Chapter 11
Big Data Analytics and Internet of Things for Urban Transportation:
A Case of Pune City, Maharashtra, India

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ABSTRACT

The idea of smart city has assumed popularity in numerous countries across the globe. In 2015, the Government of India embarked on a mission of creating 100 smart cities to sustain the burgeoning urban population. While a wide-ranging set of fundamentals has a key role in enhancing the quality of life of citizens, the chapter revolves around transportation issues and traffic management concerns in one of India's smart cities, Pune. Transport is one of the few areas where Pune lags behind compared to its urban counterparts in the country. Public transportation in the city has been ineffectual, and auto rickshaws have been unyielding and pricey, thus making it imperative to possess personal vehicles or resort to app-based cab services. A palpable outcome of this has been traffic congestion that leads to slower travelling speeds, extended trip times, and amplified vehicular queuing. Big data and IoT can make a considerable impact in realizing the smart city objectives for efficient transportation in Pune by serving as complementary measures to supply-side policies.

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INTRODUCTION

The idea of smart city – an urban region where information and communications technology (ICT) is the fundamental infrastructure for offering essential services to citizens – has assumed popularity in numerous countries across the globe. The smart city transformation is fueled by technology advancements. A smart city is known to efficiently leverage technology, transportation, communications, amenities, government policies and citizen involvement for designing an urban setting that reinforces modernism, progress, productivity, and sustainability. It is a concept that primarily considers the needs of citizens to draw up plans for meeting their requirements in real time. A smart city makes us envision a host of conveniences. For instance, streetlights would turn up or turn off depending upon the movement of people and vehicles. Trash would be cleared as soon the garbage container gets crammed with the waste. Notification on traffic and air pollution could be received on mobile phones with respect to the intended travel destination. Availability of parking spaces could be learnt through mobile apps. Eateries and cafés would put forward menus suiting popular tastes and preferences. Billboards and hoardings would flash advertisements in conformity with the bystanders' latest purchase patterns. Such services are deemed to improve livability for city dwellers.

A smart city, although, is not just about infusion of technology into the life of people, but a lot more. It is also about smart governance and smart citizenry (Khanna, 2015), wherein the benefactors and the beneficiaries are expected to be committed towards fulfillment of their obligations for the realization of smart city initiatives. Smart cities are "places where information technology is combined with infrastructure, architecture, everyday objects, and our own bodies to address social, economic, and environmental problems" (Townsend, 2014).

The concept of smart city has not originated today but has prevailed since several years in different epithets and forms. The introduction of programmed traffic lights in Houston, Texas, in the early 1920s, was categorically a smart initiative (Poole, 2014). However, the model that typifies the present-day smart cities and those likely to emerge in the future has undergone massive transformation in recent decades to reflect sizeable concepts upheld by advocates and stakeholders. Likewise, the significance of various terminologies has altered over time, contingent upon the ideas forwarded by academia, entrepreneurs, political groups and civil society (Eremia, Toma & Sanduleac, 2017). A major development in this regard happened in 2008 when the American multinational IBM commenced working for a 'Smarter Planet' vision to come up with intelligent systems that were far more advanced and user-oriented than ever before (Puri, 2014).

One of the contemporary ways having enormous potential to advance smart city services is big data analytics (Al Nuaimi, Al Neyadi, Mohamed & Al-Jaroodi,

2015). Big data implies extensive datasets which were not within the realm of perception, acquisition, organization, and processing of conventional information technology and software/hardware tools within a suitable time dimension (Chen, Mao, & Liu, 2014). The vastness of big data is evident from five Vs – Volume, Veracity, Variety, Value and Velocity (Yin & Kaynak, 2015). The progression of big data and the development of Internet of Things (IoT) technologies have played a crucial role in the viability of smart city initiatives. Big data extends the potential for cities to get hold of meaningful insights from copious datasets gathered through a range of sources; likewise, IoT permits the adaptation of sensors, Radio-Frequency Identification (RFID), and Bluetooth in the real-world setting by means of highly networked services (Hashem et al., 2016). With the technical support from big data and IoT, a smart city thus leans on a triad – being instrumented (mechanized), being interconnected (unified) and being intelligent (smart, automatic and self-regulating).

A concept, popularized by IBM and pulled off by numerous nations across the world, caught India's attention in 2015 when the government embarked on a mission of creating 100 smart cities to sustain the burgeoning urban population. Concomitantly, the Ministry of Housing and Urban Affairs, Government of India, stated that there is no time-honored general definition of smart city as the same varies for different cities and distinct nations, depending on the extent of development, availability of resources, readiness to change and aspirations of the city dwellers. Nevertheless, some of the principal infrastructure rudiments in a smart city include sufficient water supply; regular distribution of electrical energy; hygiene and sanitation, inclusive of solid waste management; well-organized means of transport and urban mobility; housing within means for the deprived; robust IT connectivity; effectual governance, principally e-governance; citizen engagement; sustainable environment; safety and protection of general public; and provision of efficient healthcare and education facilities ("What is Smart City," 2017). The Indian government, since 2015, has introduced a string of smart city initiatives for the furtherance of urban development.

Even as an all-encompassing set of fundamentals has a key role in enhancing the quality of life of citizens in a smart city, the present study calls attention to the significance of transportation in the urban setting. Urbanization brings with it a series of challenges owing to the increasing numbers of residents in cities. As the cities develop and expand, there emerges a need for improved transportation services to facilitate enhanced mobility. This leads to a rise in the purchase and ownership of private vehicles (Reddy & Balachandra, 2012). According to a study by Dargay, Gately, & Sommer (2007), vehicle ownership across different countries in the world exhibits a unique S-shaped pattern in conformity with the Gompertz function of per-capita income; thus, countries with low levels of per-capita income in their initial development stage show evidence of less vehicle ownership, which

increases eventually with the increase in per-capita income, but then declines at exceptionally high income levels to come to a point of saturation. Developing countries, particularly in Asia, are presently experiencing a phase of gradual increments in income complemented with a rise in ownership of private vehicles – a trend that is likely to continue for one more decade (Dargay et al., 2007).

Although increase in vehicles is an evident and palpable outcome of urbanization, there are several implications of this inexorable phenomenon. One of these implications includes traffic congestion that leads to slower travelling speeds, extended trip times, and amplified vehicular queuing. Insufficient capacity of public transportation with respect to reliability and security, pathetic road conditions, congested and jammed road network, substandard traffic management, parking woes, and dearth of modal alternatives together with pedestrian walkways, linger as critical issues in most of the cities (Prabhakar, Gupta & Mehrotra, 2015). Additionally, a large number of cities also fall short of integrated transportation plans resulting in considerable demand-supply mismatch and ineffectual transportation network. Thus, improving mobility and lessening traffic congestion constitute some of the major challenges confronting smart cities today.

The present chapter revolves around transportation issues and traffic management concerns in one of India's smart cities – Pune. Pune is the ninth most densely inhabited city in India ("Cities Profile of 20 Smart Cities," 2017) and the second largest in Maharashtra (Krishnamurthy, Mishra & Desouza, 2016), after Mumbai (*Smart Pune's Step Towards Sustainable Transportation*, 2016). A report released in 2017 by World Economic Forum on the migratory trends in cities bears out the fact that while India witnessed a twofold increase in interstate migration during 2001-2011 in contrast to the preceding decade, Pune stood as one of the two foremost influenced cities in India and among four most influenced in Asia, with respect to increase in inflow of migrants ("Interstate migration in India doubled between 2001-2011: WEF," 2017). The report further stated that interstate migration is escalating at 4.5 percent per annum. With respect to Pune, it was observed that population of urban agglomeration expanded by 34% for the decade 2001-2011, not as an upshot of natural growth but due to migration in vast numbers (Umbrajkar, 2012). Pune's vehicular density trends since 1999-2000, as exhibited in table 1, clearly point the rationale for the extent of traffic congestion the city has been experiencing during this period. A Google Maps impression of Pune at 7:30 pm on weekdays further corroborates the magnitude of the problem, with 70 percent of prominent roads marked "deep red," signifying acute traffic congestion ("Reimagining Pune: Mission Smart City," n.d.).

With the launch of smart city initiatives in Pune in the year 2016, several projects specifically relating to transportation were outlined. While the city has successfully

Table 1. Vehicles registered with Regional Traffic Office (RTO), Pune (1999-00 to 2013-14) Source: Regional Transport Office (RTO), Pune

Year	Two Wheelers	Four Wheelers	Number of Vehicles
1999-00	54463	10807	72037
2000-01	59436	10803	78605
2001-02	62409	12823	82643
2002-03	69426	12766	90308
2003-04	77382	15030	100269
2004-05	84186	19711	113279
2005-06	95073	23561	129673
2006-07	104406	28608	148403
2007-08	87499	27893	129899
2008-09	94346	28266	131756
2009-10	102620	30962	143116
2010-11	127960	40499	181604
2011-12	155540	49194	219014
2012-13	146240	47374	202556
2013-14	145794	41507	197028

cracked a few, one of which is the linking of e-challan system with the CCTV camera to check unbridled traffic outlawry (Banerjee, 2017), numerous others such as delineation of zones for striders, bicycles and motors vehicles; traffic mobility plan for the city; development of mobile applications for obtaining details on the arrival and departure time of buses; etc (Bari, 2017) are yet to be accomplished. It is further observed that for a number of projects, the targets have not been realized within the preset deadlines: only 10% of the total projects have actually commenced, some are pending in anticipation of approval, and few have been written off altogether on account of controversies and debates surrounding them (Kulkarni, 2017).

This chapter shall closely examine the role of big data analytics and IoT in actualizing the smart city initiatives for Pune city from the standpoint of transportation and traffic management; the focus will be on objectives identified in the smart city plan, those attained so far, those waiting to see the light of day, and the way ahead for further action. The outcomes of this chapter can go a long way in realizing the objectives of citizen-friendly transportation for smart city Pune, and also serve as a cue to accomplish the same in other Indian cities having similar concerns. This is further important considering the fact that India reports the highest number of

fatalities in road accidents across the globe, and one in every ten fatality occurring is reported from India (Dash, 2017).

BACKGROUND

While the idea of smart city has assumed recognition today, it can be modeled in distinct ways, from the exhaustive use of ICT in urban milieu to the initiation of ground-breaking services, managerial capacities, and physical infrastructure (Rodríguez Bolívar, 2015). Technology investiture is one of the prominent ways in which a smart city attains 'smartness.' With respect to transportation, technological enhancements supported by big data analytics can assist in augmenting reliability and stability of public transportation network by imparting information at fingertips on arrivals/departures/route information to travelers for trouble-free journey, managing traffic, locating parking spaces, facilitating easy payments, etc. However, a city needs to meet critical supply requirements with respect to transportation for its residents, before heading for technological enhancements. As an instance, Pune's transport system, akin to that in other Indian cities, has for long been reeling under the demands of growing populace, insufficient bus fleets and derisory resource availability, mounting competition from personal modes of transport, and disregard from the political and executive machinery (Sekhsaria, 2004). The fleet is old and tottering; the buses are in a dismal state; few buses lack window panes; few others are either short of seats or have broken seats; frequent breakdowns are reported; there is paucity of qualified people to guide passengers; there are inadequate bus depots and washing facilities; hygiene is abysmally poor; bus stops and bus stands are pathetic. For years together, the scenario has been so appalling that the administration lacks funds to complete even preventive maintenance that is required to keep the buses running and forestall accidents. Even if the funds are available, there is problem with regard to judicious utilization of funds. With supply-side bottlenecks in public transport system, the foremost priority for the administration is to strengthen the city's public transport in terms of availability, regularity and frequency. Only when the basic supply requirements are met adequately, the potential of big data analytics can be realized for smart transportation in the city, which the present chapter draws attention to.

URBANIZATION AND SMART CITIES

Rationale for Smart City Initiative in India

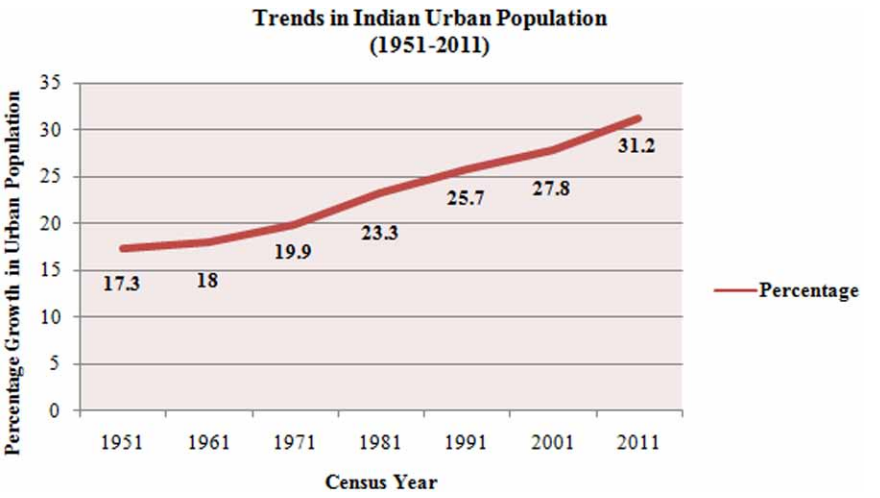
India, second most populous country in the world after China, has witnessed sweeping internal migration on account of regional disparities prevalent in the country. The past decade has seen a phenomenal rate of migration within the country wherein people have moved from rural areas and hinterlands to cities in search of employment opportunities. The Census 2011 reports an increase in urban residents by 9 million from what was reported in the earlier Census (Joshi, 2016). Cities have customarily been the focal point of financial influence of a nation. In the case of India, they occupy roughly 31% of existing populace (refer to Figure 1) and put in 63% of GDP ("Census 2011 - Census of India", n.d.). The present-day cities persist with this drive, befitting economic hubs, both at a national and global level, because of the economies of scale they command; they exert a pull on foreign investment, draw in business, and attract first-rate intellectuals from around the world (Khanna, 2015). If this trend continues, the cities shall be required to equip themselves to accommodate such a growing population, provide them housing, work, civic amenities, effective governance, speedy means of communication, swift transportation, continual access to power, water supply and comfortable living. The smart city initiative in India was mainly instated to enable the cities offer a decent quality of living to their inhabitants, considering the fact that Indian cities have been performing poorly in global rankings with respect to livability and workability, as reflected by Mercer's Quality of Living Index (Mathur, 2017).

Smart City Mission in India: Execution, Features and Strategies

The execution of smart city initiative in India is brought into effect through a host of selected consulting firms entrusted with the task of supporting the cities to partake in a contest. A total of 100 cities, evenly strewn among the States and Union Territories, shall be chosen over the span of 5 years ranging from financial year 2015-2016 to financial year 2019-2020 ("Coverage & Duration: Smart Cities Mission, Government of India," 2017).

The selection process shall be elaborate and meticulous, and run through a series of well-defined steps. Each aspiring city shall be in the race known as a 'challenge.' The first part of challenge for a city would be to compete with its counterparts within the State/Union Territory; those emerging successful at this stage shall move on to the next stage whereby the subsequent challenge will be to create proposals reflecting incorporation of the strategic elements (discussed later in this segment).

Figure 1. Trends in Indian urban population (1951-2011)
Source: Census 2011 - Census of India



These proposals, made with due consideration to estimations held by city dwellers and stakeholders, shall be communicated to the Ministry of Housing and Urban Affairs, Government of India. A panel of connoisseurs and experts from India and overseas, alongside a group of recognized organizations and institutions, shall then scrutinize these proposals to arrive at the list of winning cities.

The Smart City Mission in India aims at all-inclusive development in the selected cities, as listed in Table 2.

According to the Ministry of Housing and Urban Affairs, Government of India, the strategies outlined for the fulfillment of the smart city mission in India have been presented in Figure 2.

The strategies are further discussed as follows:

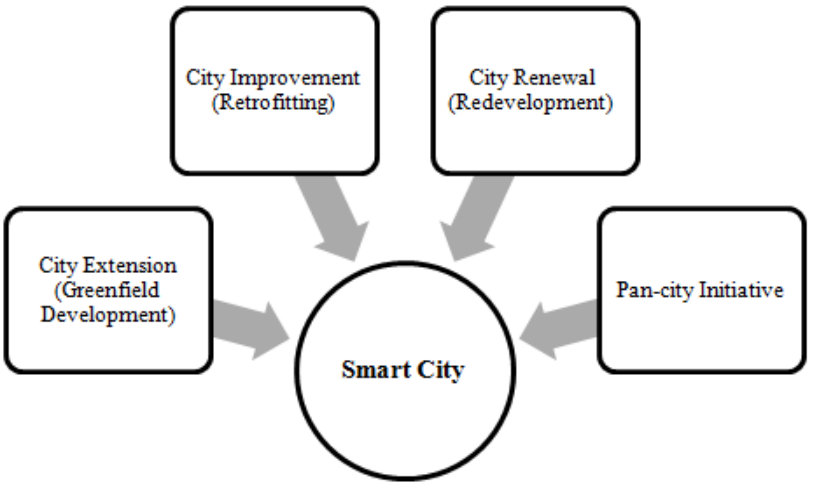
1. **Retrofitting:** This strategy mainly emphasizes development of a prevailing inner-city area to make it more resourceful, ecologically aware and livable. For this, the principle of citizen engagement shall be brought to the fore for selection of area that exceeds 500 acres. Considering the existing state of infrastructure and intent of local residents, a plan shall be designed for initiation of smart initiatives within the identified area. The current structures would mostly stay untouched in this paradigm; nevertheless, additional comprehensive infrastructure and numerous smart applications would be integrated and fitted into the retrofitted smart city. The premeditated objectives of this plan would be attained over a shorter duration in order to simulate similar strategies in other parts of the city.

Table 2. Features of India's smart city mission

Dimension	Explication
Mixed land use	Encourage effective use of land in target areas that supports a host of interconnected activities: positioning distinct kinds of activities in close proximity (contiguous); for instance, stores, supermarkets and schools in or around residential neighborhoods that moderates the time of travel needed to access daily errands
Housing	Ensure availability of affordable housing to all
Walkability	Develop zones which make walking a pleasing experience and warrant safe pedestrian movement – moderate jamming and congestion, lessen air pollution, conserve resources, encourage connectivity and exchanges, ensure safety; create roads supporting movement of vehicles as well as non-motorized transport – striders and cyclists
Open spaces	Building up open spaces – parks, playing fields, and recreational areas to offer a better quality of life to residents
Transport	Provide numerous travel alternatives to the residents - Transit Oriented Development (TOD), an efficient mass transport system that includes regular bus service, Metro, etc.
Governance	Offer governance that suits the comfort and convenience of citizens with respect to cost of delivery, ease of access, answerability, intelligibility and transparency; recourse to electronic modes – internet and mobile – for reaching out citizens, obtaining their views and feedback; bring into play online supervision of programs, schemes and actions with the assistance of cyber journey of worksites
Distinctiveness	Imparting distinctiveness and exclusivity to the city based on economic pursuits such as native cuisine, wellbeing, edification, civilization, fine art, ethos, ethnicity, sports merchandise, furnishings, fabric, dairy, etc.
Infrastructure	Application of Smart Solutions to create disaster-free zones, deployment of limited resources, providing economical services

Source: Smart City Features: Smart Cities Mission, Ministry of Housing and Urban Affairs, Government of India, 2017

Figure 2. Strategic outline for India's smart city mission
Source: Strategy: Smart Cities Mission, Ministry of Housing and Urban Affairs, Government of India, 2017



2. **Redevelopment:** In contrast to retrofitting where a good deal of existing setup remains intact and untouched, redevelopment intends significant makeover of an area within the city that exceeds 50 acres, selected by Urban Local Bodies through citizen engagement. In this strategy, the area selected would undergo major transformation as a new landscape with an all-embracing infrastructure, effective usage of land for diverse activities, advanced Floor Space Index and wider ground coverage would be created.
3. **Greenfield Development:** Towards the fulfillment of this strategy, an already unoccupied area exceeding 250 acres would be selected for realization of Smart Solutions by means of ingenious arrangements, premeditated financing and plan execution tools (land reformation through land pooling or land reconstitution) with availability of reasonably priced housing, particularly for the poor. Greenfield developments are a requisite in the vicinity of cities to cater to the needs of the growing populace.
4. **Pan-City Development:** It envisions employment of programmed Smart Solutions to the on hand urban infrastructure. This shall entail the utilization of ICT and data to improve infrastructure and services. For example, smart transportation system that allows diminution in the time required for traveling and commuting along different paths across the city can contribute to the quality of life of citizens.

The smart city proposition for each selected city is projected to incorporate either of the first three aforementioned strategies or a combination of these in addition to a Pan-city element with Smart Solutions. It is critical to note that pan-city initiative is a supplementary aspect to be built-in. Smart city being a miniature efficient area development scheme, it is crucial that inhabitants in the city feel a part of this development wherein there is something in reserve for them too. For that reason, the auxiliary requisite of a minimum 'one across-city smart solution' has been installed to make the scheme all-encompassing and thorough.

SMART TRANSPORTATION IN THE SMART CITY CONTEXT: ANCHORED IN THE INTERNET OF THINGS USING BIG DATA ANALYTICS

One of the essential imperatives of a smart city is 'smart transportation system inclusive of smart traffic management.' This comprises smart vehicles, smart infrastructure, ecologically friendly fuels, intelligent transport system, etc. A smart city is a distinctive arrangement to swap the traditional mode of services to smart and sophisticated ones (Babar & Arif, 2017). In the context of 'smart city,' the

idea of smart mobility has been gaining importance in recent years. Smart mobility assumes visibly smart connectivity through digital systems in a manner that people, goods and services are effectively connected by means of internet; it also calls for a considerable increase in efficacy and safety of transport and communication systems in cities (Kourtit, Nijkamp & Steenbruggen, 2017). As an exemplar, sensors and cameras installed on the roads bunch up traffic information relating to the number of vehicles plying on roads at a given time and based on real time processed data, the existing state of affairs is shared with the traffic control unit. Concurrently, the traveler is notified regarding the selection of route to avoid traffic congestion. Citizens can establish how long it may take to get to a destination on the basis of existing traffic intensity and the standard pace of the vehicles (Rathore, Ahmad, Paul & Rho, 2016). The trends acquired from the copious sums of traffic records can help perk up transportation systems with respect to lessening traffic congestion by presenting substitute routes and reducing the frequency of accidents by examining the chronicle of mishaps, as well as aspects such as their cause and the driver speed (Hashem et al., 2016). Thus, the fusion of data sources and big data analytics serves as an expedient solution to ease real-time management of the smart city.

Big data refers to a vast pool of raw data that can be seized, amassed, dissected and managed (Chauhan, Agarwal & Kar, 2016). This voluminous data is not helpful until it is scrutinized and assessed by the big data analytics which reveals the indefinite associations, concealed patterns and other constructive information (Tachizawa, Alvarez-Gil & Montes-Sancho, 2015). The IoT imparts a platform for sensors and connectors to link impeccably within the smart city environment and allows progressively more convenient information exchange across platforms (Gubbi, Buyya, Marusic & Palaniswami, 2013). As illustrated by Babar and Arif (2017), IoT offers the basis for developing smart cities supported by diverse sensors, intelligent meters, closed-circuit television / video surveillance, display monitors, recording devices, and actuators, which contribute massive amounts of data that can be dissected by the techniques of big data analytics. Big data analytics is applied to sizeable datasets to expose unique patterns and relationships for evolving efficient policy framework.

Although numerous constructs go into making a transportation system smart, there are few which may be deemed as the mainstay for the fulfillment of this objective. Table 3 lists the popular constructs of transportation in a typical smart city.

A model smart city possesses all/most of the features described in Table 3. The new-fangled information and communications technologies explored here assist movement of automobiles along roads as securely, effectively, and humanely as possible.

Table 3. Makeup of smart transportation in a smart city

Construct	Description
Automatic Vehicle Location System (AVLS)	• Facilitates commuters with real-time information on arrival and departure times of buses via mobiles and online platforms; enables real-time booking of cabs through mobile applications; examples include London, Seattle and Sydney (Debnath, Chin, Haque and Yuen, 2014). • Enhances dependability and consistency of public transportation (Prabhakar, Gupta and Mehrotra, 2015).
Automatic Fare Collection System (AFCS)	• Collection of fares through contactless smartcards/RFID cards; this sort of a system can be introduced in various forms of public transportation, particularly state buses, to ensure no traveler/passenger undertakes journey without a ticket (Datta, Kaur and Garg, 2015; Chen, Fung, Desai and Sossou, 2012; Pelletier, Trépanier and Morency, 2011; Trépanier, Tranchant & Chapleau, 2007). • Intermodal fare collection mechanism whereby one smartcard can be utilized for all modes of transport; examples include New York, London and Seattle (Debnath, Chin, Haque and Yuen, 2014). • Several cities across the world allow both – cash payments and smartcards – leaving the choice to commuters; however, to encourage increased adoption of smartcards, a higher tariff is collected if the mode of payment is cash (Debnath, Chin, Haque and Yuen, 2014). • Examples: Hong Kong's Octopus Card; London's Oyster Card (Report of the Sub-Committee on Automatic Fare Collection System, 2013).
Real-time Traffic Information	• Enables travelers to have up-to-date traffic status to strategize their trip before traveling, and choose the path accordingly for reduction in travel time and perking up travel safety (Lee, Tseng and Shieh, 2010).
Smart Parking System	• Car owners can locate and attain an unoccupied parking space deemed suitable and expedient to them (Idris, Leng, Tamil, Noor and Razak, 2009). • Such an arrangement helps reduce fuel consumption of vehicles (Rathore, Ahmad, Paul and Rho, 2016). • Instead of moving around the entire area searching for parking space, drivers would receive intimations and alerts over Wi-Fi regarding empty spaces available in vicinity. Furthermore, drivers would be informed about the shortest possible routes to take for reaching the intended destination, from the viewpoint of keeping vehicular emissions under check. Such an arrangement could as well forewarn motorists concerning school zones where there could be hordes of children crossing roads and a substitute path may be suggested (Sherly and Somasundareswari, 2015). • Furthermore, this also helps creation of profit for vendors (merchants/ traders/ retailers) in the city; citizens prefer to go shopping where there is lesser amount of congestion and where parking is readily available, resulting in larger profit for vendors in such areas (Rathore, Ahmad, Paul & Rho, 2016). • Examples: New York and Seattle (Debnath, Chin, Haque and Yuen, 2014).
Bus Rapid Transit Systems (BRTS)	• Dedicated tracks for buses and accelerating their pace through precedence signaling on account of their enhanced capacity to transport a greater bulk of people for the same street space; introduce a system that encourages commuters to use alternative forms of transport than personal vehicles; create bicycle lanes and broad walkways (Rangarajan, 2010).
Smart Bike-sharing System	• Renting bikes for travelling short distances; these bikes are tactically placed throughout the city and can serve as an alternative form of transportation; their real-time availability can be tracked online and by means of mobile applications; this system has been in effect in countries such as Spain, Sweden, France, etc. (Midgley, 2009).
Smart Car-sharing System	• Also known as carpooling that matches supply and demand through connecting people via smartphone applications (Prabhakar, Gupta & Mehrotra, 2015). • Travelers can rent or lease a car for travelling between desired destinations; this resolves issues arising from lacunae in availability of state buses; helps lessen traffic congestion by cutting down vehicular movement on the road, reduces air pollution, and state expenditure; allows increased availability of space for walking and cycling (Shaheen, 2004).
Vehicular Rules Violation Monitoring	• An arrangement for monitoring and registering occurrences of traffic infringement at traffic sites. The framework encompasses a digital camera system installed at a traffic site. This digital camera is distantly tied to a data processing centre. The data processing centre includes a picture processor for assembling photos of motor vehicles and on-sight events generated via digital camera, a corroboration procedure for confirming the authenticity of the motor vehicle snapshots, an image processing arrangement for ascertaining information of the motorist from the captured images of the motor vehicle, and a notification/warning procedure for diffusing information on breaching/contravention to concerned law enforcement bureaus (Ciolli, Whyte, Ercan, and Mack, 2003; Khan, Khan, Zaheer and Khan, 2012). • Automatic Number Plate Recognition System (ANPR) to recognize the number of the vehicle violating traffic rules (Debnath, Chin, Haque and Yuen, 2014; Patel, Shah and Patel, 2013). • The far-reaching CCTV network in Glasgow supervises traffic and street lighting in addition to law-breaking and criminal acts (Marr, 2015).
Coordinated Adaptive Traffic System by Means of Smart Traffic Lights	• Regulating traffic lights corresponding to the flow of traffic and traffic occurrences; example, Sydney Coordinated Adaptive Traffic System (SCATS) which is in force at Sydney and Melbourne, Australia (Debnath, Chin, Haque and Yuen, 2014). • Apply technology to discern traffic scenario and regulate traffic lights to facilitate synchronized flow of traffic (Al Nuaimi, Al Neyadi, Mohamed and Al-Jaroodi, 2015; Prabhakar, Gupta and Mehrotra, 2015; Kanungo, Sharma and Singla, 2014).
Road use payments	Direct fees such as congestion levies and tariffs intended to dissuade use of specific categories of vehicles, fuels or highly polluting motor vehicles on roads. Such charges inhibit peak hour travel and allied traffic jamming or other community/environmental negative externalities (Prabhakar, Gupta and Mehrotra, 2015).
Electric Drive Vehicles	Promote vehicles running on electricity and renewable energy (Prabhakar, Gupta and Mehrotra, 2015).

Source: Various Sources

PUNE SMART CITY PROFILE

Pune City Profile

Pune, fondly referred as the 'Detroit of India' due to the burgeoning automobile industry, and reverentially addressed as the cultural capital of Maharashtra, is a city that has witnessed an august urban tradition: at the outset as a historical seat of pre-colonial urbanism, followed by a major military base during the course of British rule, post-independence as a fast rising advanced industrial hub, and in the present day as an evolving conurbation. Pune is also known as 'Oxford of the East' for the vast number of educational institutions that the city boasts of (*Smart Pune's Step Towards Sustainable Transportation*, 2016); with nine prominent universities and approximately 811 operational higher education centres to meet the demand

Table 4. Pune city profile

Indicator	City (Municipal Corporation)	State (Urban)	India (Urban)
Demographic Indicators			
Total Population*	3124458	50818259	377,106,125
Total Population of Urban Agglomeration (if)*	5057709		
Share of Urban Local Body population in District Urban population (%)*	54.33		
Population Growth Rate (AEGR) 2001-11*	2.08	2.12	2.76
Area (sq. km)**	276.4		
Density of population (person per sq. km)**	11304		
Literacy Rate (%)*	89.56	88.69	84.11
Schedule Caste (%)*	13.42	11.38	12.60
Schedule Tribes (%)*	1.09	2.96	2.77
Youth, 15 - 24 years (%)*	18.51	19.63	19.68
Slum Population (%)*	22.10	2.02	17.36
Working Age Group, 15-59 years (%)*	67.24	66.68	65.27
Economic Indicators			
Per Capita Income (Rs.) at 2004-05 constant price ***	88341	60431	35, 947
Urban Poverty Ratio (% of urban population)#	2.73	9.1	13.7
Unemployment Rate, 2011-12##	3.29	2.3	3.4
Work Participation Rate, 2011-12##	35.07	36.5	35.5
Work Status, 2011-12 (%) ##			
Self-employed: Regular/wage salaried employees: Casual labour:	28.00 66.38 5.62	36.1 54.6 9.4	42.0 43.4 14.6

continued on following page

Table 4. Continued

Indicator	City (Municipal Corporation)	State (Urban)	India (Urban)
Sectoral Distribution of Workers, 2011-12 (%) [##]			
Primary Secondary Tertiary	0.34 32.16 67.50	4.8 31.3 64.0	7.5 34.2 58.3
Primary Commodities Manufactured**	Automobile engineering Software Chemical engineering		
Major Industries[###]	Metallic – Automobile Spares Machine Tools Non metallic – IT Industries & Software Technology Parts Agro Based		
Infrastructure Status			
% of households with access to tap water (from treated source) within premises•	99.20	85.69	84.14
% of households with access to electricity•	98.31	96.16	92.68
% of households having toilet facilities within premises•	76.47	67.28	72.57
% of household waste water outlet connected to drainage•	98.04	91.15	81.77
Type of sewerage system**	Underground sewerage		
Type of solid waste system**	Door to Door		
% households with access to PC /laptop with internet• % households without access to PC /laptop internet•	22.01 16.60	11.74 11.86	8.27 10.40
% of households with access to mobile phones•	64.36	64.16	64.33
Ownership Pattern of Housing (%)			
Owned Rented	66.66 30.63	69.78 27.19	69.16 27.55
% of households living in congested houses•	40.07	44.84	32.94
No. of Hospitals per 1,00,000 people**	0.03		
No of Schools per 1,00,000 people•	90		
Financial Status			
% of households with access to banking facilities•	86.36	76.02	67.77

*Census of India, 2011

**District Census Handbook, Census of India, 2011

***Directorate of Economics and Statistics of respective State Governments and for all India-Central Statistics Office

[#]Unit Level Data of National Sample Survey Organization, Household Consumer Expenditure in India, 68th Round, 2011-12

[##]Unit Level Data of National Sample Survey Organization, Employment and Unemployment Situation in India, 68th Round, 2011-12

[###]District Industrial Profile, Micro, Small and Medium Enterprises, Government of India

•Tables of Houses, Household Amenities and Assets, Census of India, 2011

Source: Various sources, adapted from "cities profile of 20 smart cities – Pune," http://smartcities.gov.in, 2017

of an ever-rising student population (Joshi, 2017), the city is making headway as an academic center with progressing years. It is also widely recognized for its landscape, amiable climate, historical value, vivacious ethos and imminent IT-BT centres. Furthermore, the city has been performing well compared to its counterparts in the country in terms of Mercer Quality of Living Index and Resilient City Index (Chandiramani & Airy, 2017). Table 4 details the profile of Pune city on the basis of vital indicators.

Pune has effective e-governance and digitalization; the city is further enveloped by Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Urban Infrastructure and Governance (UIG) component of Jawaharlal Nehru National Urban Renewal Mission (JNNURM) and National Urban Information System (NUIS) ("Cities Profile of 20 Smart Cities," 2017).

TRANSPORTATION ISSUES AND TRAFFIC CONCERNS IN PUNE

A Prelude

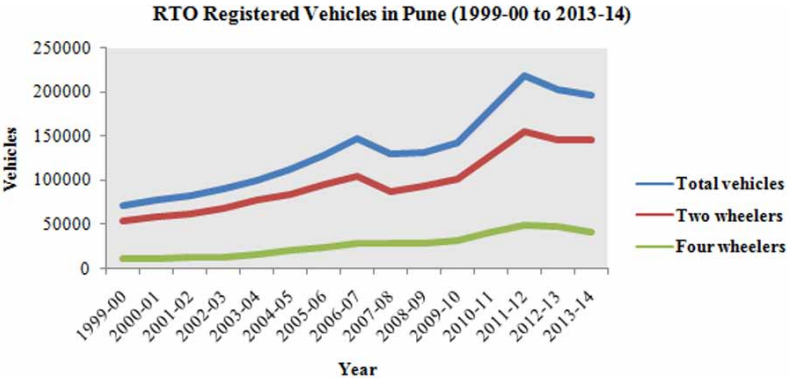
India's mounting traffic congestion has the capacity to let cars creeping at less than 5 kms an hour – thus incentivizing travel by foot than drive; traffic jamming is expected to balloon further with swift growth in urban populace and vehicle ownership (Sanjai, 2017). According to a report by KPIT Technologies Corporation, India incurs losses worth Rs. 60,000 crores annually in traffic jams (*Realizing Smart Cities with Technology - A KPIT Perspective*, 2016). While the state of affairs is true for the nation at large, the city of Pune is no exception when it comes to transportation issues and traffic congestion woes. Numerous reasons are cited for this rapid gush in traffic in the city. One of the prime reasons is rise in population which contributes to a rise in the number of vehicles on roads. Additionally, congestion may be also attributed to sparse capacity of roads, signal delays, deficient information concerning traffic, incompetent transport management, uninhibited demand, etc (Shinde & Jagtap, 2016); thus, it is indispensable to optimize traffic control and ensure it is more active from the standpoint of accommodating the erratic traffic density. Transportation and mobility have evidently come out as the chief pan-city problems to deal with.

Public Transportation in Pune

Pune depends exclusively on buses for public transportation. The city fails to keep pace with other big cities in India with respect to public transportation alternatives. According to the Smart City Proposal for Pune Smart City Challenge – Stage 2,

Pune lacks a mass transit system; rather, it is the only megacity among top eight in the nation without a mass rapid transit system (MRTS). The number of buses per population is lower than the required standards: 37 buses per lakh as against a yardstick of 55 per lakh. Furthermore, buses in Pune are marked by sizeable issues with respect to 'accessibility' – 25 percent fleet off-road more often than not and, 'consistency' – 84 percent routes have a waiting time of more than 20 minutes. For that reason, the public transport trip share has been a meager 18 percent as against the 50 percent target. Additionally, there is a growing perception that natives drawing an income of more than Rs. 20,000 per month scarcely use buses. Complementing to public anguish, congestion has amplified radically in Pune due to supplementary reasons beyond public transportation. A good number of roads are not evenly wide and contribute to restricted access, signal timings are not synchronized, and on-street parking is prominent owing to constrained parking alternatives. There is lesser than standard share of Non-Motorized Transportation (NMT): 33 percent as against 40 to 45 percent, attributable to the paucity of secure NMT infrastructure and pedestrian walkways: 60 percent of walkways have less than 2 m width. A dearth of ring roads adds to the existing set of problems. As an outcome, the average speed is 18 km per hour which is likely to come down considerably to 12 km per hour by 2030 if no measures are initiated; this has been an important projection in the Smart City Proposal for Pune Smart City Challenge – Stage 2. It further assumes that on the basis of positive upshots of the latest BRTS corridors – where there has been a 12 percent modal shift to public transport – there is vivid substantiation that citizens shall utilize more public transport if the quality, consistency and availability of buses are enhanced.

Figure 3. Vehicular density in Pune (1999-2000 to 2013-2014)
Source: Regional Transport Office (RTO), Pune



**For a more accurate representation see the electronic version.*

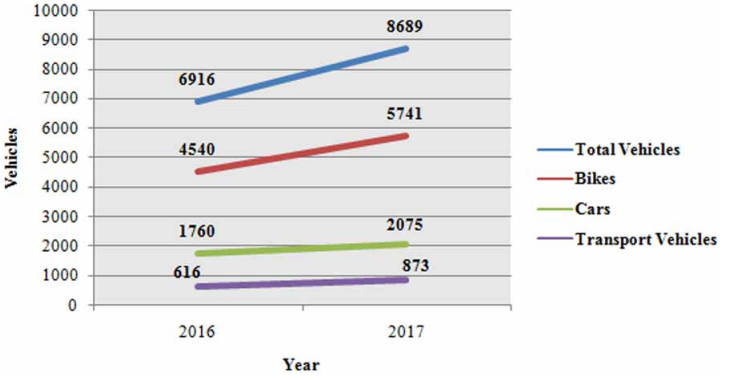
Vehicular Growth in Pune

One of the foremost causes for traffic congestion in Pune is the soaring number of vehicles. There has been a phenomenal growth in numbers of two-wheelers, four-wheelers and total vehicles in the city. Figure 3 depicts the vehicular density in Pune in recent years, based on the number of vehicles registered with Regional Transport Office, Pune. As vehicles in the city mount, parking becomes a hassle, consuming all accessible spaces meant for other road users in addition to creating a demand for all available open spaces to be converted into parking lots.

It was observed that the average registration of vehicles with RTO, Pune, went up to 22,000 per month, during the financial year 2016-2017 (Dastane, 2017). The Environment Status Report (ESR) for the same year stated that the number of vehicles in the city is equivalent to the number of residents in the city (Khairnar, 2017). Consequently, the city has been experiencing startling escalation in the levels of air and noise pollution (Joshi, 2017). During festive season, the vehicle registration with RTO receives further impetus. In September 2017, during the auspicious occasion of Dussehra – a festival that is reckoned as one among three and a half propitious events for Hindus – the number of vehicles registered with RTO saw an increase by 25%; this was due to special offers run by manufactures and retail outlets to attract more customers (Biswas, 2017a). A similar trend was observed along the same time during the previous year. Figure 4 indicates the numbers for two years in succession.

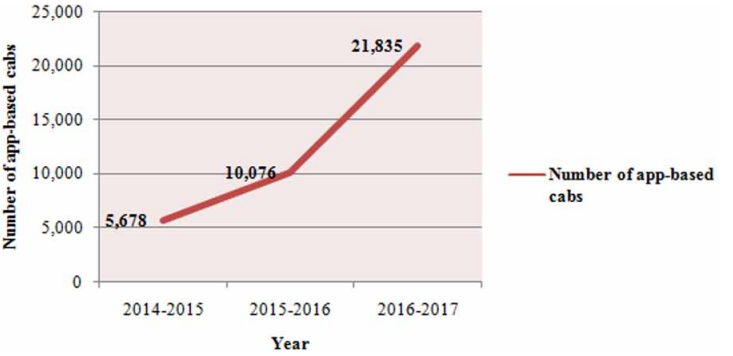
Cab operators in Pune, who are affiliated to the app-based cab provision services – Ola and Uber – have appreciably contributed to the fleet of cabs in the city. According to Pune Regional Transport Office (RTO) statistics, the number of such

Figure 4. RTO registered vehicles in Pune during Dussehra (2016-2017)
Source: (Biswas, 2017a)



**For a more accurate representation see the electronic version.*

Figure 5. Number of app-based cabs registered in Pune (2014-2017)
Source: (Biswas, 2017b)



cabs registered during the financial year 2016-2017 nearly doubled – crossed the mark of 21,000 – as compared to the previous financial year when the number was slightly over 10,000 (Biswas, 2017b). Figure 5 reflects these trends.

The massive rise in the number of vehicles has contributed significantly to traffic jams in Pune. It is observed that in some parts of the city, bicycles are ridden on walkways. From 9 am to 11 am in the morning and 5 pm to 7 pm in the evening, the roads are swarmed by vehicles, thus adding to the time of travel required between destinations. For instance, a brief distance of 3.6 kms from MKSSS's Cummins College of Engineering, Karvenagar, to SNDT Arts and Commerce College on Karve Road, Erandwane, takes double the time to travel during peak hours than what it takes during non-peak hours. It is important to examine the raison d'être for private ownership of vehicles in the city. Why do residents of Pune prefer to possess their own vehicles rather than rely on public transportation? Citizens cite a number of reasons for this.

There are locations in the city which are not connected by buses. The number and frequency of Pune Mahanagar Parivahan Mahamandal Limited (PMPML) buses plying between prominent locations in the city are way too less than the demand for them. It is further reported that the allocation of buses along a given route is also subject to a vicious cycle – because there are not enough commuters, buses are cancelled, and because buses are unavailable, commuters have to look up for alternative forms of transport. During peak hours, buses are teeming and filled to capacity. It is a sight to see commuters hanging out from overcrowded buses without much concern for their lives. Alternate forms of transport are either rigid or pricey or both. The nuisance of auto rickshaws plying on the roads but turning down rides to the needy citizens is a concern reported by many. The auto rickshaw pullers are unyielding, uncompromising and express readiness to take a trip only

between such destinations where there is probability of getting passengers for the next travel. At times, they charge higher tariffs for trips to remote locations or longer distances. This may not suit everyone's pockets and is particularly unaffordable for the non-working/dependent population. Nearly 245 applications were sent by traffic regulators to RTO from January-June 2017 for suspension of license of auto rickshaw pullers for declining rides to impending commuters (Shinde, 2017). With such a pathetic state of public transportation, the dependence on app-based cab providers and personal vehicles becomes an inevitable affair. To deal with this conundrum, PMPML intends to float new buses on roads; 50% of the buses will be running on CNG, while the remaining 50% shall run on diesel. The decision to buy 50% buses running on CNG is driven by requests and petitions from citizens, civil activists and organizations, from the standpoint of controlling air pollution. Nevertheless, it may take a year or two for the buses to come on roads. Till that time, a further spike in ownership of personal vehicles is expected.

Impending Flyovers

It is a customarily held credence that traffic woes in a growing city can be cracked by instigating actions such as broadening of existing roads, constructing new roads, flyovers, etc. Nevertheless, such solutions are ephemeral and barely sufficient on account of mounting number of vehicles, discussed earlier. As a result, the roads get crammed and jammed again within a short span of time. Furthermore, pedestrians and other travelers have to bear the brunt of vehicle-centric initiatives. Long-drawn-out flyover projects contribute significantly to traffic congestion. As regards Pune city, there are numerous flyovers that have been built recently and few those are presently under construction. The construction of flyovers on Satara Road and Swargate is through. However, construction of flyovers adjacent to College of Engineering, Pune, and the one that stretches along Cummins College Chowk at Karvenagar is

Figure 6. Impending flyover at Karvenagar, Pune, as on September 6, 2017 (A)
Source: Authors

Figure 7. Impending flyover at Karvenagar, Pune, as on September 6, 2017 (B)
Source: Authors

Figure 8. Impending flyover at Karvenagar, Pune, as on September 6, 2017 (C)
Source: Authors

Figure 9. Impending flyover at Karvenagar, Pune, as on September 6, 2017 (D)
Source: Authors

still underway. The latter is a vital junction and the flyover is anticipated to lessen traffic in Warje and contiguous areas. The erection of flyover commenced in 2012, was expected to be completed by the end of 2015, then by 2016, but still remains unfinished. The amount of work finished so far is evident from Figures 6, 7, 8 and 9. The extent of inconvenience to travelers using that road is of great consequence. The Pune Municipal Corporation intends to construct more flyovers in the coming years. Nonetheless, flyovers are by a hair's breadth remedy to moderate tailbacks as they are inclined to simply alter the point of congestion from one place to the other, in conformity with the Comprehensive Mobility Plan (CMP) of the PMC. Studies relating to transportation across the world validate that constructing flyovers only draws in more vehicles (Puri, 2015). Consequently, experts have expressed reservations about the real efficacy of flyovers beyond offering provisional respite from congestion. The only established sustainable remedy to the problem of traffic congestion is imparting a high-quality public transport structure in addition to secure, sufficient and functional amenities for striders and cyclists. This shall make it feasible for citizens to travel expediently without using personal vehicles, thus limiting the number of vehicles on road. Consequently, the traffic congestion woes as well as pollution problems will gradually disentangle.

Parking Issues

One of the key concerns facing the city corresponding to those discussed earlier is the availability of parking space. A typical automobile is functional for one hour on an average and is parked for 23 hours in a day (*Smart Pune's Step Towards Sustainable Transportation*, 2016). Vehicles are randomly parked at roadsides, walkways and vacant spaces in an unorganized fashion. It needs to be realized that creation of additional parking spaces is going to be an uphill task considering the current rate of growth of vehicles. There shall always be a massive shortfall if the present trend continues. The roads are not outfitted to offer parking space for every vehicle. According to administration's ballpark figure, nearly 50% of the city's traffic comprises personal vehicles. A major factor for this colossal number is free parking on roads. Unlawful parking along roadsides and alleys has contributed to unruliness; striders are unable to use walkways due to occupation of those spaces by vehicle users. As an alternative, focused measures need to be initiated to bring down the number of private vehicles. PMC is evolving a new parking policy that recognizes the importance of access to roads for every citizen within the city; this shall involve greater emphasis upon public transportation, availability of space for striders and cyclists, and charging personal vehicle owners for utilizing parking space. Thus, parking would be controlled and closely monitored to give preference for higher priority uses and promote efficiency.

Air Pollution

The rise in number of moving vehicles on roads in Pune has contributed significantly to high concentration of contaminants and noxious wastes. It is setting off pollutants in ambient air to ascend sharply. Of particular significance is the rise in nitrogen dioxide (contingent upon vehicular emissions) and particulate matter (PM); these are perilous to human health and increase the incidences of respiratory and cardiovascular disorders. The trends in NOx and PM10 levels at three prime locations in Pune are depicted in Figures 10, 11, 12, 13, 14 and 15. Environmentalists associated with National Air Quality Monitoring Programme suggest that although the amount of

Figure 10. Interannual variation of NOx at Bhosari, Pune (2000-2017)
Source: Pollution Control Board, Government of India

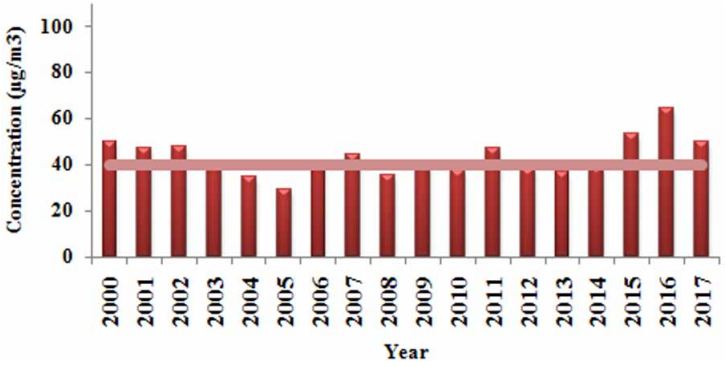


Figure 11. Interannual variation of NOx at Nal Stop, Pune (2001-2017)
Source: Pollution Control Board, Government of India

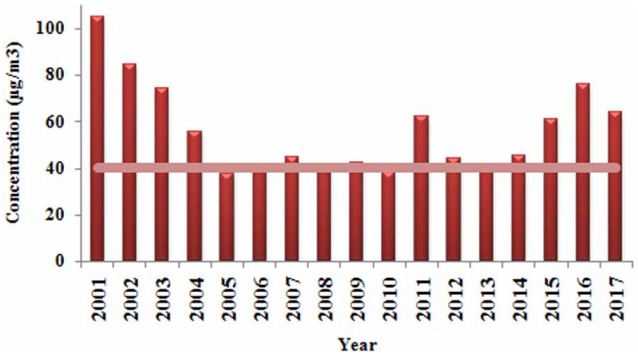


Figure 12. Interannual variation of NOx at Swargate, Pune (2000-2017)
Source: Pollution Control Board, Government of India

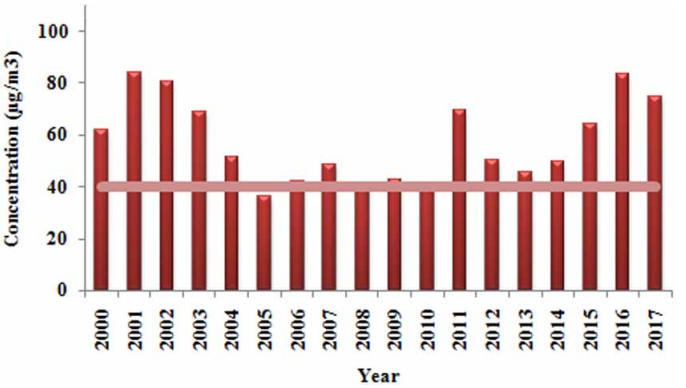


Figure 13. Interannual variation of PM10 at Bhosari, Pune (2000-2017)
Source: Pollution Control Board, Government of India

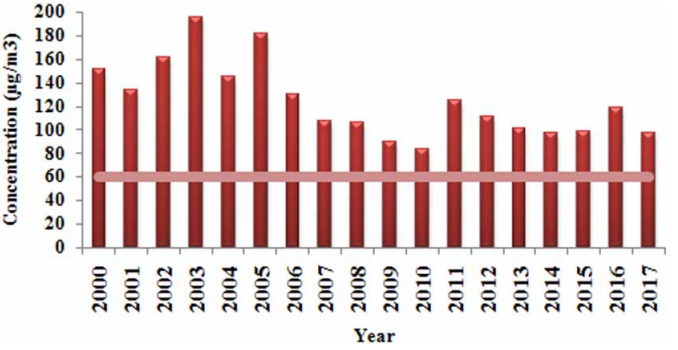


Figure 14. Interannual variation of PM10 at Nal Stop, Pune (2001-2017)
Source: Pollution Control Board, Government of India

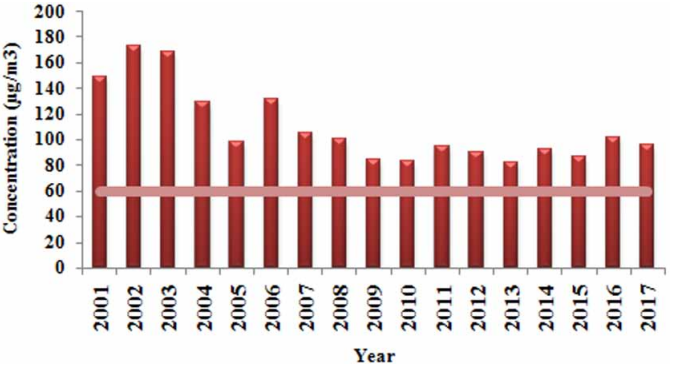
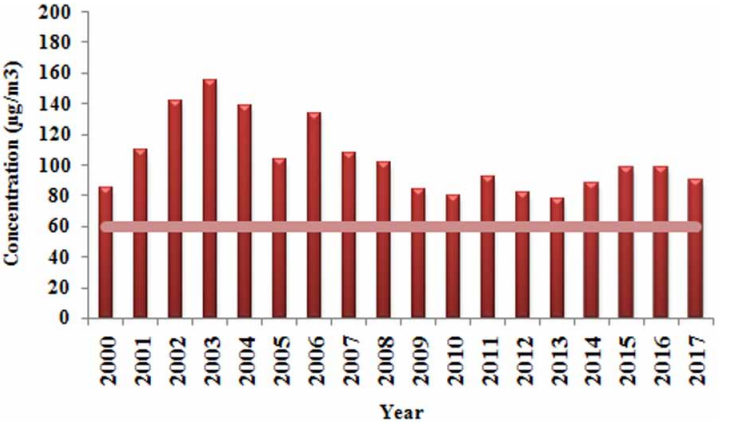


Figure 15. Interannual variation of PM10 at Swargate, Pune (2000-2017)
Source: Pollution Control Board, Government of India



PM10 is showing a declining trend in recent years, it is still above permissible limits and poses considerable concerns to human health. Recent studies point a direct relationship between traffic congestion and air pollution. The higher the traffic jams, the greater is the extent of vehicular emissions and lesser is the ambient air quality (Zhang & Batterman, 2013).

The time is ripe to necessitate actions for controlling air pollution in Pune – a city which has for long enjoyed the reputation of being green city.

REMEDIAL MEASURES: ACTIONS TAKEN TO TACKLE TRANSPORTATION ISSUES IN PUNE SMART CITY – IOT PERSPECTIVE

The ambitious and elaborate smart city project commenced for Pune with a series of planned initiatives in target areas for infusion of technology from the standpoint of improving livability for the Puneties. One of the prime target areas has been effectual, economical & 'smart' multimodal transportation arrangement that is accessible to all residents. It is significant to ensure effective mobility by optimum utilization of prevailing stock and well-planned schemes and investments for highest bang for the buck (Pune Smart City – Vision Document (Version 1.0) Volume – II, n.d.). Table 5 lists the initiatives taken so far to improve transportation and combat traffic congestion as well as scope for further improvement through employment of big data and IoT.

Table 5. Smart city initiatives for transportation in Pune – present scenario and future prospects

Dimension	Initiatives Taken	Further Scope
Supply-side Policies	• Mass Rapid Transit System (MRTS) – Pune Metro Rail project for improved connectivity across the city has begun after significant delays and numerous obstacles spanning across land possessions and environmental consents. • Bus Rapid Transit System (BRTS) called 'Rainbow' stretching over 30 kms is proposed. This is an important step in the milieu of the fact that 16 kms of the stretch out of intended network of 68.80 kms is completed.	• Such additional travel options with real-time tracking and passenger information can significantly deal with supply-side bottlenecks in transportation system.
Automatic Vehicle Location System (AVLS) by means of Commuter Information Plan	• Vehicle Tracking System (VTS) that enables real-time tracking of buses by means of GPS setup; 1,750 buses are presently equipped with GPS tracking system (Bari, 2017) • Information concerning arrival time of buses is available on PMPML website • PMPML website provides details on standard service and nighttime service; planned and actual trips; planned and actual buses running on roads; availability of passes and mobility cards; tariffs for differential routes on the basis of distance, types of commuters, category of service availed; ridership; grievances – received, addressed and closed, etc. • PMPML also ensures availability of information concerning bus routes, schedules and timings through mobile apps.	• Mixed response to mobile app, mostly inclined towards dissatisfactory • Response to mobile app is summarized as follows: → Welcomed by passengers → Contains outdated information and fails to reflect up-to-date information → Not-user friendly • There is further requirement to improve real-time tracking of buses through installation of GPS by extending it to a larger number.
Automatic Fare Collection System (AFCS) through Common Mobility Card	• Mobile Integration (MI) card, which is a contactless smart card, has been introduced in January 2017 and rolled out in phases • Facilitates cashless payments • This is known to be a single payment card for all modes of transport – PMPML buses, metros, railways, cabs, parking, etc. • Forestalls ticketless travel and ensures greater transparency in collection of fares • This arrangement shall run parallel alongside cash payments; nevertheless, to encourage the usage of this card, more discounts and concessions will be given to users	• Execution is taking longer than expected; still in implementation stages • The setting up of requisite infrastructure for electronic ticket issuing has been a challenge. • The usage of this card was enforced upon employees of PMPML and all civic body-run schools; this too involved more time than projected. • Although PMPML has called forth disabled persons to migrate to this form, the response has been disheartening from beneficiaries. • If implemented successfully through extended outreach, this will be a major IoT initiative for Pune smart city.
City Command Control Centre	• Video Management System for close inspection and surveillance • Integrated Traffic Management for traffic detection; traffic re-routing apps founded on real-time traffic information • Transport Management System for easing transportation for citizens such as electronic ticketing system • Event Management System for crisis management and emergency warnings • Flood Monitoring System • Parking Management System	• A huge headway is made in this regard and the role of IoT towards recognizing and responding to the needs of citizens has been impactful. • However, there is vast scope for further improvement as the outreach has been limited and few initiatives have witnessed considerable delays. • Measures for adaptive traffic management for smart traffic project are still underway.
Traffic Mobility Plan	• This is used to collect information on people's whereabouts, activities and travels through Internet of Things (IoT) sensors; data so obtained can be utilized for creating an enhanced traffic mobility plan	• It is yet to be fully implemented and may involve sizeable time considering the delay in execution of other smart city projects.
Smart Traffic System	Gadkari (2017) explains execution of smart traffic system in Pune city: • Implementation to be in phases instead of all at once • Syncing of traffic signals such that the time span of red light and green light can be attuned and in sync with the traffic flow • Updates on signals shall be shared on mobile application • People having access to mobile app shall get alerts about traffic jams, mishaps or mayhem in specific areas • The app shall also suggest options/ other paths to reach the destination	• This is intended to be rolled out in phases to ensure economy and efficiency through trial and error

continued on following page

Table 5. Continued

Dimension	Initiatives Taken	Further Scope
Vehicular Rules Violation Monitoring	Banerjee (2017) discusses effectiveness of linking e-challan system with the city's CCTV camera to check unbridled traffic outlawry. • A traffic lawbreaker receives an SMS notifying his contravention, along with photo confirmation of the same, as well as a link directing him to the nearby police station where the fine can be paid. • Fines may be paid through cards as swipe machines are available with city police to facilitate cashless payments. • Currently, about 1,250-odd CCTV cameras are installed across the city, providing live feed to the main police control room; a screen-grab of infringement is captured from this footage as photographic proof, which is saved online. • Text messages are composed and sent to the mobile number of the lawbreaker, along with the e-challan	• This arrangement has worked wonders with respect to controlling infringement in traffic rules. • The system, however, faces following challenges: → Non-payment of fines owing to technical glitches with swiping machines or non-availability of debit/credit cards with lawbreakers to make timely payments (Bengrut, 2017) → Inability to catch hold of violators of rules by government vehicles as they are not registered in the names of specific individuals Banerjee (2017)
Walkways and Bicycle Tracks in Selected Areas	• Measures for allotment of ample space to striders and delineated tracks for cyclists have commenced in Aundh, Pune.	• There is further scope to have marked out zones to bring about mixed land use for diverse activities and ascertain a sustainable mobile ecosystem underscored by tracking of human movements through IoT sensors.
Parking System and Road Use Payments	• Revised parking policy has come into effect that lays emphasis on supply aspect in terms of limited capacity of roads to provide parking space for all motor vehicles, rather than the demand for the same. • Policy envisages payment for using parking spaces on a graded scale to limit the use of personal vehicles • Parking fees shall be contingent upon area rentals, motor vehicle size and traffic congestion in a given area • There will be vehicle-free zones in busy areas of the city. • Parking shall be prohibited on walkways and cycling tracks.	• Smart parking solutions are yet to be extended across the city. • The city is yet to make great strides with respect to real-time tracking of vacant parking spaces that can save time in searching for them.

Source: Various Sources

RECOMMENDATIONS

The rapid progression of smart city and Internet of Things applications creates numerous logical and designing difficulties that call for astute research endeavors from both scholarly world and industry, particularly for the advancement of proficient, adaptable, and dependable smart city in view of IoT. Pune needs prompt arrangements and urban body's regard for matters concerning transportation through citizen engagement. Citizens' apathy and indifference can do no good for the city. It is important to realize the needs of citizens and tailor the policies suiting their requirements. It is equally important to make them realize their responsibilities in this process. In addition to providing an effective public transport system and pedestrian-friendly roads, the administration needs to take cues from countries around the world, who have struck the chord for betterment of lives for their masses – Beijing for its public bus service; London, Seattle and Sydney for their Automatic Vehicle Location System; Hong Kong and London for Automatic Fare Collection System; New York and Seattle for Smart Parking System; Spain, Sweden, France for Smart Bike-sharing System; Paris for Electric Car-sharing System; and Sydney for its Coordinated Adaptive Traffic System. Another prerequisite for the IoT system to be

prepared sooner is the correct sort of skill development and capacity enhancement for data innovation experts. Furthermore, the administration ought to consider the security concerns of employing big data. The gathering of substantial information and the utilization of analytics obviously ensnare privacy concerns. The targets of guaranteeing information security and ensuring protection end up obviously harder as data is duplicated and shared at all times broadly around the globe. Data with respect to people's wellbeing, location, power utilization, and online action is out in the open for scrutiny, raising worries about profiling, separation, exclusion, and loss of control. Policymakers should likewise address the concerns pertaining to individual consent in privacy and protection of confidentiality.

DIRECTIONS FOR FUTURE RESEARCH

Each city has its own established setup and concerns that need to be addressed for citizen welfare. While the smart city initiative is launched in India with the objective of creating 100 smart cities, it is important to identify how the efforts for advancing these cities have fared in terms of administration's capacity to introduce progressive measures and people's responsiveness and acceptance of the same. Future research can be centred on ways and means adopted by the administration of each city towards making the city smart and livable, the time dimension across which these means were adopted, the period taken for attaining the desired outcomes and citizen engagement to make the mission a grand success. The findings of such studies can provide meaningful insights to other cities intending to embark upon similar initiatives. Future researchers can also aim to establish people's willingness to share their personal information in the context of privacy concerns and evolve ways to ensure anonymity and confidentiality. They should come up with a model that strikes a balance between the advantages of data for businesspersons and researchers and potential gains/losses arising out of privacy concerns of individuals.

CONCLUSION

Pune, the city which has witnessed extensive development in diverse domains and arenas in the last three decades, began its smart city journey with targeted initiatives for improving the quality of life of citizens. The rationale has been to improve access to basic services through greater infusion of ICT initiatives. The present chapter, which primarily focused upon transportation sector in Pune and issues surrounding therein, wraps up with the finding that the city has a long way to go with respect to perking up mobility. Transport is one of the few areas where the city lags behind

compared to its urban counterparts in the country. Although big data and IoT can make a considerable impact in realizing the smart city objectives for efficient transportation in Pune, they can serve as complementary measures to supply-side policies for expanding travel alternatives for the residents. Public transport has been ineffectual, auto rickshaws have been rigid and pricey, thus making it indispensable to possess personal vehicles or resort to app-based cab services. Traffic congestion and air pollution have been the obvious outcomes as a consequence. Although flyovers are constructed for strategic routing of vehicles and parking policies are redesigned to accommodate a rising number, these are short term solutions to a longstanding problem. The administration realizes its responsibilities and is making efforts to holistically deal with the issue. As mentioned earlier, only when public transportation picks up and a large number of travel options are made available to citizens, ICT can contribute to easing of traffic congestion in the city.

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