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► **To cite this version:**

Sriram Rajagopalan, R. Sriram. Aspects of Digital Urbanism in India and Abroad. International Working Conference on Transfer and Diffusion of IT (TDIT), Dec 2020, Tiruchirappalli, India. pp.259-273, 10.1007/978-3-030-64861-9\_24 . hal-03744766

**HAL Id: hal-03744766**

**<https://inria.hal.science/hal-03744766v1>**

Submitted on 3 Aug 2022

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# Aspects of Digital Urbanism in India and abroad

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**Abstract.** Digital urbanism is described as an emergent understanding of city administration shaped by the influx and pervasiveness of information and communication technologies. This description covers three aspects of Information and Communication Technology, Pervasive Computing and City Administration driven by social organs. This paper has observed the aggregate use of computing technologies linked to social organs of cities through a digital transformation. International cities, have benefitted from the use of such computing technologies in resolving social problems, understanding different models of its implementation. However, for Indian cities where social problems are aplenty, use of such technologies has its intuitive experiences. Further, while past literature on digitally urbanized global cities relies primarily on technology dimensions of administration, this is found wanting in Indian context. Our paper focuses on bringing out pertinent aspects of computing technologies across India and international cities, observing how these technologies are linked to social organs of city administration.

**Keywords:** Digital Urbanism, Information Communication Technology (ICT), Pervasive Computing, Social organs, International cities, Dimensions

## 1 Introduction

An early literature on “Digital Urbanism” has described the concept as “Influence of information and communication technology (ICT) and pervasive computing in City Administration” (Chatterji, 2017). Two themes, “ICT” and “Pervasive Computing” evolve from this precise description linking technologies to cities. To study them in detail, relevant literature in the last two decades were reviewed on these themes (from 1999 - until recent). A large number of studies on “ICT” has revealed its significance in social transformation across international cities (Mazihnan, 1999; Hollands, 2008; Toppeta, 2010; Chourabi et al. 2012; Washburn et al. 2012). In India, the journey of using ICT began much later during the process of digitalizing city administration (Khatoun et al. 2017). Of all measures undertaken for using ICT in India, “E-Governance” was the first (Khatoun et al. 2017). The emergence of a more advanced computing technology in International cities through interconnected systems, allowed ubiquitous

networks to access data worldwide (Malhalle and Dhotre, 2020). For India, the applicable use of technology in different forms to communicate between users like RFIDs, Smart phones, and Sensors had already ensured an active presence of such computing technologies in every organ of Indian city administration (Aggarwal and Mohanty, 2015). However, social skeptics on technology placed their critiques in endorsing a planned approach in transforming city administration in India (Ayon Datta, 2018). As evidenced in research studies quoting International cities, the objective of digital urbanism in India too should focus more in approaches that eradicate social problems, improve efficiency, and optimize resources in administration absorbing technology (Kennedy et al. 2018).

This paper is prepared with this context addressing the objective of bringing out literature on (a) aspects of using ICT in India, (b) the various computing technologies in practice at disposal for communication between devices and users, and (c) the social organs which has utilized this technology to make its effective contribution in society.

## **2 Background**

Developing nations have benefitted from the use of ICT. The ICT has brought-in structuring changes in society and economy for India (De and Bandyopadhyay, 2020). For India, the ICT began with “E-governance” as a model oriented towards automation in collection and accounting of any payments, registration and approval of housing plan documents (Ojo, 2014). The arguments placed to diffuse an ICT enabled service often required the adaptability of innovation in technology (Khanh, 2014). The different models of e-governance vis-à-vis “four” pillar and “six” stage models contemplated an enterprise transformation for departments, municipalities, and government agencies. The social focus of a governance system also encouraged Indian administration to move away from making a “participatory” role in processes (Vinoth Kumar, 2015). Further, these developing nations were ambitious to embrace a complete digitalization for enhancing quality of infrastructure, service delivery and citizens’ interface in cities (Aijaz and Hoelscher, 2015; Hatuka and Zur, 2020). During this same period, research organisations like McKinsey identified challenges on availability of internet infrastructure, its cost of access and usage, awareness and literacy among public, and the narrow range of applications available (Vinoth Kumar, 2015). International literature on smart cities are also continuously identifying different frameworks and factors contributing to create an informational urbanism (Barth et al. 2017). People in small towns of India too are faced apprehensions within their local bodies stating a lack in technical capacity and knowledge to operate digital structures (Housing and Land Rights Network, 2017). At the macro-level, the use of ICT in development plans has promoted for a clean and sustainable livelihood in urban areas. The economic issues in India like deficient development plans, slacks in implementing plans, apportioning land availability, and fund insufficiencies have been a challenge for improving the quality of governance in cities (Kennedy et al. 2018).

The role described of ICT's in literature was as an agent of development to steer enabling environment with (a) Transparent governance systems, (b) Efficient technology infrastructure, (c) People oriented capacity resources and (d) Effective policy measures (UN Habitat and Ericsson, 2015). The international cities have adopted them into their urban development plans. In the initial stages, these cities oriented themselves to integrating physical and social infrastructure with technology infrastructure (Hollands, 2008; Washburn et al. 2009; Toppeta, 2010). The progress of digitalization proved to have an economic transformation with set goals in cities of East Asia, Europe and Americas, illustrating the benefits on using technology for social concerns (Mazihnan, 1999; Harrison et al. 2010; Aggarwal et al. 2014; Trivellato, 2016; Talari et al. 2017; Zhuhadar et al. 2017). The advantages drawn from his progress resulted in investments for infrastructure by government and private corporates embedding technology with society, citizens' participation for campaigns and policy changes at local / regional / national level (Mazihnan, 1999; Beranek et al. 2014; Kar et al. 2019). Literature and secondary sources reveal an amount of Rs.273 lakh crore as outlay in the budget for an extended period to making these investments (Chatterji, 2017).

### **3 Motivation**

The motivation for this paper evolves from assessing achievements and failures at micro / macro-scales in bringing development reforms in Indian city administration (Aijaz and Hoelscher, 2015). To recap the development plans, each one (1979, 1993, 2005 and 2015) made significant efforts in improving the economy and physical infrastructure of cities, creating urban settlements on agglomeration metrics (Wu, 2016). The urban development reforms for International cities were completely based on understanding trivial needs of society gathering information from citizens' participation on technology (Chourabi et al. 2012; Beranek et al. 2014). The active innovation factor used by international cities in tracing down checks for social organs gives a larger substantive evidence of involving technology in administration (Talari et al. 2017; Zhuhadar et al. 2017). The progress of innovation (in last two decades) in cities is explained in the below Figure 1. This significant difference in development reforms between nations and a promotion for the concept "future cities" in India kindled the interest to analyze various approaches to digitalize administration of cities (Kennedy et al. 2018). The other reason is driven by the fact that penetration levels of ICT has been more than 75 percent in urban clusters with 18 percent influenced by Internet usage in India (Chatterji, 2017). The information published from media reports observes the process of digitalization to have a major lack in conceptualizing city administration. These reports show nearly 67 percent of the work pending at desk level with rest in implementation stages (Hindu Business line, dt: December 16, 2018). This clueless situation, a desperate need for planned approach, differences between nations in implementing a full-fledged ICT enablement has motivated the academia to choose digital urbanism and identify functional areas where such enablement can help improve city administration in Indian context.

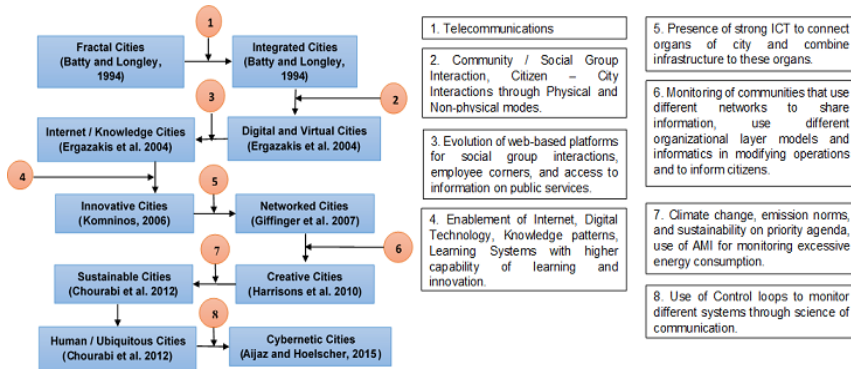


Fig. 1 Innovative progresses categorizing cities

## 4 Research Questions

The objectives set for the article discloses three important areas of interest. The aspects of using ICT in India, the computing technologies in practice for communication between devices and users, and enumerating the social organs that has utilised the technology for social contribution in India. In line with these three themes, the set of questions answered throughout this article includes

- The preparedness or readiness in Indian cities to use ICT enabled technologies,
- The approach observed by Indian cities in implementing plans to adopt / extend ICT in city administration,
- The salient features available in an advanced technology operated service for adoption in cities,
- The measurability of technology infrastructure to social organs like land and other infrastructure.
- The outcome of enabling computing technology and its sustainable benefits to society.

## 5 Information and Communication Technology - India

India has begun its journey in using ICT to digitalize city administration through the e-Governance measures (Khatoun et al. 2017). This ICT has induced a structural change in economy and society through urban centres to the global world (Castells, 1996; Thrift, 1996; Hall 1998; Sassen, 2001). The concept of future cities were built on the premises of using ICT to create technology infrastructure in the international cities (Giffinger et al. 2007). An early literature quoted “E-governance” as one of the mechanisms in extending services to citizens using internet (Mittal and Kaur, 2013). In its initial stages for India, the “e-governance” laid a greater emphasis on digitalizing documents in various departments although the key initiative was on merging the divide between urban and rural clusters (Vinoth Kumar, 2015). The ICT did not stop only with digitalizing departments but also delivered online services through e-payments, rail

ticket bookings, online transactions, and ordering food in India (De and Bandyopadhyay, 2020). The core social benefit of an ICT was primarily to build clean sustainable infrastructure and a safe environment that enhances the income for poor and disadvantaged in India (Aijaz and Hoelscher, 2015). The measures undertaken by government (state and central) to enable ICT in different states of India are enlisted in the below table 1.

**Table 1.** State-wise brief Digital Measures in India (Vinoth Kumar, 2015)

State	Digital Programs	Purpose
Andhra Pradesh	Two Cities Network Service and Integrated Citizen Services Centre	Linking two cities of Hyderabad and Secunderabad. Help citizens to access information about state and central governments, pay utility bills, pension, taxes, purchasing certificates and licenses. Receiving information regarding building permits, property registration, and transport procedures.
Madhya Pradesh	E-Governance	Provision of payrolls, budgets, official communication, land records, public programmes and other operations. Use Hindi as an official language for state departments to communicate with.
Karnataka	Centre for E-Governance	Computerisation of Department records and to support vision of creating awareness on use of Information Technology.
Tamil Nadu	E-Governance Tamil Internet Research Centre	Computerisation of Department records, building technical capacity, creating awareness, digital cooperative banking and credit societies through core banking services, Recording tax collection, welfare schemes, government orders.
Kerala	Information Kerala Project Transliteration Technology	Information Kerala is to computerise and connect 1214 local bodies through digital network. The project has adopted the model of e-Governance for three constituent villages under core district panchayat to build information on land holdings, age structure, health and tax payments.
	Facilitation Booths	The Facilitation booths help provide internet access to cooperative societies, aids to deliver information relating to agriculture, health and education to people in villages.
	Dr.SMS	Dr. SMS - To provide comprehensive information on healthcare facilities available within the locality through SMS.
	Transport Services	Transport related services - To provide information on schedule of state, private buses, details on road tax, and vehicle registration.
	Utility Services	Utility Services - Kerala State Electricity Board and Kerala Water Authority to provide consumer billing and complaint resolution.
Rajasthan	Education Services	Education services - to provide information on various examinations to students.
	RajSWIFT RajNIDHI	RajSWIFT - Facilitates the use of online data and communication among officials. RajNIDHI - Providing services to citizens in e-Nagars and rural areas through.
Gujarat	E-Nagar	E-Nagar - Connects all offices, complexes and corporations in the state.
	SWAGAT	SWAGAT - A state wide grievance system to provide state wide attention to grievances using technology.
	E-Procure	E-Procure - to provide a system for efficient and transparent process for tendering.
	E-Jamni e-Governance Self-help Kiosks E-Ward	E-Jamni - to provide a system for accessing land records in a transparent way.
Maharashtra	e-Governance	Transforming Mumbai and Pune into IT hubs, developing skills and awareness among employees through training while linking all district level offices through WAN.

## 6 Moving ahead from ICT to Computing Technologies

The participation of citizens in society was the focus of the e-governance measure in India. The ICT has encouraged such participation by society through a planned approach (Vinoth Kumar, 2015). This approach began with building the vision for a vibrant computing technology (Mitton et al. 2012). It was the power sector in the initial stages to map customer databases through networks using Geographical Information Systems (GIS) for collecting data on energy consumption (MoP, 2005). Three years later, the power department established a customer service center to handle grievances (MoP, 2008). It was observed that the grievance handling at these customer centres faced challenges of making huge expenditures with lack of capacity for action (Aggarwal et al. 2010). Additionally, the government made policy decisions to bring operational efficiencies in power sector with installation of Automatic Meter Reading (AMR) / Automated Metering Infrastructure (AMI) to assess energy consumption (TERI and NASSCOM, 2011). It was further extended with Supervisory Control and Data Acquisition (SCADA) for accounting purposes (Powerline, 2012). These strategic decisions yielded the department to lower down its revenue losses and manage peak loading issues at the grid level (Powerline, 2013). During this period, the government took efforts in setting up command / control centers to support a data-driven networked

model of urbanism (Townsend, 2013). Computing technologies were effectively utilised by public services in setting-up a network between a series of user driven essentials like Aadhar (personal information) and banking services; spatial data support systems (SDSS) and GIS (for fund allocation); dashboards to report critical field level information to the command centres (Vinoth Kumar, 2015). The spatial data support systems uses its infrastructure (SDI) to help small towns in urban regions identify hotspots for reducing time lapses in offering public services (Sridharan, 2015). Computing technologies have been utilised by international cities to procure data and prepare analytical reports for administration to ensure a sustainability of future resources (Bibri S E, 2018). The development of command centres and its cyberspace has brought-in a new digital environment, communicating between devices and users. Technology literatures in computing has observed the performance of innumerable tasks by these command centres in communicating information between devices and users (Haldorai et al. 2019). The four-layer structure in command centres and their design architecture captures data on different aspects for actions by authorities (Sarabeshwar P, 2020) This design architecture of command center is enlisted in the below table 2.

**Table 2.** Design Architecture of Command Control Centres (Sarabeshwar P, 2020)

Four Layers of Command Centres	Details of information available from these layers
Application and Devices Layer (Top)	Sub Layer 1: Collects information on audio, video, sound, sensing and crowdsourcing through devices in the secured network.
	Sub Layer 2: Sensors and edge-level devices collect information and make public announcements or actionable information available to citizens.
	Sub Layer 3: Back-end support services like call centers and messaging services supply information using devices and actuators.
Integration Layer (Second)	This layer aggregates the data, interacts with API in different urban centres for processing voluminous information. This layer brings together platforms and data through software development kits / Web services.
Platform and Analytics (Third)	This layer involves the platform in which the command center is created and different analytical approaches created within for handling information. For ex. Data analytics, AI, Video and Predictive Analytics.
Integrated Control Center (Fourth)	This layer involves the physical set-up of infrastructure involving technology like Computer Terminals, Simulation Rooms, and Server Rooms.

## 7 Digital Urbanism – linking social organs to computing technologies

Erstwhile measures on urbanization during 70s (for cities) had described the presence of sociological characteristics in cities (Goist, 1971). These descriptions were reiterated in the recent past when preparing redevelopment plans of cities explaining the compounded sociological challenges prevalent in the present society (Aijaz and Hoelscher, 2015). International cities had involved computing technologies to support city administration in resolving the sociological challenges. A detailed list of applications in computing technologies used for administering social organs in international cities are given in the below Table 3.

**Table 3.** Details of Applications in Computing Technologies Administering Social Organs

The inception of the computing technologies to support urban development evolves from use of pervasive models where-in, the physical aspects of the environment (or

social organs) is integrated into a technology system (or computing system) through different models (Haldorai et al. 2019). Category of technology services like Infrastructure-as-a-Service (IaaS), Software-as-a-Service (SaaS), and Platform-as-a-Service (PaaS) has helped city administration identify solutions to the problems of social organs (Vinoth Kumar, 2015). The progress of experimenting integration of computing technologies to social organs in these cities continued for more than two decades (research literatures quote references from 1994 till-date). Some of the notable progresses include (1) The concept of measuring landscapes using fractal geometry (Batty and Longley, 1994); (2) Behavioral aspects of society like positive intentions and attitude in using technology is measured with interactive models on adoption (Davis et al. 1989; Dabholkar, 1994; Dabholkar, 1996; Eastlick, 1996; Asop, 1999; Mosberg, 1999); (3) e-Commerce for society to procure products (Hoffman et al. 1999); (4) Technology platforms for social interactions between community groups (Ergazakis et al. 2004); (5) Knowledge platforms and learning systems for innovation (Komminos, 2006); (6) Assessment of risks in climate change, extraction of natural resources, floods, black-outs, pollution, inundation of solid wastes, and use of hazardous chemicals (Kitchin et al. 2007); (7) Absorbing public sentiments on different issues to educate society and de-risk society from its problems (Nohara et al. 2008; Cucchiara et al. 2011; Mora Mora et al. 2015); (8) Monitoring urban activities through network, layer models and informatics (Harrisons et al. 2010); (9) Protecting environment from use of obsolete technology products (Morton et al. 2012); (10) Creating virtual proto-types in visualization of landscapes using advanced networks (Morton et al. 2012); (11) Measuring availability of land and natural resources making it effective for use in society using computing technologies (Carli et al. 2013); (12) Different models of pervasive computing uses Urban IoT for finding solutions to social problems (Mitton et al. 2012; Kitchin, 2014); (13) Using different applications like 3E Housing and ZigBee (in housing) for measuring scale and capacity of computing technologies to handle large sets of data / information (Gubbi et al. 2013).

In this time-period, a conceptual model “Technology readiness indices (TRI)” measuring the propensity of a readiness in cities for adopting technology having four constructs was prepared covering service industries to test its delivery among customer, company (community for sociology) and environment (Parasuraman, 2000). The other literature studies on service industries, measured challenges in a four factor model vis-à-vis ideation plans, web-portals (for recording inquiries), continuous quality in delivery, and recovery of service failures (Bitner et al.2000; Parasuraman, 2000; Batty et al. 2012; Zaslavsky et al. 2013; Kumar, 2015). The revised model of TRI had enablers and inhibitors as measuring variables testing the overall change in state of mind among people who use technology resources (Parasuraman and Colby, 2015). This readiness to utilize technology helps administration of Indian cities replicate progressive strategies followed by international cities (McLaren and Agyeman, 2015).

For urban development and social organs, a progressive growth in research was visible with creation of a strong framework linking dimensions in urban development and computing technologies. The framework prepared by Hollands (2008; 2015) clearly differentiates the purpose of urbanization in cities underlining the strategies of branding them with people-orientation. Chourabi et al. 2012 in their research study on assessing



performances of cities brought-out an eight-dimensional framework consisting of Organization, Technology, Policy Context, People, Economy, Built infrastructure and Natural environment as critical factors for observance. This research study observed the use of AMR / AMI in power and energy department to assess consumption. The use of AMR / AMI combats the issues of climate change and emission norms maintaining a sustainable future. Batty et al. 2012 in their research on post-modern urbanization discusses the incubation of intelligent technology infrastructure for assessing social needs. A model framework for linking technology with modern urbanization tracking changes through mobile applications in city was also developed through the concept of Urban IoT (Zanella et al. 2014; Aijaz and Hoelscher, 2015).

Ruta et al. 2010 in their research on frequencies of technology, observed the sufficient need for possessing technical skills among users of technology – from low-end to high-end. Modern infrastructure are already set-up for the ambitious use of digital technology in India a decade ago (Gann et al. 2011). The progress observed in such infrastructure is larger than what was found to resolve social problems (Aggarwal et al. 2015; Vinoth Kumar, 2015; Talari et al. 2017). Bibri S E (2018) in their research on ensuring sustainability of information resources for urban centres, discuss the progress of different thematic approaches (Green ICT development, pervasive computing and deep learning) for decision making and countering actions on society to utilize environmental resources. Kennedy et al. 2018, too in his research on outsourcing urban e-governance as a state subject, re-emphasizes the need for making a conscious effort to promote use of ICT in urbanization plans.

Different schools of thought emerge in society for adopting technology during these years of experimentation. These schools of thought – restrictive, reflective, rationalistic, or pragmatic and critical has placed its views on technology vs. anti-technology sentiments (Kummitha et al. 2017). The larger negatives include (1) Unemployment / under-employment (Hollands, 2008), (2) State authored market fundamentalism (Harrisons and Donnelly, 2011; Watson, 2013; Washburn et al. 2010), (3) Addressing inequalities (Carvalho 2015; Hollands 2015; Caragliu et al. 2011; Leydesdorff and Deakin 2011; Mudler 2014), (4) Privatization of urban space (Hogan et al. 2012; Gibbs et al. 2013; Waart et al. 2015), (5) Vendor push (Kominos et al. 2013; Bunnell 2015; Moser 2015; Datta, 2015), (6) Closed planning (Datta, 2015), (7) Reduced social capital (Calzada and Cobo 2015), land grabbing (Datta, 2015), (8) Land grabbing (Datta, 2015), (9) Distant dream (Datta, 2015; Jazeel, 2015)

In addition, several critiques were placed on use of technology for cities. These include (a) Creating social inequality and income differences among people, their educational and employment standards (Graham 2002; Caragliu et al. 2011; Leydesdorff and Deakin 2011), (b) Use of technology for cities are considered to be increasingly speculative, risky and arcane (Kirkpatrick and Smith, 2011), (c) Focus on achieving sustainability than on reality as a strategic vision in enabling technology (Angelidou 2015; Kominos, Pallot, and Schffers 2013; Wolfram 2012), and (d) The arguments on achieving social order through adoption of ICT given the social realities (Helgason, 2002).

A common sentiment too prevailed in India where discussions on urban development were conducted in different forums with the idea of building advanced technology systems with challenges faced by administration (MoUD, GoI, 2015; 2018). Today, the

adoption of ICT and pervasive computing goes beyond these critiques and negativities to address social concerns of city administration. Recent literatures on engineering research reveal continuous efforts taken to link social organs to technology. In this approach, the following social organs were tested in engineering for linking them to computing technologies. They are (1) Water / Sewer treatment and Energy Management (Pampana et al. 2020), (2) Traffic and Transport congestions in roads (Singh and Srivastava, 2020), (3) Healthcare and Patient Management (Prabhu et al. 2020), (4) Housing and Security Administration (Govindaraj et al. 2020), (5) Restoring natural resources and environment (Rathore et al. 2016)

## **8 Benefits and Managerial implications of adopting computing technologies in social organs**

The international cities have utilised the pervasive computing systems for social organs largely as described in the previous picture, explaining how different social organs are linked to these computing technologies. This salient technology tools mentioned in the picture table helps the administration in taking decisions towards adopting these computing technologies for Indian cities. The social benefit in utilizing these computing techniques have been the improvements observed in quality of life as the authors Harrison et al. 2010, Washburn et al. 2010, Toppeta, 2010 describe them in their research papers on technology enabled cities. The two-factor TAM model evolved a decade ago, brought-in the interest of adopting technology measuring it with ease of use and satisfaction of the user (Venkatesh and Bala, 2008). Later, the readiness in innovation brought strategies to encourage effective utilization of data and its resources with emerging technology products like dashboards in society for cities (Rosenthal, 2010; Morton et al. 2012). This innovation continued in manufacturing to make advancements for identifying alternate use of raw material to make products. For example, the use of bagasse for peppre wood is a real-time illustration (Perera et al. 2014). Further, the sentiments and opinions of people in society on administering cities too, can be measured from the advancements in digital technology (Mora Mora et al. 2015). The efforts to create sustainability in optimizing future resources prospected the digital technology to measure the quantum of de-risking required for administration (Bibri S E, 2018).

For India, where the challenges listed in adoption of ICT and pervasive computing are absorbed from literature review, some of these challenges often point to the methods adopted in handling them (Aggarwal and Mohanty, 2015; Aijaz and Hoelscher, 2015; Vinoth Kumar, 2015; Bhattacharya et al. 2016). The reiterated need for a planned approach required in adopting technology, enlisted as a social skeptic leads the discussion to have an advanced approach in assessing the progress of linking technology to social organs in an Indian context (Ayon Datta, 2018). This need has encouraged us to analyse factors contributing to digital urbanism that can be measured for observing the degree of enablement, technology has made in administration of social organs for Indian cities. The related constructs and their references are provided in the below table 4.

**Table 4.** Proposed dimensions of Digital Urbanism in India

Proposed Dimensions of Digital Urbanism in India				
Dimensions	Possible options	Key elements	Representative Work	
Conceptual	City Theory	Topography, climate, history, economy, culture, space and time	Goist, 1971	
	Definitions	Social organs, Post-modernism, Information communication technology, Community, Urbanisation	Ajaz and Healscher, 2015 Hall et al. 2000 Washburn et al. 2010 Chourabie et al. 2012	
		Case Studies	Singapore city - National IT Plan, Intelligent Island: IT2000 report, National Information Infrastructure, Pactive city - Urban IoT	Mazhinan, 1999 Zanella et al. 2014
	Stakeholders	Swachh Bharat Mission (SBM), Atal Mission for Rural Urban Transformation (AMRUT), Heritage City Development and Augmentation Yojana (HRIDAY)	Ministry of Urban Development, Govt 2015 Gore M. et al. 2018	
	Experimental	Urbanism, creative industries (Brisbane, Australia), Future city (San Diego), Entrepreneurial city	Hollands et al. 2008	
	City Administration	Policy / Vision	Retrofitting, Redevelopment, Green and Brown field development	Ministry of Urban Development, Govt 2015, Ministry of Housing and Urban Affairs, Govt. 2018
Organs		Traffic, Transport, Road Network, Power / Energy, Housing, Environment, Water, Healthcare, Community, Security and Administration	Giffinger et al. 2007 Toppeta, 2010	
Institutions		ITIL, Aayog, TECOM Dubai, Hitachi, Siemens, CII	Bhattacharya et al. 2015	
Agglomeration		Movement of people, Excessive Population, Poverty, Unemployment	Ratti et al. 2006 Girardin et al. 2008	
Infrastructure	Types	RFID, NFC, SCADA, Sensors, Wifi, Wireless Sensor Nodes (WSN), Fibre Optic, Network Effects, Map Layering	Aggarwal et al. 2015 Harrison et al. 2010 Vinoth Kumar, 2015 Ling, 2015 Mazhinan, 1999 Ruta et al. 2010 Taheri et al. 2017 Zuhadar et al. 2017	
		Levels	Lower end technologies - RFIDs, Sensors, Wireless Sensor Nodes, Wifi High end technologies - SCADA, Cloud, Space Time Mapping, Map layering, Machine Learning Methods	Washburn et al. 2010 Gubbi et al. 2013
	Application	Electronic Road Pricing (ERP), 3E Housing, ZigBee, Transport IoT, Internet of Energy (IoE)	Carlie et al. 2013 Dodge et al. 2007 Kitchin, 2014	
	Pervasive Computing	In-vehicle sensors, cloud computing, software abstraction layers	Milton et al. 2012 Kitchin, 2014	
	Service Encounter	Categories	Area-based development, Part-based development, Infrastructure as a Service, Platform as a Service, Software as a Service	Batty et al. 2012 Vinoth Kumar, 2015
		Customer Interface	Self-service technology, Customer Web Portal, Sensor Data Consumer layer, Expanded Conceptualization	Parasuraman, 2000 Vinoth Kumar, 2015
Service Delivery		Sensing as Delivery, Sensor Owner Layer, Sensor Publisher Layer	Zaslavsky et al. 2013 Perera et al. 2014	
Service Quality		Pyramid model, Technical Quality, Functional Quality, Customer loyalty	Bitner et al. 2000 Parasuraman, A. 2000	
Service Recovery		Interactive, Internal and External Marketing, Customer Feedback portal, Critical Problems, Feasibility	Batty et al. 2012 Perera et al. 2014, Parasuraman, A. 2000.	
Continuum of Service		Storage, archiving, processing of data, SFPAk, Square kilometer array (SKA), Customization, Spontaneous delivery	Parasuraman, A. 2000 Zaslavsky et al. 2013	
Disruption	Innovativeness	New and Emerging Technologies, Peer learning	Bitner et al. 2000 Parasuraman, A. 2000	
	Competitiveness	Technology Readiness, Technology paradoxes, Drivers, Inhibitors	Bitner et al. 2000 Parasuraman, A. 2000	
	Uniqueness	Stability, Loyalty Chain	Bitner et al. 2000 Parasuraman, A. 2000	
	Relevance	Competitive leverage, Redemption value	Bitner et al. 2000 Parasuraman, A. 2000	
Physis	Climate Change	Chloro Fluoro Carbons, Carbon Emission, Pollution	Kyziazis et al. 2013 Bathore et al. 2016	
	Deluge Protection	Fire, Flooding, Inundation of solid and liquid waste	Bitner et al. 2000 Dodge et al. 2007	
Sustainability	Strategy	Green ICT, Thematic Analysis, Efficiency of Energy systems	Perera et al. 2014 Bibri et al. 2018	
	Mechanism	Inductive analytic approach, precise applications, storing, integration, processing, and	Perera et al. 2014 Bibri et al. 2018	
Data Utilisation		Big Data, Pattern recognition, Optimizing Resource Utilization, Operational functioning, Mitigate Environmental risks.	Perera et al. 2014 Bibri et al. 2018	
	Obsolescence	Technological changes, Electronic Waste, Recycling of Waste, Virtual City Models	Rosenzthal, 2010 Morton et al. 2012	
Measurement	Spatial	Mark-up, Availability of Land, natural resources, global positioning	Harrison et al. 2010 Cali et al. 2013	
	Traceability	Intruder Detection, Sophisticated filtering techniques, Transferable belief model	Cucchiara et al. 2011 Mora Mora et al. 2015	
Social Interaction / Fear		Human Capital Interaction (HCI), Twitter.com, Orkut.com,	Hohara et al. 2008 Cucchiara et al. 2011	

## 9 Limitations and future scope of the study

The present paper is only a literature review of all relevant studies conducted in adoption of ICT and pervasive computing across Indian and International cities. The aspects covered in this paper limits itself only bringing out use of ICT and pervasive computing technologies in social organs of cities where such technologies are either implemented or under-implementation stage evidenced in literature. The study does not include other administrative aspects such as investments and financial outlay undertaken for utilising such technologies. The timelines chosen for the literature review is from post-period of liberalization (in India) to the current period during which continuous technological changes are observed across international cities. The research literatures cited from engineering studies are only to enlist the technical use of the concept and not to elucidate the mechanism involved in its use for social organs. This paper does not make comparative studies on approaches undertaken by Indian and international cities in lieu of adopting computing technologies for their social organs. The

reviews given in this paper are a collation of social actions taken by international cities for adopting computing technologies and are not prescriptive to other nations or cities.

The future scope of the present study attempts to understand the factors contributing to digital urbanism in detail for India absorbed from the above table. Hence, the literature pertaining to these factors have been presented lucidly in this paper. A detailed study on each factor is presently under progress for the topic involving a qualitative analysis to aggregate critical sub-factors contributing to the concept.

## 10 Conclusion

The concept of digital urbanism was described in this article with three important aspects - ICT, pervasive computing and social organs respectively. These aspects were studied in this article providing several relevant literature references from India and international cities. The article also made available relevant literature and concepts covering the research questions mentioned. The summary of this literature elucidates the involvement of computing technologies (from low to high-end) in supporting social organs for administering international cities. Studies on Indian context, had some recent references from technical literature implying the progressive approach adopted by society to transform city administration. News from the Indian digital media had recently claimed that more than 67 percent of the urban development projects are either partially being implemented or at the desk-level with no forward movement in paper work (The Hindu Business Line, December 16, 2018). This scenario encourages us to study the critical factors contributing to adoption of technology. The literatures referred in this paper and the factors observed in the above table would be studied further not only for understanding the use of computing technologies in India but also how the social organs of city administration are linked to these computing technologies and their social benefits to cities.

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