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Strategic Use Cases of Digital Transformation Implementation in Cities in Developing Countries

Wendy Junaidi

Management Department, BINUS Business School Undergraduate Program,
Bina Nusantara University,
Jakarta 11480, Indonesia
wendy.junaidi@binus.ac.id

Correspondence: wendy.junaidi@binus.ac.id

ABSTRACT

Global competition for business process efficiencies and investment, rapidly growing and aging populations, rising concerns about climate change, economic inequality, digital gap, and keeping pace with technological innovation are just a few of the challenges cities around the world face in meeting citizens' expectations for personalized, mobile government services. To address these complex systemic challenges, cities must design smart city initiatives as part of digital transformation implementation to connect disparate operations and siloed processes, starting with smaller, focused projects at the department level and progressing, step by step, toward an integrated city ecosystem. The purpose of this research is to provide insights into some strategic use cases for implementing digital transformation in cities in developing countries as a reference for prioritization so that local governments in developing countries can manage the complexities of smart city implementation through the empowerment of internet of things (IoT) technology. This research focused on some smart city use cases found in developing countries, i.e. Pune (India), Da Nang (Vietnam), and Mexico City (Mexico).

Keywords: *Smart City; Digital Transformation; Internet of Things*

INTRODUCTION

The United Nations (UN) reported that the world's population would reach 8 billion in November 2022 and is expected to increase to 9.7 billion in 2050 and around 10.4 billion in 2080 (United Nations, 2022). In addition, the UN estimated that there would be 43 megacities in 2030, with an increase to 2.5 billion people living in cities and urban areas by 2050. Increasing population density will trigger the urbanization and drive the need for smart city solutions to address challenges ranging from resource management to environmental sustainability. Rapid acceleration of urbanization has influenced the government's focus on sustainability approaches, including the implementation of smart grids, green city planning, smart transportation, and energy-efficient buildings, which will ultimately help address existing and potential environmental issues while improving the quality of life.

Contaminated water, water, and other sources of pollution are critical issues facing cities as they harm both people and the environment. In the inauguration ceremony held on September 7, 2024 at the UGM Senate Hall, Professor Slamet Suprayogi addressed the concern of increasing urbanization which affects water quality as pollutants in urban areas settle and pollute water sources (Universitas Gajah Mada, 2023). Eng (2023) predicts that these challenges would worsen as population density increases due to rapid urbanization. Therefore, there is an increasing need for sustainable solutions that can identify and address pollution sources.

Rapid urbanization will undoubtedly increase the demand and utilization of transportation, especially private vehicles, which in turn will put more pressure on existing challenges such as traffic congestion and lack of parking spaces together with the high levels of emissions. Solutions such as traffic management systems, shared micromobility services, and more engaging public transportation and electric vehicles (e.g., providing real-time information, community engagement, etc.) can address these challenges and help achieve carbon neutrality. Juniper Research (2021) claimed that smart traffic management systems could save cities $277 billion by 2025 through reduced emissions and congestion. Moreover, smart traffic management can significantly reduce congestion, with Juniper Research (2023) estimating savings of 7 billion hours through intelligent traffic management solutions globally by 2028.

Cities also continue to face the challenges of natural disasters, with the potential for greater losses due to climate change and larger, denser populations. This is especially true in countries that are more vulnerable to such events, such as Japan and Indonesia. More natural disasters result in loss of life and infrastructure and are extremely costly, but the adoption of technology services and solutions, including better early warning systems and predictive analytics, has the potential to mitigate these challenges. As more applications are developed and more data is generated, the need for stable, reliable connectivity in networks increases exponentially. The need for low latency is also evident, especially for use cases such as healthcare and disaster management that require immediate response.

Based on the research background described above, the author formulated the problem that would be answered in this study, i.e. "What are the relevant smart city use cases from developing countries which can be applied by local governments as lessons learned from the success stories to overcome challenges across environmental sustainability, high pollution level, transportation and mobility, and vulnerability to natural disasters?"

The completion of this study is expected to provide insights on the smart city use cases from developing countries which can be applied by local governments as lessons learned from the success stories to overcome challenges across environmental sustainability, high pollution level, transportation and mobility, and vulnerability to natural disasters.

Peggy et al. (2020) defined smart city as an urban area developed with a high level of technological advancement by utilizing various methods and electronic sensors to collect certain data. A similar definition in a more specific description was expressed by Eng (2023), who had seen smart city as an urban environment enabled through the integration of technology that leverages data and digital infrastructures to improve quality of life and overcome potential or existing challenges in the city. The data collected will then be used to efficiently manage assets, resources and services, with the understanding that the data would in turn be used to improve operations across the city (Stephen, 2021). The ability to use data exchanges and data spaces for ecosystem insights will provide transformational experiences to city services and will become mainstream in the next five years (Tratz-Ryan, 2024). Going mainstream means that rapid increases in automated transactions will support contextualization of service delivery at the locations where they are needed.

Despite the many beauties described, the smart city concept only works when innovation and business opportunities come together to drive the well-being and resilience of the entire community. Many smart city projects focus on developing and implementing smart technologies (IoT, connected devices, city sensors, cloud platforms) instead of meeting the real needs of ordinary citizens and solving pre-existing urban problems. Eng (2023) exposed four pillars of smart city which would play a pivotal role, i.e.:

Digital transformation through technology integration: Digital transformation is described as the process of adopting and implementing digital technologies by an organization to create new products, services, and operations or modify existing products, services, and operations by translating business processes into digital format (Mirzagayeva & Aslanov, 2022). Internet of Things is one of the core technologies, using devices, sensors, and infrastructure to interact with each other (Gillis, 2021); other common technologies include AI and robotics, which have given rise to a variety of use cases, such as AIoT-enabled traffic management systems and delivery robots. It communicates with the physical world through actuation, sensing, and management, using state-of-the-art internet protocols to facilitate data transmission, analytics, and decision-making (Darabkh et al., 2019). Based on a survey of 717 companies in Asia that are in the process of implementing IoT solutions, Rehak (2019) concluded that IoT is a success story for companies in Asia Pacific, but it is still too early considering that the adoption rate is still less than 30% of companies in most regions, although 57% of companies in the region stated that increasing efficiency and productivity are their top three IoT goals. This finding is also supported by Canali (2022) who later cited that IoT continues to be widely implemented based on his 2022 survey covering 490

respondents in Asia, America, and Europe because ninety percent of them said that IoT is at the core of digital transformation or is being implemented in various areas of their organization.

The global economic value of IoT would reach a total of $5,500-12,600 billion by 2030 with smart city solutions as pivotal contributor with a percentage of 18% (Chui, 2021).

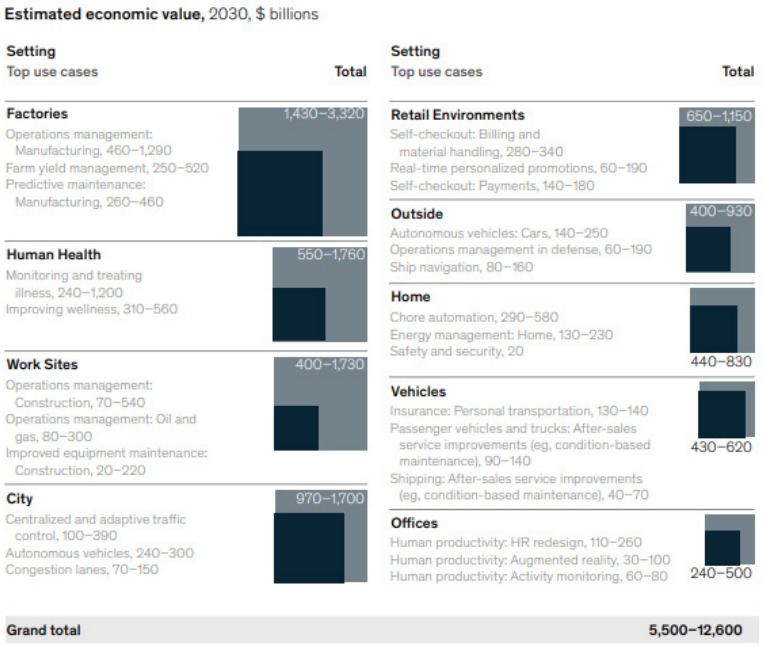

Figure 1. Estimated Economic Value of IoT in 2030 (Source: McKinsey, 2021)

Policies and framework: As technology advances and more data becomes available, it is important for city governments and agencies to establish effective technology governance and guidelines to address challenges such as data ownership and data security. Data captured by the sensors will be transmitted, collected and analyzed by governments and other local authorities to extrapolate information about the challenges facing cities in areas such as crime prevention, traffic management, energy use and waste reduction. This serves to facilitate better urban planning and allows governments to tailor their services to local residents, which is often a serious problem in cities in developing countries.

Partnerships: Collaboration is critical in smart city development, especially among governments, private sector organizations and technology providers, and the public. These three-way partnerships allow for the sharing of expertise, resources, and feedback to continue developing innovative and effective smart city initiatives and services.

Public acceptance: After launching new smart city initiatives and services, it is important to gauge the participation and willingness of local residents to adopt these changes. As such, government agencies and technology providers are required to build trust through various means, such as ensuring data security/privacy and creating portals where people can provide feedback on the changes.

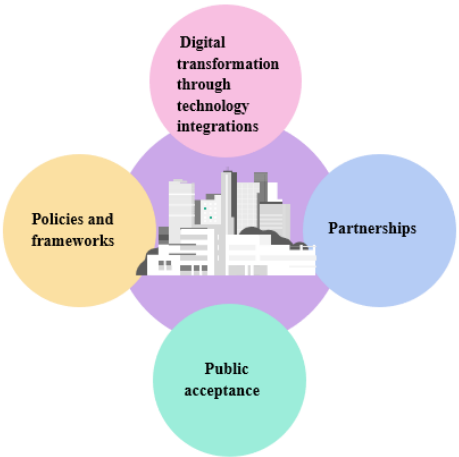

Figure 2. Smart City Pillars (Source: Omdia, 2023)

METHODS

In line with the objectives of this study, an in-depth study focusing on the sustainable challenges faced by cities as key drivers of smart city implementation is the best approach in identifying some relevant strategic use cases in smart city development as lessons learned for local governments in other developing countries. Data sources used to complete the study came from both primary research (in-depth interviews) and secondary research (documentation from local government's public announcements, master plans, statistics, etc). The primary data for this study came from two stakeholders, i.e. key management team from certain international IT vendors delivering the smart cities implementation in certain developing countries together with business consultants. International IT vendors and consultants interviewed here consisted of 30 key executives from certain developing countries and included those who have extensive experience leading the implementation project of smart cities in Asia, from the design stage to the implementation stage supported by a research team with good reputation. Methodology used by the vendors and consultants in completing the smart city project involved global use case benchmark, discussions with local government to understand smart cities implementation pain points and needs in certain cities in Asia, followed by use case assessment, development, prioritization, partnership development with private vendors, and operating model definition.

This study focused on exploring strategic smart city use cases in developing countries, such as Vietnam, Mexico, and India.

RESULTS AND DISCUSSION

During in-depth interviews with international IT vendors and business consultants which were intended to understand the key drivers of smart city implementation in certain countries, the author also learned about ongoing challenges face which cities face as described in the research background, with key takeaways as summarized in Figure 4. Those key drivers stimulated further explorations on use cases to overcome environmental sustainability, pollution, transportation and mobility, together with natural disaster concerns.

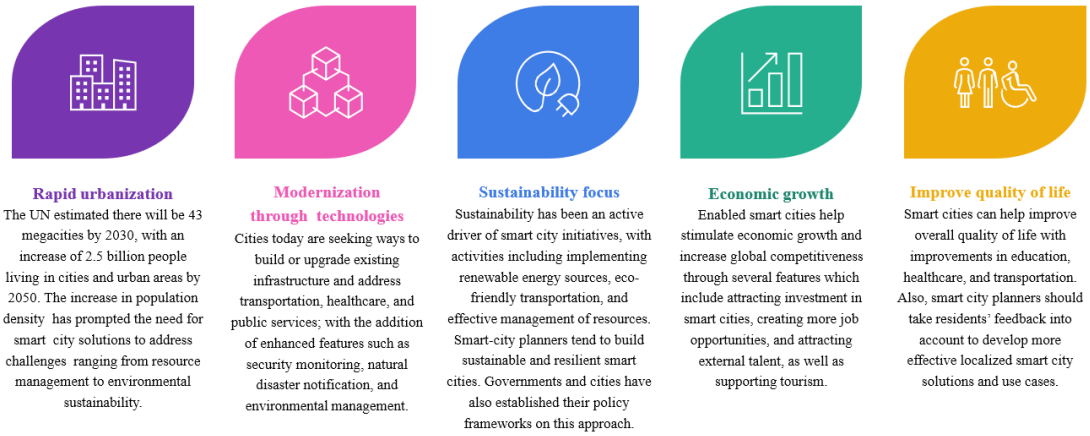

Figure 3. Key Drivers of Smart City Implementation

Smart City Use Case in Pune, India: Integrated Command and Control Center (ICCC)

The ICCC was launched in March 2022 with a full city rollout, with the aim of enabling the city administrations and its stakeholders to make informed decisions with real-time information related to various operational aspects of the city, including traffic management, emergency response, and environmental quality monitoring. To address the lack of centralized monitoring, the ICCC aggregates various data feeds from over 1,000 IoT sensors and systems installed throughout the city. Advanced dashboards show these feeds in real-time, including the use of geographic information system-based (GIS-based) tracking and heat-mapping, thus enabling effective decision-making and swift response. The ICCC's control room is equipped with 20 stations and 4 IP telephones.

The ICCC provides oversight over various citizen-centric services that include traffic management, water, sanitation, safety and security, emergency services, flood control, air quality monitoring, and public grievances redressal, which is integrated with the following smart elements:

- **City Wi-Fi** provides on-demand and fast internet connectivity for citizens at 199 hotspots, including parks, police stations, hospitals, government offices, and bus stops.
- **Emergency call boxes** enable users to seek immediate assistance by pressing a button across 136 locations throughout the city. Public address systems allow civic bodies to collaborate more effectively when dealing with emergency cases.
- **Environmental sensors** across 50 locations measure the following parameters: temperature, humidity, radiation, noise level, and air quality index.
- **Water level sensors** enable flood detection on streets and provide flood warnings via display channels in localities, nearby water sources and bridges across 30 locations.
- **Variable messaging displays (VMDs)** across 161 locations in the city provide useful information related to traffic status, roadwork zones, speed limits, and key messages about an emergency or disaster.

The city planned to leverage the public address (PA) system to promote ICCC services and increase awareness among citizens. Systems including vessel traffic service (VTS), city planning, and disaster management would be integrated with the ICC platform for more impactful data analytics. The city would also utilize environmental sensors or flood sensor data for more in-depth analysis at its respective administrative units. Figure 6 shows the external applications which are integrated with Pune's ICCC platform.

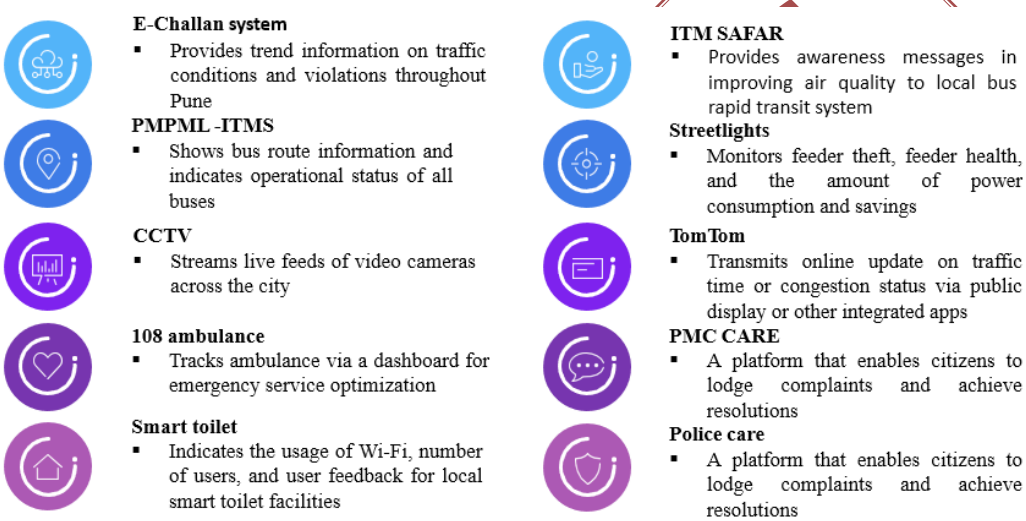

Figure 4. List of External Applications Integrated with Pune's ICCC Platform

Smart City Use Case in Da Nang, Vietnam: Intelligent Transport System (ITS)

The development of ITS in Da Nang began in 2012. The initial implementation involved the installation of traffic lights at 64 intersections, one meteorological monitoring station, 32 cameras, and one traffic control center with the aim of reducing traffic congestion in Da Nang by applying big data and AI as part of an ongoing effort to manage the city's traffic more efficiently. As of December 2021, Da Nang has the following infrastructures:

- Traffic lights at 181 road intersections, of which 62 are linked to the municipal Traffic Signal and Public Transport Operation Centre
- A system that monitors temperature, wind, and structure at the Thuan Phuoc Bridge, a section of the Tran Thi Ly Bridge and the Hue T-junction overpass for management and maintenance, as well as warning for tourist boats; such a system is now being installed at the Rong bridge and the remaining sections of Tran Thi Ly bridge
- 177 on-street surveillance cameras to oversee traffic violations
- 16 speed measurement devices
- Surveillance cameras on board 151 buses that operate on 12 intra-city bus routes
- 26 cameras on board tourist boats that travel on the Han River
- In-cabin surveillance cameras onboard approximately 13,000 trucks and vehicles with over nine seats

As part of a digital transformation effort to develop ITS in the future, the Department of Transportation (DoT) has deployed an integrated database to enable efficient storage and utilization of data on various aspects

of Da Nang's traffic operations: infrastructure such as traffic signal system and toll stations; means such as types, characteristics, and levels of use; and operator such as behavior and movement. The modernization of Da Nang's traffic management system is currently ongoing with the development of a traffic data center, extension of the monitoring camera network, and upgrade on the traffic signal system. In 2021 and 2022, Da Nang city administration gradually deployed bus information system and infrastructure, bus monitoring and e-ticket system, illegal parking management system, and traffic planning map solutions.

The surveillance system on the 139km Da Nang–Quang Ngai Expressway was launched in June 2020, with the aim of helping improve public awareness in complying with traffic safety regulations on the expressway. The traffic police can use the images recorded by the monitoring system as evidence in handling traffic safety violations as per the law. However, there was no information found regarding the communication technologies that the surveillance system uses for data transmission.

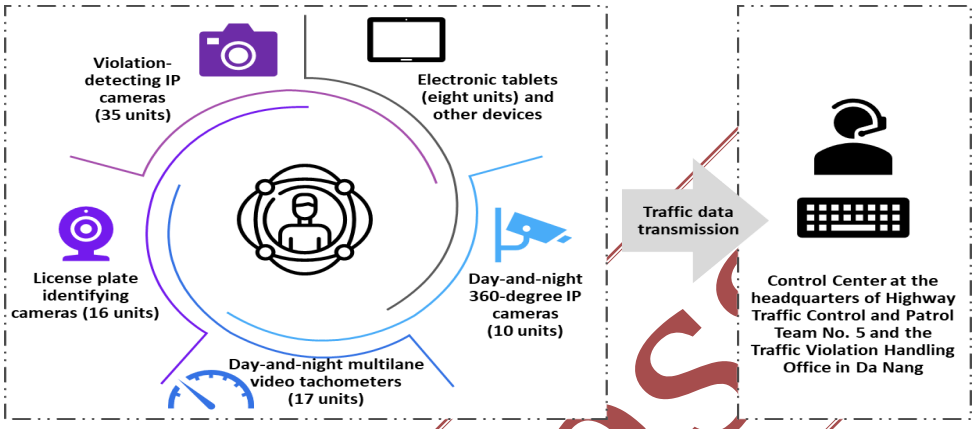

Figure 5. Traffic Surveillance System on Da Nang – Quang Ngai Expressway
(Source : Ministry of Public Security, Vietnam)

Smart City Use Case in Mexico City, Mexico: Safe City and C5

The city government launched its Safe City (Ciudad Segura) program in March 2009, which consists of five pillars: attention to the causes, greater police presence, intelligence and justice, coordination, and legal framework, with the aim of establishing a city-wide video surveillance project that enhances urban security and safeguards residents from various threats such as crime, terrorism, strategic site attacks, and natural disasters. The initial phase of the project involved a three-year contract with Thales (a Mexican telecom operator, which provided a dedicated fiber optic network for the Safe City program) and Telmex (which implemented video surveillance technologies with image analysis and intelligence information for the program), costing $460m.

The Safe City initiative includes field equipment such as cameras, automatic license plate recognition systems, gunshot detectors, emergency intercoms, and mobile communication devices for law enforcement. How the initiative works is as follows:

- Thales' video management system processes the data feed from all these cameras. By compressing the captured images, the system can simultaneously distribute the data to multiple command centers.
- Moreover, the Computer-Aided Dispatch (CAD) software oversees the incident management process, starting from when an issue is detected by a camera or a complaint is filed by a citizen, and links to all emergency services.
- When a call is received, it triggers a digital procedure designed by Thales that was integrated into the security system. The call undergoes initial screening to eliminate false alarms before the incident is forwarded to the appropriate sector's C2. An officer is tasked with reviewing the incident using footage from nearby cameras. Relevant video clips can be added to the incident file with a few clicks. If necessary, the file is promptly escalated for decision-making. This procedure enables quick, informed decisions based on the information in the file and the officers' GPS locations. Once the incident is resolved, a report is added to the file, which is then archived and can be utilized in legal proceedings.

The Command, Control, Computers, Communications, and Citizen Contact (C5) integrates several key services, including:

- **Safe Trail:** This allows citizens to activate a panic button, either through the CDMX App or physical button
- **MyTaxi:** Users can access information about the taxi driver and verify if the vehicle is registered and

in good condition. Users can also share their location with the taxi driver and activate the panic button in case of an emergency

- **Mi C911e:** This feature enables citizens to send an alert for assistance while at home
- **My Business:** Business owners can use this feature to request help and trigger an alert for the relevant authorities to connect to the chambers of commerce and dispatch police units
- **LOCATEL:** This was initially established in 1979 with the primary purpose of assisting in the search and location of missing individuals. Over time, the service has expanded to include additional features such as telephonic psychological counseling, as well as medical care and advice delivered via video call for issues related to COVID-19.

Five years after the Safe City program was launched in 2009, Thales reported a 32% reduction in crime rates and a decrease in average police response time from 15 minutes to under four minutes. The system handled 1 million incidents, leading to 102,000 arrests. A decade after its launch, Thales reported that crime rates had dropped by 56%, and incidents of car theft had seen a reduction of 58%.

According to the Security Report presented by the Head of Government of México City in July 2023, the percentage of cases resulting in preventive detention, a measure to retain a person in custody during investigations or legal proceedings, increased from 43% to 57%. On October 18, 2020, the Safe City initiative received the Gold Award in the "Safe City" category from the World Organization of Smart Sustainable Cities (WeGO), an international partnership based in Seoul, South Korea, dedicated to transforming cities into sustainable and smart entities. On December 7, 2023, a 5.7 magnitude earthquake triggered the seismic alert system in México City, which broadcast a warning through almost all speakers installed on the Mi 911CE poles. The alert sounded for 28 seconds and allowed people to evacuate buildings and seek safe places.

Smart City Use Case in Mexico City, Mexico: Via Verde – Smart Vertical Gardens

The project, named Via Verde, was approved in 2016, including the installation of vertical gardens on more than 1,000 columns, spanning approximately 27 kilometers and covering an area of over 60,000 square meters. It was funded by a consortium of 50 private companies, with the stipulation that 10% of the columns would be allocated for corporate advertising. The goal of this project is to green Mexico City's urban infrastructure while reducing noise and air pollution, involving Verde Vertical is responsible for supplying the technology and overseeing the installation process.

Each vertical garden is sensor-equipped to monitor environmental conditions such as water level, light conditions, temperature, and nutrients. The garden's structure is supported by concrete columns, designed to hold metal rings in place using tension from metal posts and crossheads. This ensures stability. The primary structure of the vertical garden is the foldable panel made of alloy steel. The plastic insulators are made of poly-aluminium, a mixture of steel and polyethylene, whereas the textile substrate is crafted from recycled PET bottles, processed into threads and tailored into fabric. The garden uses a drip irrigation method, where water slowly drips to the plant roots. This water is harvested from rainwater collected from the upper asphalt. According to the company, the irrigation system is automated and remotely controlled through an application. Each square meter of the vertical garden embeds 36 plants, amounting to a total of 2,300 plants per garden. For every 50 columns under the elevated highway, one machine room is deployed to receive and transmit information from sensors to the control center for daily analysis.

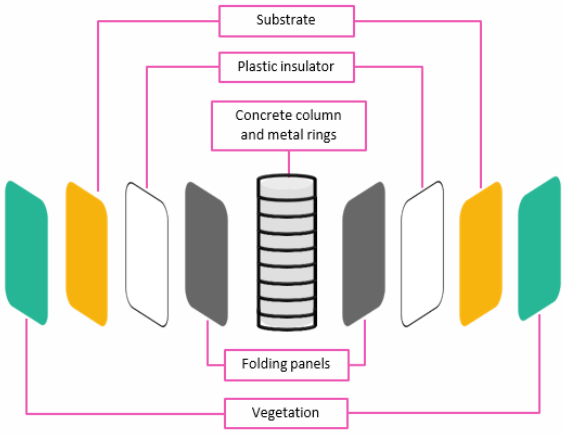

Figure 6. Cross Section of the Vertical Garden

In July 2019, the World Economic Forum acknowledged Via Verde as part of its 2019 Technology Pioneers cohort. This recognition has allowed Verde Vertical's solutions to gain worldwide attention. The company has received requests for installations from various regions, including the US, Latin America, Europe, and Asia. Locally, in México, there are plans to set up vertical gardens in Monterrey, Guadalajara, and Puebla. The projected total coverage is around 10 million square meters (3.86 square miles) across different structures such as walls, roofs, bridges, and tunnels. The firm is also developing a "plug and plant" model of the vertical garden, designed to be user-friendly and easily replicable. The creation of the textile substrate is a process that is both ecofriendly (it uses recycled materials) and socially inclusive. It offers job opportunities to a disadvantaged group, specifically women prisoners. These women transformed recycled materials into the textile substrate through tailoring and sewing.

Table 1 shows a recap of the key findings from each smart city use case discussed in Pune, Da Nang, and Mexico City.

Table 1. Key Findings of Smart City Use Cases in Pune, Da Nang, and Mexico City

No	Smart City Use Case	Location / Country	Rollout Period	Objective	Smart City Elements
1	Command and Control Center	Pune, India	March 2022	To enable city governments and their stakeholders to make informed decisions with real-time information on various aspects of city operations, including traffic management, emergency response, and environmental quality monitoring	1. City Wi-Fi at 199 hotspots 2. Emergency call boxes 3. Environmental sensors across 50 locations 4. Water level sensors across 30 locations 5. Variable messaging displays (VMDs) across 161 locations
2	Intelligent Transport System	Da Nang, Vietnam	2012	To alleviate traffic congestion in Da Nang by applying big data and AI as part of the ongoing effort to manage the city's traffic more efficiently.	1. Traffic lights at 181 road intersections 2. Temperature, wind, and structure monitoring system 3. 177 on-street surveillance cameras 4. 16 speed measurement devices 5. Surveillance cameras on board 151 buses 6. 26 cameras on board tourist boats 7. In-cabin surveillance cameras onboard approximately 13,000 trucks and vehicles
3	Smart Kiosks	Mexico City, Mexico	March 2009	To establish a city-wide video surveillance project that enhances urban security and safeguards residents from various threats such as crime, terrorism, strategic site attacks, and natural disasters.	1. Cameras 2. Automatic license plate recognition systems 3. Gunshot detectors, emergency intercoms 4. Mobile communication devices for law enforcement
4	Smart Poles	Mexico City, Mexico	March 2016	To green Mexico City's urban infrasturcture while reducing noise and air pollution	1. Sensor-equipped to monitor environmental conditions such as water level, light conditions, temperature, and nutrients 2. Folding panels 3. Plastic insulators 4. Concrete column and metal rings

Source : Author (2024)

CONCLUSION

There are four key findings from this study to be considered as suggestions for implementing smart city initiatives in developing countries. First, IoT will not be the only technology enabling smart cities, with differentiation among technology integrations, although it has served as one of the core technologies used in smart city solutions, especially via the collection of real-time data from devices and sensors that allow planners to make better-informed decisions. It is expected that there will be an exponential increase in technology adoption, with AI, big data analytics, blockchain, and robotics integrated with IoT to build an interconnected and integrated ecosystem for more smart-city use cases (especially localized solutions) such as Artificial Intelligence of Things (AIoT) for traffic management, healthcare monitoring, and delivery via robots.

Second, hybrid connectivity - including cellular (4G/5G) and satellite, will be leveraged to enable smart cities. Connectivity networks play a pivotal role in enabling smart cities as they help address diverse and complex challenges, supporting a wide range of technology applications as well as ensuring resilience and reliability. From a high level overview, the deployment of hybrid networks allows smart city planners to save costs through efficient resource allocation and the integration of multiple networks in a single infrastructure. This approach could also help spur economic growth by attracting outside talent and investors to a well-established technology ecosystem with high quality of life.

Third, potential challenges, including connectivity outreach (especially in rural areas), data utilization, and cybersecurity, will remain ongoing concerns for technology adoption. Therefore, technology providers should take additional measures ranging from researching the area where the technologies will be implemented to providing substantial cybersecurity solutions that could mitigate threats. Besides, it is expected that both public and private sectors will launch initiatives to expand the talent pool for smart city services and solutions to help address these challenges and at the same time reducing the possibility of talent shortages and mismatches.

Finally, governments and the private sector are increasingly focusing on sustainability approaches due to the rapid urbanization and hopes that this will in turn lead to more smart city use cases with sustainable practices. Examples of such practices include the implementation of green city planning and smart transportation, which will ultimately help address existing and potential environmental issues while improving quality of life.

This study was conducted by focusing on sustainable challenges faced by cities as key drivers of smart city implementation is the best approach in identifying some relevant strategic use cases in smart city development as lessons learned for local governments in other developing countries. According to Omdia's 2023 Global IoT Enterprise Survey, security (35%) and complexity (33%) are the top two challenges companies face when implementing IoT; these concerns are magnified for smart city projects due to their larger scale and easier access by malicious actors. Privacy is also a concern as more data circulates, especially in smart cities, and it is difficult to determine ownership of the data, requiring effective governance. Technology providers that can provide end-to-end security are likely to gain more traction as partners for smart city projects, and governments should revise and amend their smart city policy frameworks to set better standards to prevent data breaches and leaks. Also, Smart city projects typically involve long-term, sustainable improvements that can incrementally improve the overall state of a city; they should not be seen as a quick way to get an ROI for addressing pressing urban challenges (e.g., implementing a smart traffic solution today will not solve traffic congestion overnight). They are long-term investments that involve ongoing evaluation and ongoing engagement in improvements, supported by technology, networks, and infrastructure that can work together seamlessly.

Given the limitations of this study in that it did not include an examination of local government challenges related to talent, funding, security, and procurement for infrastructure and technology projects, where these challenges make it difficult to establish investment strategies to implement and maintain smart city solutions across jurisdictions, it is highly recommended that future research should conduct an in-depth study of local government governance challenges in developing countries that hinder the resources needed to visualize smart city impacts and services, and obtain real-time decisions and actions.

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