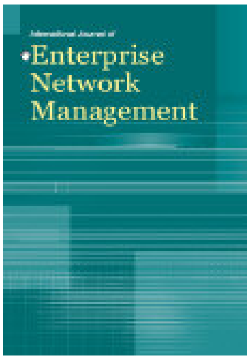

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A multi-criteria decision (fuzzy) approach for IoT adoption in developing nation: a study during COVID-19

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Abstract: The wave of IT development and adoption has changed the global scenarios. In this race, emerging economies are also competing with the developed economies. Internet of things (IoT) is now touching everyone's life. Irrespective of this growth and benefits, people from developing nations are still in fix to adopt life changing technology. This study was conducted in COVID-19 times when people were in lockdown and were becoming more dependent on technology. This study tries to understand the factors leading to adoption IoT in emerging economies. A fuzzy-MCD approach was used to rank the factors resulting from CFA. Results advocated the importance of facilitating conditions to promote the usage and acceptance of technological change followed by IT expertise and social influence. Findings provided practical reference for authorities and policy makers involved in designing strategies for technology implementations and promotions.

Keywords: analytical hierarchy process; AHP; emerging economy; fuzzy; internet of things; IoT; MCDA; UTAUT.

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Biographical notes: Sanjay Rastogi is working as a Full Professor at IIFT, New Delhi. He is having experience of more than 24 years teaching and research. He has authored many books and papers with publishers of international repute.

1 Introduction

The dynamic cycle assumes an essential part in clash free activity of any astute framework. Innovation is the answer for most issues if not all, in this day and age. At the point when web-based business to house chasing should all be possible on the web, a protected democratic construction ought not be far from innovation. The motivation behind this paper is to oblige the two previously mentioned issues and give a valuable specialised answer to address the equivalent. The strategy would empower more qualified electors to decide in favour of their up-and-comers and empower them to rank the up-and-comers from most ideal decision to the most noticeably terrible, so that, on total, the competitor who is bound to help a more prominent number of individuals, or whose plan lines up with the requests of a more noteworthy number of individuals, is chosen the victor.

Consistently, the quantity of internet of things (IoT) gadgets rises quickly per individual and will proceed to as such. This prompts the quick turn of events and improvement of IoT gadgets which additionally opens more entryways for the assortment of utilising these gadgets (Safaei et al., 2017). Such improvements likewise give a way to resolve the extra difficulties in advanced crime scene investigation and furthermore broaden the multifaceted design of getting to data of gadgets whenever required (Kranthi and Ahmed, 2018). In this manner, the stakeholder will develop expertise in proof gathering issues of the IoT environment, which incorporates gadgets, organisations or the cloud (Sofia and Kumar, 2015). The most effective way to resolve the issues early during the examination can be achieved by setting standards related to IoT legal sciences, improving cloud network protection and gadget explicit strategies (MacDermott et al., 2018; Servida and Casey, 2019). Moreover, Zawoad and Hasan (2015) recognise difficulties with huge informational indexes and data processing in an IoT working environment and propose a pragmatic model which can install gadgets to give further answers.

With the demand of the time, drastic changes in the digital world, increasing demand for high speed and demand for specialised technologies, there is a boom in trend setting innovations (Joseph et al., 2018). Innovation assumes a significant role in the advancement of future apparatuses for meeting the desired demands for fantasised world. The brilliant home is a blessing from heaven for some applicants. In the tech-savvy home idea, each electric machine in our house has to be associated with the web so that it tends to be controlled by the user from any place on the planet. As of now, the typical home has a great dearth in terms of apparatuses that can be accessible with built in sensors and Wi-Fi. Every gadget needs to be modified in such a manner to work on a specific premise. A brilliant home is framed by utilising a unified control in which a PC screens the environment and orders certain progressions which we regularly do ourselves. An illustration of a keen home is the framework that screens the outside light and sets the lighting for the tech-savvy home accordingly. Typical individuals locate the keen home idea a thing that is making them sluggish even by forestalling them to do the ordinary everyday assignments without anyone else. Contrastingly, the brilliant homes can be an aid to numerous older individuals, the impaired, patients battling with a hopeless infection, and individuals with uncommon necessities. For these individuals, the tech-savvy home encourages them by providing them opportunities to independent meet their requirements through machines as opposed to indulging in costly considerations. Keen home robotisation and the IoT is the evolving subject of the IT business. The expanding number of luxurious small dwellings has brought about easy of life and joy with an extravagant existence of individuals. The keen home framework utilises AI and man-made brainpower in planning techno savvy homes and intelligent machines. Well known organisations like Amazon, Google, and Apple are creating brilliant home apparatuses generally. Google Home goes about as a remote helper by acquiring the human's solicitation and sending the solicitations to the comparing machines to play out a spot activity. These machines have acquired a great deal of prominence in ordinary homes. The IoT assumes a significant part in the advancement of the brilliant home environment. It makes the gadgets in keen homes to be smarter and act as indicated by the client's solicitation.

IoT is an organisation of interconnected genuine articles associated through the web. The expression 'things' in IoT could be any appliance with an underlying sensor and allocated internet protocol (IP) address. With the assistance of the allotted IP address, the gadget can move anything as per the instructions over the web with no manual mediation. IoT coordinates the information it gets from various gadgets and applies check mechanism to acquire experiences from it. While applying methods for investigation, the significant data is processed and the undesirable data is overlooked. Information is acquired from the significant data sifted. This article utilises fuzzy rationale for observing the gadgets in the keen home environment. Fuzzy rationale utilises strategies, for example, critical thinking, expectation, and figure to finds a route in numerous applications like showcasing, electrical burden forecast, responsibility investigation and specialised examination. The data acquired from the sensor is not generally in an exact structure or exact. At times, it could be exact however some other time it is inaccurate. In request to manage the mistaken data acquired from the sensors, fluffy thinking is presented. On the off chance that a snippet of data got is supposed to be wrong or dubious, we cannot acquire bits of knowledge from it.

Bruneo et al. (2019) IoT can be clarified as an environment in which various carefully installed gadgets speak with help of internet providers (Ferrari et al., 2020) also expounded that gadgets are frequently called 'brilliant items' and those which exist as components in constructions or vehicles or scattered in the environmental factors. The IoT development has progressed through numerous stages to arrive at its present status. IoT idea characterises the limit of organisation network of a few classes of articles in the environment, and it is not restricted to PCs (Atlam et al., 2018).

Especially, in the current changing and highly volatile times of COVID-19 where things are changing dynamically (Gupta et al., 2020). This technological change will play an important role.

2 Literature review and hypothesis development

As per 'International Telecommunication Union' (ITU, 2012), the IoT is characterised as "a worldwide framework for the data society, empowering progressed benefits by interconnecting (physical and virtual) things dependent on existing and developing inter-operable data and correspondence innovations." In this regards, Gabbai (2015) propounded the expression 'web of things', to reflect the organisation associating objects in the actual world through the internet. The thought backing this idea is that, actual gadgets in our homes or organisations are having instructive focused interface with virtual workers via internet and execute collaborations creating a huge amount of data and information (Raman, 2019). The reception of innovation assumes a significant part in IoT adoption of fuzzy logic.

2.1 Effort expectancy in IoT adoption

Prior examinations have affirmed a huge connection between execution anticipation and selection of loT (Hoque and Sorwar, 2017). The exertion anticipation is clarified as "the level of straight forwardness or the degree wherein client saw ease during the utilization of internet of things" (Joy et al., 2017; Wang et al., 2015). Past investigations led by Hadji and Degoulet (2016) have affirmed a huge connection between exertion anticipation and IoT. The 'effort expectancy (EF)' is clarified as "the level of straight forwardness or the degree to which client saw ease and comfort during the utilization of new innovation" (Wang et al., 2015). Past examinations directed via Maillet et al. (2015), have affirmed a huge connection between exertion anticipation and client expectation to embrace IoT appropriation.

H1 There is positive and significant influence of EF in IoT adoption during pandemic times.

2.2 Performance expectancy in IoT adoption

The UTAUT hypothesis involves four primary components, specifically: execution hope, exertion anticipation, social impact and encouraging condition. As suggested by Venkatesh et al. (2003), the performance anticipation is characterised as "degree to which individuals accept that the utilisation of IoT administrations will build his/her undertaking execution." As per Kaium et al. (2020), earlier investigations have affirmed a huge connection between execution hope and reception of tele-medicine wellbeing administrations. The 'performance expectancy (PE)' has been characterised as "how consistent is the utilization of technology" (Venkatesh et al., 2003). Prior examinations have affirmed a huge connection between execution anticipation and selection of technology (Kaium et al., 2020).

H2 There is positive and significant influence of PE in IoT adoption during pandemic times.

2.3 Social influence in IoT adoption

Utilisation of innovation and social impact are characterised as "the degree to which individual accepts that others suggestions are significant to embrace new technological changes" (Cho, 2016). Social impact emphatically affects client conduct towards the appropriation of IoT (Kaium et al., 2020; Cho, 2016). Creators had affirmed a huge impact of social groups on the conducts and adoption of IoT. Subsequently, it has had a backup by prior examinations by Seethamraju et al. (2018), Cho (2016) and Nysveen and Pedersen (2016) additionally support that there is a positive and critical impact of social influence (SI) in IoT selection during pandemic occasions.

H3 There is positive and significant influence of SI in IoT adoption during pandemic times.

2.4 Facilitating conditions in IoT adoption

The UTAUT model discusses motivating and encouraging conditions with execution possibilities. Here, encouraging conditions refers to "how much an individual accepts that a hierarchical and specialized framework exists to help the utilization of the framework" (Venkatesh et al., 2003). At that point, execution anticipation is characterised as "how much an individual accepts that utilizing the framework will help the person in question to accomplish gains in work execution." This is also a decent indicator of the conduct expectation to embrace the innovation (Rana et al., 2017). As suggested by Francisco and Swanson (2018), the encouraging conditions can be impacted by authoritative help, IT assets, cloud administrations, web speed and various other elements (Khan and Samad, 2020; Khan and Syed, 2018). Likewise, the 'execution anticipation' build is being perceived in the writing as a decent indicator of innovation appropriation aim (Chua et al., 2018; Singh et al., 2019). In this manner, profitability, proficiency (Kshetri, 2018), and execution of experts can be fundamentally improved too. Along these lines, we propose the accompanying speculations:

H4 There is positive and significant influence of facilitating conditions (FCs) in IoT adoption during pandemic times.

2.5 Hedonic motivation in IoT adoption

Arnold and Reynolds (2003) identified new categories of motivations namely hedonic motivations (HMs) which are in addition to existing researched motivations. UTAUT model was studied to figure our key factors which effect the selection of technology-based framework (El-Masri and Tarhini, 2017). Where as in emerging economy like India when technology adoption was investigated using UTAUT while considering shopping applications to measure its effect on client's behaviour, it was found that it affected emphatically as per the benefits drawn out of it (Damodharan and Ravichandran, 2019; Gupta and Kumar, 2017).

At the point when the clients see the details of offers in applications, they straightforwardly decide the cost and contrast the advantages and prices of the items which helps them to ensure cost saving. In this way, it can be concluded that indulgent spurs and propensity affect client expectations while utilising innovation, and the cost is significant criteria when purchasing on the web (Mohapatra and Mohanty, 2017). Besides, Yuan et al. (2015) suggested that value, worth and propensities unequivocally affect innovation model when being applied on the portable applications for wellbeing and wellness.

H5 There is positive and significant influence of HM in IoT adoption during pandemic times.

2.6 IT expertise's in IoT adoption

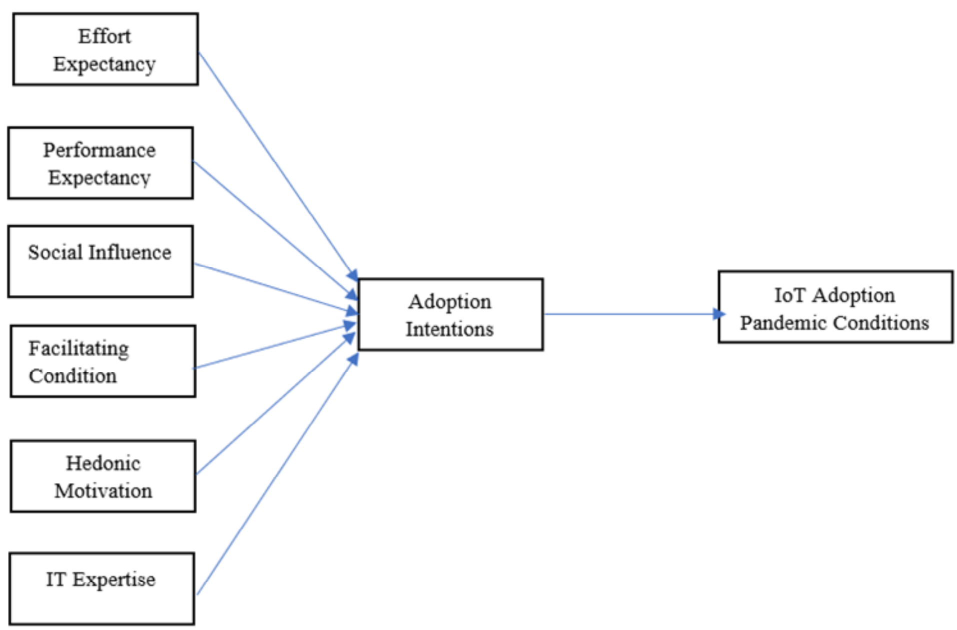
The IT framework should be created according to the need of the keen urban communities. The updated innovation must be embraced with the legitimate design (Pasolini et al., 2019; Gupta et al., 2019). The IoT reception boundaries which are recognised from the literature can be defined into three classes: 'smart city administration' (SCG), 'smart city technology and infrastructure' (SCT) and 'smart city legal and ethical issues' (SCL&E). The worldwide effect of the flare-up on various significant businesses around the world is a significant explanation behind people groups to utilise IoT. Different innovative establishments, research associations, and enterprises are attempting to utilise distinctive present-day advances to oversee and forestall the local area spread of the flare-up on close to home and modern grounds.

In the current time of networked and associated globe where everything is now data driven and innovation-based, IoT is a very crucial and table turning approach. It is a game changer in Technology 2.0 and Business 4.0 where every device can be remotely connected and easily operated because of its capacity. IoT has changed the current business operations and acquire viability information assortment and dynamism due to the predominant nature of information assortment. The innovation is utilised in an excessive number of associations; be it creation or administrations.

H6 There is positive and significant influence of IT expertise's (IT's) in IoT adoption during pandemic times.

IoT furnishes and upgrades the devices and administrations process with the possibility which enables the organisations with latest technical values. Based upon the above discussion, a framework is proposed where the user's adoption intentions are based upon the above discussed motivations as Figure 1.

Figure 1 Proposed framework (see online version for colours)



3 Research methods

The current study tries to cover and understand the motive and factors in IoT adoptions during pandemic times. For this, a survey instrument was developed to collect the responses. Convenience and judgemental sampling were used. Sample was taken from the places where internet infrastructure was good. People from Delhi-NCR, India were approached as this region has residents with good educational background and are tech-savvy too.

A Likert five-point survey scale instrument consisting of 1 (least important)–5 (most important) was used for the response collection and distributed in physical form as well as they were circulated via internet. A total of 705 questionnaires were distributed and out of which 508 fully filled responses were considered for final analysis and all the incomplete responses were removed. The time period of the study was from June 2020 to October 2020.

4 Data analysis

To address the described objectives, the data analysis was segregated into two levels. The first level consists of exploratory factor analysis and confirmatory factor analysis. In which the factors were extracted and then their reliability and validity was established. In the second level, 'fuzzy analytical hierarchy process' (F-AHP) was used to identify the most important factors.

4.1 Level 1: factor analysis

4.1.1 Exploratory and confirmatory factor analysis

The EFA technique was applied to check whether the variables are appropriately related to their corresponding latent factors. Factor extraction was done the basis of their eigenvalue (Hair et al., 1998). Total six factors were extracted from the process. It resulted with 24 variables accounting for 69.03% of total variance.

In Step 2, the reliability and validity of the extracted were checked by CFA using IBM Amos 20 (Byrne, 2001). Discriminant and convergent validity were used to check the validity of six factor measurement model. Further, in order to establish the convergent validity of the proposed measurement model, the value of standardised factor loading for each statement in the measurement model must be greater than 0.7 and significant (Gupta et al., 2019; Dhiman et al., 2018). Further, the value of composite reliability (CR) for each factor must be greater than 0.7 (Nunnally and Bernstein, 1994) and the value of AVE of each latent variable were found to within the specified range of more than 0.5 (Fornell and Larcker, 1981). Finally, the value of CR for each factor must be greater than its AVE value (Aggarwal et al., 2019; Sadhna et al., 2020).

Results of Table 1 show that all the values of all the statement have standardised factor loading more than 0.7 and they are significant at 0.01 level of significance. The value for CR of each factor is more than minimum cut-off value of 0.7 and the value of AVE is also more than 0.5. Finally, the value of CR of each factor is more than its AVE value. It shows that the present measurement model has achieved acceptable convergent validity.

Results of Table 2 show the inter-construct correlation values and descriptive analysis. As per Fornell and Larcker (1981), each construct must have its 'discriminant validity' and the square-root of AVE greater than the coefficient of its inter-construct correlation. Results show that for each construct, the inter-construct correlation value is less than its under-root of AVE. Therefore, the present measurement model shows an acceptable level of discriminant validity (Sharma and Gupta, 2020).

Table 1 Convergent validity

Factors		*Final standardised loadings*	*Composite construct reliability*	*Average variance extracted*
Factor 1	Effort expectancy		*0.9007*	*0.6944*
	EF1	0.846		
	EF2	0.884		
	EF3	0.814		
	EF4	0.786		
Factor 2	Performance expectancy		*0.8108*	*0.5179*
	PE1	0.7790		
	PE2	0.7150		
	PE3	0.6980		
	PE4	0.6830		
Factor 3	Social influence		0.766	0.523
	SI1	0.776		
	SI2	0.701		
	SI3	0.689		
Factor 4	Facilitating condition		*0.8487*	*0.5838*
	FC1	0.7820		
	FC2	0.7520		
	FC3	0.7670		
	FC4	0.7550		
Factor 5	Hedonic motivation		*0.9346*	*0.6599*
	HM1	0.7560		
	HM2	0.8200		
	HM3	0.8100		
	HM4	0.8600		
Factor 6	IT expertise		*0.8522*	*0.5919*
	IT1	0.712		
	IT2	0.702		
	IT3	0.824		
	IT4	0.83		

Source: Authors compilation

4.2 Level 2: fuzzy analytic hierarchy process

The ‘analytical hierarchy process’ (AHP) is a ‘multi-criteria decision making’ (MCDM) method established by Saaty (1980). It is a planned method for organising and investigating issues or complex judgements which contains subjective verdicts.

According to Siddiqui et al. (2017), AHP is a traditional influential decision-making method in instruction to formative significances among diverse criteria and sub-criteria, likening the decision substitutes for each criterion, sub-criterion and defining a global position of the judgement makers. The information collected from decision makers/experts comprised vagueness and uncertainty due to the fuzziness of decision environment, incomplete data and impreciseness of individual judgements. This requires a fuzzy milieu to answer such complications. The uncertainty, vagueness and fuzziness can be reduced with the application of fuzzy technique. The combination of 'fuzzy set theory' along with 'AHP' provides F-AHP as a more influential approach (Siddiqui et al., 2017) for MCDM. In F-AHP, the linguistic expressions are transformed into fuzzy numbers to determination the suspicions that come from linguistic valuation.

Table 2 Descriptive and discriminant validity

Factors	*M*	*SD*	*EF*	*PF*	*SI*	*FC*	*HM*	*IT*
EF	4.01	0.85	*0.6944*					
PE	3.91	0.74	0.124	*0.5179*				
SI	3.77	0.62	0.053	0.070	*0.523*			
FC	4.11	0.51	0.454	0.162	0.12	*0.5838*		
HM	3.49	0.66	0.193	0.347	0.055	0.101	*0.6599*	
IT	3.45	0.59	0.054	0.134	.078	0.132	0.43	*0.5919*

Note: Off-diagonal italic is square-root of AVE, M: mean and SD: standard deviation.

The initial effort in F-AHP seemed in Van Laarhoven and Pedrycz (1983), which likened fuzzy ratios defined by triangular membership functions (TMF). Later on, Buckley (1985) used geometric mean which dogged fuzzy significances of judgement ratios whose membership utilities were trapesoidal. By altering the Buckley (1985) technique, Boender et al. (1989) said the triangular estimate of fuzzy processes offers fuzzy explanations. After that, Chang (1996) presented a different method for handling F-AHP, with the application of triangular fuzzy numbers (TFNs) for pairwise judgement scale of F-AHP for the use of extent analysis technique for the artificial extent values of the pairwise judgements. Fuzzy extent analysis given by Chang (1996), and this technique was used by Kahraman et al. (2003) for the choice of the facility layout, finest catering firm and the finest transportation company respectively. In a real-world position, the TFNs are normally used as specified in Table 3.

In this research paper, we used Chang (1996) fuzzy extent analysis technique. Chang (1996) suggested extent analysis technique which has been extensively used to find weights based upon fuzzy pairwise comparison. In this technique, every alternative and sub-criteria is assessed by linguistic variables and then Chang (1996) extent analysis technique is implemented. This research paper recommends an F-AHP method to signify judgement makers' decisions to choose the final significance of dissimilar alternatives.

In the subsequent, the procedure/steps on F-AHP method are initially specified and then Chang (1996) extent analysis technique on F-AHP that will be applied for the calculation of global ranking is presented.

Table 3 Linguistic variables for fuzzy pairwise scale

Linguistic scale	*Triangular fuzzy numbers (TFNs)*	*The converse of triangular fuzzy numbers*
Equally significant	$\tilde{1} = (1, 1, 1)$	$\tilde{1}^{-1} = (1, 1, 1)$
Intermediate value between moderately and equally significant	$\tilde{2} = (1, 2, 3)$	$\tilde{2}^{-1} = \left(\frac{1}{3}, \frac{1}{2}, \tilde{1}\right)$
Moderately important	$\tilde{3} = (2, 3, 4)$	$\tilde{3}^{-1} = \left(\frac{1}{4}, \frac{1}{3}, \frac{1}{2}\right)$
Intermediate value between strongly and moderately important	$\tilde{4} = (3, 4, 5)$	$\tilde{4}^{-1} = \left(\frac{1}{5}, \frac{1}{4}, \frac{1}{3}\right)$
Strongly important	$\tilde{5} = (4, 5, 6)$	$\tilde{5}^{-1} = \left(\frac{1}{6}, \frac{1}{5}, \frac{1}{4}\right)$
Intermediate value between very strongly and strongly important	$\tilde{6} = (5, 6, 7)$	$\tilde{6}^{-1} = \left(\frac{1}{7}, \frac{1}{6}, \frac{1}{5}\right)$
Very strongly important	$\tilde{7} = (6, 7, 8)$	$\tilde{7}^{-1} = \left(\frac{1}{8}, \frac{1}{7}, \frac{1}{6}\right)$
Intermediate value between tremendously and very strongly important	$\tilde{8} = (7, 8, 9)$	$\tilde{8}^{-} = \left(\frac{1}{9}, \frac{1}{8}, \frac{1}{7}\right)$
Tremendously important	$\tilde{9} = (9, 9, 9)$	$\tilde{9}^{-} = \left(\frac{1}{9}, \frac{1}{9}, \frac{1}{9}\right)$
If criteria *i* has one of the above numbers allocated to it when compared to criteria *j*, then *j* has the reciprocal value when compared with *i*		Reciprocals of above $\tilde{M}_1^{-1} = \left(\frac{1}{u1}, \frac{1}{m1}, \frac{1}{l1}\right)$

Process:

Step 1 In the pairwise fuzzy assessment of matrix $\tilde{A} = [\tilde{a}_{ij}]$ is established as shown in equation (1):

$$\tilde{A} = \begin{bmatrix} 1,1,1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{12} & 1,1,1 & \cdots & \tilde{a}_{2n} \\ \cdots & \tilde{a}_{32} & 1,1,1 & \tilde{a}_{3n} \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1,1,1 \end{bmatrix} \quad (1)$$

where $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$, where *i* and *j* = 1, 2, 3, ………, *n* is in 'TFNs'.

Step 2 The 'fuzzy synthetic extent value' (S_i) with respect to the criteria *i*, is demarcated as:

$$S_i = \sum_{j=1}^{n} \tilde{a}_{ij} * \left[\sum_{i=1}^{n} \sum_{j=1}^{n} \tilde{a}_{ij} \right]^{-1} \quad (2)$$

And to obtain equation (2), $\sum_{j=1}^{n} \tilde{a}_{ij}$ and $\left[\sum_{i=1}^{n}\sum_{j=1}^{n} \tilde{a}_{ij}\right]^{-1}$ are designed by applying the fuzzy addition operation [as shown in equations (3) and (4)] of n extent analysis for a fuzzy pairwise comparison matrix. The procedure is as follows:

$$\sum_{j=1}^{n} \tilde{a}_{ij} = \left(\sum_{j=1}^{n} l_j, \sum_{j=1}^{n} m_j, \sum_{j=1}^{n} u_j\right) \tag{3}$$

$$\sum_{i=1}^{n}\sum_{j=1}^{n} \tilde{a}_{ij} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right) \tag{4}$$

Then, the converse of the vector is calculated as shown in equation (5):

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{n} \tilde{a}_{ij}\right]^{-1} = \left[\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right] \tag{5}$$

Step 3 To associate the fuzzy statistics, the degree of possibility of $M_2(l_2, m_2, u_2) \geq M_1(l_1, m_1, u_1)$ is defined in equations (6) and (7):

$$V(M_2 \geq M_1) = \sup_{y>x}\left[\min\left(\mu_{M1(x)}, \mu_{M1(x)}\right)\right] \tag{6}$$

This can be unvaryingly stated as:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M1(d)} = \begin{cases} 1, & \text{if } m_2 \geq m_1 \\ 0, & l_1 \geq u_2 \\ \dfrac{(l_1 - u_2)}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise} \end{cases} \tag{7}$$

Step 4 The degree of probability/V values for a fuzzy integer to be larger than k fuzzy integers S_i ($i = 1, 2, \ldots, k$) can be demarcated by [equations (8) and (9)]:

$$V(S \geq S_1, S_2, \ldots, S_k) = \min V(S \geq S_i), i = 1, 2, \ldots, k \tag{8}$$

Suppose that:

$$d'(A_i) = \min V(S_i \geq S_k), i, k = 1, 2, \ldots\ldots, n; k \neq i \tag{9}$$

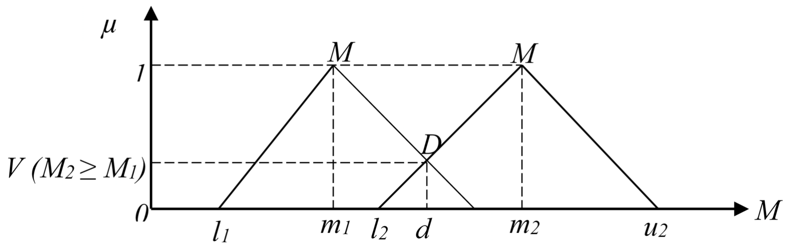
Then, the fuzzy weight/ranking is calculated through equation (10):

$$W' = \left(d'(A_1), d'(A_2), \ldots, d'(A_n)\right)^t \tag{10}$$

Step 5 The normalised/non-fuzzy weight/ranking is calculated by equation (11):

$$W = \left(d(A_1), d(A_2), \ldots, d(A_n)\right)^t \tag{11}$$

Figure 2 Graphical representation



5 Fuzzy analytical hierarchy process

In the initial stages, the criteria and their subsequent sub-criteria of the survey have been shortened with abbreviations, for instance, criteria, i.e., EF and sub-criteria, i.e., 'Learning how to use IoT learning is easy for me' (EF1). The creation of the judgements of pairs of traits for the criteria was carried out using fuzzy numbers. The same procedure was followed for the sub-criteria. The *TFN* decision matrix of the criteria is shown in Table 4.

Table 4 TFN-based pairwise decision matrix for criteria

Criteria	*FK*	*FB*	*FP*
EF	(1, 1, 1)	(0.17, 2.43, 8)	(0.11, 0.15, 0.17)
PE	(0.13, 4.71, 6)	(1, 1, 1)	(0.11, 4.7, 8)
SI	(6, 7, 9)	(0.13, 3.10, 9)	(1, 1, 1)
FC	(6, 5.67, 6)	(0.17, 2.47, 6)	(0.13, 0.18, 0.25)
HM	(0.13, 3.10, 9)	(0.13, 2.45, 6)	(0.11, 0.16, 0.25)
IT	(0.12, 2.10, 8)	(0.13, 1.95, 5)	(0.11, 0.19, 1.25)
Criteria	*FA*	*FC*	*IT*
EF	(0.17, 0.18, 0.17)	(0.11, 4.7, 8)	(0.13, 3.7, 9)
PE	(0.17, 3.38, 6)	(0.17, 4.05, 8)	(0.15, 5.15, 8)
SI	(4, 5.67, 8)	(4, 6.67, 9)	(3, 7.67, 9)
FC	(1, 1, 1)	(6, 7, 8)	(7, 6, 8)
HM	(0.13, 0.14, 0.17)	(1, 1, 1)	(0.12, 0,18, 7)
IT	(0.13, 2.12, 0.20)	(0.11, 0.19, 8)	(1, 1, 1)

After making aggregate TFN-based pairwise decision matrix for criteria (as shown in Table 5), we compute the fuzzy synthetic value and ranking/weight for all the criteria and sub-criteria. The calculation facts of fuzzy synthetic value and ranking/weight are specified below. The same procedure was done for each sub-criteria pairwise decision matrix. The fuzzy synthetic extent value with admiration to the i^{th} criteria ($i = 1, 2, \dots, 5$) is calculated as below by using equations (2), (3) and (4).

Similar procedure was repeated to measure the ranks and weights for the sub-criteria which are shown in Table 6. All the calculations have been done using MS-Excel.

Table 5 Weight and ranking of criteria

Criteria	*Weights*	*Ranking*
Effort expectancy (EF)	0.1	*6*
Performance expectancy (PE)	0.18	*3*
Social influence (SI)	0.15	*4*
Facilitating condition (FC)	0.230	*1*
Hedonic motivation (HM)	0.14	*5*
IT expertise (IT)	*0.20*	*2*

Table 6 Comparative weights and ranking of criteria and sub-criteria

Criteria	*Relative preference weights*	*Relative rank*	*Sub-criteria*	*Relative preference weights*	*Relative rank*	*Global preference weight*	*Global ranking*
EF	*0.1*	***6***	***EF 1***	***0.352***	***1***	***0.0314***	18
			EF 2	***0.146***	***4***	***0.0281***	20
			EF 3	***0.291***	***2***	***0.0217***	22
			EF 4	***0.211***	***3***	***0.0188***	23
PE	*0.18*	***3***	***PE 1***	***0.342***	*1*	*0.0428*	13
			PE 2	***0.291***	*2*	*0.0319*	17
			PE 3	***0.204***	*3*	*0.0478*	10
			PE 4	***0.163***	*4*	*0.0575*	5
SI	*0.15*	***4***	***SI 1***	***0.453***	*1*	*0.0668*	2
			SI 2	***0.321***	*2*	*0.0438*	11
			SI 3	***0.226***	*3*	*0.0393*	15
HM	*0.14*	***5***	***HM 1***	***0.215***	*3*	*0.0551*	6
			HM 2	***0.234***	*2*	*0.0233*	21
			HM 3	***0.401***	*1*	*0.0295*	19
			HM 4	***0.15***	*4*	*0.0324*	16
IT	***0.2***	***2***	***IT 1***	***0.278***	*3*	*0.0504*	8
			IT 2	***0.213***	*2*	*0.0576*	4
			IT 3	***0.38***	*1*	*0.0422*	14
			IT 4	***0.129***	*4*	*0.0498*	9
FC	*0.23*	***1***	***FC 1***	***0.295***	*1*	*0.072*	1
			FC 2	***0.198***	*4*	*0.0605*	3
			FC 3	***0.246***	*2*	*0.0431*	12
			FC 4	***0.261***	*3*	*0.0544*	7

6 Conclusions

The present study makes use of inter-disciplinary approach to investigative the factors affecting the adoption of IoT devices and technology in emerging economies. The current study involves EFA technique followed by CFA to figure out and confirm the antecedents that influence use of IoT in emerging economy. Additionally, this study has involved multi-criteria decision technique (F-AHP) to evaluate the influencing factors of IoT adoption. For literature review and based upon existing fundamental theories, 23 technology adoption indicators were shortlisted. Outcomes of EFA exhibit six constructs such as 'EF', 'PE', 'SI', 'FC', 'HM' and 'IT'.

FC resulted into the top influencing factor while IoT adoption in emerging economy like India from the F-AHP approach followed by IT and PE. SI also emerged out to be an important influencing factor. The results showed EF as the least influencing factor.

The theoretical implication is the identification of key factors that affect the IoT adoption. Second, implication is the validation of these factors. Further with the use of F-AHP in the identification and ranking of different factor that affect IoT adoption. Also, in theoretical implications, the construction of the model shows the causal relationship between factors affecting the IoT adoption. There are certain practical implications also. The results of the study portrayed that the FC has the highest impact IoT adoption. Hence, the policy makers should focus on providing the basic infrastructure and conditions which makes user to thing to look for latest technologies available. For this, the policy makers should plan first before launching anything and SI has influence once choice, so the things can be marketed in the way it caters at community level.

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