Challenges of IoT Implementation in Smart City Development

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Abstract The smart city aims to ease the city-related decision by facilitating its citizen with the appropriate information at the right place and at the right time. IoT-based systems provide a foundation for smartification of services by enabling person-to-object and object-to-object communications. However, there is a challenge in integrating the IoT in city services to make the city smart. This paper put forward an objective to identify and prioritise the challenges in the implementation of IoT in the smart city. IoT devices represent emerging decentralised computing era and have capability to communicate with other computing devices over a network. Ten challenges to IoT implementation in making cities smart were identified using literature review and expert's opinion. Further, TOPSIS approach is used to analyse the identified challenges. The findings suggest that the major challenge is IoT interoperability, as companies are developing IoT solution independently by utilising different platforms which result in poor integration in the devices and data security issues. The companies need to develop an open-source platform to promote an interoperable framework. The study will help the practitioner and policy planner in realising the potential challenges in IoT implementation and easing the life of the citizen.

Keywords Smart cities · IoT · TOPSIS · Challenges · Big data

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1 Introduction

Cities as an essential aspect of urban development have always been an attraction to the citizens as the cities provide more opportunities for employment and business, excellent facilities, and availability of resources. It is due to the attraction towards the cities that more and more people dwell in the cities. As the cities become more and more populated, the need to organise resources, transportation, services, infrastructure is also increases. Thus, to provide a sustainable quality life for its citizens, a city needs to become smart. Thus, keeping in view the current scenario, cities need to identify various ways towards managing newer challenges/threats. Cities globally have initiated to see forward for solutions enabling mixed land uses, transportation linkages, and urban services of high-quality with long-lasting economic growth [1].

The concept of the smart city is emerging with an aim to provide a solution to the challenges by rapid uncontrolled urbanisation and increase in population density in the cities. ICT plays a vital role in smartening the services of the cities. The term "smart city" is easy to understand; however, there is no globally recognised definition of the smart city due to its different perspective of the term "smart". In literature several definitions were reported, one of the most popular definition is offered by IBM which defines the smart city as: "the city that makes optimal use of all the interconnected information available today to better understand and control its operations and optimise the use of limited resources".

Smart cities based on the thought of using the Internet of things (IoT) with multiple sensors to meet the end need of modern citizens [2]. IoT systems improve the quality of life by creating an autonomous environment through devices which are able to compute, sense, and network. Future urban landscape equipped with IoT provides a smart solution in the area of transportation, energy management, health, education, city services, surveillance, and technology-related issues [3, 4]. IoT-based smart solutions will impact the life quality of the citizens [5]. Characteristics such as the ability to connect objects and allows to interact with the human pervasively and intelligently, implementation of IoT is crucial for realising the potential of smart cities [6, 7]. The proliferation of IoT-based services is conceptualised to automate, control, and monitor human activities in the smart environment [8, 9]. However, diversity in the domain of application of IoT makes its deployment a challenging task. IoT implementation is a complex and tedious process and needs a lot of planning and resources in terms of finance. Being decentralised makes it adds more to the degree of randomness and raises a security concern. Therefore, this study developed a framework for the deployment of IoT in smart city environment based on the prioritisation of challenges of implementation using the TOPSIS approach.

2 Background and Related Works

The concept of IoT gained interest both in literature and among professionals during the last decade. IoT enables interaction between users and devices. IoT enables individuals to make better decisions about the use of energy and health practices by providing the right amount of information at the right time. These decisions increase the living convenience of the citizen. Several authors have reported the implication of IoT on smartification of city services. Rathore et al. [10] proposed an IoT-based system for smart city development using big data analytics. Luthra et al. [11] identified the challenges of implanting IoT systems in the Indian context. Mehta et al. [12] describe IoT along with its vision, possible application domains, and key challenges faced in making IoT a reality. Grammatikis et al. [13] provide a comprehensive security analysis of the IoT by examining and assessing the potential threats and countermeasures. Bello and Zeadally [2] highlighted the requirement of quality of service in IoT-based services by providing relationship between inter-operation of different communication standards. Tzounis et al. [14] presented the potential use of recent IoT technologies in the agriculture sector and their value for future farmers. This study also explored the challenges in the propagation of IoT in smart farming. As reported above, studies have focused on recognising the challenges IoT implementation, however, no studies have reported challenges faced by IoT implementation in a smart city context. This study put an attempt to identifying and prioritising the challenges for implementation of IoT in the smart city. Next sub-section deals with challenges followed by a brief description and source.

2.1 Challenges for Implementation of IoT in Smart City

The implementation of IoT depends upon various vital factors. An understanding of the challenges of implementation may help management in designing, directing, and controlling services of smart cities. Policymakers can do planning for IoT implementation in order to provide better quality services. After reviewing the relevant literature following (shown in Table 1), challenges were selected for this study.

3 Research Methodology

In this study, the ten significant challenges are identified using the literature review. Further, these challenges are prioritise using the TOPSIS method which is discussed in the upcoming section.

Table 1 Challenges for implementation of IoT in smart cities

S. No.	Challenges	Description	Sources
C1.	Lack of compatibility and interconnection among IoT devices	The inability of IoT devices from different manufacturers to communicate and exchange data	[15, 16]
C2.	Poorly designed IoT devices	Poorly designed and implemented might negatively affect the utilisation of network resources and overall smart city operation	[5, 17]
C3.	Interoperability (homogenous networks)	Interoperability challenge is to make all IoT devices operate in integrated software platforms	[2, 18]
C4.	Lack of standards	Improper regulatory standards pose a challenge in structuring and handling big chunks of unstructured data	[19, 20]
C5.	Data security and privacy concern	IoT devices deal with data containing private/confidential information related to the behaviour of citizens. A weak security protocol or a data breach can lead to profiling of the citizens	[21–23]
C6.	Difficult networking plan implementation	The enormous number of devices connected to networks puts a significant strain on it, and the primary challenge in this area is network implementation	[24, 25]
C7.	Lack of Internet skill (developers and designers)	Internet skills matter for the use of IoT. IoT companies are faced with a shortage of talent to plan, execute, and maintain IoT systems on the market	[9, 26]
C8.	Economic viability	The IoT application employs a vast number of sensing and actuating devices, components and in consequence, its cost and its payback period will be an important factor	[27, 28]
C9.	Mobility of city infrastructure	The mobility of city infrastructure in the smart city requires IoT systems which can deal with a mobile data source	[20, 29, 30]
C10.	Updation and insufficient analysis of data collection	Need for updated hardware and software of an IoT device plays a significant role in senses and security as to enforce data-specific rules and detect anomalies (anomalous data) and traffic pattern	[31]

3.1 TOPSIS

To cater multi-criteria decision making (MCDM), Hwang and Yoon [32] proposed "technique for order performance by similarity to ideal solution (TOPSIS)". This technique became very popular and being used extensively in MCDM situations

[33, 36]. The underlying concept of TOPSIS is that the alternatives which need to be chosen should have the shortest distance from the "positive ideal solution (PIS)"; and the farthest from the "negative ideal solution (NIS)" [34]. The steps for finding solution through utilising TOPSIS are mentioned below [35]:

Step1: *Construct a decision matrix*

Challenges labelled as $B = \{B_1, B_2 \ldots B_m\}$ will be evaluated against n criteria, i.e. $C = \{C_1, C_2 \ldots C_n\}$. This implies that the decision matrix will have "*m*" number of rows and "*n*" number of columns (refer Table 3). Five-point linguistic scale against which importance of the challenges will be rated are shown in Table 2. x_{ij} indicates the elements of the decision matrix, which represent the importance of *i*th challenges against *j*th criterion.

Step 2: Obtain normalised decision matrix

Equation (1) shown below is used to calculate the normalised value of x_{ij}

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{n} x_{ij}^2}} \quad i = 1, 2, \ldots, m; \ \ j = 1, 2, \ldots, n \tag{1}$$

Step 3: Determine the weighted normalised decision matrix.

The elements of weighted normalised decision matrix are the product of decision matrix element and its associated weights as represented by Eq. (2).

$$v_{ij} = r_{ij} * w_j \tag{2}$$

where w_j symbolise the weight of the *j*th criterion, and $\sum_{j=1}^{n} wj = 1$.

Step 4: Find the PIS and NIS by following equations (i.e. Eqs. 3 and 4).

$$A^+ = \left\{v_1^+, v_2^+, \ldots, v_n^+\right\} \quad i = 1, 2, \ldots, m; \ \ j = 1, 2, \ldots, n \tag{3}$$

$$A^- = \left\{v_1^-, v_2^-, \ldots, v_n^-\right\} \quad i = 1, 2, \ldots, m; \ \ j = 1, 2, \ldots, n \tag{4}$$

Table 2 Linguistic scale for the importance

Linguistic scale	Importance intensity
Very low	1
Low	2
Medium	3
High	4
Very high	5

In this study, as mentioned importance of challenge is prioritised. Thus, PIS is taken as 5, whereas NIS is taken as 0.

Step 5: Estimate the separation measures between the challenges through Euclidean distance Eqs. (5) and (6).

$$D^{+} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^{+})} \quad i = 1, 2, \ldots, m; \tag{5}$$

$$D^{-} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^{-})} \quad i = 1, 2, \ldots, m; \tag{6}$$

Step 6: Estimate the *relative closeness,*

The relative closeness of the alternative i_{th} is calculated as:

$$CC_i = \frac{D^{-}}{(D^{+} + D^{-})} \tag{7}$$

Here, $0 \leq CC_i \leq 1$, $i = 1, 2, \ldots, m$.

Step 7: Descending order of relative closeness will decide the rank of the alternatives.

4 Result

The challenges in the implementation of IoT solutions in smart city are finalised by having a focus group discussion with four members comprising of academician as well as practitioner and same is presented in Sect. 2.1. This focus group discussion helped in gaining deeper insight and developing a consensus. After finalisation, members were asked to evaluate the importance of each challenge using a linguistic scale. Linguistic variables for each challenge are presented in Table 2. Table 3 shows the linguistic assessment of the challenge as obtained through the experts (E_1, E_2 … E_4).

Table 4 represents the conversion of linguistic assessments into initial matrix using the corresponding importance intensity as per Table 2.

The elements of weighted decision matrix are obtained using Eq. (2). In this case, all decision-makers have been given equal importance. Hence, the weight given to each expert is ¼ = 0.25, i.e. w_j = (0.25, 0.25, 0.25, 0.25) for all j. Weighted decision matrix as shown in Table 5.

Table 3 Linguistic assessment by the experts

Challenges	Expert 1	Expert 2	Expert 3	Expert 4
C1.	H	VH	H	VH
C2.	L	M	L	L
C3.	H	VH	VH	VH
C4.	H	H	VH	H
C5.	H	H	VH	VH
C6.	VH	H	M	M
C7.	M	H	H	M
C8.	M	L	M	L
C9.	VH	M	VH	M
C10.	VH	H	H	H

Table 4 Initial matrix

Challenges	Expert 1	Expert 2	Expert 3	Expert 4
C1.	4	5	4	5
C2.	2	3	2	2
C3.	4	5	5	5
C4.	4	4	5	4
C5.	4	4	5	5
C6.	5	4	3	3
C7.	3	4	4	3
C8.	3	2	3	2
C9.	5	3	5	3
C10.	5	4	4	4

Table 5 Weighted decision matrix

Challenges	Expert 1	Expert 2	Expert 3	Expert 4
C1.	0.315244	0.405554	0.306786	0.419591
C2.	0.157622	0.243332	0.153393	0.167836
C3.	0.315244	0.405554	0.383482	0.419591
C4.	0.315244	0.324443	0.383482	0.335673
C5.	0.315244	0.324443	0.383482	0.419591
C6.	0.394055	0.324443	0.230089	0.251754
C7.	0.236433	0.324443	0.306786	0.251754
C8.	0.236433	0.162221	0.230089	0.167836
C9.	0.394055	0.243332	0.383482	0.251754
C10.	0.394055	0.324443	0.306786	0.335673

Table 6 Weighted normalised matrix

Challenges	Expert 1	Expert 2	Expert 3	Expert 4
C1.	0.078811	0.101388	0.076696	0.104898
C2.	0.039406	0.060833	0.038348	0.041959
C3.	0.078811	0.101388	0.095871	0.104898
C4.	0.078811	0.081111	0.095871	0.083918
C5.	0.078811	0.081111	0.095871	0.104898
C6.	0.098514	0.081111	0.057522	0.062939
C7.	0.059108	0.081111	0.076696	0.062939
C8.	0.059108	0.040555	0.057522	0.041959
C9.	0.098514	0.060833	0.095871	0.062939
C10.	0.098514	0.081111	0.076696	0.083918

Table 7 Ranking of the challenges

Challenges	D^+	D^-	CC	Rank
C1.	1.819283	0.182693	0.091256	2
C2.	1.909815	0.092112	0.046012	10
C3.	1.809627	0.191535	0.095712	1
C4.	1.830192	0.170363	0.085158	5
C5.	1.819782	0.181617	0.090745	3
C6.	1.850239	0.153473	0.076594	7
C7.	1.860163	0.141125	0.070517	8
C8.	1.900505	0.101034	0.050478	9
C9.	1.841262	0.162966	0.081311	6
C10.	1.829954	0.170905	0.085416	4

The range of importance intensity belongs to the closed interval (0, 1). Therefore, PIS is 1 and the NIS is 0 (Table 6).

Further, the distance of each challenge from PIS and NIS is calculated using Eqs. (5) and (6). Finally, the relative closeness (CC_i) is calculated using Eq. (7) and shown in Table 7.

Through the analysis, it was found that the "IoT interoperability" is ranked on the top (please refer Fig. 1) followed by "lack of collaboration among IoT devices" and "poorly designed IoT devices" is the least prioritised challenge.

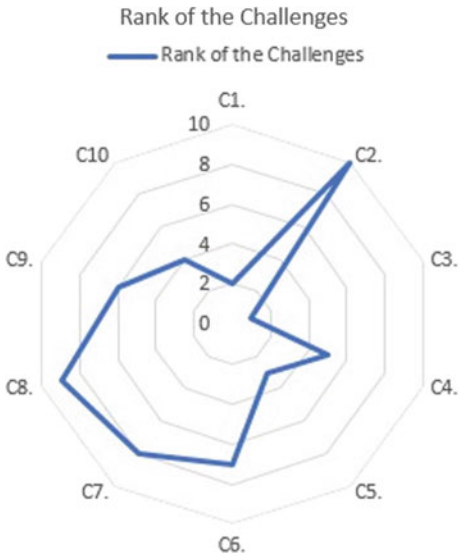

Fig. 1 Web diagram showing ranking of the challenges for implementation of IoT in smart cities

5 Discussion

Rapid growth in the city is causing different issues such as traffic congestion, health issues, environmental degradation, insufficient power, inadequate housing, and increase in crime rates. IoT is considered as the next big prospect to the world of the Internet. IoT as a computing device connects different electronic appliance and devices, interpret and understands human interaction, and also achieving high-quality two-way interaction. However, the implementation of IoT systems to achieve urban sustainability is a multifaceted approach. The findings of this study suggest that interoperability of IoT devices is a significant issue as the interoperability challenge is to make all IoT devices operate in integrated software platforms. The companies are developing IoT solution independently on the base-specific needs utilising different platforms which result in poor integration in the devices which is now only possible through selective pre-programmed API's. The companies and IoT-based organisations need to develop open-source platforms to promote an interoperable framework. This will help in the integration of any hardware or software easier across all platform. The next major challenge is the amount of skill required for operating IoT devices as these devices run autonomously. This suggests that users should be able to scrutinise the device hardware and software development. Besides, users should be skilled enough to visualisation, interpret, and analyse advance data. The mobility of city infrastructure is also an important issue as IoT systems in smart city environment must be able to deal with mobile data sources. IoT devices from different manufacturers hinder seamless communication and exchanging of data as these devices capture data in different formats and employ distinct operating systems. The lack of seamless collaboration hinders the smartification of the services by developing island of non-collaborative and non-standardised services. Lack of standards leads to poorly designed IoT devices which negatively impact network utilisation. However, the standardisation of IoT devices will lead to interchangeability and ultimately better utilisation of the resources. Security and privacy in a smart city integrated with IoT devices is an important issue. Data containing private/confidential information related to the behaviour of citizens and policies of government needs to be protected against unauthorised use. Agencies responsible for providing various smart services need to deploy high-security protocol across the network. IoT devices in a smart city environment exchange and communicate data about financial records, health, and medical records of the citizen. High profile hacks and breach of these data will lead to profiling of citizens which defies their private life.

IoT devices can detect anomalies in data and its interconnected system with advanced data visualisation techniques. The traffic inflow and outflow can be monitored which lead to better defence technique against breaches as autonomous systems evolve after implementation. Visualisation is indispensable to depict all devices/sensors that are most indicative of a pending failure points and more interconnected sustainable systems. The consumerisation of IoT devices with advance small but powerful computation devices with miniature sensors is the way to mass adoption as a paradigm shift for brimming device intelligence. IoT devices enable to make tailored data-based decisions satisfying quality of service metrics such as security, cost, service time, energy, autonomy, consumption, accuracy, reliability, and availability.

6 Conclusion Limitation and Future Scope

Smart urbanisation needs efficient services to improve the quality of services. This requires a platform which redefining the traditional urban process parameters. However, this activity requires a collection of large amounts of data for better planning and development by exploiting the merits of IoT systems. This study deals with the challenges faced in the implementation of IoT systems that later prioritised as per their weight using the TOPSIS approach. This study opens up direction and actuates conducting empirical research to quantify the challenges. The identified challenges can further be evaluated other MCDM techniques like AHP, ANP, ISM, and DEMATEL under fuzzy environment and result can be compared. A case-based validation may further improve the findings. Smart cities using IoT do have their challenges and implementation nightmare like data security, AI fuelled autonomy, and mesh interconnection. Implementation of IoT requires a high degree of knowledge of designing and developing IoT and deep consideration of the *C* points.

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