OPPORTUNITIES & CHALLENGES IN UTILIZING INTERNET OF THINGS IN PUBLIC TRANSPORT

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ABSTRACT

This research work was undertaken with the objectives of studying the opportunities & challenges for internet of things in public transport system (PTS). Ten experts in the field (6 Depot Managers and 4 Drivers) were interviewed. Their views were cross-validated through a survey of 400 commuters each from two smart cities, Pune and Ahmedabad. A questionnaire seeking responses on 5-point Likert scale was used. Findings show that for the variable problems with the current technology, the agreement of the sample is 80%. For the variable opportunities for IOT in PTS the agreement of the respondents is 82%. It was found that for the variable challenges for IOT in PTS the agreement of the sample is 80%. In case of the variable proposed model using IOT the agreement of the respondents is 79%. None of the six demographic variables (smart city, gender, age, commuting mode, commuting experience, and use of technology) have any significant impact over the four set of responses related to problems, opportunities, challenges, and suggestions. Overall, it can be concluded that there is a great opportunity for IOT in PTS provided the accompanying challenges are duly addressed. The proposed model can make a significant contribution. A three-tier model of advance-integrate-control has been proposed which can make a significant contribution, for implementing IOT in PTS.

Keywords: *Internet of things, Public Transport System, Smart cities*

Introduction

This work discusses Opportunities & Challenges in utilizing Internet of Things in Public Transport system (Buses) in the context of Indian smart cities of Pune and Ahmedabad.

Evolutions of Internet of Things (IoT) in Public Transport System (PTS)

Regarding IoT, each linked device is measured as an object. Objects frequently comprise of physical sensors, actuators, and an embedded system including a microprocessor. Objects necessitates to communicate with each other, creating the requirement for Machine-to-Machine (M2M) communication. The communication can be short-range employing wireless machineries such as, Bluetooth, Wi-Fi, and ZigBee, or wide-range employing mobile networks such as 3G, 4G, 5G, CAT M1, GPRS, GSM, LoRa, LTE, NB-IoT, Sigfox, and WiMAX. Due to the enormous usage of IoT devices in all sorts of day-to-day life events, it is vital to keep IoT devices cheap and affordable. Moreover, IoT devices must be capable to handle fundamental responsibilities such as data gathering, M2M communication, and even few pre-processing of the data relying on the application. Therefore, it is compulsory to discover an equilibrium among cost, processing power, and energy consumption while designing or choosing an IoT device. IoT is also firmly attached to “big data”, since IoT devices unceasingly gather and exchange a huge amount of information. So, an IoT infrastructure frequently implements methodologies to handle, store, and assess big data. It has become a normal practice in IoT organizations, to apply an IoT platform such as DeviceHive, Kaa, Mainflux, Thingsboard, or Thingspeak, in order to support the M2M communication, applying protocols like AMQP, CoAP, HTTP, MQTT, STOMP, and XMPP. Also, IoT platforms deliver surveillance abilities, node administration, data storage and analysing, data driven configurable guidelines, etc. Relying on the application, it is occasionally vital that some data processing takes place in the IoT devices instead of some centralized node as it occurs in the “cloud computing” infrastructure. So, as the processing partly moves to the end network fundamentals, a new computing model is presented, named “edge computing”. Though, those devices are most of the times low-end devices, they may not be apt to handle intense processing challenges. As a result, there is a necessity for an intermediate node, with adequate resources, capable to handle advanced processing tasks, physically positioned close to the end network elements, in order to diminish the excess load caused by huge transmission of all the information to few central cloud nodes. The solution offers with the overview of the "Fog nodes". Fog nodes assist IoT devices with big data handling by offering storage, computing, and networking facilities. Lastly, the information is stored in cloud servers, where they are accessible for advanced scrutiny applying a variety of ML methods and distribution among other devices, leading to the formation of contemporary added value smart applications. IoT applications have already occurred in several features in newly created smart city (Zantalis et al., 2019).

Operational Definitions

IOT

The Internet of things describes the network of physical objects - "things"- that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet.

Smart City

Smart city is one of the 100 cities selected by the Government for their development. The initiatives include: Transport and Mobility, ICT and IOT – Technological interventions, Sanitation and waste, Urban infrastructure, Safety and security, Water and sewage, E-governance and Education and health.

Public Transport Management

Public Transport Management is a suite of solutions that help make Public Transport Services more efficient for operators, drivers and passengers.

Research Objectives

In the context of the current study, we have set the following objectives for the research:

1. To study the current advancements in IOT technologies for Public Transport
2. To study the current scenario of IOT usage in Public Transport Management
3. To take inventory of prevailing technologies for Public Transport Management
4. To study the opportunities and challenges in the application of IOT in PTS
5. To suggest a comprehensive model using the available IOTs for Public Transport Management in Smart Cities

Need and Significance of study

One of the most important development agenda of PM Modi-led present government is development of Smart Cities. Around 100 cities were selected for this visionary initiative wherein, the most important components of the Smart City is the Transport and Mobility system. The current situation of the Public Transport Management using outdated systems and processes is outdated and not satisfactory. Significant achievement is possible if latest technologies are used. The public Transport systems could then become suitable for the Smart City's infrastructure requirements.

With this backdrop, the study is expected to make the following significant contributions to the existing knowledge:

1. Understand the opportunities and challenges for use of IOTs in the current scheme of things.
2. To develop a comprehensive model using the IOTs for Public Transport Management in Smart Cities.

These contributions are expected to benefit both academicians and policy makers and government agencies.

Scope of the study

In terms of concept, the key area of study is IOT. In terms of context, the study focuses on Public Transport of Smart Cities.
The conceptual model adopted for the study is as under:

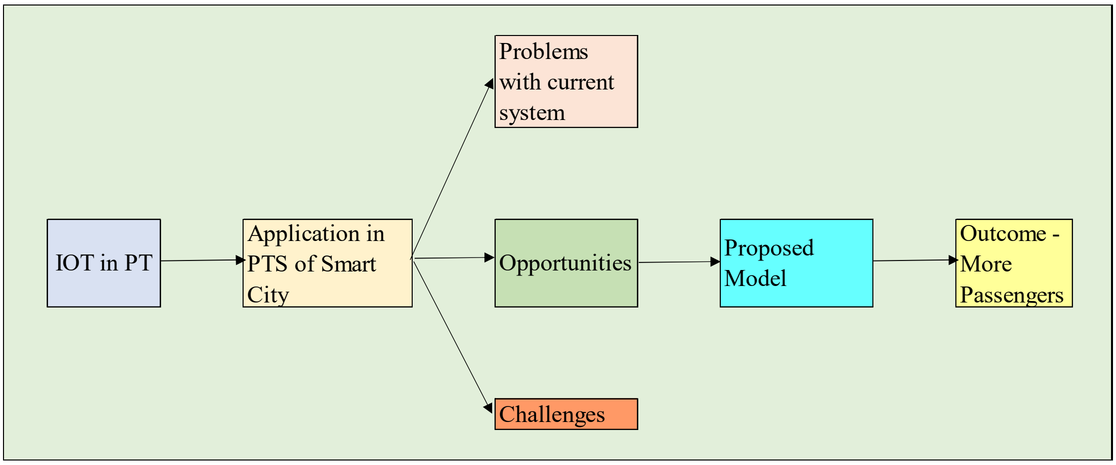

Figure 1: Snap-shot view of the research

Included in the scope of the study is a recommendation. The objective is to develop a comprehensive model using the IOTs for Public Transport Management in Smart Cities.

Primary data was gathered from 400 passengers of Public Transport and additionally, primary data was also collected from field staff by interviewing Depot Managers and Drivers.

Research Questions

As a corollary to the above-mentioned objectives and hypotheses, the present study attempts to focus upon the following research questions:

RQ1 – What are the current advancements in IOT technologies for Public Transport?

RQ2 – What is the current scenario of IOT usage in Public Transport Management?

RQ3 – How is the prevailing technology used by the PTM performing?

RQ4 – What are the opportunities and challenges in the application of IOT in PTS?

RQ5 – Can there be a model using IOT in PTS for smart cities?

Review of Literature

Public transport plays a vital role in decreasing utilization of private vehicles by populace which will ultimately decrease traffic overcrowding, pollution, and consumption of fossil fuel. But, for that public transport requires to be dependable. Without having any knowledge regarding bus arrival, individuals should not have to wait for the bus for a long time. Moreover, individuals must get a seat in the bus. (Patel et al., 2019). Smart Public Transportation (SPT) is a subsystem of Intelligent Transportation Systems (ITS). It can regulate public transportation systems in an extremely intellectual way to keep up their performance, and to give data on tours and system working settings to clients (Jalaney & Ganesh, 2019). At present, rising urbanization along with the huge demands of daily travel for working professionals has augmented the fame of public transport systems (PTS). The traditional PTS is in huge demand in metropolitan cities and deeply contributes to air pollution, traffic accidents, road overcrowding, upsurge of greenhouse gases like oxides of carbon (OC), methane, and oxides of nitrogen releases (Ladha et al., 2020). The fundamental challenge for any public transport information system is to update the travellers swiftly and precisely. The study offers an IoT based intelligent real-time traveller information system which communicates with passengers in an effort to decrease passenger waiting time (Anudeep & Prakash, 2019).

With the development of the IoT, applications have become cleverer and linked devices give upsurge to their manipulation in all features of a contemporary city. As the quantity of the gathered information rises, Machine Learning (ML) techniques are used to further increase the intellect and the competences of an application (Zantalis et al., 2019). Road related accidents have continuously been an annoyance to drivers and walkers in a same manner. Every year innumerable accidents and deaths occur because of potholes which could have been avoidable if there had been a previous cautioning or if the public establishments were capable to patch-up these potholes in time (Bansal et al. 2020). Internet of Things (IoT) is a podium that creates a device smart such that daily communication becomes more enlightening. A Smart Transportation system fundamentally comprises of 3 components which comprise smart vehicles, smart roads, and a smart parking system. Smart roads are employed to describe roads that employ sensors and IoT technology which creates driving harmless and greener (Mishra et al. 2019). Smart city has hugely advanced in regards of developing technology such as Information and communications technology (ICT), Block chain, Internet of Things (IoT), Machine Learning (ML), and Artificial Intelligence. The Intelligent Transportation System (ITS) is a significant application in a swiftly increasing smart city. Forecast of the automotive accident brutality plays a very essential role in the smart transportation system (Mohanta et al. 2021).

Advancement of IoT permits smart city development worldwide. Growing number of vehicles has brought attention on road safety measures and in-vehicle communication. This is the accurate time to pay attention on the growth of new applications and facilities for vehicular environments (Saleem et al. 2019). Internet of Things (IoT) is swiftly rising and contributing severely to enhance the quality of life. Enormous technological modernizations and development is a significant aspect in IoT developments. Readily accessible low cost IoT hardware is vital for constant adaptation of IoT (Zikria et al., 2019). Transportation and logistics administration play an essential role in the growth of a nation. Smart transportation has become a truth with the development of the Internet of Things (IoT) devices. Though, these ample linked IoT devices are susceptible to safety attacks. Lately, Blockchain has arose as one of the most broadly acknowledged technologies for reliable, safe and reorganized smart transportation systems (Humayun et al., 2020).

The array of development of transportation in current decade and the dependency allied to it by the industrial and domestic domains have brought the issues of traffic overcrowding, transport overload, and as well as worry of security and resource accessibility to the travellers (Bhardwaj et al., 2019). As the approval of 5G New Radio technology is being finalized, permitting network architectures are anticipated to undertake a matching effort. Conventional cloud and edge computing examples may thus become inadequate in subsidiary the progressively strict functioning necessities of smart IoT devices that can move randomly and at high speeds (Andreev et al., 2019).

Intelligent Transportation Systems (ITS) focus at incorporating detecting, regulate, analysis, and communication technologies into travel infrastructure and transportation to enhance mobility, ease, security, and efficacy (Hahn et al., 2019). Big data analytics are extensively used in various areas such as effective designing and planning of smart conveyance, smart control systems, smart cities, smart groups, and more. Though, analysing big data for smart control systems has various challenges and problems applying conventional engineering techniques (Jan et al., 2019).

Internet of Things (IoT) is a developing structure which goals to inter-connect all smart physical devices, so that the devices collectively can offer smart facilities to the users which eases the transportation. Some of the IoT applications comprises smart homes, smart cities, smart networks, smart retail, etc. (Sobin, 2020). The continuing distribution of Internet of Things (IoT) technologies is inaugurating new potentials, and one of the most outstanding applications is related with the smart city model, which is endlessly developing. In general, it can be well-defined as the incorporation of IoT and Information Communication Technologies (ICT) into city management, with the goal of addressing the exponential development of urbanization and populace, therefore suggestively growing people's quality of life (Belli et al., 2020). The innovative mobile technology, 5G, challenges the present situation in communications by resolving the defects of presently functioning 4G. an innovative way to become entirely integrated by permitting huge instantaneous connections and omnipresence of network, even under high mobility circumstances or dense inhabited areas is provided by such novel technology to smart cities and smart transportation systems (Guevara & Auat Cheein, 2020).

Several cities around the globe implement the Intelligent Transportation Systems (ITS) idea to decrease road traffic overcrowding. This notion suggests the application of Internet of Things (IoT) technologies to safeguard an improved traffic flow, particularly in crowded urban regions (Pop, 2020). Currently, consistency in public transportation is very crucial. Individuals who use public buses wastes quality amount of time in waiting for buses on bus stops by without knowing the existing status of bus. In daily life, movement of bus is affected by several features such as traffic or irregular departure time of buses. If travellers get the bus data such as bus location and time of the bus arrival based on usual traffic circumstances, the passengers count would rise the reliability for passengers in the public transport system (Harini et al., 2020).

The world is about to become a spectator of revolution in communication and technology after internet in the form of IoT and IoE. They will be employed to generate smart surroundings for populace worldwide. IoT has become one of those objects that has gradually made its way into almost all features of all segments and made more suitable for the shifting world (Mishra et al., 2020). Intelligent Transport System (ITS) is a section of Internet of Things (IoT) which offers intellect to vehicles, Infrastructure and offers communication among them for a smart conveyance. For enhanced security, efficacy and mobility of the transport system at actual time communication (John et al., 2019).

There is a substantial rise in the quantity of vehicles running on the road as smart transportation is getting famous in smart cities, which in turn upsurges the overcrowding in the system traffic. Thus, it is becoming a challenge to find parking positions in contemporary societies around the world (Chauhan et al., 2020). In current setting, Internet of Things (IoT) podium is the incorporated segment for the growth of smart cities worldwide. The scholars stated that there must be around 30 billion devices for IoT in 2020. Thus, there is a requirement of enormous study for Internet of Things (IoT) in upcoming 2 decades (Roshan et al., 2019). There has been a marvellous growth in technological advances in the arena of automobiles and autonomous vehicles. With the upsurge in the number of driven vehicles, the security concerns with the same have also augmented. The accidents and life-threatening injuries are increased. It has become a requirement to offer satisfactory security measures in automobiles (Das et al., 2021). A smart city focuses at evolving an ecosystem where the citizens will have immediate access to facilities needed for a healthy and safe living. Since the mission of smart city is to grow and incorporate several amenities, it is envisioned that there is a requirement for making the information accessible immediately for correct use of such infrastructure (Rajan et al., 2021).

Due to several reasons comprising the decrease in the cost of vehicles, deprivation of the quality of public transport amenities and augmented wealth of populace, vehicular traffic has increased all worldwide particularly in urban regions. The traffic overcrowding generated by these vehicles causes several issues (Firdhous et al., 2021). The study is constructed on the exploration of the potentials of applying Big Data, Machine Learning and the IoT technologies for the requirements of transport planning and modelling (Iliashenko et al., 2021). The Internet of Things (IoT) and Industrial Internet of Things (IIoT) are measured regarding the growth and digital revolution of the transport and higher education sectors (Nikolayev, 2021).

A clear contextual gap is seen with reference to a specialized application with reference to smart cities. The concept of smart cities in India is of a recent origin in India. There is no study that is available on application of IOT in PTS in the context of smart cities in India. At the same time development in the smart cities is happening at a rapid pace. Substantial investments is being made by the Government to bring-up select cities in India as smart cities. Therefore, this study will provide timely inputs to policy-makers highlighting various aspects of IOT in PTS.

Research Design

Type of Research

This research is a blend of quantitative and qualitative and subsequent scientific analysis.

Since most of the primary data is in terms of opinions and views of the respondents the fundamental nature of the data utilized is qualitative. Yet, due degree of evaluation has been done in the study to arrive at quantifiable and objective outcomes. The main objective of this research work is to study Opportunities & Challenges in utilizing Internet of Things in Public Transport. Notwithstanding the utilization of a decent number of quantitative estimates, it might be noticed that the quantitative results are more directional in nature.

Approach

An empirical approach was adopted. Both primary and secondary data were planned for use.

A cross-validation method of study was used. First, responses were collected from the public transport service suppliers, Depot Managers, and Bus Drivers. Ten such managers and drivers were interviewed. Their responses were collated and analyzed. They were then cross-validated from the public transport system users, that is, the daily commuters from the two smart cities of Pune and Ahmedabad (400 each).

Research Variables

Independent Variables – Problems with existing technologies, Opportunities for IOT, Challenges for use of IOT.

Dependent Variables – Proposed Model using IOT.

Resource identification for variables identified above:

Table 1: Resource identification for data collection for research variables

Sr. No.	Area	Primary Data resource
1	Problems with existing technologies	Responses to sections I of the questionnaire
2	Opportunities for IOT in PTS	Responses to sections II of the questionnaire
3	Challenges for use of IOT in PTS	Responses to sections III of the questionnaire
4	Proposed Model using IOT	Responses to sections IV of the questionnaire
5	All of the above	Interviews with Drivers and Depot Managers

Secondary Data resource used were agency research, publications by individuals, research publication by institutions, annual reports etc.

Research Purpose and formulation of hypotheses

The research seeks to study Opportunities & Challenges in utilizing Internet of Things in Public Transport.

Based on the above scheme the hypotheses formulation is presented below:

Ho1 - There are no significant problems with existing technologies for Public Transport Management

Ha1 - There are significant problems with existing technologies for Public Transport Management

Ho2 - There are no significant opportunities for the use of IOT in PTS of SCs

Ha2 - There are significant opportunities for the use of IOT in PTS of SCs

Ho3 - There are no significant challenges for the use of IOT in PTS of SCs

Ha3 - There are significant challenges for the use of IOT in PTS of SCs

Ho4 – There will be no significant increase in number of passengers due to proposed model using IOT in PTS

Ha4 – There will be significant increase in number of passengers due to proposed model using IOT in PTS

Outline of Scheme for Testing of Hypotheses

- Based on the responses from the ten Depot Managers and Drivers also with some inputs from Literature Review, questionnaire was formed with four main sections
- Responses were collected from commuters under sections 1 to 4 of the questionnaire with 10 questions each on a 5-point Likert scale,
- The responses were: 0 Cannot Say, 1 Somewhat Agree, 2 Strongly Agree, 3 Somewhat Disagree, 4 Strongly Disagree.
- For each of the extreme responses (strongly), a weight of 2 was assigned to distinguish them from the non-extreme responses (somewhat),

- An average response was calculated considering all the questions under the respective section.
- This average response was taken as the sample mean and compared with a hypothesized population mean of 50%, assuming it to be an even by chance.
- A t-test was then employed to check if the difference between the sample means and the hypothesized mean of 50% is statistically significant or not. This was done at a 95% confidence level.
- If the p-values were less than 0.05, the null hypotheses were rejected in favor of the alternate.
- A t-test was to be employed given the fact that the SD of the population was unknown.
- Other statistical functions like standard deviation were also planned. MS Excel formulae like t-dist. were also deployed.

Population and sample selection

Population

The population of commuters using public transport in smart cities of Pune and Ahmedabad is very large (>10,000), representing our population for the study.
Pune has 14 operational bus depots **(**Pune Mahanagar Parivahan Mahamandal Ltd. (2018). The areas covered are: Swargate, Narveer, Tanaji Wadi, Kothrud, Katraj. Hadapsar, Market Yard, Pune Railway Station, Bhakti Shakti, Nigdi, Nehrunagar, Pimpri Sadgurunagar, Bhosari, Jakat Naka, Aundh, Wagholi, Bhekraingar and Shewalewadi. Total fleet of buses is around 2000 with around 2400 bus stops. On an average there are around 1400 buses on road per day. Thus, the number of bus drivers working for PMPML is 1400. (Source: Pune Mahanagar Parivahan Mahamandal Ltd. (2018).
Ahmedabad (Gstrc.in, 2019) has 10 operational bus depots. The areas covered are: Ahmedabad, Chandola, Bareja, Sanand, Viramgam, Dholka, Dhandhuka, Bavla, Dahegam, and Gandhinagar. Total fleet of buses is around 1500 with around 2000 bus stops. On an average there are around 1000 buses on road per day. Thus the total number of bus drivers working for the Ahmedabad bus services is around 1000.

Sample Size

Based on the standard sample size tables at a 95% confidence level and a 5% confidence interval, the sample size for a population of 10000 comes to 370 which was rounded off to 400 each for Pune and Ahmedabad.

Selection of sample and data collection

The selection of the respondents was done based on judgment where the possibility of getting the responses was relatively higher. Judgmental sampling is a non-probability sampling technique where the researcher selects units to be sampled based on their knowledge and professional judgment. This type of sampling technique is also known as purposive sampling and authoritative sampling. The name of the respondents was not recorded for ensuring confidentiality.
Additionally, semi-structured interviews with 10 drivers and depot managers were also conducted. Dworkin (2012) have specified that in case of expert interview any number between 5-50 is considered reasonable. Hence for the interviews a sample size of 10 was chosen that was divided as 6 depot managers and 4 drivers.

Data collection method

The data collection method envisaged the collection of both primary and secondary data. The primary data wascollected from 400 commuters each, who are using public transport from smart cities of Pune and Ahmedabad. Additionally, expert interviews with 10 drivers and depot managers were also conducted.
Secondary data was collected through journals, articles, the internet, and other sources.

Primary data collection scheme

Primary data was collected from respondents through a consolidated questionnaire comprising of four sections.

Design of questionnaire

The questionnaire was designed in Google Forms / MS Excel.

Names were not taken for the sake of confidentiality. In the response scheme, the "DK" (Don't Know) filter was used as suggested by Menold and Bogner (2016). Hence the first response option for each question was kept as "Cannot say" to provide an early exit option for the respondent from the question in case he doesn't know the answer or doesn't want to answer or has a neutral view.

Data analysis methodology

Descriptive analysis was done to provide information about the profile characteristics of the sample like age-wise, and gender-wise distribution. Inferential analysis was done to test the hypotheses. Finer data analysis was done to find out special relationships between variables if any.

Validity & Reliability

The instruments' validity was confirmed with the help of the guide and other experts in the field.

Reliability was ascertained by performing the Cronbach's Alpha tests for sections of the questionnaires for the commuters separately and in aggregate.

The results of the reliability test were:

I-Problems with existing technologies 0.940, II-Opportunities for IoT in PTS 0.892, III-Challenges for the use of IoT in PTS 0.926, IV-Proposed Model using IoT 0.744, and entire questionnaire 0.878. Since the Cronbach's Alpha was found to be more than 0.70, the questionnaire was considered as reliable.

Data Analysis and Interpretation

Data analysis and interpretation scheme explained

The scheme formulated was as under:

Table 2: Data analysis and interpretation scheme explained

Sr. No.	Data Analysis	Expected Outcome	Interpretation
1	Problems with existing technologies	Agreement/Disagreement percentage on specific problems with existing technologies and the resultant p-value	If the agreement percentage p-value is < 0.05, reject the null hypothesis that there are no significant problems with existing technologies
2	Opportunities for IoT in PTS	Agreement/Disagreement percentage on specific opportunities for IoT in PTS and the resultant p-value	If the agreement p-value is < 0.05, reject the null hypothesis that there are no significant opportunities for the use of IoT in PTS of SCs
3	Challenges for the use of IoT in PTS	Agreement/Disagreement percentage on specific challenges for the use of IoT in PTS and the resultant p-value	If the effectiveness percentage p-value is < 0.05, reject the null hypothesis that there are no significant challenges for the use of IoT in PTS of SCs
4	Proposed Model using IoT	Agreement/Disagreement percentage on proposed model using IoT and the resultant p-value	If the agreement percentage p-value is < 0.05, reject the null hypothesis that there will be no significant increase in number of passengers due to proposed model using IoT in PTS

Summary of data analyses of responses &overall interpretation

The following table summarizes key parameters and the overall interpretation:

Table 3: Summary of data analyses of responses &overall interpretation

Sr. No.	Data Analysis	Outcome	Interpretation
1	Problems with existing technologies	Average agreement percentage 80% p-value <0.0001	As the p-value is < 0.05, rejected the null hypothesis that there are no significant problems with existing technologies for Public Transport Management
2	Opportunities for IoT in PTS	Average agreement percentage 82% p-value <0.0001	As the p-value is < 0.05, rejected the null hypothesis that there are no significant problems with existing technologies for Public Transport Management

3	Challenges for the use of IoT in PTS	Average effectiveness percentage 80% p-value <0.0001	As the p-value is < 0.05, rejected the null hypothesis that there are no significant challenges for the use of IOT in PTS of SCs
4	Proposed Model using IoT	Average agreement percentage 79% p-value <0.0001	As the p-value is < 0.05, rejected the null hypothesis that there will be no significant increase in number of passengers due to proposed model using IOT in PTS

Findings, Conclusions and Suggestions for Further Research

Table 4: Respondent Details

<table>
<tr><td rowspan="2">Smart Cities of Respondents</td><td colspan="3">Pune</td><td colspan="3">Ahmedabad</td></tr>
<tr><td colspan="3">400</td><td colspan="3">400</td></tr>
<tr><td rowspan="2">Gender wise distribution</td><td colspan="3">Males</td><td colspan="3">Females</td></tr>
<tr><td colspan="3">381</td><td colspan="3">419</td></tr>
<tr><td rowspan="2">Age Groups</td><td><20 yrs</td><td colspan="2">20-30 yrs</td><td colspan="2">30-40 yrs</td><td>>40 yrs</td></tr>
<tr><td>213</td><td colspan="2">187</td><td colspan="2">191</td><td>209</td></tr>
<tr><td rowspan="2">Means of Commute</td><td colspan="3">Public Transport</td><td colspan="3">Own Vehicle</td></tr>
<tr><td colspan="3">394</td><td colspan="3">406</td></tr>
<tr><td rowspan="2">Commuting Since</td><td colspan="2"><3 years</td><td colspan="2">3-5 years</td><td colspan="2">>5 years</td></tr>
<tr><td colspan="2">274</td><td colspan="2">275</td><td colspan="2">251</td></tr>
<tr><td rowspan="2">Regular users of technology like GPRS or other Apps</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td colspan="3">419</td><td colspan="3">381</td></tr>
</table>

Research Findings

1. Findings show that for the variable problems with the current technology, the agreement of the sample is 80%.
2. For the variable opportunities for IOT in PTS the agreement of the respondents is 82%.
3. It was found that for the variable challenges for IOT in PTS the agreement of the sample is 80%.
4. In case of the variable proposed model using IOT the agreement of the respondents is 79%.
5. Study reveals that demographic variable i.e. age has not a significant impact over the four set of responses collected in the research.
6. The study also depicts that gender also has not a significant impact over the four set of responses collected in the research.
7. None of the other four demographic variables (i.e. smart city, commuting mode, commuting experience, and use of technology) have any significant impact over the four set of responses related to problems, opportunities, challenges, and suggestions.

Conclusion

1. There is a strong agreement for specific factors identified as ones that are the problems with existing technologies. Wide agreement to the ten factors, namely, Heavy traffic, High pollution, Roadway congestion, High commute and waiting hours, No concrete timings for buses , Traffic accidents, Lack of planning, Lack of coordination, Less use of technology and Technologies are outdated, show that these are specific factors identified as ones that are the problems with existing technologies.
2. A high agreement is there for opportunities for IOT in PTS. Opportunity areas like Lower commute time and waiting time, Real-time status information to commuters, Commuters can know the exact ETA for their buses , Commuters can also know if buses and trains are filled or empty, Commuters can know the number of people waiting at the bus stop , Preventive maintenance leading to lower breakdown instances, Better planning of transport routes, Plan new transit routes and start new bus services, Minimizing traffic as

more number of people prefer public transport and Minimizing pollution were widely agreed to by the respondents and hence it is concluded that there is a major opportunity for IOT in PTS.

3. There was an overwhelming agreement to the identified challenges for IOT in PTS. Challenges like Higher operational or running costs, Lack of investments by private sector, Lack of technical knowledge among the planners, Lack of access to technology, Privacy and security issues, System failure issues, Lack of integration of IT networks, Internet connectivity, Lack of IT infrastructure and Lack of standardization were largely agreed to by the respondents.
4. The proposed model using IOT has been validated strongly by the respondents. This conclusion has been drawn based on large agreement from the respondents to statements like Passenger information systems such as smart boards by L & T, Smart cards and integrated ticketing, Real time parking management, Automated speed enforcement, Electronic toll collection, Vehicle control technologies, Cyber security of traffic systems, Connected cars (A connected car is one that has its own connection to the internet), Bus Stand Surveillance and Safety equipment and Use of RFID technology.

Overall it can be concluded that there is a great opportunity for IOT in PTS provided the accompanying challenges are duly addressed. The proposed model can make a significant contribution.

Suggestions

A model has been proposed for implementing IOT in PTS based on inputs from secondary data and ten elements that were suggested by the experts and validated by the commuters. These elements are:

1. Passenger information systems such as smart boards by L & T,
2. Smart cards and integrated ticketing,
3. Real time parking management,
4. Automated speed enforcement,
5. Electronic ticketing,
6. Vehicle control technologies,
7. Cyber security of traffic systems,
8. Connected cars (A connected car is one that has its own connection to the internet),
9. Bus Stand Surveillance and Safety equipment, and
10. Use of RFID technology

Based on common themes, the following three-tier model of advance-integrate-control is proposed as shown below:

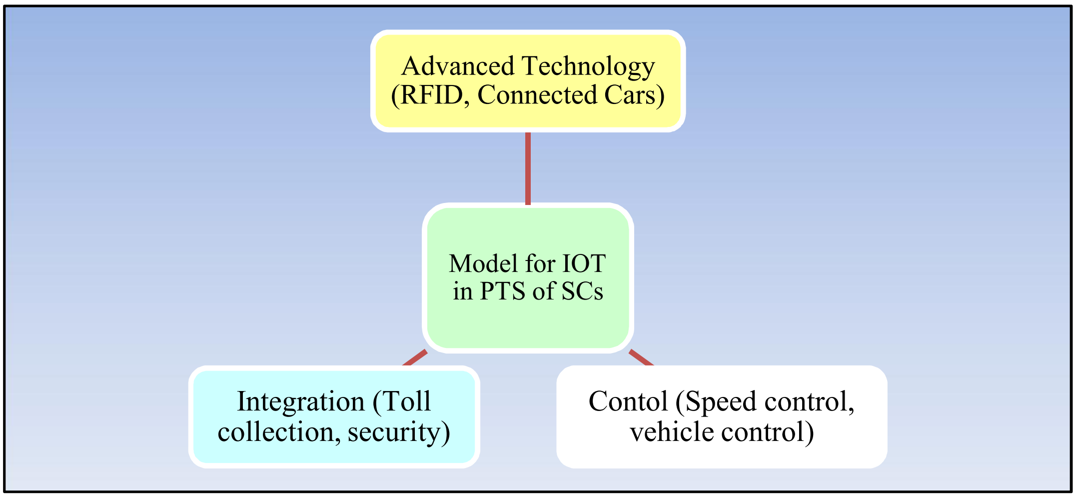

Figure 2: Suggested three-tier model of advance-integrate-control for IOT in PTS

Advanced technological initiatives like use of RFID technology, connected cars, and others reflects the design angle of the proposed model. The integration dimension of the proposed model is shown through connectivity with other systems like toll collection, cyber security of traffic systems, etc. And finally, the control dimension is reflected through initiatives like automated speed control, use of vehicle control technologies, etc.

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