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Analyzing challenges to Internet of Things (IoT) adoption and diffusion: An Indian context

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Abstract

The Internet of Things (IoT) arena has gained a significant attention in recent years. IoT presents an image of a future internet and recognized as an ecosystem of connected devices, computing mechanisms and other items to exchange data/information cooperate with higher ease and financial benefits. However, IoT adoption and diffusion still remains a challenge due to existence of many challenges. Therefore, this work put forward an objective to recognize and analyze the challenges in implementation of IoT systems in Indian context. Nine challenges to IoT adoption and diffusion were identified by literature survey and experts' opinions. Further, Grey Relational Analysis (GRA) and Analytical Hierarchy Process (AHP) approaches were used to analyze the challenges to IoT adoption and diffusion in Indian context. This study may help practitioners and policy makers in removing the hurdles to successful IoT adoption and diffusion. Finally, conclusions and future research directions are presented.

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*Keywords:*Analytical Hierarchy Process (AHP); Challenges; Internet of Things (IoT); India; Industry 4.0; Grey Relational Analysis (GRA)

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1. Introduction

The Internet of Things (IoT) is a novel pattern and known by name 'future internet' with basic idea of connecting all things in the globe to the internet [1]. The IoT started in 1926, when Nikola Tesla emphasized on the implications of wireless. Prof. K. Ashton invented the term Internet of Things at Procter & Gamble in 1999 [2]. IoT can be used to describe systems of physical objects having independent communication among them. IoT allows integrating any physical objects having/computation and communication capabilities such as mobile networks, social networks, and intelligent components at different levels and with no limits to the Internet to deliver better services to their users [3-4].

The emergence of the long proposed "Internet of Things" marks the beginning of this development as technologies and innovative solutions are mixed, from standalone devices in a network to an intelligent object network in which the physical and virtual worlds interact [1]. In this next technology leap of the fourth industrial revolution ("industry 4.0"), "cyber-physical systems" are expected to propel the amount of data generated by and available to companies to unforeseen new levels [6]. Nearly, 50 billion devices will be connected by 2020 [5], thus specific consideration is needed to access and process the data produced by these devices [7]. To this support, IoT is going to make significant applications in improving the human life and world's economy [8]. IoT is also considered as one of the most important aspects of adopting Industry 4.0 for India in the near future [9-10]. In the meantime, wider adoption of IoT still remains a challenge. Therefore, it is important to identify and analyze the challenges in implementation of IoT systems in Indian context.The paper helps to achieve the given objectives –

i. Identifying the challenges in implementation of IoT systems;
ii. Ranking of identified challenges to segregate key challenges in implementation of IoT systems in Indian context.

In the present research, Grey Relational Analysis (GRA) and Analytical Hierarchy Process (AHP) methodologies have been used for ranking of the identified challenges to recognize key challenges in implementation of IoT systems in Indian context. GRA is an efficient assessment approach that is globally used in Multi Criterion Decision Making (MCDM) problems especially when there is an uncertainty in the decisions [11]. AHPmethodology is an efficient methodology to solve a MCDMproblem by using pair wise comparison [12].

Rest of the paper comprises of: Section 2 explains the literature on the identification of the challenges to IoT. Section 3 explains the solution methodology to solve the current problem. Section 4 comprises of data analysis and related results of ranking of the key barriers to IoT. Section 5 discusses the findings with the management implications of the present research. Finally, Section 6 provides concluding remarks with the limitations and future scope of the present research.

2. Challenges to Internet of Things adoption and diffusion

Nine challenges to IoT adoption and diffusion were identified determined from reviewing of literature using various databases like Google scholar, Google and Scopus etc. Further, these identified challenges were validated through experts' input. These identified challenges are explained in Table 1.

Table 1.Challenges to Internet of Things adoption and diffusion.

Challenges to IoT adoption and diffusion	Description	Sources
Costing issues and longer payback period (CH1)	The IoT application employs a huge number of sensing and actuating devices, and in consequence its cost and its payback period will be an important factor.	[9]
Lack of talent (CH2)	As per the Labour Bureau Report of 2014, there is very limited skilled workforce is available in India as compared to the developed nations.	[13]
Security issues(CH3)	Security has a crucial role in successful deployment of any network at any scale. Billions of devices are connected through IoT which calls for the need of efficient security mechanisms that not only helps in protecting the information but also allows sharing of data over IoT based smart cities network.	[4]; [14]; [15]
Privacy issues (CH4)	Personal privacy issue (data ownership) is a major concern in employing IoT networks as the connected objects and devices can be easily traced and hacked.	[10]

Changes in business model (CH5)	In implementation of IoT, an organization needs to upgrade and adopt new business models.	[10]
Lack of infrastructure (CH6)	The IoT application needs a higher infrastructure to support and manage the interconnected devices efficiently.	[7]
Lack of standardization (CH7)	Fragmentation of standards with new ones evolving every day makes a difficult situation for the IoT practitioners.	[8]
Lack of mobility (CH8)	Mobility is considered as an important challenge for the IoT adoption because most of the services are delivered to mobile users.	[8]
Poor internet connectivity (CH9)	Poor internet connectivity is the one of the key challenges in IoT adoption and diffusion. With a varying accessibility of internet connection across the nation,	[13]

3. Solution methodology

In the present study, challenges to IoT adoption and diffusion were analyzed using GRA and AHP approaches. GRA technique is used in MCDM problems. GRA is mainly used where there is an uncertainty in the decision [16]. The AHP methodology helps in decision making/ranking of the variables in the light of various alternatives [12].

3.1. Grey relational analysis

It is an efficient assessment technique for decision making problems. Grey theory is firstly used in the 80's by Prof. Deng [16-18]. It performs evaluation by measuring the involvement of each factor to a perfect solution [19-20]. In GRA approach, mainly five steps are followed, given as below.

Step 1: Collect the data from experts and make decision matrix.

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

Wherex_{ij}($1 \leqslant i < m$, $1 \leqslant j \leqslant n$) denotes the assessment value of the i^{th}data sequence with respect to criterion j.

Step 2: Normalization and reference sequence. "Smaller - the better" is the cost criterion.

$$r_{ij} = \frac{\max_i(x_{ij}) - x_{ij}}{\max_i(x_{ij}) - \min_i(x_{ij})} \quad (2)$$

Step 3: Then, we framed all the criteria to the category of the "smaller-the-better." And, the normalized matrix is formulated.

Reference sequence is given as:

$$\Delta_{ij} = |z_{oj} - z_{ij}| \quad (3)$$

Difference matrix is given as:

$$\Delta = \begin{bmatrix} \Delta_{11} & \Delta_{12} & \cdots & \Delta_{1n} \\ \Delta_{21} & \Delta_{22} & \cdots & \Delta_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \Delta_{m1} & \Delta_{m2} & \cdots & \Delta_{mn} \end{bmatrix} \quad (4)$$

Step 4: Grey relational coefficient is developed using the expression given as below:

$$\gamma_{ij} = \frac{\Delta_{\min ij} + \xi \times \Delta_{\max ij}}{\Delta_{ij} + \xi \times \Delta_{\max ij}} \quad (5)$$

Where, j $\xi(0 \le \xi \le 1)$ is the distinguishing coefficient i.e., used to control the range of the grey relational coefficient; usually j $\xi = 0.5$

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Step 5: Determining the grey relational degree and rank the factors.

$$\Gamma_i = \sum_{j=1}^{n} [w_j \times \gamma_{ij}], \quad (6)$$

Where, Wjis the weight of the j^{th} criterion. Grey relational degree decides the ranking of challenges and its priority in the list .The one with the lowest grade of relation is recognized as the best solution.

3.2. Analytical Hierarchy Process (AHP)

AHP has the following three steps[21]:

1) To select the goal for the study i.e. to prioritize the challenges to IoTadoption and diffusion
2) To make pair-wise comparisons between identified challenges to IoT adoption and diffusion using Saaty's nine-point scale.
3) To obtain the priority weights of the identified challenges. For this, the consistency index (CI) and consistency ratio (CR) are calculated. The acceptable consistency ratio (0.1 for all larger matrices greater than 5 by 5) range varies according to the size of matrix. An acceptable CR ensures the consistency in decision-making[21].

The research flowchart is shown in Figure 1.

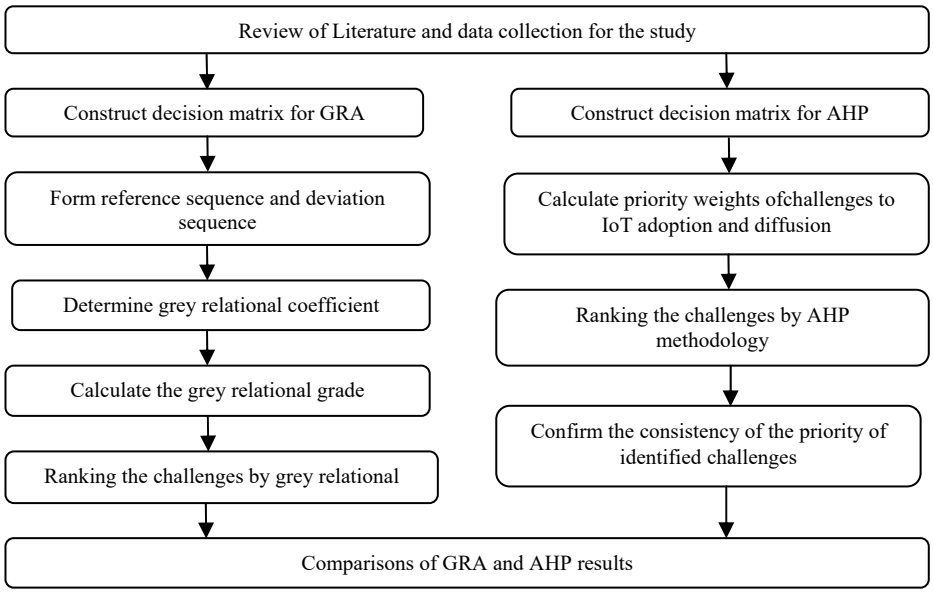

Fig. 1.research flowchart.

4. Data analysis and results

Nine challenges to IoT adoption and diffusion were identified from the literature support and further validated from experts' input. Scale is made after the discussion with four experts from academia and industry (one professor from Operation management area, one professor from Information systems and two managers from IT industry). Determination of data from expert's opinion i.e. based on the 0-7 scale (No influence=0and Extremely high influence=7). We collect the ratings from expert's and constructs the decision matrix for the challenges to IoT adoption and diffusion by using equation (1) as provided in Table 2.

Table 2.Decision matrix for the challenges to IoT adoption and diffusion.

Challenges	Expert 1	Expert 2	Expert 3	Expert 4
CH 1	4	7	5	6
CH 2	5	6	7	7
CH 3	7	4	6	6
CH 4	7	4	6	6
CH 5	4	6	2	5
CH 6	6	6	7	6
CH 7	4	5	6	5
CH 8	3	1	3	3
CH 9	7	5	5	6

After construction of decision matrix, normalization and reference values are calculated for the cost criteria.Next Δ_{ij} is the deviation sequence for the challenges to IoT adoption and diffusion are calculated with the help of equations (3-4). Then, we compute the grey relational coefficient and the grey relational grade by using the equation (5) and (6) and mentioned in Table 3.

Table 3.Deviation sequence for the challenges to IoT adoption and diffusion.

Deviation sequence	$\Delta_{ij}(1)$	$\Delta_{ij}(2)$	$\Delta_{ij}(3)$	$\Delta_{ij}(4)$	$\gamma_{ij} = \frac{1}{3}(\xi 1 + \xi 2 + \xi 3 + \xi 4)$	Rank
CH 1	0.666	0.333	0.454	0.400	0.617	2
CH 2	0.500	0.374	1.000	1.000	0.958	7
CH 3	1.000	0.500	0.384	0.400	0.761	5
CH 4	1.000	0.500	0.384	0.400	0.761	5
CH 5	0.666	0.374	1.000	0.500	0.846	6
CH 6	0.400	0.374	1.000	0.400	0.724	4
CH 7	0.666	0.428	0.384	0.500	0.659	3
CH 8	1.000	1.000	0.714	1.000	1.238	8
CH 9	0.333	0.428	0.454	0.400	0.538	1

Next, same four experts were contacted for framing pair-wise comparisons between identified challenges to IoT adoption and diffusion using Saaty's nine-point scale as mentioned in the AHP methodology.Table 4shows the pair wise comparison matrix, priority weights and ranks of identified challenges to IoT adoption and diffusion.

Table 4.pair wise comparison matrix, priority weights and ranks of identified challenges to IoT adoption and diffusion.

Challenges	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8	CH9	Priority Weight	Rank
CH 1	1	2	2	2	2	1	1	3	1	0.1508	2
CH 2	0.5	1	0.5	0.5	2	0.5	0.5	2	0.5	0.0791	7
CH 3	0.5	2	1	1	1	0.5	0.5	2	0.5	0.0873	5
CH 4	0.5	2	1	1	1	0.5	0.5	2	0.5	0.0873	5
CH 5	0.5	0.5	1	1	1	1	1	2	0.333	0.0852	6
CH 6	1	2	2	2	1	1	1	2	0.333	0.1224	4
CH 7	1	2	2	2	1	1	1	3	0.5	0.1331	3
CH 8	0.333	0.5	0.5	0.5	0.5	0.5	0.333	1	2	0.0766	8

CH 9	1	2	2	2	3	3	2	0.5	1	0.1782	1
C.I.=0.11188; CR=0.07716											

5. Discussion of Findings

India is still in the stages of understanding the potential and impact of IoT [22]. Therefore, in the present research identifies and analyses the challenges in implementation of IoT systems in Indian context.Our research analysis suggests 'Poor internet connectivity (CH9)' attains the highest grey relational grade in the list with value of (0.538) and identified a key as a key challenge in adaption of IoT in Indian context. Therefore policy makers should focus to improve internet connectivity across the country especially in the rural areas. 'Costing issues and longer payback period (CH1)' holds the second position in the grey relation grade list with value of (0.617). Initial high investment and demonstrating return on investment is also seen as a current weak spot in IoT. 'Lack of standardization (CH7)' capture third place in the grey relational list with value of (0.659) and does mainly affects understand the potential and impact of IoT. The lack of standards is considered as a major challenge towards Cloud IoT and supported by several studies [7].

'Lack of infrastructure (CH6)' holds the fourth position in the grey relational grade list with value of (0.724). Government bodies and policy makers must focus on developing supportive infrastructure. 'Security issues (CH3)' and 'Privacy issues (CH4)' come at the fifth place in the grey relational grade list with value of (0.761). Issues of security and privacy have been addressed widely in literature with recognized significant impacts on IoT applications [10]. 'Changes in business model (CH5)' comes at the sixth place in the grey relational grade list having value of (0.700). IOT requires a proper action plan and need the changes in existing business models. The key issue is that business organization reluctant to changes in business due to fear of failure and/or huge investment.'Lack of talent (CH2)' holds the second last place in the grey relational grade list having value of (0.958). Being IoT as a new technology, business organizations will require skilled workforces. India lacks skilled manpower in this new technology and it will definitely take time to train the workforce and completely deploy them for the various functionalities in the IoT environment. 'Lack of mobility (CH8)' comes at the last in grey relational grade list having value of (1.238).

According to AHP results, the ranking order based upon priority weightsof the challenges to IoT adoption and diffusion in Indian context is provided as: CH9-CH1-CH7-CH6-CH3-CH4-CH5-CH2-CH8. The results of AHP methodology are also in line with the result of GRA methodology.

The present research may provide a great help to academicians, researchers, managers/practitioners and policymakers in understanding of various challenges to IoT adoption and diffusion in Indian context. Ranking of these challenges using GRA and AHP will help practitioners and policymakers in priority setting in their removal to successful IoT adoption and diffusion.

6. Conclusions, limitations and future scope

The key aim of present research was to identify and analyze the key challenges in implementation of IoT network. Nine key challenges were identified through literature support and experts' input. Further, these identified challenges were analyzed through GRA and AHP methodologies. Results of the present research suggested that 'Poor internet connectivity (CH9)'; 'Costing issues and longer payback period (CH1)' and 'Lack of standardization (CH7)' are the key challenges to IoT adoption and diffusion. Our research has implications for policy makers, Practitioners and managers to focus on these key challenges in their removal to effectively adopt IoT applications in Indian context. Our research made an initial attempt to analyze the challenges to IoT adoption and diffusion in Indian context. The list of identified challenges may not be complete list of challenges. In future research, some more challenges may emerge. Our research has used experts' opinions to collect the data to analyze the challenges to IoT.

Our research used GRA and AHP approaches and they have their own limitations. The main limitation is that the experts were not randomly selected and results may be biased. In future research, fuzzy GRA/AHP may be used to avoid biasness.

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