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Telecommunication Infrastructure:Using Statistical Analysis to Identify Significant Factors and to Design Policies for Indian Smart Cities

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ABSTRACT

Connectivity provided by telecommunication infrastructure provides a dominant platform and plays a vital role in realization of a smart city. Objective of this paper is to identify telecommunication indicators that will form the foundation and bridge the gap towards realization of smart cities in India. Smart Cities Council has broadly prepared the Smart Cities Framework which identifies various Technology Enablers that applies to various aspects of smart city realization. Technology enablers of Smart Cities Framework are Instrumentation and control, Connectivity, Interoperability, Security and privacy, Data management, Computing resources, Analytics. They set targets for high-speed broadband access and citywide wireless network and connecting all devices with a citywide multi service communication system etc. Connectivity Index and various telecommunication indicators that drive the connectivity index of 134 countries is collected from various sources. Regression analysis of this data is done to identify the most significant telecommunication indicators that drive the Connectivity Index of Smart Nations. These indicators are further validated with experts from industry and academia. Significant telecommunication indicators that influence the connectivity index include wireless coverage, speed of connection, device cost etc. Policy analysis of Nations with high Connectivity Index is done. Learnings, best practices and policy changes from these countries are analyzed and recommendations derived. Recommendations are captured under both Supply side policies and Demand side policies of telecommunication infrastructure. Supply side of policy changes span across regulatory changes to grants and subsidies, policies to increase public-private-partnership, policies to accelerate penetration, making broadband service basic right of citizens. Demand side policy includes subsidies in supply of PCs, internet access not limited to the young and college educated, digital literacy and adult education.

Keywords

Telecommunication infrastructure; smart cities; telecom policies; connectivity

INTRODUCTION

In the last two decades, telecommunication sector has witnessed radical changes both in terms of supply of infrastructure and demand of services. India has become the second largest telecommunication market in the world. Yet, with the smart city initiative by GoI, it is important that Government driven strategy along with collaboration from various industry players will be key to achieve success and come at par with global standards.

International Organization for Standards has set the standard ISO 37120. This standard applies to city performance. It establishes data indicators that measure the delivery of city services. Services span areas like energy, governance, health, recreation, telecommunication etc. Telecommunication core indicators emphasis on the number of internet connections per 100,000 population and number of cell phone connections per 100,000 population etc.

Supply of ubiquitous broadband telecommunication infrastructure and demand for the same is a prerequisite for a smart city. Smart City Council framework sets targets for high-speed broadband access, citywide

wireless network and connecting all devices with a citywide multi service communication system etc. Smart Cities framework has identified and defined Technology Enablers. These enablers play a vital role in the realization of smart cities. Each Technology Enabler is further divided into key indicators. Technology enablers and corresponding indicators of Smart Cities Framework are 1) Instrumentation and control, 2) Connectivity, 3) Interoperability, 4) Security and privacy, 5) Data management, 6) Computing resources, and 7) Analytics

Recently, India has seen various positive changes in the telecommunication sector. Some of the key changes are spectrum availability through spectrum auctions, significant 4G roll outs, entry of mobile virtual network operators (VNOs), full mobile number portability and significant carrier consolidations, policy around the installation of towers on Government buildings and land to improve coverage and service quality. All these will lead to the creation of the telecom infrastructure to cater to ease of doing business. Additionally, initiatives like net neutrality, SLAs on wireless services, internet telephony, Broadband access through Wi-Fi networks are way to go to meet the upcoming demands. Yet, a lot needs to be done to create the supply and demand of the telecommunication infrastructure for the realization of the Smart Cities in India.

The focus of this paper is to analyze various facets of Telecommunication indicators, which are significant to realize Smart City implementation. As per Smart City Council Framework, Connectivity is one of the Technology Enablers to be used for the Indian cities to become one of the top smart cities in the world. To find the factors that influence Connectivity, GSMA Intelligence data is analyzed. GSMA Intelligence data is also validated with World Economic Forum Network readiness data reports. GSMA data report is used for further study. As per regression model of the GSMA report, it is found that the connectivity index of a country and in turn of the city is influenced significantly by the key factors of infrastructure, service components, and cost factors. Infrastructure related factors are Access to electricity, Mobile latency, and Wireless coverage. Service components are Internet bandwidth per user, mobile download speed and information available and accessible through the web. Cost factors include the cost of handset and cost of call basket. It studies and analyzes smart nations and smart cities wrt supply and demand side policies of telecommunication infrastructure development and shares policy recommendations for the GoI to aim the efforts around this.

LITERATURE REVIEW

The literature review is done from the perspective of connectivity indicators of smart cities, and various methodologies used in the analysis. In the context of the huge need of telecommunication infrastructure capacity supply and demand of a smart nation, various telecommunication and broadband policy related literature review done. Policy related literature of various nations analyzed to find linkage between the connectivity indicators and key aspects of a policy framework. This would help in the traceability from the connectivity indicator to the policy change required in the implementation of a smart city.

Policy aspects related to technology and residential broadband is examined(Papacharissi and Zaks, 2006). Discussions are around internet capabilities brought in by broadband, its cost and applications of broadband in future. Policy recommendations are around regulating guaranteed open access. Focus also remained on affordable and reasonable pricing plans and innovation in content. Telecommunications providers are classified into groups based on the type of service they provide (Lee and Chan-Olmsted, 2004). Different regulations and incentives need to be applied to encourage them to invest in less explored area. Complete development process of Indian National Broadband Plan along with key success factors which contribute to success of broadband deployment and adoption (Jain, 2014). Falch captures various factors and role of policies in penetration of broadband services (Falch, 2007).

Comparison of telecommunication policy making process in India and China is studied (Liu and Jayakar, 2012). Formal structure, interest groups and rule-making procedures for the telecommunication policy-making in India and China is analysed. Digital infrastructural policies of provincial governments of Canada contributed in the development of BB networks (Rajabiun and Middleton, 2013). Broadband network speed

and network performance growth is studied across the country in terms of geography, usage, and competition and broadband policy.

Key drivers of broadband supply and broadband demand based on empirical analysis is done (Cava-Ferreruela and Alabau-Munoz, 2006). Findings suggest key drivers of supply are low cost in infrastructure deployment and technological competition. Key drivers of broadband demand is the tendency and inclination towards usage of new technologies. Policies that aim to foster these drivers are most effective. Penetration with respect to connectivity can grow by increasing both demand and supply over 2 dimensions - Infrastructure and Content (Falch, 2007). Supply of Content and Infrastructure will be influenced by various factors like Technology, Economy, Culture or Policy. Similarly, Demand of Content and Infrastructure will be influenced by the factors like Technology, Economy, Culture or Policy.

In smart city component architecture (Al-Hader et al., 2009), it is mentioned that service of smart city are accessible through wireless mobile devices. Smart city infrastructure relies a lot on the wireless infrastructure as well as on hard-wired or fixed broadband infrastructure.

Mobile Broadband provides better coverage with lower cost compared to fixed Broadband (Alderete, 2017). With respect to mobile broadband penetration, developed and developing countries seems to have huge gap. 84% penetration in developed countries vs 21% in developing countries. But, the good part is its growing exponentially in developing countries.

Lessons from development of baseband in Korea, Japan, Canada and US are studied in detail (Frieden, 2005). In 2005, ITU reported that the top 5 nations with BB network penetration were Korea, HK, Netherlands, Denmark and Canada. USA was ranked 16th. These top nations achieved success despite different political, geographical and market place conditions.

Role of government in broadband access is discussed extensively along with analysis of broadband deployment in US, EU and Korea with a focus on distinction between different technology platforms (Picot and Wernick, 2007). South Korea is in leading position due to active role of govt in establishing a high-speed backbone network and promotion of demand through public programs. US broadband market focuses more on the regulations related to competition of various network operators. Member countries in EU adopt a mixed with small to medium intervention from the Govt in both supply and demand side.

Broadband policies of Nordic countries like Finland and Sweden (Eskelinen et al., 2008) are investigated. It focuses on the network infrastructure and its geographical coverage. Finland and Sweden are leading countries in the growth of information society.

Policies stimulating broadband development in EU, South Korea, US and Japan are captured (Falch, 2007). Falch categorises government's policy interventions under 3 types, which help in the penetration of broadband services - Direct intervention, Regulation, Facilitation. Direct intervention is the strongest type in which Government actively provides services in terms of infrastructure and content. Regulation is a type of legal form and legal consequences are associated with it. Facilitation is the mildest form which involves decisions and orders to ensure a good environment but do not lead to legal consequences for third parties.

RESEARCH METHODOLOGY

The research objectives are to

- Identify indicators of telecommunication sector, which are requirements of Smart City and Smart Nation
- For these indicators, collect data from various countries (countries with smart cities or with potential smart cities)
- Identify the key significant indicators that would help a country to bridge the gap towards realization of the smart cities
- Identify the driving and driven indicators to help the policy makers prioritize the indicators appropriately
- Recommend policy changes, based on the policy analysis and practices of various Smart Cities and Nations

Research is done following the below steps:

Step 1: Multiple regression analysis is applied to the data. Most significant indicators that drive the Connectivity Index score are identified. This is validated through expert opinion to arrive at the most significant indicators.

Step-2: Practices and policies in the development of telecommunication infrastructure of smart nations studied with a focus on the leading indicators identified in above step.

Step-3: Recommendations with respect to policy consideration and changes are shared. This would support the improvement of the leading indicators and help implementation of smart cities.

DATA COLLECTION

The GSM Association (GSMA) represents the interests of mobile operators and related eco system worldwide. It ties approximately 800 operators with approximately 300 companies in the ecosystem. These include internet/software companies, device manufacturers and companies in adjacent industry sectors. It organizes events like MWC (Mobile World Congress), Mobile 360 Series conferences and MWC Shanghai conference. GSMA Intelligence provides mobile operator data, accurate industry metrics. It also does analysis and forecasting. It has more than 25 million data points and updated daily. It covers a wide range of data points. These include the performance of 1,400+ operators, 1,200+ MVNOs (Multiple Virtual Network Operators) across 4,400+ networks worldwide. GSMA has computed Mobile Connectivity Index, which covers 134 countries. These 134 countries account for 95% of world's population. GSMA has defined Connectivity Index Score based on 24factors.

The factors that influence the connectivity index of a country are2G Coverage, Spectrum below 1GHz, 3G Coverage, Spectrum above 1GHz, 4G Coverage, 500MB postpaid tariff, Years since 3G launch, 500MB prepaid tariff, Mobile download speeds, Call basket cost, Mobile latencies, Handset cost, Access to Electricity , Online Service Index score for E-Government, Fixed-broadband subscriptions, Wikipedia edits per internet user, International Internet bandwidth per user, Wikipedia articles accessible to population, Servers per population, Websites accessible to population, Fixed download throughput, Accessibility of mobile applications, Fixed latencies, Facebook user penetration

The ones related to the underline network infrastructure are 2G, 3G, 4G coverage, which implies wireless coverage in the country, spectrum below and above 1GHz implies the frequency bands used for wireless access. Speed, throughput and bandwidth related indicators like mobile latencies, fixed latencies, mobile download speed, internet bandwidth per user, fixed download throughput etc.

There are cost related indicators like call basket cost, handset cost, pre and post-paid tariff for a 500MB pipe. These are the cost incurred by the end-user to get the connectivity and associated services.

Availability of various online services related indicators is information availability in the form of Wikipedia edits and accesses, websites accessibility. Online services like online service index for e-Government, accessibility of mobile applications, social media access like Facebook user penetration etc.

GSMA has collected data of 134 countries across the 24 indicators. Connectivity index score of these countries computed using the data collected for all the indicators across all countries.

The list of countries for which data is collected by GSMA are: Afghanistan, Colombia, India, Moldova, Serbia, Albania, Congo, Indonesia, Mongolia, Singapore, Algeria, Congo, Democratic Republic, Iran, Montenegro, Slovakia, Angola, Costa Rica, Iraq, Morocco, Slovenia, Argentina, Croatia, Ireland, Mozambique, South Africa, Australia, Cyprus, Israel, Myanmar, Spain, Austria, Czech Republic, Italy, Nepal, Sri Lanka, Azerbaijan, Côte d'Ivoire, Japan, Netherlands, Sudan, Bahrain, Denmark, Jordan, New Zealand, Swaziland, Bangladesh, Dominican Republic, Kazakhstan, Nicaragua, Sweden, Belarus, Ecuador, Kenya, Niger, Switzerland, Belgium, Egypt, Korea, South, Nigeria, Tanzania, Benin, El Salvador, Kuwait, Norway, Thailand, Bhutan, Estonia, Kyrgyzstan, Oman, Togo, Bolivia, Ethiopia, Laos, Pakistan, Tunisia, Bosnia and Herzegovina, Finland, Latvia, Panama, Turkey, Botswana, France, Lebanon, Paraguay, Uganda, Brazil,

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Georgia, Lithuania, Peru, Ukraine, Brunei Darussalam, Germany, Luxembourg, Philippines, United Arab Emirates, Bulgaria, Ghana, Macedonia, Poland, United Kingdom, Burkina Faso, Greece, Madagascar, Portugal, United States of America, Cambodia, Guatemala, Malawi, Qatar, Uruguay, Cameroon, Guinea, Malaysia, Romania, Venezuela, Canada, Honduras, Mali, Russian Federation, Vietnam, Chad, Hong Kong, Malta, Rwanda, Zambia, Chile, Hungary, Mauritania, Saudi Arabia, Zimbabwe, China, Iceland, Mexico, Senegal.

GSMA repository is used to analyze the capacity of telecom infrastructure of these countries. This data is compared and validated with the network readiness index report published by World Economic Forum (WEF).

GSMA Intelligence generates Connectivity Index of 134 countries based on various parameters (Ref: http://www.mobileconnectivityindex.com/#year=2016&dataSet=indexScore). World Economic Forum (WEF) publishes Network readiness index of various countries (Ref: http://reports.weforum.org/global-information-technology-report-2016/?doing_wp_cron=1480258511.6654999256134033203125). GSMA connectivity index and WEF Network readiness index for every country are plotted in **Figure 1**.

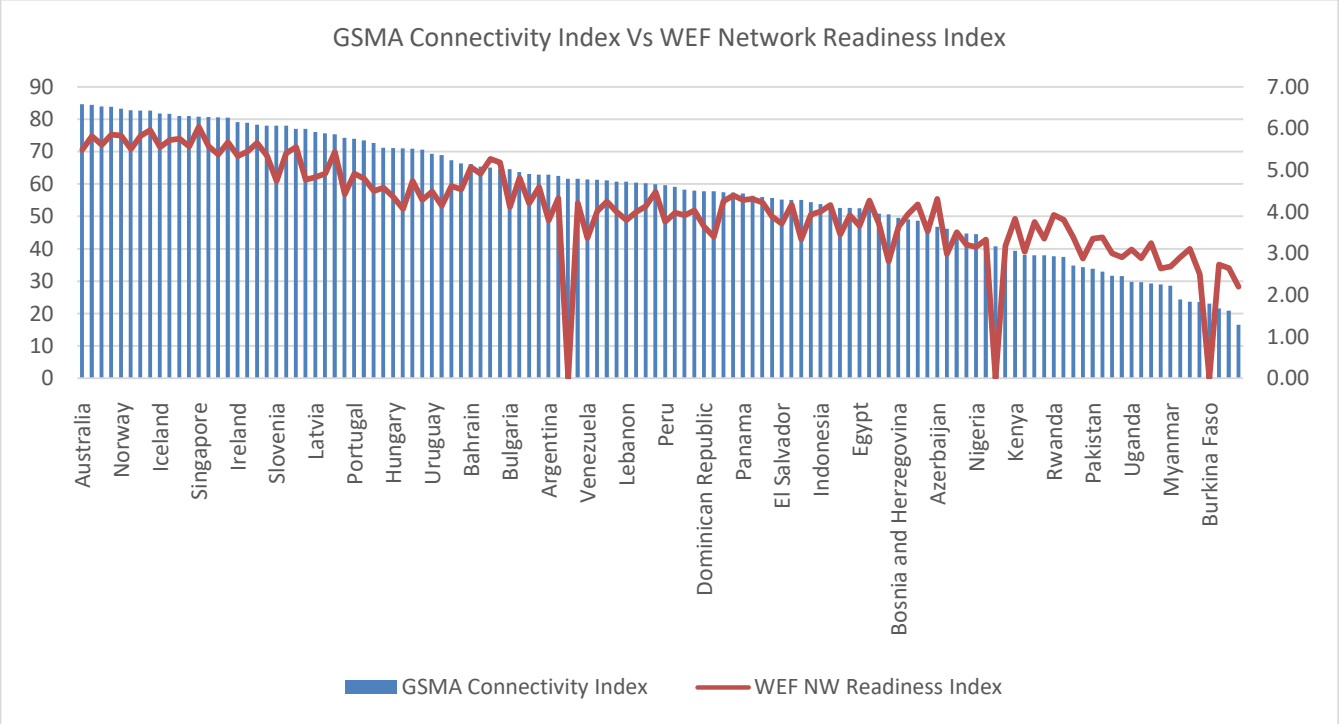

Figure 1: Comparison of GSMA connectivity index and WEF network readiness index

It clearly indicates that the trend of GSMA Connectivity Index and WEF Network Readiness Index are aligned. In other words, higher the GSMA Connectivity Index of a country, higher its WEF network readiness index.

MULTIPLE REGRESSION ANALYSIS

Multiple Regression Analysis is a form of Statistical Analysis which is used to identify significant factors in a regression model. Using SPSS tool, multiple regression analysis is done to arrive at the most significant indicators that influence the Connectivity Index score of a nation. Also, based on the beta value, it is found that parameters in Table 1 have the impact on the Connectivity Index in the order as mentioned in the table. In other words, Internet Bandwidth per User has maximum impact and Hand set cost has the least impact.

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IJETSR
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Table 1: Independent factors derived from regression analysis using SPSS

Order	Factor	Standardized Coefficients	
		Beta	Sig.
1	InternetBWperUser	0.239	0
2	WikiAccessibleToPopulation	0.23	0
3	SpectrumAboveOneGHz	0.129	0
4	MobileLatencies	0.117	0
5	SpectrumBelowOneGHz	0.057	0.001
6	FourgCoverage	0.063	0
7	AccessToElectricity	0.128	0
8	MobileDownloadSpeed	0.074	0
9	CallBasketCost	0.074	0.001
10	HandsetCost	0.053	0.003

It is found that these independent Factors are statistically significant and impacts the Connectivity Index Score. Accordingly, the Regression Model below is generated.

Connectivity Index = 8.085 + (0.239 x InternetBWperUser)
+ (0.23 xInfoAccessibleToPopulation)
+ (0.129 xSpectrumAboveOneGHz)
+ (0.128 x AccessToElectricity)
+ (0.117 x MobileLatencies)
+ (0.074 xMobileDownloadSpeed)
+ (0.074 xCallBasketCost)
+ (0.063 x FourgCoverage)
+ (0.057 x SpectrumBelowOneGHz)
+ (0.053 xHandsetCost)

R Square = 99.4%. This is the strength of the relationship and implies that the collection of predictor factors together predict or account for 99.4% of the variance of the Connectivity Index.

In other words, independent factors like Internet bandwidth per user, Spectrum above and below 1 GHz, Access to electricity, 4G coverage, Mobile latencies, Mobile download speed, Call basket cost, Hand set cost and Wiki accessible to people are the key factors that significantly impact the Connectivity Index score of a country.

Opinion taken from domain and technology experts, industry experts, research scholars and experts from academia. Findings from the regression analysis with respect to indicators impacting Connectivity Index is shared. Opinion taken in terms of any addition, deletion, modification required to be done along with the rationale to do so. The spectrum of >1 or <1 GHz is not found relevant as Internet BW per user covers it. 4G is replaced with wireless coverage (2G EDGE, 3G, 4G, 5G, WiMAX, Wi-fi etc.). Information available in digital form to support smart services is recommended as one of the key factors.

Table 2 shows the list of significant factors which impact the connectivity index of a country. This list is arrived at based on the output from the regression model, which in turn is also validated based on expert's opinion.

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 8
August 2017

Table 2: Significant factors that influence connectivity index, based on expert opinion

Order	Factor	Description
1	InternetBWperUser	Internet bandwidth per user (Rajabiun and Middleton, 2013)
2	InfoAccessibleThroughWeb	Information or the content available and accessible through internet (Falch, 2007)
3	WirelessCoverage	Wireless coverage (Eskelinen et al., 2008)
4	AccessToElectricity	Access to electricity (Chaurey et al., 2004)
5	HandsetCost	Cost of handheld devices (Al-Hader et al., 2009)
6	CallBasketCost	Cost of call basket (Eskelinen et al., 2008)
7	MobileDownloadSpeed	Speed in MBPS during mobile downloads (Picot &Wernick, 2007), (Eskelinen et al., 2008)
8	MobileLatencies	Latency i.e. speed at which connection is established (Picot &Wernick, 2007)

Bandwidth depicts the amount of data transferred per second. Bandwidth as 10/10 Mbps means 10 megabits/sec of data can be uploaded and downloaded from a website, say Youtube. 10 megabits/sec is the MobileDownloadSpeed. Latency measures the time taken to establish a connection between source and destination. Bandwidth measures the speed at which data is transferred between source and destination. Latency through a satellite connection is higher than that of a copper wire cable. This, in turn, is higher than that of a fiber optic connection.

The impact of low latency is felt when small data files are downloaded. For large data files, low latency will not impact much if the speed is good. If the latency goes beyond 200ms then one would experience a sense of delay. Such delay is not felt if the requested web page like Netflix, Youtube loads fast. For monitoring street lights a slow round trip network (high latency) is sufficient. To monitor electric power substations a high round trip (low latency) network is a must.

Electricity is a fundamental resource. Access to electricity is key to success in a world which is driven by technology. The need of electricity is everywhere like powering the base station towers of cellular infrastructure or the smart phones and smart devices, need of access to electricity is everywhere. AccessToElectricity sits in the foundation of the smart city infrastructure. Electricity needs to be sufficiently and consistently supplied. This can be achieved through efficiency in its generation, transmission, and distribution.

HandsetCost depicts the cost of the smart device, which is used to access smart services from the internet. HandsetCost is the cost of the handset device. CallbasketCost is the price of availing the services provided by the operator. Typically, various features like internet access/data plan, call plan/SMS etc. are packaged in one basket.

Network bandwidth is the data speed supported by a network connection. Higher bandwidth implies higher capacity but does not indicate higher performance. However, the speed of the network is limited by the speed provided by the operator, which also varies depending on the location, number of users and quality of infrastructure.

International Journal of Engineering Technology Science and Research
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Practices and Policies from Nations with Smart Cities

Smart nations focus on both the supply and demand side of telecommunication infrastructure. Some of these practices and policies are already adopted by GoI. Based on analysis of practices and learning, recommendations for GoI shared in subsequent sections.

Govt of Singapore has the vision to become a Smart Nation. On the supply side, proactive government strategy, state-of-the-art telecommunications and enforcement like strong quality and infrastructure standards to be followed by Govt agencies, Planners, Developers and Enterprises to follow. On the demand side, public policies address skills development, funding is provided for small to medium-sized IT companies, high focus on special demonstration projects to help replicate them at the national level.

Japan provides the fastest and cheapest broadband service. It is the leader in the wireless broadband. Govt's national goal is to create a society which is based on an advanced telecommunication network with access to information and communication technologies and capability to use these technologies. On the supply side, effective Govt strategy and policies to provide nation-wide high-speed internet services. Also, deployment of optical fiber network involved mandatory sharing of access to fiber network and replacement of copper-based DSL technology. On the demand side, considered broadband development to promote digital literacy. Also, the presence of large domestic high-tech industry like Nintendo, Mitsubishi, Panasonic, Sony and Toshiba helped in faster diffusion.

In South Korea, Govt-led infrastructure plans demonstrate more successful than the private sector-led plans of more advanced countries like US and Japan. On the supply side, key success factors that distinguish Korea from other countries are policy focus in four distinguished areas like (1) Telecommunication infrastructure development, (2) Content promotion, (3) Industrial policies and (4) Policies related to Competition and Regulations. On the demand side of the broadband market, Korean Govt has equal focus by providing the initial market of services by aggregating demand for broadband among public sector. After the initial roll of the broadband network, 31 e-Govt policies focused towards development and promotion of public service along with a roadmap for G4C (Government for Citizens System), G2B (e-procurement, e-application, e-contracts etc), G2G (like service which connects financial systems of all govt bodies).

In Finland, access to broadband services is a legal right of citizens of Finland. The optical fiber network is at the level of other basic services like water, road, and electricity. Govt targets 99% of the permanent residents to get 100mbps connection via an optical fiber or cable TV network. On the supply side, PPP (Public-Private-Partnership) is the focus for projects where 100% investment by the private sector is not viable also federal subsidy capped at one-third of total investment need. To achieve the national goal, funding is expected from federal subsidies, local govt and the European Union. The market competition has helped to drive growth since the nation never had a single national service provider. The presence of wireless manufacturer Nokia created large scale employment and appreciation of broadband services, which led to boost on demand side.

Despite a country with one of the world's lowest population density, Sweden has been successful in promoting broadband and has almost universal broadband access. With the nation's strength in engineering and innovation and with cooperation between Government and business, national level strategies use both supply and demand side policies.

Discussion and Conclusion

Synthesis of the analysis done around the Smart City Framework, Regression Model of GSMA Intelligence data, Policy Analysis of various smart nations is done and recommendations shared for developing countries like India.

Using GSMA data graph drawn for the significant factors. It shows the positioning of India across countries having top 5 smart cities across the significant factors. It clearly indicates that India scores lowest in all parameters – Wireless Coverage, Internet B Wper User, Access To Electricity, Mobile Latencies, Mobile Download Speed, Info Accessible Through Web, Call Basket Cost, Handset Cost.

International Journal of Engineering Technology Science and Research
IJETSR
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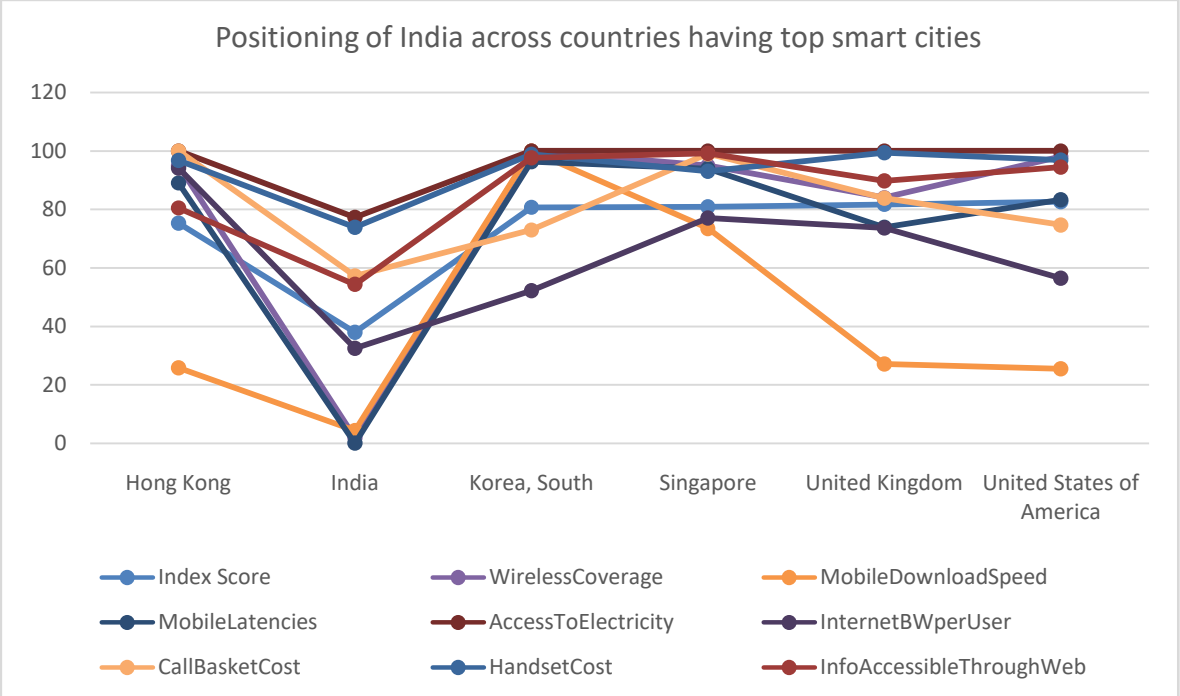

Figure 2: Position of India across countries having top smart cities in the world

As a first step towards smart city realization, it is recommended that the stakeholders of smart city implementation need to prioritize and focus on the above indicators especially the leading factors like Access to electricity, Mobile latency, and Wireless coverage.

Seoul, a smart city in South Korea is studied in detail and comparative analysis of South Korea and India is done from the point of view of strategy and policies adopted in both countries. As a first step towards smart city realization, it is recommended that the stakeholders of smart city implementation need to prioritize and focus on the above indicators especially the driving factors. While making policy changes to improve Connectivity Index score, GoI need to set up yearly goals on the key significant factors.

Here are the recommendations for Supply-side policies

- All policies to be driven with the goal of treating access to broadband services at the level of other basic services like water, road, and electricity. All supply side policies should evolve around it.
  - Govt should target 100% of the permanent residents of the smart city to get the broadband connection within a specified timeline along with strong monitoring and control via dash boards and score cards for accountability.
  - Encourage private investments through incentives and penalties for litigation and delays
- Policies to encourage gas, water, electricity and telecommunication infrastructure and service providers to collaborate and develop a robust infrastructure for all and ensure disturbance in one does not impact the other.
- Collaboration across multiple stakeholders in the deployment of sensors and sensor networks to collect raw data from sources of energy, water, transportation, and buildings systems in real time. Apart from data collection, transmit data through low-cost communication protocols like and networks (either wired or wireless) like Zigbee, BLE (Blue Tooth Low Energy), LoRA (Long range).
- Cyber building certification to buildings with high-speed network access.
- Deploy real time management systems to increase efficiency and optimize performance. Advanced data analytics to provide intelligence and actionable items to improve utilization of resources.

- While making policy changes to improve Connectivity Index score, there is a need to set up yearly goals on the key significant factors along with strong mechanisms of tracking progress and accountability.

We assert that the recommendations for the Demand-side policies be as follows:

- Laws and regulation to encourage e-working by less restriction on work hours in the physical workplace.
- Focus on policies related to subsidized computers, loans for building internet networks in less developed areas, online education programs for disabled, elderly and homemakers, encourage e-learning by providing internet infrastructure in schools and introducing online education system.
- e-Govt policies to promote public services along with a roadmap for G4C, G2B, and G2G.

Limitations and Future work

Access to electricity, Mobile latency, Wireless coverage, Information accessible through the Internet, Mobile download speed, hand set cost, and the cost of call basket are the significant factors to be focused on to increase connectivity as an enabler for Smart Cities. It is recommended that the stakeholders of smart city implementation need to prioritize and focus on these improvements in these factors.

The following limitations were identified as part of this study.

- The study focuses on the basic telecommunication factors, which impact the Connectivity Index. For smart cities, there is a possibility of a higher number of parameters like Cloud infrastructure and Analytics, which are required to be considered as part of telecommunication infrastructure requirement.
- Traceability from the key significant factors to the policy change could be added in future study.
- Supply-Demand matrix for content and infrastructure along with factors of influence can be explored further to identify an exhaustive list of recommendations in NTP 2012 and Broadband policy.

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