Introducing IOT in the Realm of Public Space – A Case Study of Bhopal

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Abstract— *Public spaces are pivotal in fostering community engagement, urban activity and economic activity. However, considering the rapid growth in population density due to sudden urban shift, significant amount of pressure is being applied on the existing infrastructure. Such strains result in generation of problems like safety issue, traffic congestion etc. This study analyses the transformative role of IoT (Internet of Things) in overcoming these challenges, using Bhopal's 10 Number Market as a case study. Prioritizing community input through interviews and site studies established a clear understanding of local desires, which later became the basis for IoT proposals. IoT solutions consisted of air quality sensors, smart bins, adaptive traffic lights etc. These measures aimed to help solve the existing problems while also enabling sustainable urbanization. This research elucidates that influence of communities' cooperation, of several stakeholders is vital for IoT technologies' efficient integration. Also, it indicates that education campaigns, advanced technology and legislation can facilitate the adoption of technologies. This paper serves as a facilitator of realization of smart devices and evaluates prospects of using new technologies for efficient management of urban areas. The knowledge acquired contributes to a better and more user-centric urban future by offering cities around the world a template on how to address the same challenges.*

Index Terms— *Public Space, Internet of Things (IoT), Urbanization Challenges, Smart Urban Solutions, IoT Applications in Public Space.*

I. INTRODUCTION

Presently, Gartner [1] estimates that cities will host an additional 73 percent of the world's population by 2050. Immense urban growth in itself places a major strain on existing infrastructure along with public spaces and this is only going to get worse now with more people making the move to urban living. Urgent need envisaged to catering the deleterious conditions currently occurring, that would only accelerate with time is called for. IoT today is virtually everywhere from industrial applications to emergency services, city lighting, city utilities, other city applications to public transportation and public safety, as seen in [figure 1].

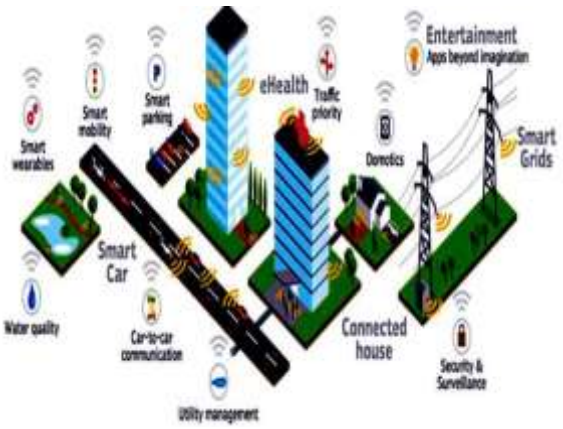

Fig. 1: The Internet of Things Domains [1]

In addition, it is expected that within the next ten years, a large number of enterprises will be involved in delivering IoT applications across different domains. For instance, Peter McYntire quoted Cisco in the prediction that proper 24 billion objects will connect via internet by 2019 [2]. Alternatively, a forecast from Morgan Stanley predicted that 2020 will see the connection of nearly 75 billion different networking devices [3]. The research organization Huawei forecasted 100 million will connect to IoT devices by 2025 [4]. The aim of IoT, therefore, within the urban space, is to provide for easier and specific access to public resources, so that a favorable utilization and optimization of surveillance of transportation and the power along with maintenance of public areas can be optimally achieved. During 1999 the British tech pioneer Kevin Ashton first coined the term of IoT [5], the interconnection of devices, actuators, and sensors over the internet has bridged the gap between the physical world and technology for efficient communication and management [5].

This paradigm is particularly significant for rapidly urbanizing countries like **India**, where emerging cities like Bhopal are experiencing unprecedented growth. This influx to urban areas imposes a huge burden on the infrastructure and especially public space, which consists of heavy volumes of traffic like **10 Number Market**, a lively residential, commercial and social hub.

This research paper seeks to reflect on the multiple domains of IoT (Internet of Things) applications and devices that can be immediately used to counter urban challenges taking place at a public space, example: 10 No. Market.

II. 10 Number market

The 10 Number market lies in the Eidgah Hills Ward, Bhopal, M.P. It originally emerged as an amenity center for satisfying the needs of the largest, most popular and posh residential colony, the Arera Colony, Bhopal. It lies in the heart of the residential land-use area. Although residential is the land use that dominates the area, 10 Number has grown into a major retail destination. It came with time to evolve as one of the leading markets of the city. It features numerous showrooms, a variety of food outlets, and other commercial establishments, all situated strategically at the heart of this bustling residential area.

Given the conditions above the Arera colony has changed into a high-density mixed use; there has been a mixing of commercial with residential that eventually changed it to an evolved fabric. Within this dynamic context, the main 10 No. Road became unique due to its amalgamation of high- and medium-intensity retail activity, with Zone 2 representing the highest retail density and footfall vis-à-vis other blocks. Over time, commercial activities began to spill along the pedestrian lane, increasing vibrancy but also serious problems.

The intrusion of the informal activities of hawkers and vendors into the roads and pedestrian walkways resulted in congestion and reduced flow of shoppers and pedestrians. This overabundance of informal activity along the margins of the area renders the pedestrian walkways and open space buffers largely unusable. Despite its vibrant character and potential to offer a rich user experience, 10 No. falls short of the mark as a visionary urban marketplace because it lacks basic requirements such as cleanliness, organization, and pedestrian-friendly infrastructure.

Given these challenges, the area of study holds immense potential for improvement. By addressing these issues through target specific interventions, like implementation of **IoT-based solutions**, the market can be transformed into an organized, convenient, and user-friendly public space. These initiatives would not just enhance the quality of community engagement of the region but also minimise the hassle for citizens to move around along with opening ways for a more sustainable and smarter urban marketplace.

III. Problem Identification – Method and Result

Methods

The contextual evaluation of the Market extends beyond its immediate physical attributes to incorporate its climatic, cultural, and socio-economic context. This holistic assessment includes examining the market's role within the local community, its economic significance, sun path, wind direction, and land use patterns. Understanding these broader contextual factors is crucial for ensuring that any design or development interventions align with community needs and contribute to the socio-economic vitality of the area.

To identify and analyse the challenges faced by 10 No. Market, the following methods were employed:

1. **Questionnaire Surveys**: A set of questionnaires consisting of 50 questions each, were distributed and responses were collected from various respondents including consumers, shopkeepers, pedestrians, hawkers, and residents of the colony. The questionnaires provided both qualitative and quantitative information regarding everyday issues.

2. **Secondary Data Analysis**:

    1. **Air Quality Index (AQI)**: The data was downloaded from the Madhya Pradesh government portal to analyse the environmental condition of the city.

    2. **Newspaper Clippings**: Reports and articles from local newspapers were considered to comprehend the problems and events taking place at the market.

3. **Literature Review:** Books, research papers, and other literature materials were referred to provide a theoretical base and context for the study. Few references include the "Town and Country Planning" book and Bhopal Gazetteer; these helped in gaining valuable insights on historical, socio-economic, and urban development aspects of the city.

4. **Site Observations**: The market area's physical conditions, encroachments, pedestrian flow, traffic management, and functionality were observed during the site visit.

Combining these methods provided a wholesome understanding of the key issues impacting 10 Number Market, which became the basis for making specific interventions that would help overcome these challenges effectively.

A Glimpse of the foundings

The findings were based on the answers of detailed questionnaire, the few questions which stood out as the most important based on their relevance and the consistency of the responses were "What time of day do you find the most traffic congestion in the market?" (80% said peak evening hours), "Is there enough parking space?" (65% said insufficient), "Are waste bins well placed and accessible?" (75% said inadequate) along with many more pertinent to the context. Answers to these questions, along with information from research papers, books such as the Town and Country Planning and newspaper clippings from Times of India together provided a deeper understanding of the challenges. The clippings from newspaper brough out the concerns of some residents. *Shantanu Sharma of Arera Vikas Samiti expressed his misgivings over the unregulated commercialization of the colony, saying its future was going to resemble a congested chawk market. Rajesh Khare pointed out improper development, giving the example of buildings without parking provision, which causes chaos on the roadsides* [6]. Together, all these challenges formed the

foundation for problem identification and issue mapping, which were targeted at traffic congestion, waste management, utilities, and environmental well-being to make the market more functional and sustainable.

According to AQI Dashboard [7], the Air Quality Index in Bhopal is currently poor, and throughout the years 2020 to 2024, there is a concurrent rising trend in deterioration. Now the city is a hair-breadth away from being in the category of 'unhealthy' reaching just 3 points away. This reduction can be attributed to the use of public areas (market, schools etc.) that are often dominated by things like heavy traffic jam and informal hawker areas which eventually become smoking zones. Consequently, these activities further increase the localized air pollution and hence the overall AQI of the region.

Fig. 2: Air Quality Index of Bhopal

Fig. 3: Air Quality Index of Bhopal, comparison of annual AQ Indices (2020–2024)

(Source: Real – Time Air Pollution – Air Quality Index)

Issue Mapping

Based on these findings, issue mapping focuses on the following crucial dimensions:

1. Traffic Congestion

1. Inadequate road space and traffic management has contributed to very high levels of traffic congestion.
2. The 10 No. Road has a fast-moving traffic, making it very difficult for pedestrians to move.
3. Some users frequently spill out on footpaths, thus preventing smooth movement.
4. Accidents happen as a result of either inefficient planning or a lack of well organised traffic management systems.

2. Air Quality (Environmental Well- Being)

1. The hawker's area (zone 2) is a high-smoking area, contributing significantly to deteriorating air quality & localized air pollution.
2. Another cause behind the fast degradation of air is heavy vehicle emissions, especially during peak hours.

3. Parking Spaces

1. It is to note that no proper demarcation of car parking was done in zone 3 & 4 leading to disoriented parking and inefficient use of space.
2. Insufficient parking for two-wheelers, the hawkers' eatery area is sharing parking space, reducing the area's functionality.
3. Footfall of the market is not matched with the parking space available due to which illegal on street parking takes place.

4. Public Safety

1. No proper fire safety systems were present in the market putting people at risk during emergency.
2. No installation of zebra-crossing or pedestrian-systems were present on the busiest road, making pedestrian safety a concern.
3. Overhanging cables and exposed wiring from electric posts turns to be a menace especially for people walking on the roads.
4. The state of the area is so haphazard that you can tell that no asset management or tracking systems are in place to help monitor with respect to safety.

5. Utility Management

1. No green spaces were present to improve air quality or enhance the ambiance of the market.
2. There is a lack of adequate dustbins, leading to littering on streets and footpaths, contributing to significant environmental degradation.
3. Existing dustbins are in a broken state or are placed in improper positions, making them less effective for waste management.
4. There are insufficient street lights in the narrow lanes of the market where illumination is dependent only on shop lights.

Hawker's Area
(Serving as Parking cum Sitting.)

10 Number Road
(Depicting encroached footpath & traffic congestion.)

10 Number Market's retail area
(Exposed & low lung electric wiring.)

Fig. 4: Images depicting the current condition of the market. (Source: Author)

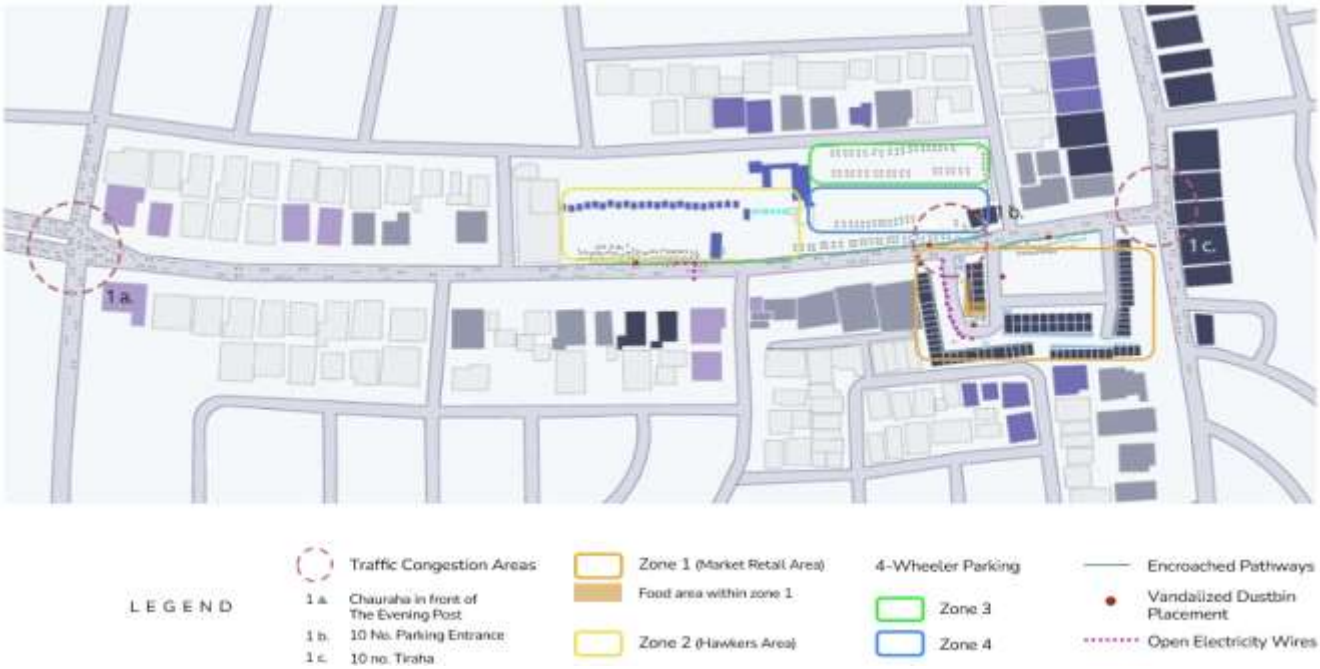

Fig. 7: 10 Number Market's zoning & Issue Mapping

IV. Applications of IoT for a Public Space

There are multiple applications of IoT which can be deployed for smart urbanism, smart homes, wearable gadgets, smart grids, the industrial internet, connected cars, smart farming, smart traffic, health applications, retail, security, energy, water management, waste management, noise management, and pollution management. It generally provides a high level of knowledge about the environment by continuous monitoring.

Nowadays, IoT helps in rendering a number of services to people, managing different fields with less effort and lesser time. Connectivity towards IoT has leads to a new industrial evolution in the life of common people. This innovation changed the way people and machines communicated with eachother, thus improving the standards of living.We will summarize below the complete outline describing most of the real use IoT cases, which have already been implemented in public settings around the globe.

1. IoT in Road Traffic

The spaces should be such, that citizens can move from point A to point B as safely and efficiently as possible. Hence, municipalities nowadays are mostly turning their attention to IoT development and deployment towards smart traffic systems. These smart traffic systems use several types of sensors and GPS data from driver's smart devices to regulate the count, placement, and speed of vehicles [8]. Concurrently, smart signals connected to a cloud management platform allows the monitoring of green light timings and provides automatic adjustment of lights according to real-time traffic conditions to put a stop to congestion. Above all, utilizing

historical data, smart solutions for traffic management can predict where the traffic could go and take remedial action to prevent probable congestion [9].

Various studies have focused on applications of such technologies. L. T. Manera, Paulo Denis Garcez da Luz in their research proposed a smart traffic light control system based on the Internet of Things (IoT) to manage urban traffic. They applied data integration system that connects cameras, sensors, and various inputs to analyse statistics for real-time traffic updates and improve traffic light timings. They integrated machine learning algorithms and traffic models to predict traffic flow patterns and to dynamically adjust light cycles. Additionally, the system's potential for recognizing traffic accidents and notifying nearby emergency services helped in city management and traffic safety [10].

Real – Life Cases

New York: Conducting project of connected vehicles (CTV) to eliminate injuries and damage to life & property due to traffic related accidents [9] .

Los Angeles: Deployed CCTV and road surface sensors to control traffic flow with real time updates. The city has also diploid smart controllers that auto adjust traffic lights based on changing traffic conditions [9].

Europe has encouraged many countries to adopt Smart City technology for traffic management. The European commission allocated 365 million euros to member nations for this purpose. The United Kingdom has deployed smart electric cars and bike sharing programs [11].

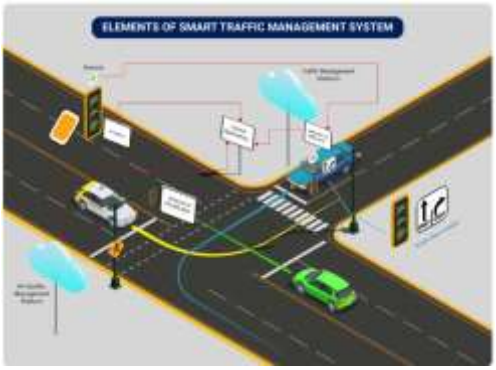

Fig. 8: Smart traffic management system. [9]

2. IoT in Air Quality (Environmental – Well Being)

IoT can provide means to monitor the quality of the air in crowded areas, parks or fitness trails [12]. Therefore, allowing humans to find the healthiest path for outdoor activities and still be connected to their preferred particular training application. Such a service requires air quality and pollution sensors to be installed around the space and the sensor data to be made available, publicly to citizens. It can alert the administration to take necessary actions after detection of pollutants in the air, enhancing public safety. IoT air quality monitoring can help make our public settings more sustainable [13].

To measure the air quality several methods of monitoring have been proposed and used. In the research by Zheng et al. [14], they use public and private web services together with a list of public websites to provide real time meteorological, weather forecasts and air quality information. Air quality for subway tunnels in South Korea was monitored by Jun Ho Jo, Byung Wan Jo, Jung Hoon Kim, Ian Choi [15] as 8 million passengers use subway on daily basis. The study offers an implementation of an IoT-based air quality monitoring system with the aim of improving the monitoring of particulate matter (PM10) levels. The system was experimented in the subway tunnels at Incheon, South Korea. The system showed good performance along with the convenience in monitoring air quality, particularly particulate matter. Some of the conclusions that were made includes: (a) The IoT based air quality monitoring system was efficient in monitoring the air in the tunnel. (b) The air quality in the subway tunnel could be monitored continuously using IoT and cloud computing. (c) It was simple to expand the monitoring area with the help of this system. In addition to the fixed sensors, public transportation infrastructure such as buses has also been used to collect air quality data [16].

Exemplary Case

China: Beijing along with many cities have built their own air quality monitoring stations and publish the real time air quality information every hour [14].

3. IoT in Public Safety

The city can use the deploying of IoT-enabled cameras and sensors in public places to monitor security threats, such as suspicious activity or unattended bags. IoT-enabled solutions come integrated with analytics, real-time tracking, and decision-making capabilities. It analyses data generated from CCTV cameras, acoustic sensors (embedded throughout the city) and data generated from social media feeds for predicting crime incidents. This would enable the agencies to respond far more quickly and effectively to possible threats [9]. Safety concerns go beyond security threats. The IoT also extends to fire safety with devices consisting of

smart smoke detectors, fire alarms, and temperature sensors. Such systems provide real-time alerts for speedy evacuation and immediate action to prevent disasters. Together, all these IoT-enabled solutions significantly raise the level of urban safety by addressing a really large range of risks.

Several other studies have focused on applications of such technologies. For instance, Shin-Juh Chen, in his study, probed the unusual high rate of false fire detection alarm in fire detection systems used in air cargo settings where flight must be brought down within 15 to 20 minutes to avoid any permanent damage. Despite these systems boasting a 99.9% of success rate in detecting actual fire emergencies, false alarms remain a critical challenge [17].

Furthermore, Lakshmana Phaneendra Magulur et al. designed an IoT-based emergency response system for fire hazards. The design of the system is based on low-cost components such as an ESP-32 Wi-Fi module, flame and smoke-detecting sensors, a flammable gas sensor, and a GPS module. This system detects hazards and can send location-based alerts to emergency services through the cloud-based MQTT protocol, enabling fast and reliable communication. This creates an intelligent, integrated solution for efficient fire hazard management [18].

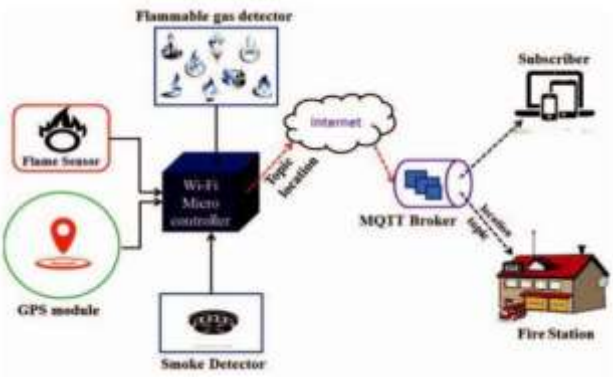

Fig. 9: Block Diagram of smoke detection system [18]

In another topic related study Saad et al. designed a fire detection system to prohibit the fire hazards [26]. The authors propose a system implemented with ZigBee technology as a protocol to receive the data from multiple sensors like smoke sensor, gas sensor, heat sensor, and UI/IV sensor. Then, the system processes the data with Raspberry Pi in order to identify the fire. On the other hand, motion detection systems are using infrared sensors or cameras to detect the movement. [19] [20]. Moreover, anomalous situation detection has been achieved by smart surveillance system driven by Artificial Intelligence (AI). These systems analyse images to detect irregularities [20].

Real - Life Cases

New York (USA): NYC fire department are using predictive modelling and data analytics to identify crime hot spots. The city has also introduced a gunshot detection solution that uses connected microphones to transmit data to a cloud platform. This platform records the time taken by the sound of a gunshot to reach the microscope and estimates the gun's location to alert the police on a mobile app [9].

4. IoT in Smart Parking

The assist of GPS data from driver's smartphone, smart parking solutions determine whether the parking spots are engaged or not engaged and then creates a real-time parking map. When the nearest parking spot becomes free, smart parking systems will send drivers a notification who then would use their phone's map to find a parking spot in quicker and hassle-free manner as opposed to driving aimlessly around [8]. Additionally, IoT sensors could also be placed on parking spots to detect when a spot is taken and transmit that information to a central server. This can direct drivers, to free parking spots thus reducing congestion and search time. Sensors, which are embedded in the ground, sends information to the cloud, which then informs drivers almost immediately about vacant spots in the vicinity [9].

Smart parking IoT devices do have a significant benefit when it comes to the reduction of excess emissions caused by vehicles idling or circulating in search of a parking space. In addition, they also minimise fuel consumption and reduce congestion on roads, therefore creating a sustainable and efficient urban environment.

Some of the work in this area includes that done by Sezer Gören, Dilan Fatma Öncevarlık, Kemal Doruk Yıldız, and Taha Zahit Hakyemez, who have approached the problem of on-street parking through cameras installed on roadsides. In contradistinction to the indoor parking lots managed by pricey sensors, their solution utilizes cameras that monitor parking spots. Street images are collected to build a dataset and a Convolutional Neural Network is trained to search for available spots in images. They also developed a mobile application that activates cameras on the road side according to user's request which informs drivers about free parking slots and provides navigation to the spot when confirmed [21].

Fig. 10: Street Illustration (Top) Proposed System (Bottom) [21]

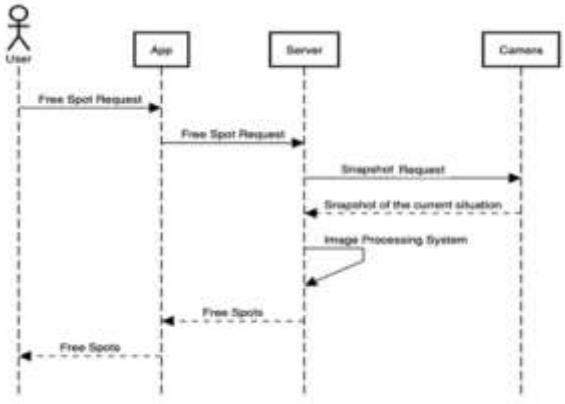

Fig. 11: Sequence Diagram of Proposed System [21]

Another useful study in this area is by C. Ajchariyavanich and T. Limpisthira, which focuses on developing Park King, an IoT-based, cloud-integrated smart parking system for university campuses. Park King consists of an IoT module for monitoring parking spot availability and controlling parking flaps, along with a web-based application for advance booking of parking spots. Key features include spot availability checking, reservation of spaces by using a QR code and scanning the code to have access to reserved parking spots. The ultrasonic sensors measure the distance between the vehicle and the ceiling to detect occupancy for efficient parking management [22].

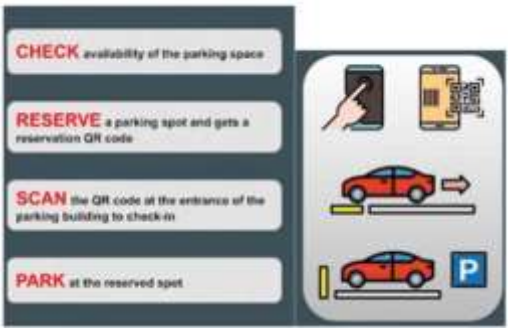

Fig. 12: Park King's system overview [22]

Real – Life Cases

London (UK): The SmartPark project deployed in Westminster lets driver's find parking while on the move. It saves the frustrations of lengthy searches for an empty space and reduces congestion [9].

Paris has already benefited from this technology by setting up an electric car smart city called Autoli. Nearly 3000 vehicles are connected by GPS to help drivers find reserved parking [12].

5. IoT in Utility Management

Under utility management, in this paper, we are looking at how to address the needs of streetlights and garbage bins. Most garbage collection operator empty containers according to predefined schedules. This is not a very efficient procedure since it leads to the unproductive use of garbage containers and unneeded fuel consumption by garbage collecting trucks. IoT-enabled smart solutions help to optimize garbage collection schedules by tracking waste levels, route optimization, and operational analytics. Each garbage container is equipped with a sensor that gathers data on the level of the garbage in that container [23]. If it is near a predefined threshold, a record from the sensor is sent to the garbage management solution, which then processes it and further sends notification to a truck driver's mobile app. This way, the truck driver will unload a full container and will not unload the half-full containers. Alternatively, the intelligent street lighting solution uses IoT to make street lights controllable and manageable remotely. These systems optimize the usage of power in public places by ensuring that electricity is used only when necessary [9].

Gianfranco Gagliardi and Marco Lupia, in their work, developed a system that autonomously adjusts street lamp's brightness based on the presence of vehicles (such as buses, trucks, cars, motorcycles, and bikes) and pedestrians in specific areas of streets or roads. This approach significantly reduces energy consumption [24].

Andi Muhammad Saad and Badillah Ode Jul [25]developed an IoT- Based smart dustbin prototype for the management of waste. The system operates on ultrasonic sensors to measure waste height and detect objects, a load cell sensor is used to measure waste weight, and GPS to provide the dustbin's location. NodeMCU ESP8266 processes sensor data and sends it to users via WhatsApp notifications. The system automatically opens and closes the dustbin for objects within ≤50 cm, with error rates of 0.4% for height detection and 0.15% for weight measurement. Notifications are triggered when the waste height reaches 3 cm from the sensor or a weight of 4000 grams, aiding efficient waste collection and management. These works align with the growing trend of integrating IoT solutions for energy-efficient and sustainable urban environments, complementing other smart initiatives.

Real – Life Case

New Jersey (USA): The municipality of East Brunswick has rolled out a recycling app enabled with IoT capabilities. It helps improve their communication with residents to create a positive environmental impact. The app connects all the residents to improve recycling rates and reduce waste [9].

V. SUGGESTIONS

Data collected from multiple sources were analyzed and different IoT devices were employed in order to create harmonious space. The zoning of the site itself became an essential step as it allowed for the development of a lively and useful urban space. In order to optimize and arrange the different spaces within the market, a vigorous brain storming session based on the analysed data was conducted to identify the most suitable devices for each area. Through the application of these devices and technologies the design sought to establish a dynamic market where each space is function and properly planned with reference to the demands of its users. The devices proposed for each zone or area are mentioned below.

Zone 1 (Market Retail Area)

1. **Smart Street Lighting**: To minimise electricity consumption solar-powered smart streetlights must be integrated. These lights modify their brightness levels based on the required luminance, maintaining and ensuring energy efficiency.
2. **Pedestrian Pathways**: To facilitate efficient flow of movement well designed footpaths need to be build adjacent to the road. Adaptive pedestrian systems, consisting of smart crossings, must be installed. These systems would detect the number of people waiting to cross and adjust the movement light accordingly, ensuring safe and streamlined passage without mishaps.
3. **Smart Waste Management**: To improve cleanliness of the zone, placing smart dustbins in the food area to detect when they are full and require emptying would be necessary. This would also lessen the visits of waste collection trucks hence overall preventing the vehicle generated emissions and time wastage of the workers.
4. **Surveillance and Safety Systems**: To ensure safety and security within the market premises smart poles equipped with Smoke detectors, fire alarms, acoustic sensors, and CCTV cameras must be installed systematically.

Zone 2: Hawkers' Zone

1. **Parking Adjustments**: To reduce the disorganization caused by two- wheeler parking in the hawker's zone. Parking area should be relocated to zone 3, resulting in relieving traffic congestion and prevention from pedestrian pathway encroachment.
2. **Air Quality Monitoring**: The area is considered as a high smoking zone, which has heavily impacted the ambient air quality. Smart air quality sensors should be installed to monitor pollution levels.
3. **Smart Infrastructure**: The only source of light for the entire area is the dissipated light received from the stalls. The area also lacks proper waste disposal system. Smart dustbins along with and street lights must be evenly distributed to ensure proper waste disposal and adequate lighting.
4. **Pedestrian Pathways**: A proper footpath should be introduced consisting of adaptive pedestrian systems to enhance the safety and accessibility for pedestrians. The footpath would also act as a line of division between the hawker zone and the main road.

Zone 3: Parking Area

1. **Two-Wheeler Parking**: Replacing four-wheeler parking with the current on-street two-wheeler parking would help with overall reduction of 4-wheeler traffic congestion taking place on the main 10 No. Road.
2. **Smart Parking System**: To save the time spent searching for parking spots, installing advanced parking systems with cameras would be necessary. They'll detect available parking spaces and guide vehicles as per requirement.

Zone 4: Public Green Space

1. **Green Space Conversion**: To reduce and to amend the already deteriorated air quality the existing on-street four-wheeler parking will be converted into a public garden or green space. This transformation will also help cater traffic congestion along with lowering vehicular emissions.
2. **Smart Parking Facility**: As the current on street parking was unable to provide sufficient amount of parking spaces in accordance with the footfall of the market, a multi-level smart parking building should be constructed on the nearby ground adjacent to the Naveen School's ground.

Additional Measures

1. **Smart Traffic Management**: To improve the overall flow of traffic at the intersection near the evening post, a smart traffic system consisting of an adaptive traffic light and CCTV cameras (to monitor any sort of accident, so as to alert the near-by emergency services) should be installed. This system will help decongest traffic by predicting rush patterns and would direct the drivers to alternate routes.

VI. Conclusion

This research comprehensively estimates the opportunities and challenges within a public space by undertaking an exemplary case of the 10 No. Market in Bhopal, highlighting the transformative potential of IoT technologies. Rapid growth in urban sprawl and population density have exacerbated challenges like poor air quality, traffic congestion, compromised public safety, insufficient waste management etc. Using IoT to cater these issues would substantially present a creative and unique pathway which would lead to enhanced user experience and urban functionality.

The study addressed traffic congestion as a critical issue, which was made worse by haphazard parking conditions, high footfall rate etc. These issues can easily be improved by incorporating IoT solutions like smart parking systems, adaptive traffic lights and machine learning. Furthermore, concerns related to issues like deteriorating air quality (driven by vehicular emissions and smoking), compromised public safety (Examples include exposed wiring, inadequate lighting along with fire risks) and insufficient waste management can be resolved by installing air quality sensors, sensor - equipped smart bins and smart poles integrating smoke detectors, fire alarms, CCTV cameras respectively. In order to enhance usability of market space and the well-being of the community while reducing emissions, the study advocates for pedestrian-friendly pathways, adaptive crossings, and green spaces. Interventions which are IoT-driven and have the potential to dramatically change the market into a safer, cleaner, and more sustainable urban hub.

On the contrary, though IoT offers extreme potential, it does face certain obstacles such as data security concerns, connectivity limitations, interoperability issue, high cost etc. However, these hurdles can successfully be addressed through collaborative efforts between government, manufacturers and other stake holders. Strategic planning, continuous innovation and robust policy framework would ensure that these remain manageable. Furthermore, to make people delve into adopting IoT it is crucial to provide affordable options, multiple variations (as per varying needs) and providing accessibility to all. Enabling enhanced transparency would play a vital role.

From a wider perspective, this research tries to call attention to the important role of collaboration between community engagement and multi stakeholder so as to provide successful IoT implementation. The proposed interventions cater existing challenges along with developing a path to sustainable urban future.

This study serves as a prototype for exploring the vast potential of IoT in public spaces. By inculcating technologies, upcoming cities like Bhopal can drastically change the congested and disorganized public space into a beautiful, self – sustained space.

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