A Study on Measuring the Index of Technologies (Smart and Conventional)

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Humans have been developing technologies that make living easier and open unimaginable horizons. Scholars have been combining technologies to innovate and evolve newer concepts. The evolution of smart devices has led to the concept of creating smart cities. Several nations intend to develop a smart technology ecosystem for ease of governance, economic growth, and comfort of their citizens. The not-so-nascent concept of a smart city requires a scale to measure the levels of technology in the system. The study aims to propose a framework or model to measure the technology index available in areas of interest. There are several instruments available, but most of them require specialised training to use. The proposed tool is a simple device that can be used with basic knowledge of the concept and handling of data. The tool aims to facilitate technology assessment and planning acquisition of deficient or new technologies. While doing so, the study examines the concepts of human settlements, technologies, and the evolution of smart technology and briefly touches upon the concept of the administrative divisions of a nation, with particular emphasis on India. The article outlines a model framework for measuring the technology index

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based on the levels of administrative divisions amalgamated with the hierarchy of settlements. The article concludes by describing the results of a test case scenario applied to the proposed indexing technologies model.

Keywords: *Technology, Smart Technology, Smart Device, Smart Organisation, Smart City, Technology Indexing, Concept of Settlement, Administrative Division, Smart Settlement*

Introduction

Since the 1990s, communication and computing technologies have disrupted human lifestyles, bringing them ease of living while also making them more dependent on digital technological solutions. Due to the histrionic stance of early adopters of technology, there is an exponential surge in demand for new technology.[1] This demand has triggered a scramble amongst commercial start-up entities for a competitive edge, sparking scintillations of technological innovation for fresh methods to enhance convenient living.

So what has happened in the last few decades? The 1990s saw a digital computing device, the 'Personal Computer', entering everyday life of common people. The amazing technology brought a rush to learn software solution development for managing day-to-day chores and entertainment. Computer technology leaped to higher echelons with the world getting connected over the World Wide Web (WWW). WWW was not the end because the artificial intelligence concepts also materialised in parallel, disrupting how people did things. Inanimate devices were brought to life and evolved into intelligent devices with perceptible decision-making capabilities.

Globally, governments noted the evolution of smartness in technologies and earmarked resources with an intent to adopt environment-friendly contemporary smart technologies to assist in optimising human efforts and enhance the overall quality of life. Various governments and international alliances have set up organisations with dedicated funding for creating smart cities as time-based projects. The success of such projects relies on the practical implementation of theoretical concepts presented by scholars and study literature. While approving a project, an assessment of areas requiring lesser effort to graduate as a smart city is conducted. Literature does not show any readymade instrument that can readily establish the levels of smart technologies without special project efforts. The study attempts to understand the basic concepts of smart cities and present a model to assess the degree of technology prevalent in an area of interest.

Technology

Before we come to the main topic, let us first understand some basic definitions and meanings. To begin with, let us understand what technology is and how it affects us. In the book *Technology and Creativity,* Subrata Dasgupta asserts that humans and their hominid predecessors have been conceiving, shaping, and using artefacts from as far back as the early Stone Ages. We now call this activity technology. Dasgupta describes technology as a cognitive activity involving the use of knowledge and the faculties of reasoning, remembering, and understanding, as do all cognitive processes. Dasgupta opines that because of the ubiquity of technologies across time and space, the histories of cultures, societies, economies, and everyday life are inextricably entwined with the growth and evolution of technology.[2]

In *Management of Technology,* Tarek Khalil defines technology as all the knowledge, products, processes, tools, methods, and systems employed in the creation of goods and services. In simple terms, technology is the way we do things.[3]

Digital technologies denote a wide range of technologies, tools, services, and applications using various types of hardware and software.[4] In *Traditional Versus Digital Assessment Methods: Faculty Development,* Devran and Alev describe digital technologies as the digital tools, systems, devices and resources that generate, store or process data such as social media, online games, multimedia and mobile phones.[5]

Smart Technology

Another important term is '*Smart Technology*'. Smart technologies encompass mechanical systems and systems equipped with sensors, actuators, and pre-programmed controllers, which allow a structure to adapt to unpredictable external loading conditions.[6] In *Smart Houses and Smart Technology: Overview and Implications Independent Living*, Keith Storey explains that smart technology involves a variety of systems such as computers, cell phone, personal digital assistant (PDA), voice activation system, touchpad controllers, and/or other devices such as remote control that can interact with and manipulate the devices on a network.[7] Smart technology is grouped into three areas: Internet-of-Things (IoT) devices, Smart Connected Devices, and Unconnected Smart Devices. Examples of Smart Connected devices are smart security cameras, smart bulbs, and smartphones. For Unconnected Smart Devices, 'smart' simply refers to the fact that these devices can be programmed to perform certain tasks, like a coffeemaker starting to brew at a given time.[8]

Why should we call technology or device smart? As the name suggests, a smart device is an electronic gadget that can connect, share and interact with its user and other smart devices, or do scheduled tasks. Small, smart devices typically have the computing power of a few gigabytes,[9] but why call them smart? The term *SMART* is an acronym for Self-Monitoring Analysis and Reporting Technology. SMART is a fault detection, monitoring, and maintenance technology that computers use to provide advanced notification for hard disk drive (HDD) failures. Over the period, the term SMART has morphed beyond the original concept into its actual meaning of clever or intelligent to describe any device capable of connecting with internet networks and thus connecting with other devices or remote databases.[10] To summarise, smartness in the technology context implies the automatic computing principle like self-configuration, self-healing, self-protection, and self-optimisation.[11]

Let's examine the origin of the thought that a device can be clever or intelligent. The genesis of intelligent systems may be attributed to the 'Automata Theory' presented in *A Logical Calculus Of The Ideas Immanent In Nervous Activity* by Warren and Walter Pitts, who were the first to present a description of finite automata machine aiming to model the human thought process, whether in the brain or a computer (artificial neurons).[12] Many scholars were at work and in *Computing Machinery and Intelligence*, Alan Turing began his article with a question "Can machines think?" and attempted to develop a logic through a test which he called as "Imitation Game". The test, now popularly known as the "Turing Test", checks if the machine can exhibit intelligent behaviour similar to human intelligence.[13] The Automata Theory was generalised into much more powerful machines by computer scientists G.H. Mealy[14] and E.F. Moore[15] through infinite-state machines, invented independently. In recognition of their work, the machines were named 'Mealy machine' and 'Moore Machine'. Allen Newell and Herbert A. Simon invented the "Logic Theory Machine". It was the first complex information processing system to discover proofs for mathematical theorems in symbolic logic.[16] The buzz term "Artificial Intelligence" was coined in 1955 by John McCarthy in a proposal for a Dartmouth summer research project.[17] Ever since, the concept gained importance and software such as ELIZA, humanoid robot WABOT-1, Expert Systems, XCON, IBM Deep Blue, Google Now, Eugene Gootsman, Project Debater, and others captured the attention of scholars, business people, governments, as well as laymen users.

Until now we have understood the terms technology, SMART and smart technology. The next relevant term in the study of smart city is 'city'. To understand what 'city' means, let's examine the origin of the concept of settlements.

Concept of Settlements

The basic unit element of a society is an individual.[18] The human settlement begins with a single individual and grows in size. Why does the size of the settlement grow? It is because humans have a natural urge to live an associated life with others for survival and happy life. This inherent trait causes to develop humans to form a small group or society or family. A group of families form a settlement.[19] As the population of a settlement grows, a social or settlement hierarchy is formed. Brian Berry was the first to introduce the hierarchy system for urban societies through his work *Cities as systems within systems of cities*.[20] Berry categorised the human settlements based on the '*size*'. The human settlements are classified as rural and urban. On the rural side, the settlements are classified as '*Isolated Dwellings'* (few people), '*Hamlet'* (less than 100 people), and '*Village'* (100–1,000 people). On the urban front, the settlements include 'Town' (1,000–20,000 people), '*Large Town*' (20,000–1,00,000 people), '*City'* (1,00,000–3,00,000 people), '*Large City*' (3,00,000–1 million people), '*Metropolis'* (1–3 million people), '*Conurbation'* (3–10 million people) and '*Megalopolis'* has a population of more than 10 million people.[21] Thus, a '*city*' is only a term from a set of definitions to identify a large human settlement in urban areas.

We may assert that every city has groups which maybe families, societies, business firms, and likewise. All groups need leadership. Every sovereign State or country has a government (leadership) that guides it, facilitates livelihood and life, guarantees security, and ensures freedom. This aim is chiefly achieved by decentralisation or delegation of responsibilities through division of jurisdiction. Let us briefly examine the broad concept of delegation of responsibilities.

Concept of Administrative Divisions

The concept of settlements describes only how the human population is categorised. The concept of Administrative Divisions defines the governmental bodies responsible for the management of affairs. A nation is divided into administrative regions or areas. An administrative division, subnational entity, geopolitical division, or country subdivision is a portion of a country or other political division, established for the purpose of government.[22] According to Soja, administrative areas are spatial units organised in hierarchical order where each level has specific functions.[23] Several countries have recast their administrative map under varying conditions.[24]

For this study, the administrative division of India is considered. During the British period, territorial changes were governed mainly by imperial interests. The British divided India into '*British Provinces*', where the States were governed directly by British Government, and '*Princely States*', wherein the control rested with native Princes but was subject to British Crown Paramountcy. On enforcement of the Constitution on 26 January 1950, the nation was categorised into four parts—Part A (Sates that were under British Governor's Provinces), Part B (States with their legislature), Part C (States under British Chief Commissioner and a few Princely States) and Part D (Andaman and Nicobar Islands). Using the '*Report of the States Reorganisation Commission*' constituted in 1955 as a foundation, the four categories were abolished. On 01 November 1965, India re-casted its administrative areas into States and Union Territories.[25] Presently, India follows a Federal Political system, wherein the political power is vested with the Union (Central) and State Governments which are further decentralised to Panchayati Raj (Rural) and Municipal (Urban) Governments. For administrative convenience, the nation was divided into six tiers of hierarchy—Indian Union, State, Division, District, Sub-district, and Block. The components of each of the six tiers are structured in a hierarchical manner as shown in Figure 1.

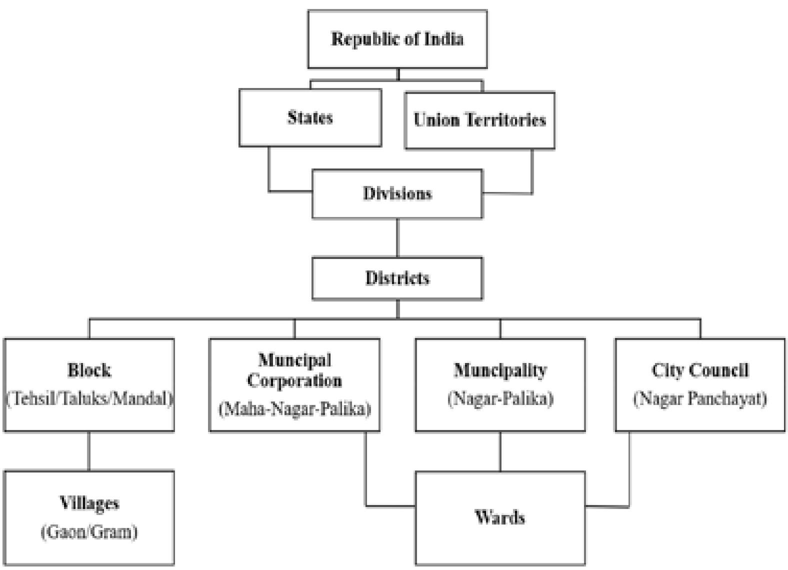

Figure 1 Components of India's Administrative Divisions
Source: Constitution of India, Report of the States Reorganisation Commission

The government's administrative divisions ensure constitutional freedom and government services to the private lives and livelihood of the citizens. Such division also ensures effective and efficient governance and aims to bring democracy to every doorstep. Policies issued by administrative elements also provide a legal framework and methodology for non-governmental organisations such as business companies, gated society governing boards, and others to draft by-laws conforming to the articles of the Constitution. These by-laws and charters permit ease of business and facilitate management of private affairs in a uniform way within the ambit of laws of the land.

Concept of Smart City

Yet another critical aspect of the study is examining the smart city concept. The smart city is primarily a concept without a clear and consistent definition among practitioners and academia.[26] The label "smart city" can be perceived as an indistinctive concept and is not always used consistently.[27] There is no universally accepted definition of a Smart City. It means different things to different people. The conceptualisation of a Smart City, therefore, varies from city to city and country to country, depending on the level of development, willingness to change and reform, resources and aspirations of the city residents.[28] Several researchers, through respective studies, have presented their version of the definition of a smart city. A smart city, according to Hall, is one that integrates and monitors the State of all of its vital infrastructures, including roads, bridges, tunnels, rail/subways, airports, seaports, communications, water, power, even major buildings, can better optimise its resources, plan its preventive maintenance activities, and monitor security aspects while maximising services to its citizens; which in long term will have systems and structures that will monitor their own conditions and carry out self-repair as needed.[29] Giffinger et al. use the term smart city to describe various aspects of a city which range from Smart City as an IT-district to a Smart City regarding the education (or smartness) of its inhabitants.[30] Harrison and his fellow researchers claim that a smarter city connects the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city; and assert that it continues the long-standing practice of improving the operational efficiency and quality of life of a city by building on advances in IT.[31] Nam and Pardo ruminate that a smarter city infuses information into its physical infrastructure to improve conveniences, facilitate mobility, add efficiencies, conserve energy, improve the quality of air and water, identify problems, and fix them quickly, recover rapidly from disasters, collect data to make better decisions, deploy resources effectively, and share data to enable collaboration across entities and domain.[32] Organisation for Economic Co-operation and Development (OECD) defines smart cities as "initiatives or approaches that effectively leverage digitalisation to boost citizen well-being and deliver more efficient, sustainable and inclusive urban services and environments as part of a collaborative, multi-stakeholder process".[33]

Whatever may be the definitions and descriptions according to the academics, it is asserted that the concept of "smart cities" mainly focuses on enhancing community habitat through contemporary technology as artefacts, mainly information and communication technologies.

Characteristics of a Smart City

Akin to the definition of a smart city, there is no explicit and consistent enumeration of characteristics of a smart city. Scholars worldwide have selected certain broad aspects of a community as judged correctly to gauge the levels of technology and measure smartness. To cite a few examples, Giffinger et al. analysed smart city performance by characterising the economy, people, governance, mobility, environment, and living.[34] Hollands has identified the utilisation of networked infrastructures to improve economic and political efficiency and enable social, cultural, and urban development; infrastructures including ICT, business-led urban development, and social and environmental sustainability as three fundamental elements characterising a Smart City.[35] An executive report sponsored by IBM cogitate transport, government services and education, public safety and health profoundly influences the quality of life and the attractiveness of a city.[36] China's smart-eco landscape vision is characterised by security, construction, liveability, administration and service, industry and economy, information and communication network, and convenient public services. India launched Smart Cities Mission on 25 June 2015 to promote cities that provide core infrastructure, clean and sustainable environment, and give a decent quality of life to their citizens through the application of 'smart solutions'.[37] The guidelines issued by Govt of India evaluates potential smart cities by applying scores on criteria of Existing Service Levels, Institutional Systems/ Capacities, Self-Financing, and Past track record and reforms.[38]

Importance of the Concept of a Smart City

A need to study the concept of a smart city has emerged because smart devices and smart technologies touch all the nooks of life and nature. The term 'life' refers to all living things, including plants, animals, and people. The term 'nature' concerns natural elements such as water, soil, and air.

Technology is abundant, and new technologies are invented to meet challenges or needs as they occur. The rate at which new technologies are adopted is growing exponentially. This trend is evident from a study on 'Technology Adoption' by Ritchie and Roser, in which they visualised data on diffusion and adoption rates of a range of technologies in the United States, measured as the percentage of US households with access or adoption over time.[39]

'Technology Diffusion' is a technical term which refers to the technology people adopt. Everett M. Rogers first introduced the concept of Diffusion of Innovation (DOI) Theory in 1962. As per Rogers, Diffusion is the process by which an innovation is communicated through specific channels over time among the members of a social system.[40] In simple words, technology diffusion is a process by which people in a society adopt an innovation.

Technologies have positive and negative impact on life as well as nature. The negative impact can be intentional but is mostly inadvertent. The negative impact of polyethylene plastic bags is well known. Therefore there is a need for control over the way technology is introduced. A Technology Control such as a Policy or Procedure, must be applied on abundantly available technology that reasonably ensures that the technology is used for the purpose intended within the ambit of applicable laws and regulations. Such controls will prevent technology misuse, minimise health hazard, and provide social and environment safety.

The study on smart city or smart settlement facilitates consolidating the technologies existing and needed in an area of interest, analysing social and environmental impact, and the benefits that would accrue. Such study also assists in identifying the technologies that are obsolete and require upgrade or replacement. Scholars have observed that the need for focus on smart cities is due to widespread use of smart technologies, their ubiquitous use in everyday life, and the insufficient level of their reflection both as a phenomenon and as a concept.[41]

The study on smart city is gaining relevance and momentum as countries worldwide adopt the concept with their approaches to achieving social and governance goals. The 'Smart Sarajevo Initiative' is a 15-month project launched in December 2018 and implemented by UNDP in partnership with the City of Sarajevo, the Municipality of Stari Grad and Canton Sarajevo, intending to catalyse interest in innovative ideas contributing to a smarter and more liveable city.[42] In 2019, OECD, which has more than 35 member nations, joined the smart city campaign through its first Roundtable on Smart Cities and Inclusive Growth, intending to redefine the concept of smart cities around the contribution of digital innovation to better lives for all people; measure how smart cities perform and ultimately deliver well-being outcomes for citizens; and guide local and national governments in their efforts to reshape city governance, business models and stakeholder engagement.[43] The smart city mission of India aims to drive economic growth and improve quality of life through comprehensive work on social, economic, physical, and institutional pillars of the city.[44]

Smart City vs Smart Settlement

Human settlements have been categorised based on population. The way of earning a livelihood in rural areas is generally noted to be relying on farming and handicrafts. In urban lifestyles, the earnings are generally modernised methods such as street work, self-employed business, organised sector working, and others. When it comes to application of smart technology, the focus currently is on cities only. It is primarily because, during the onset of the concept, Information and Communications Technology (ICT) was more advent in urban settlements than in rural areas. Thus, the buzzword is a 'smart city'. Technology has no barriers and is touching the lives of rural settlements too. The government and non-governmental organisations have been using ICT to develop rural areas[45] as well. The rural ICT applications aim to present the services to citizens at their village access stepladder.[46]

Information and communication technologies (ICT) play an essential role in addressing the growing demand for agricultural products and offer opportunities for producers to improve the livelihoods of rural citizens.[47] Every nation must examine the potential ICT for rural applications to empower rural populations for capacity building.

Therefore, it would be more appropriate to progress the study by using the term '*Smart Settlement*' instead of a smart city because smart settlement encompasses all settlements ranging from a single person to a whole nation.

Smart Settlement Index Tool

Need for Smart Settlement Index Tool

This article proposes a measurement tool to evaluate the smart index of technologies adopted in an area of interest. But what is the need for such a tool? To stay abreast with technological advances, the growth of industries is essential. The industries are attracted by the conducive macro environment that is created and updated regularly by the Central and State governments and private communities or bodies. A favourable business environment attracts investors because it is essential to create opportunities and incentives for firms to invest productively, generate jobs, and grow.[48] Investors bring technology along, and technology facilitates the evolution of smart cities. The quantitative data of the indicators, processed with statistical tools, permits to draw decisive conclusions about technology levels prevalent in the settlement. Lower technology indexes suggest a business opportunity niche.

The tools proposed by academics and scientists are specialised tools that require prior training in the subject and evaluation methodologies. Further, the assessment based on such tools is a long-drawn, tedious and complex process. Moreover, the literature shows that criteria for assessing smart cities are gauged at national levels with little focus on measuring tools and technology at the fundamental unit levels.

The methodology to capture data for the assessment of smart city is cost-intensive. The cost factor is exacerbated by the need to create data collection processes, infrastructure, and other resources. Literature ignores these important aspects and recommends autonomous assessment projects.

Thus, there is a need for a tool that is simple, easy-to-use, and compatible with data across the spectrum.

So, can we design a technology index measurement tool or devise a method that could simplify the approach for assessing the smart (technology) levels? To address this question, we will need to understand who uses technology, where the technology comes from, who controls the movement of technology, and what is the relationship amongst these elements?

Technology Controllers

We already have briefly discussed above that technology control is a policy or procedure to ensure technology is used within the ambit of applicable laws and regulations. Evidently, technology controls are formulated and enforced by government and its administrative divisions. For private bodies, the head of the family, managing committees, and so on, enforce technology controls.

Transfer of Technology

Let us look at who uses the technology and where the technology comes from. It is understood at the beginning of the study that technology is all the knowledge, products, processes, tools, methods, and systems employed in the creation of goods and services. The process of acquiring technology, conventional or smart, is known as *Technology Transfer*. Technology transfer is a process by which various elements of technology are transferred from one source (owner of the technology) to the receiver (beneficiary of the technology) to meet the needs of business or society.[49] Khalil explains that the source of the technology transfer can be an *Individual, Organisation, or Nation*. The recipient in the technology transfer process would be akin to the source. Thus, a user of the technology can be an individual, an organisation, or a nation who may acquire the technology from an individual, organisations, or a nation.

The three types of users and sources when placed in a hierarchical pattern represent a relationship.

Hierarchy of Smart Technology Users

As argued before, a person in a society is the unit element who adopts and uses technology. Therefore, the basic level of smart technology can be named '*Individual*'. Individuals may acquire technology for personal needs, wants, and desires, or to deliver a service or produce value-added goods or services. The next level is formed as '*Region*' comprising of individuals using technology at a site. A '*Region*' encompasses families, residential societies, businesses, enterprises, and government organisations. The technologies acquired are intended for use by or for a group of individuals in the region. The apex level in the hierarchy is the '*Nation*'. At the national level, technology is acquired to fulfil political promises according to the Constitution or to realise national interests according to the doctrines that define the country's agenda. Figure 2 depicts this hierarchy.

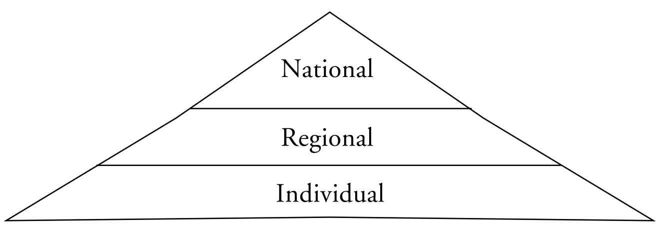

Figure 2: Hierarchy of smart technology adoption

The relationship between elements of hierarchy model provides an abstract to develop a management framework to measure the degree of technology diffusion or its deficiency in addition to what more could be adopted at each level. However, this abstract does not include technology controllers. In order to do so, let us attempt to merge the administrative divisions and settlements vis-à-vis the hierarchy of technology users. The chart in Figure 3 shows the overlaid hierarchy of technology use by groups as per the administrative divisions of the government and private groups. The chart abstracts unit entities at each level from bottom to top. The chart at the bottom of the hierarchy depicts the various types of settlements. It may be observed that the individuals acquiring technologies for personal satisfaction are the ones who come together to form large groups and hence are not shown separately in the chart. A node at each level in the model indicates a governing body that has an opportunity to monitor the technology status at its level, peer groups, and subordinate entities. For example, a family can plan developing a Smart Home. A smart home or house broadly refers to any technology that automates a home-based activity.[50] Smart houses may be thought of as networks between systems controlled by smart technological devices that are then controlled by an individual or individuals.[51] Government offices or business companies have technologies for capacity building and for refining core competency.

Likewise, private gated society managers can record the levels of technologies held and plan for improvement in services by adopting newer technologies. Higher levels at State and Centre can compare the current state of technology available at lower levels and plan infrastructure creations that drive economic growth and improve efficiency and quality of life.

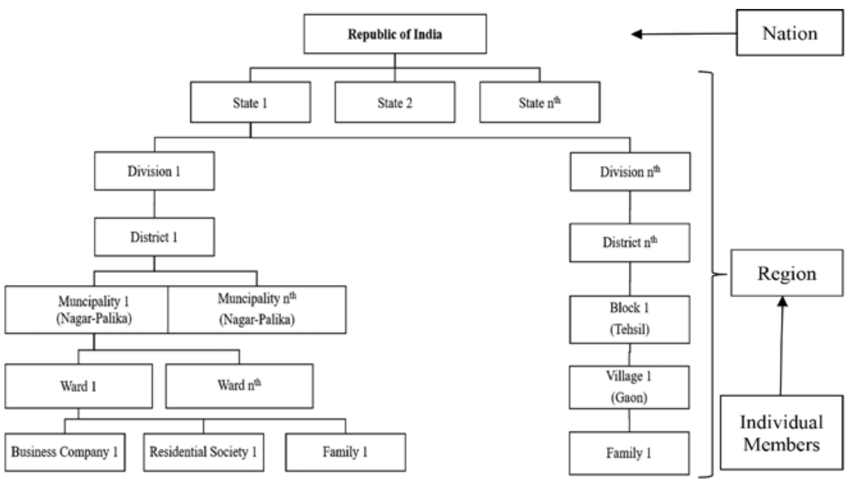

Figure 3 Hierarchical mapping of settlements and administrative divisions

Salient Features of the Smart Index Device

The smart index device is a set of inter-related data tables containing simple enumeration of settlements, technologies and their associated properties operated upon by arithmetic. To create a smart index device, following broad salient features or set of rules must be applied:

- The device must accept master details of settlements and permit mapping the levels at which the settlement is present.
- The device must allow modifying the master details of the settlement without affecting the data related to that settlement.
- The device must accept master details of all technologies, irrespective of whether the technology is smart.
- The device must allow operations to add and update the master list of technologies.
- The identity of each technology must be unique.
- The device must identify the level at which the technology is adopted hierarchically.
- If a technology is already included at a certain level, the device should automatically replicate at other levels of the hierarchy.
- The device should accommodate variations in the list of technologies of peers at a given level.
- The device must permit enumerating the unique attributes of each technology.
- The device must allow operations to add and update the unique attributes of each technology without affecting the data related to that technology.
- The tool must accept a percentage formula for each technology by using a few or all attributes created for that technology.
- The device must permit updating the percentage calculation formula vis-à-vis benchmark targets.
- The device technology progress percentage and/or index must consolidate and contribute towards progress percentage and/or index at higher levels if such technologies are created at the higher levels of the hierarchy.
- Technology may be omitted from the assessment on achieving the target of one hundred per cent and activated later in case of a need to monitor or measure.
- The device may include a property to assign weightage to each technology to evaluate the smart index.

What should the scale measure?

The level of a technology present in an area is the total quantity of that technology that people or a group of people have adopted or are using. The smart index tool must take input values on the quantity of a technology linked to an identified entity and aggregate the values based on a target area and level at which analysis is intended. Thereafter, the aggregate value can be manipulated to display the data as desired and inferences drawn for appropriate use or decision-making. Thus, the scale should measure the value of a technology prevalent in an area of study.

Identifying a technology for indexing

To assess the degree of technology used by the population or a settlement, it is first essential to identify the technologies prevalent in that settlement. The first step is to just list all the technologies that are discernible in the target area and assess its significance for effective analysis. The names of the technologies that are irrelevant and insignificant can be ignored from assessment. Thereafter, attempt be made to identify such technologies that can be upgraded.

A few examples of technologies that an individual uses could be smartphones, wearable devices, health status sensors, and other devices. Similarly, smart technologies are available for common use by an organisation, which may be as small as two people living together as a family, gated communities, societies, commercial or non-profit organisations, and other groups. A few examples to cite would be smart TV, smart CCTV network, smart face recognition, and identification devices. Technologies are also acquired for governance at higher levels, such as district, state, and central/federal governments, to achieve political, economic, and social objectives. For example, to provide essential services to the general populace, governmental bodies may use SCADA (supervisory control and data acquisition) systems to manage water, electricity, sewage systems, and such centrally manageable systems, smart road traffic management systems, and other similar systems.

The second stage of identifying a technology for measurement of its index is to identify the properties unique to each technology that would be used in evaluating the index. Identifying a technology as conventional or smart permits separate listing and measurement of indices. Each technology has characteristics that enable arithmetic operations. For example, the properties of sewage treatment plant could include its total capacity against the population demand in an area, the capacity of solar power plant is related to contracted power load for a facility or area, total number of street lights of a society is related to quantity of LED light units or motion sensors or smart timer switches installed, and so on.

Another key factor while identifying technologies is understanding the limit of indices achievable and benchmarking it as maximum achieved. It is so because there are some technologies in which hundred percent index can be achieved but for some it would be limited to lesser values due to varying reasons. To explain this, let us consider the example of rooftop solar power plants. India has taken up a mission for commissioning solar parks and rooftop plants through its renewable energy mission. The State governments lay down permissible limits for installation of solar plants capacity because the State needs to sustain operations of power distribution companies. Thus, if a consumer has a State government power supply connection of say 10kW, the rooftop solar power plant capacity may be restricted to about 80 per cent only. So, in that area, the achievement of 80 per cent solar power plant must be accepted as 100 per cent.

Estimated benefits of the proposed tool

It cannot be denied that technology is essential to create a smart settlement, and technology may be conventional or smart. The proposed system permits developing a list of technologies and assists in identifying if they are in vogue, obsolete, or are on the verge of replacement. The tool will enable assessing the technologies available at a particular location or with an individual.

An important question is whether the availability of a technology alone is sufficient to measure it quantitatively. For a settlement to be measured for smart technology, it is also essential to identify the technologies that could be upgraded to smart technology, or the settlement should be capable of inducting a smart technology directly. For example, consider a human settlement where all households have water sources, say, shallow-well or bore-well. Thus, an attempt to introduce a central smart SCADA system for water supply is not an appropriate technology to measure. It would therefore be more prudent to assess the availability of water to the households against the total number of households in that settlement. This measure would change when the total number of households increases or decreases. The proposed method provides an assessment of technologies present for deciding on a possible upgrade or replacement.

The list of technologies captured on the tool, when shared across peers or other bands of governance spectrum, facilitates ease in understanding the possible technologies that can be used for improving social well-being. Lateral comparison of technologies from higher perspective of administration provides an insight of the technology lacking in the zones, thereby indicating the possible technology gap. The term "technology gap" refers to the difference between the type of technology that is currently available and the one which is expected. Therefore, the model is estimated to provide a mechanism for technology assessment and set up a road map for acquiring technology to achieve desired levels of technology index.

In its smart city mission, India has identified 100 cities through a selection process to shortlist potential cities based on criteria on a grading instrument to assess the levels of technologies available.[52] To add more cities, a fresh assessment would require collection of data of potential cities. The proposed tool may become a ready reckoner on the status of technology index for various levels and for seeking inputs from the selected few cities.

On the proposed technology index tool, consolidation of technology diffusion at unit levels contributes to higher grading at superior levels. It means that the level of technology acquired at the individual level produces higher index scores at the regional level, and higher regional-level indexes help in gaining higher average smart indices at the national level. Therefore, the scale would capture and measure advances in technology already in use at the individual, regional and national levels, thereby, minimising the effort and automating the index measurement process. A trend line would become visible by adding an attribute to the data.

For administrators, managers and service providers, action of acquiring and commissioning of technology is incomplete without measuring the serviceability status. It is also essential to monitor the serviceability status of the technologies. The measuring device would assist in capturing the serviceability status, usage, downtime, maintenance cost, and other such data. The tool may be configured to trigger alert messages and notifications, making it a versatile technology.

The output of the measurement device is data visualisation. The analysis tool visualises the evaluated data with a graphical representation of the percentage achieved and the value generated from the smart index. Such graphical representation is useful for quick analysis and informed decision-making on planning technology management.

The model's simplicity provides easy accessibility and bears minimal or no cost. The construction of tool does not require any specialised training and basic computer handling knowledge is adequate.

Smart technology tool construction

A model analysis tool was developed using MS Excel 2016 to validate the concept proposed in the article. Each worksheet of the workbook hosts data for a specific purpose. The first worksheet is designed to contain data related to various technologies identified for measuring the index, attributes of technology for arithmetic, benchmark target percentage, formula using the attributes for measuring percentage achieved and weightage for evaluating index. Table 1 depicts worksheet1 of the model tool without any emphasis on technology being conventional or smart with very basic attributes.

Table 1 List of technologies and their attributes

Technology	Attributes	Formula (% Achieved)	Benchmark %	Weightage
1	2	3	4	5
Solar Power Plant	Contracted Load (In KW), Solar Plant Capacity (In KWp)	= Plant Capacity/Contracted Load * 100	60	15
SCADA Water Supply	Total Number Pump Houses, Number Pump Houses With SCADA	=Total with SCADA/Total Pump Houses * 100	100	10
SCADA Electric Supply	Total Number of Sub-Stations, Number Sub-Stations With SCADA	=Total with SCADA/Total Sub-Stations * 100	100	10
PNG Connections	Total LPG Connections, Total PNG Connections Installed	=Total PNG / Total LPG Connections * 100	50	15

Solid Waste Management	Locality Population, Collection, Segregation, Treatment, Disposal	=Average of Collection, Segregation, Treatment, Disposal / Locality population * 100	75	10
Sensor Lights	Total Lights Points, Total Sensor Triggered Lights Installed	=Total Sensors Lights / Total Light Points * 100	80	10
LED Lights	Total Lights Points, Total LED Lights Installed	=Total LED lights / Total light points * 100	95	10
Smart Meters	Total Meters sanctioned, Total Smart Meters Installed	=Total Smart meters installed / Total Meters sanctioned * 100	100	10
Smart Policing Smart Fence	Smart Fence System Available (Y/N), Additional Smart Fence System Required (Y/N)	Y, Y=50% Y, N=100% N, Y=0% N, N=Not Applicable	50	5
Smart Policing Integrated CCTV	Integrated CCTV Systems Available (Y/N), Additional Integrated CCTV Systems Required (Y/N)	Y, Y=50% Y, N=100% N, Y=0% N, N=Not Applicable	50	5

The above columns are only indicative and more columns may be added for recording more data. For example, a column can be added to explain the reasoning for the benchmark value, dateline to amend the benchmark value, on whether the technology is smart or conventional, and so on.

The next worksheet enumerates the data related to settlements mapped to their hierarchical governing entities. A sample of such mapping is shown in Table 2.

Table 2 Listing and mapping of settlements

Region_1	Region_2	Region_...	Region_n
1	2	3	4
Region_1_ Locality_1	Region_2_ Locality_1	Region_..._ Locality_1	Region_n_ Locality_1
Region_1_ Locality_2	Region_2_ Locality_2	Region_..._ Locality_2	Region_n_ Locality_2
Region_1_ Locality_...	Region_2_ Locality_...	Region_..._ Locality_...	Region_n_ Locality_...
Region_1_ Locality_n	Region_2_ Locality_n	Region_..._ Locality_n	Region_n_ Locality_n

The above table shows mappings at two levels only, that is, localities to specific regions. Similarly, a separate worksheet can be created to map the regions to next higher level of governance or administration, or gated societies, firms, shops in a given locality.

The next step is to create individual worksheets for each technology and copying the data from Tables 1 and 2 in a manner that would automate calculations and evaluations. Table 3 shows extract of worksheet created for a Solar Power Plant. The column 3 of Table 3 contains the formula from column 3 of Table 1 and application of benchmark value, as compatible to MS Excel. The column 4 is the product of the value in column 3 and the weightage assigned to technology Solar Power Plant as seen in column 5 of Table 1.

Table 3 Data worksheet for technology Solar Power Plant

Region	Locality	% Achieved	Smart Index	Contracted Load (In KW)	Solar Plant Capacity (In KWp)
1	2	3	4	5	**6**
Region_1	Region_1_Locality_1	14.35	1.29	1741	150
Region_1	Region_1_Locality_2	9.49	0.85	2193	125
Region_2	Region_2_Locality_1	61.11	5.50	3000	1100
Region_2	Region_2_Locality_2	166.66	15.00	600	600
Region_3	Region_3_Locality_1	1.85	0.17	900	10
Region_3	Region_3_Locality_2	0.85	0.08	3900	20

The percentage achieved values in column 3 of Table 3 are application of 60 per cent target benchmark otherwise the values would be 8.62, 5.70, 36.67, 100, 1.11 and 0.51, respectively. Attributes can be added at a later time after column 6 and the formula be adjusted accordingly without much changes to the first four columns.

The final action in construction of the tool is creating pivot tables, pivot charts and slicers. Two separate worksheets are added one each for pivot tables and another of pivot charts and slicers. The pivot tables contains the combined list of all technologies, settlements, and respective values for percentage achieved and smart index. Based on this pivot table, pivot charts are created along with slicers to calculate, summarise, and analyse data for comparisons, patterns, and trends in the data as required.

Creating a worksheet for each technology and copying standard data is a tedious process. The task is laborious when standard information is amended. To overcome this challenge, MS Excel has built-in functionality to write blocks of source code to automate repetitive tasks, called 'Macro'. A macro will automate creating data worksheets for each technology and copy the regions and localities, attributes, and formulae for evaluating percentage achieved and smart index based on weightage assigned. Separate macros create new worksheets when the list of technologies is updated, changing formulas and pivot tables without affecting existing data.

Smart Index Model—Use Case Scenario

An experiment was conducted on the template model to validate the concept and the framework. The tool was populated with details of ten technologies as shown in Table 1 and with common weightage and benchmark of 10 and 100 percent. Worksheet2 was created for mapping the settlement. The settlement scheme for the study was developed for two levels—Region and Locality. For the proposed study, eight regions with varying numbers of localities under each region were mapped. In the next step, the MS Excel analytical tool was populated with the master data of technologies and settlements and filled with data, numerical (whole and fraction), and Boolean values. The device produced output in the form of percentages achieved by arithmetic operations on the data using the pre-determined formula for each technology.

Technology Index Measurement Tool Readings

The measurement device produced data visualisation graphs as estimated. The analysis tool visualises the evaluated data with a graphical representation of average percentage achieved and average smart index based on region, locality and technology. Figure 4 depicts the overall technology-wise achievement and index for the various regions.

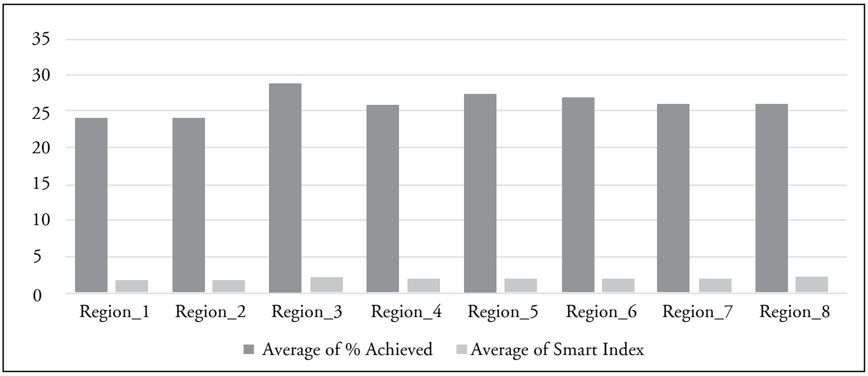

Figure 4 Technology Wise Overall Index for All Regions (Test scenario)

To ascertain the device's scalability, Sensor Lights and LED Lights technologies were split into Internal and External. This change provided an expansion of the list of technologies. A weightage was adjusted to five each for internal and external technologies of sensors and LED lights. The measuring scale provides a better insight into the status of all technologies by adopting the changes made to the master details of technologies. Figure 5 depicts the status of a Locality based on the master list of technologies.

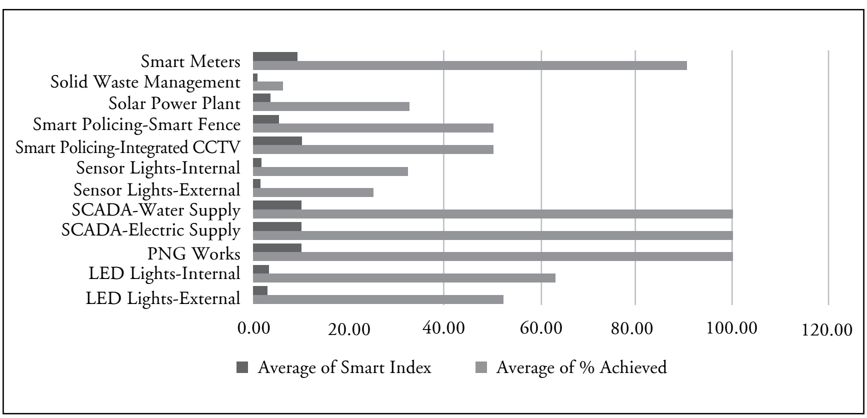

Figure 5 Technology-wise index of a Locality (Test scenario)

Conclusion

New technologies are emerging and trending rapidly. Many technologies are disruptive and, if acquired deliberately, would cause ease in governance, administration, and economic growth, enhance the quality and comfort of life, and provide a conducive working environment. The article examines the concepts of smart technology, human settlements, and administrative layers, which are paramount in technology assessment for planning technology acquisition or inducement in the environment. For knowledge-based decision-making, a measuring tool for analysing available technology is essential.

The article proposes a proof of concept on Smart Settlement Index tool, which is simple, easy to construct and operate, and requires bare enumeration and arithmetic skills. The salient features of the indexing tool were applied for validation using MS Excel, and the model's results are promising. The model provides graphical visualisation of the technology's indexes with simple inputs and can be easily handled with basic knowledge. The output of the smart settlement indexing tool can provide a starting point and direction for laying roadmaps by governing entities for induction of deficient or new technologies in respective areas of interest.

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