a measure for the information amount and is illustrated by a discrete probability distribution. According to Weaver (1947), Impact values for entropy can be calculated as given below.

$$\text{Ent}\ (p_{1,\ldots\ldots\ldots}p_j) = \frac{1}{\ln(j)} \sum_{i=1}^{j} p_j \ln p_j \qquad (2)$$

where $\frac{1}{\ln(j)}$ is a non- negative constant.

The new model by taking into consideration the effect/ impact reduces ambiguity and improves the dependability and practicality of judgment for better resource allocation. Many studies in the past have been done using "fuzzy Importance-Performance Analysis" (FIPA) a refined version of IPA approach. The present study is an improvement over these studies as it integrates info(n.) entropy and the Fuzzy IPA (FIPA) into a combined approach. (FIPIEA).

## 4. Algorithm for FIPA with information entropy approach.

The proposed algorithm for FIPA with an information entropy approach is formally given as shown below.

Step 1 The sum total value of attributes is shown by (r = 1…. J) whereas n :( i= 1,2… n)

Signifies the no. of customers who provided the data .

Step 2: $A_{ir}$ denotes rth attribute for ith respondent. $A_{ir}$ is a triangular fuzzy numner (TFN) given by

$$A_{ir}^{Imp} = \left(\frac{a_1+2a_2+a_3}{4}\right) \qquad (3)$$

where $a_1$, $a_2$ and $a_3$ represent the three values (two extreme both low and high and one middle ) of the linguistic term

Step 3 This step involves determining importance value $A_{ir}^{Imp}$ by using Exploratory factor analysis on each defuzzified value.

Defuzzification is done for each attribute of importance score by using the following formula.

$$\text{Defuzzify importance}\quad A_{ir}^{Imp} = \frac{a_1+2a_2+a_3}{4} = a_r \qquad (4)$$

where $a_1$, $a_2$ and $a_3$ represent the the three values ( lower,middle and higher ) of the linguistic term. $a_r$ is established for r = 1, 2…. j by using above equation. Exploratory factor analysis are conducted for $a_r$ $values$ r= 1, 2… for each feature and is the importance score.

Step 4 This step involves calculating $A_{ir}^{Perf}$ score by using fuzzy approach .

$A_{ir}^{Perf}=\sum_{i=1}^{n}\frac{A_{ir}^{Perf}}{n}$, r=1,2…… j. (5)

Defuzzification is made for each value of $A_{ir}^{Perf}$ by using equation ….

Defuzzify performance $A_{ir}^{Perf}=\frac{a_1+2a_2+a_3}{4}$= Perf r (6)

Step 5 The last step involves calculation of entropy for impact values.

This step involves collecting k number of bank's managers as decision makers d = 1, 2… k. The manager's were requested to measure all these features on 5-point instrument from 1 to 5 where 1 is least effective and 5 is most effective

The values were normalized using the following equation.

$N_{dr}=\frac{y_{dr}}{\sum_{d=1}^{k}y_{dr}}$ (7)

where $y_{dr}$ is the attribute score of any rth attribute obtained by dth decision maker. r= 1,2…… j.

Step 6 Calculate information entropy measure by using equation

$E_r=\frac{1}{\ln(k)}\sum_{d=1}^{k}N_{dr}\ln N_{dr}$ r= 1,2……. J (8)

Impact r= $\frac{E_r}{\sum_{r=1}^{j}E_r}$ r = 1,2……j (9)

## 5. FIPA with info (n. ) entropy for mobile bank's service quality: A case approach

The research begins with the identification of significant characteristics of FIPA with info(n.) entropy model. The study's questionnaire was developed from past research and tailored according to the perspectives of bank managers. The senior managers possessing minimum of 5years of job experience in the banking sector, predominantly in the client service field participated in this study. The bank officials were provided a set of attributes collected from previous studies and also asked to suggest other crucial characteristics they considered important . The most important attributes were scrutinized by moderators in a focus group study. The focus group participants included 5 banks mangers and 5 customers who were using mobile technology for banking. industry

The data was collected using questionnaires. The questionnaire had four major parts. The scope of each linguistic variable is covered in the first section. The second and third part contained statements based on importance and performance of attributes . Demographic data on the respondent was given in the fourth section. The five linguistic variable expressions used are

demonstrated by( Triang Fuzzy No ) TFNs and are expressed as follows. To ensure consistency through the assessment and to remove bias one bank has been chosen for conducting this study. The scale used to collect responses for services were " Highly unimportant," to "Highly important" and "very poor" to " Excellent " (ref Table 1).

**Table 1**

Triang FN( TFN ) to denote linguistic variables for importance and Performance.

Linguistic variables for importance and performance

| Scale relative | Linguistic variables (Importance) | Modelled Values | Linguistic variables (Performance) | Modelled values |
|---|---|---|---|---|
| 1 | Highly Unimportant | (0,1,1) | Very Poor | (0,1,1) |
| 2 | Unimportant | (1,2,3) | Below average | (1,2,3) |
| 3 | Slightly Important | (2,3, 4) | Average | (2,3,4) |
| 4 | Important | (3,4,5) | Above Average | (3,4,5) |
| 5 | Highly Important | (4 , 5, 5) | Excellent | (4,5,5) |

The study got an aggregate of 212 surveys that were properly filled out. The fuzzy means values of each characteristic were computed in order to get the performance value by using Eq (5). By defuzzifying the generated fuzzy triangular numbers, performance scores were determined using Eq (6) (see Table 4). The importance values, were measured by defuzzifying each characteristic score collected from every customer as shown in Eq (4), and crisp score were calculated from each importance value as expressed in (see Table 5).After assigning crisp numbers to attribute importance. Exploratory factor analysis was performed using principal component analysis and oblimin rotation. After repeated iterations loadings < 0.5 were removed and a refined scale comprising of 19 attributes was obtained. The factors having eigen value larger than 1 were retained and subsequently after rotation the factor matrix resulted in six factors ( Functional benefit, Information Quality, Efficiency, Trust, Service Quality and System Quality). The Cronbach's α scale with value of 0.769 was found reliable for questionnaire items. Cronbach's α for factors varied between 0.65 to 0.78. The values for KMO are 0.725, and the Bartlett's test of sphericity (p = 0.000) was significant for this study.

In the next step info(n.) entropy was ascertained by means of equation 8. Subsequently, the bank managers were advised to allocate the impact values for attributes for measuring info (n.) on a 5-point scale from 5 being most significant to 1 being least significant. Finally, the Fuzzy IPA figure was constructed with both horizontal and vertical axis (X and Y) representing

Performance and importance. (Fig 2) To build FIPIEA matrix impact values( “importance”) and mean values (“performance”) were used to divide the X and Y axis. (Fig 3). On the basis of FIPA and FIPIEA priority areas for directing resources was identified (see Table 4) The valuation result for both Fuzzy IPA and Fuzzy IPIEA revealed huge differences. Further analysis revealed that the features which are of vital significance for the bank's efficient operation are different for the two techniques. The Fuzzy IPIEA results revealed that the five characteristics of service quality should be the focus for directing the resources. Three aspects of service quality have demonstrated satisfactory results thereby depicting that the allocation of resources is done proficiently. For the remaining aspects of service quality the other goals should take precedence when allocating resources. (table 4)

**Table 2**

| Attribute | Importance | Performance | Impact scores |
|---|---|---|---|
| M- banking is simple to use. | 0.6440 | 3.7535 | 0.05860 |
| The m-banking software is easily navigable. | 0.6800 | 3.7880 | 0.05790 |
| The m-banking software is organized. | 0.5485 | 3.6882 | 0.05995 |
| M- banking app is structured | 0.6326 | 3.455 | 0.05770 |
| The info provided by m-banking is simple to understand | 0.5380 | 3.663 | 0.0529 |
| The info supplied by m- banking is always updated | 0.6440 | 3.425 | 0.05750 |
| The info provided by m-banking is comprehensive. | 0.6770 | 3.616 | 0.05880 |
| The mobile banking offers secure banking. | 0.6990 | 3.777 | 0.05660 |
| M- banking is secure for obtaining financial statements | 0.7225 | 3.799 | 0.05442 |
| M- banking is confidential (protects personal data) | 0.6945 | 3.988 | 0.05110 |
| The call center representatives provide all possible help and support. | 0.7550 | 3.999 | 0.06882 |
| The centre employees pay special attention whenever any problem is encountered | 0.7370 | 3.6882 | 0.05881 |
| The center employees have adequate expertise to answer queries related to m-banking. | 0.6790 | 3.772 | 0.05432 |
| M -banking is effective. | 0.7115 | 3.8880 | 0.05655 |
| M- banking deals with the immediate and future needs of customers. | 0.6335 | 3.791 | 0.05110 |
| M- banking transactions require less time than transactions conducted at bank sites | 0.6990 | 3.990 | 0.06211 |
| M- banking enables anytime, anywhere transactions. | 0.5889 | 3.78 | 0.05777 |
| M- banking enables to do transactions at own pace | 0.6550 | 3.693 | 0.05910 |
| The m-banking meets requirements of customers. | 0.5680 | 3.677 | 0.06660 |

**Table 3**

| Factors | M-banking quality features | Sources | Reliability (α) values | Factor loadings |
|---|---|---|---|---|
| Functional Benefit | M- banking software is easily navigable. | (Lee & Chung 2009; Zhou 2011) | 0.721, | 0.680 |
| | M- banking is simple to use. | | | 0.644 |
| | M- banking enables to perform transactions at any time | | | 0.588 |
| Information quality | The info supplied by m-banking is comprehensive. | (Urbach et al, 2010; Tam & Oliveria 2016) | 0.781 | 0.677 |
| | The info supplied by m-banking is always updated. | | | 0.644 |
| | The info supplied via m-banking is simple to understand. | | | 0.538 |
| Structural assurance | M -banking is effective. | (Huh et al 2009) | 0.654 | 0.711 |
| | M- banking transactions require less time than transactions conducted at bank's sites | | | 0.699 |
| Trust | M- banking deals with the immediate and future interests of users. | | | 0.633 |
| | M- banking meets requirements of the customers | | | 0.568 |
| Service quality | M- banking is secure for obtaining bank statements | (Dorson 2016 ) | 0.711 | 0.722 |
| | The mobile banking offers secure banking. | | | 0.699 |
| | | | | 0.694 |

| | | | | |
|---|---|---|---|---|
| | M- banking is confidential ( protects personal data.) | | | 0.755 |
| | | (Tam & Oliveira 2016 ) | 0.763 | 0.737 |
| System Quality | The call center emplyees provide help and support . | | | |
| | The center employees pay personal attention whenever any problem | | | 0.675 |
| | with m-banking is experienced. | | | 0.655 |
| | The call center employees have sufficient expertise to answer queries related to m-banking | | 0.745 | 0.632<br>0.548 |
| | | (Urbach et al., 2010;) | | |
| | Mobile banking enables to do transactions at own pace | | | |
| | The m- banking software is perfectly planned | | | |
| | The m- banking software is perfectly | | | |
| | organized. | | | |

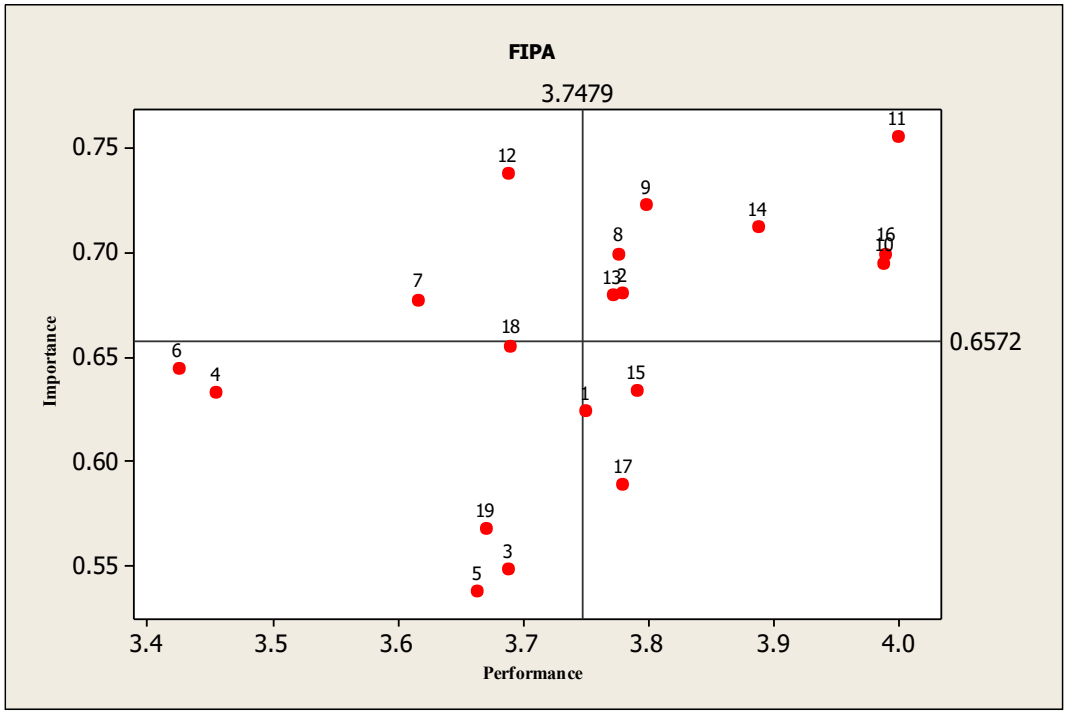


Fig 2 FIPA

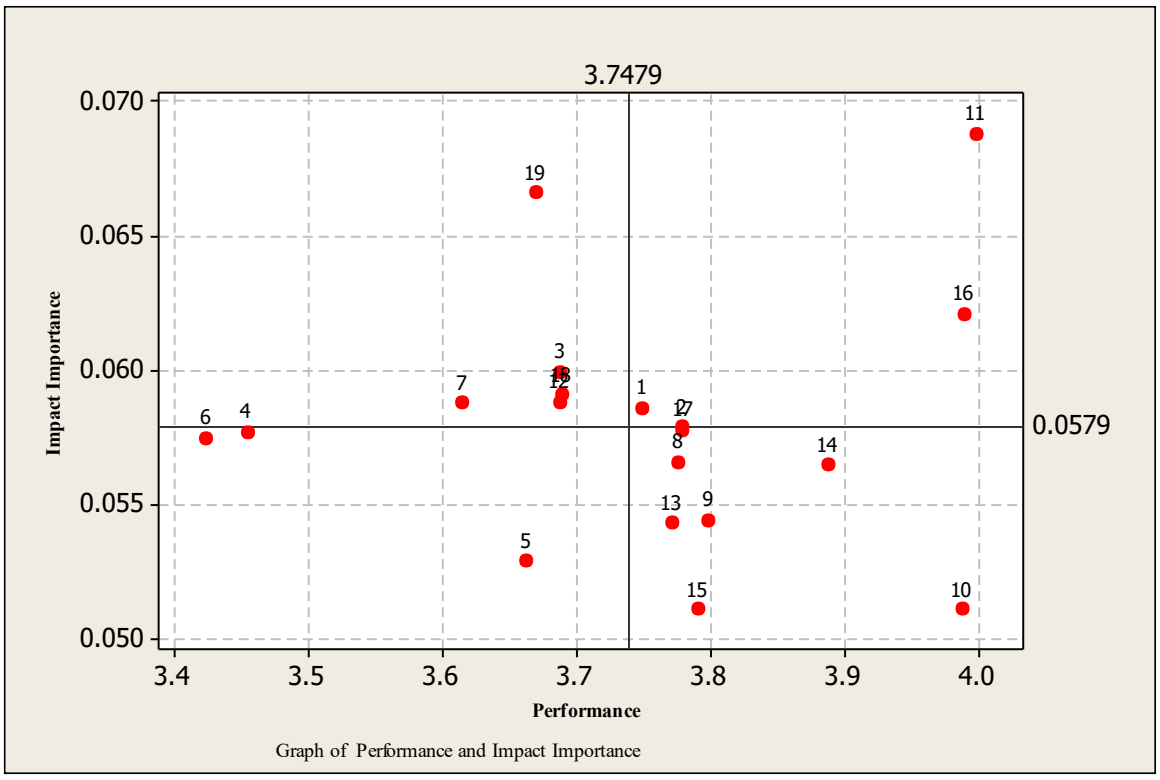


Fig 3 Performance and Impact Importance Graph

## 6. Discussion and Conclusions:

In the present paper, the authors developed an integrated framework using information entropy and fuzzy process system for distribution of resources at banks. The framework provides triple benefits, as it helps managers run their system most efficiently by reducing costs, managing resources and thereby improving the profitability of the bank. In particular, this paper demonstrates the importance of SQ and resource distribution in mobile banking, considering the Performance versus the importance. The study revealed, the six major areas of mobile banking service quality i.e, "Functional benefit, Information Quality, Efficiency, Trust, Service Quality and System Quality covering 19 characteristic features. The study emphasizes the relative importance, performance and impact of those attributes using FIPA with information entropy analysis (FIPIEA).

The assessment result is different for both FIPA and FIPIEA model. The research shows that the bank managers should focus on the "system quality dimension" while allotting resources as two out of three attributes in this dimension fall in 'concentrate here' quadrant. Another attribute, 'mobile banking meets requirements of the customers' often highlighted in previous research, also falls in the 'concentrate here' quadrant. Bank managers should concentrate on this attribute for better resource allocation. The bank's managers need to redirect their resources to other key areas as one 'service quality dimension ' and one' information quality dimension falls in the 'concentrate here' quadrant which specifies that the resource allocation was inadequate.

Another important feature of this framework is that it does not involve complex mathematical operations and has the distinguished capacity to analze the vagueness of human thinking . The findings are relevant for both researchers and experts. The measures used in this study can create competitive advantage for bankers. The results of the study can help managers in attracting more customers . The bank management team can effectively devise suitable strategy for retaining loyal customer by focusing on the key attributes and thereby leading to the higher mobile banking usage among end users. The continued efforts by banks to augment all quality dimensions and will certainly enhance the usage of mobile banking services.

### Limitations

This study has its own set of limitations, which will pave the way for future research. The study focuses on perception of a developing country. Therefore, the study should be conducted among customers of developed countries. Using the framework for comparing the results in both developed and developing countries can provide major insights . Finally, the study can be replicated by considering other demographic characteristics like gender, income etc to

measure consumer satisfaction. Also, in future the study can be replicated by taking into account a wider and extensive range of variables.

Allocation of resources

**Table 4**

| ATTRIBUTES | IMPORTANCE | PERFORMANCE | IMPACT | Management Recommendations |
|---|---|---|---|---|
| 1 | Low | High | High | Divert resources to other key areas |
| 2 | High | High | Low | Maintain resources |
| 3 | Low | Low | High | Divert attention to other key areas |
| 4 | Low | Low | Low | Correct balance, could be improved |
| 5 | Low | Low | Low | Correct balance, could be improved |
| 6 | Low | Low | Low | Correct balance, could be improved |
| 7 | High | Low | High | Concentrate here |
| 8 | High | High | Low | Maintain resources |
| 9 | High | High | Low | Maintain resources |
| 10 | High | High | Low | Maintain resources |
| 11 | High | High | High | Maintain resources |
| 12 | High | Low | High | Concentrate here |
| 13 | High | High | Low | Maintain resources |
| 14 | High | High | Low | Maintain resources |
| 15 | Low | High | Low | Recover resource to key areas |
| 16 | Low | High | High | Recover resources to key areas |
| 17 | Low | High | High | Recover resources to key areas |
| 18 | Low | Low | High | Divert attention to key areas |
| 19 | Low | Low | High | Divert attention to key areas |

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