CIVIL & ENVIRONMENTAL ENGINEERING | RESEARCH ARTICLE

Appraisal of the linkage among urban infrastructure and human resources and the growth of Information Technology (IT) industry in Indian cities

Dillip Kumar Das

Abstract: The Information Technology (IT) industry has significantly influenced the urban economy in many developing nations. Although the IT industry has created economic growth, it is argued that the establishment and growth of the IT industry depend on the availability of adequate urban infrastructures and human resources. Therefore, using data from Indian cities having significant IT industries, this study established the associations among various important urban infrastructures and human resources and the growth of the IT industry. A survey research method for data collection and statistical quantitative analyses and modelling were used for the study. The study revealed that houses, built-up spaces for offices and industry, urban roads and electrical power influence the growth of the IT industry considerably although in varying degrees. Houses and built-up space have a relatively higher influence than electrical power and roads. Human resources also influence fairly. The contributions of the study include the establishing of interlinkage among the urban infrastructures and human resources and the growth of the IT industry.

ABOUT THE AUTHOR

Dillip Kumar Das (Prof.) has a PhD in Urban and Regional Planning with a civil engineering and city planning background. Currently, he is engaged in teaching, research, and community engagement activities at the University of KwaZulu-Natal, South Africa. His research and consulting interests under sustainable urban and regional development include systems analysis, system dynamics modelling, infrastructure planning and management, smart cities, and transportation planning. He has co-authored two books as the lead author and published several peer-reviewed research articles.

PUBLIC INTEREST STATEMENT

The Information Technology (IT) industry enhances the economy by creating a knowledge economy and has become a major contributor to the GDP and employment of a city. Many factors including favourable business environment, location, investment, congenital IT industrial policy, etc., play crucial roles in the growth of the IT industry. However, the human resources and infrastructure of a city are also argued to be vital. So, for cities to attract and advance IT industries, strategies for creating or reinforcing relevant infrastructure that would attract and retain competent human resources, and offer competitive advantages for business environment and investment are essential. So, this study examined the association between various important urban infrastructures and human resources and the growth of the IT industry. It established that in addition to human resources, houses, roads, built-up space for IT industries and emergy significantly influence the growth of the IT industry. So, strategies should be focused on reinforcing or creating such infrastructure that would augment IT industries in a city.
Further, the consequent empirical models that emerged from the interlinkages will enable evaluation of the impact of infrastructure and human resources on the growth of the IT industry quantitatively, which could assist in developing policy options in the cities of developing countries such as India.

**Subjects:** Management of IT; Sustainable Development; Business, Management and Accounting; Industry & Industrial Studies

**Keywords:** Cities; human resources; Infrastructure; IT industry; policy

1. Introduction

Evidence from the cities of India and China shows that the Information Technology (IT) industry has transformed the urban economic scenario in developing nations. Many cities in the developing countries such as Bangalore, Delhi, Mumbai, Kolkata, Pune, Hyderabad, Ahmedabad, Gurgaon, etc., in India, and Beijing, Shanghai, Dalian, Guangdong, Nanjing, Shanghai, Shandong, etc., to name a few in China have embraced significant IT industrial functions besides their conventional industrial (manufacturing) and service-oriented economy. The IT industries in such cities are contributing significantly to economic growth through earnings from IT products that include software, hardware, and IT services. Similarly, IT infrastructure that includes internet and broadband also has a significant positive linkage with the Gross Domestic Product GDP (Bankole & Mimbi, 2017; Pradhan et al., 2018; Toader et al., 2018). For example, it has contributed about 9.3% to the total GDP of India (NASSCOM, 2016; Singh & Kaur, 2017). In other words, the IT industry has two facets in a city. First, it contributes to the economy from IT industrial development, which is an integral part of the smart economy (Toader et al., 2018). Second, it also creates IT infrastructure for facilitating various social, economic and transportation-related activities contributing to the smart infrastructure of a city. Consequently, the development of the IT industry contributes to making a city smart (Guma & Monstadt, 2021).

However, it is well acknowledged that while the IT industry brings in economic opportunities (Asongu & Le Roux, 2017; Das, 2019; Kuada, 2015; Tchamyou, 2017; Vu, 2011, 2013), it requires certain attributes including urban infrastructures and human resource for its location and growth in a city (Das, 2019; Das & Sonar, 2013; Yigitcanlar et al., 2008).

Realizing the potentials of the IT industry and challenges for its location and development, policies have been created by the nations and cities to make their cities IT industrial-economic hotspots. The focuses of the policies are primarily to create adequate infrastructural facilities, attract international investment, and attract and retain skilled and competent human resources that would boost economic growth. Specifically, the development of first-rate urban infrastructures and civic facilities that can attract Foreign Direct Investment (FDI), and human resources (knowledge workers) has become one of the major focuses with the expectation that such infrastructures and facilities would facilitate the establishment and growth of the IT industry in such cities (Abraham and Mario, 2015; Francis et al., 2014; De Silva & McComb, 2012; Yigitcanlar et al., 2008; Young & Keil, 2010). Furthermore, Guma and Monstadt (2021), argued that IT-driven plans with innovations for creating entrepreneurial spirit and a favourable business environment in a city region can lead to a smart economy.

The knowledge workers constitute the core component of the IT industry, which contribute to creating and enhancing a knowledge base and encourage new enterprises in cities (De Silva & McComb, 2012; Ergazakis et al., 2006: 67–81; Yigitcanlar et al., 2007, 2008; Young & Keil, 2010; Van Winden et al., 2007: 525–549). The cities with acceptable urban infrastructures, appreciable social interaction, living conditions and lower environmental pollution attract and retain competent
knowledge workers (Florida, 2002, 2005; Hartal et al., 2021). It is also argued that the availability of appropriate infrastructures while contributing to attracting and retaining knowledge workers, assist in higher productivity.

In India, the IT industry is a significant component of the economy. While many well-known cities such as Bangalore, Delhi, Hyderabad, Gurugram, Pune, etc., have become IT industrial hot spots, several other cities are aspiring to enhance their economy through the establishment of IT industries. However, many of the Indian cities suffer from urban infrastructural inadequacies and environmental challenges, which act as impediments to the sustainable development of the cities. Consequently, for the cities with poor urban infrastructure and built environment attracting FDI and quality human resources is becoming a significant challenge.

Therefore, arguments have emerged that there is a need for the strengthening of urban infrastructure to improve the built environment to attract investment and human resources for the establishment and the growth of the IT industry. Many cities have been making concerted efforts in that direction. However, to develop appropriate policies to reinforce infrastructure successfully, and attract and retain human resources, it is essential to know what urban infrastructures are and to what extent they influence the growth of the IT industry. It is also necessary to assess whether and to what extent human resources impact the IT industry.

Several studies have been made to assess the influence of the infrastructure and human resources on the IT industry (Das, 2019; Das & Sonar, 2013; Prodhan et al., 2018; Yigitcanlar et al., 2008), however, the relationships between each influential urban infrastructure and human resources and the growth of the IT industry in a quantifiable manner have not been explicitly established. In other words, empirical relationships between important urban infrastructure as well as human resources, and the growth of the IT industry are scarce, specifically in the context of developing countries including India. As a point of departure from the previous studies that essentially focussed on the dynamic interaction between IT industry growth and different urban infrastructures and human resource, this study intends to examine whether individual influential infrastructure and human resources impact the growth of the IT industry significantly and establish hypotheses linking these urban factors and the IT industry growth. Furthermore, although complex econometrics models linked to the theory of productivity are generally used to examine such issues, planners need relatively simple models to work on different parameters based on which the growth of the IT industry can be predicted at the early stage of planning before applying sophisticated models. In other words, it intends to bridge the knowledge gap by establishing empirical linkages of urban infrastructures and human resources, with the growth of the IT industry.

Therefore, considering data from three cities having reasonably significant IT industrial activities such as Pune, Kolkata and Bhubaneswar, this study established the linkages among urban attributes such as urban infrastructures and human resources and the growth of the IT industry. In this respect, the study also tested two hypotheses:

H1: Enhanced urban infrastructure (H11: Urban road, H12: Electrical power, H13: Houses and H14: Built-up space for offices and industry) enhance the growth of the IT industry and

H2: Adequate human resources (knowledge workers) enhance the growth of the IT industry.

2. Essential attributes for the growth of it industry in a city: evidence from the literature
The IT industry has been argued to become one of the main contributors to the economic development and image creation of cities (Das, 2016, 2019; Das & Sonar, 2013; Guma &
Several studies have evidenced that many cities have experienced considerable economic upturn on account of the operation of the IT industry, related investments and consequent economic transactions. In other words, there exists a strong positive correlation between enhancement of economy and IT industrial activities in a city where IT industry predominates (Bankole & Mimbi, 2017; Colecchia & Schreyer, 2002; Das, 2019; Das & Sonar, 2013; Datta & Agarwal, 2004; Jalava & Pohjola, 2008; Koutroumpis, 2009; Martinez et al., 2010; Pradhan et al., 2018; Sassi & Goaied, 2013; Vu, 2011, 2013).

Cities with the IT industry are more likely to be effective to meet the challenges that globalization has posed. It is argued to promote comprehensive socio-economic development that includes human development and the creation of employment opportunities (Alkemade & Surrs, 2012; Asongu & Le Roux, 2017; Kuada, 2015; Mishra & Bisht, 2013; Tchamyou, 2017). Moreover, in the wake of the aspirations of many cities across the world to become smart, in recent years, the contributions from both the IT industry and IT infrastructures and services can play crucial roles in transforming cities into smart cities. For example, two of the major characteristics of a smart city are smart economy and smart infrastructure including IT related or digital infrastructure. While the earnings from the products and services of the IT industry contribute directly to the GDP, they also assist in creating an environment for innovation, entrepreneurship, resource efficiency, increased productivity and competitiveness (Guma & Monstadt, 2021; Toader et al., 2018), consequently contributing to transform the economy to a smart economy. Similarly, IT infrastructure not only modernizes and facilitates various socio-economic activities but also bring efficiency in the operations for various processes and services. Moreover, it enhances the efficiency of the use of various urban infrastructure, optimises resource use, makes real-time monitoring and limits wastages, thereby assisting in creating smart infrastructure. Also, it facilitates public participation in the development process and co-creation of such infrastructure (Szarek-Iwaniuk & Senetra, 2020). As a result of these contributions of the IT industry in a city to smart economy and smart infrastructure, the development of IT industries is inherently linked to the creation of smart cities (Guma & Monstadt, 2021; Szarek-Iwaniuk & Senetra, 2020; Toader et al., 2018).

On the other hand, the IT industry requires certain important socio-economic, spatial, environmental and infrastructural elements to grow successfully in a city. Specifically, socio-economic elements constitute human resource, investment, knowledge base, innovation, Research and Development, diversity and cultural mix, and reasonably high quality of life (Berry & Okulicz-Kozaryn, 2009; Das, 2019, 2016; Das & Sonar, 2013; Yigitcanlar et al., 2008). Similarly, the IT industry requires a certain environment and spatial attributes in a city that are different from a normal industrial and service-based city to grow and also attract and retain its human resources (GlobeScan, 2007: 2). These attributes include adequate and appreciable quality infrastructure and civic facilities, the scale of a city, image of the city, and attractive and pollution-free environment (Das, 2019; Das & Sonar, 2013; Pradhan et al., 2018; Yigitcanlar et al., 2008).

However, infrastructure and human resources remained at the heart of IT industry development (Caragliu et al., 2011: 68; Das, 2019; Giffinger et al., 2007; Navarro et al., 2017). In other words, a city that spatially and institutionally synergizes the functions of IT industrial, commercial, residential and other civic activities can engender an amenable environment for the growth of the IT industry (Barcelona city, 2003; Das, 2019; Das & Sonar, 2013; Yigitcanlar et al., 2008a, 2008b).

Urban infrastructures in the form of electrical power, road transportation, housing, and built-up space remain the important and essential requirements for the development of the IT industry (Baum et al., 2006; Berry & Okulicz-Kozaryn, 2009; Das, 2019; Das & Sonar, 2013; Florida, 2005; Hollands, 2008; Moussiopoulos et al., 2010; Navarro et al., 2017; Pradhan et al., 2018). The creation of adequate and quality infrastructure and its efficient use can enable a city to attract and set up of IT industry. For
instance, housing is one of the most important aspects knowledge workers consider while deciding to relocate to a city (Berry & Okulicz-Kozaryn, 2009; Van Winden et al., 2007). In other words, urban infrastructure is considered a driver for the development of the IT industry in cities (Kumar et al., 2019). Moreover, in the context of developing smart cities in which the IT industry and infrastructure are crucial, it is argued that the focus should be on city-specific objectives and adequate shared public infrastructure (Kumar et al., 2019; De Santis et al., 2014).

So, to leverage and enhance the growth of the IT industry in a city, these spatial and built infrastructure aspects need to be assessed carefully for their adequacy to develop policies, plan and make provision for their supply, or to meet the demand in a city.

Certain studies related to the impact of infrastructure and human resources have been made. For example, Das (2019), investigated the dynamic interaction among the various urban infrastructure and human resources on the growth of the IT industry in a developing country such as South Africa. Das and Sonar (2013), assessed the impact of the IT industry on the economy and environment of cities in the Indian context. Yigitcanlar et al. (2008) explored how knowledge-based cities are developed and what attributes make a knowledge-based city successful based on the experience of an Australian city.

Using the panel data from G-20 countries, Pradhan et al. (2018) empirically examined the relationships among ICT infrastructure on the economic growth, consumer price index, labour force participation rate, and gross domestic-fixed capital formation. However, studies on the empirical relationships between each influential urban infrastructure and human resources and the growth of the IT industry have not been established. So, in continuation of the previous studies, this study intends to examine whether individual influential infrastructure and human resources impact the growth of the IT industry significantly and establish hypotheses linking these urban factors and the IT industry growth. It also intends to establish empirical relationships linkage among urban infrastructure and human resources and the growth of the IT industry, which could contribute to the existing knowledge base.

3. Study context

To conduct this study, three representative cities were chosen. The cities selected were Pune, Kolkata and Bhubaneswar. Several factors were considered for selecting these cities. A significant number of IT companies are located in these cities and are engaged in developing and exporting IT products and services. Also, these three cities belong to three different categories of cities such as Kolkata is a megacity with a population of about 15 million, Pune is a metropolitan city with a population of more than 6 million, and Bhubaneswar is a relatively smaller city with about 1.2 million people. While Kolkata and Bhubaneswar are provincial capitals, Pune is more or less regarded as a major provincial city with large-scale education, cultural and industrial activities. Moreover, previously, Pune and Kolkata were dominated by the manufacturing industry but in the last two decades, these cities have incorporated significant IT industry. On the other hand, Bhubaneswar was an administrative capital with limited industrialization, however, it has incorporated a significant amount of knowledge-based activities including IT industries and educational institutions in recent years. While Kolkata and Pune have become established IT cities, Bhubaneswar is considered an emerging IT city. Moreover, Bhubaneswar and Pune are among the top 20 cities selected for the development of smart cities (SCM, 2015). Similarly, New Town, a constituent of the Kolkata metropolitan area, where the majority of the IT companies are located is also among the top smart cities of India (The Time of India, 2015). The IT industry also contributes significantly to the GDP of these three cities and respective provinces. Furthermore, these three cities could represent the other medium and large cities in the country that are aspiring to attract the IT industry compared to larger cities such as Bengaluru, Delhi and Mumbai. These three cities represent the homogeneity in terms of IT industrial activities and heterogeneity of morphological and economic characteristics, thus become ideal candidates for the study.
However, a question might arise on why cities such as New Delhi, Mumbai or Bengaluru are not considered in this study. New Delhi is a major urban agglomeration being influenced by a number of neighbouring cities such as Gurugram, Noida, Ghaziabad, Faridabad, etc. A large number of IT industries are located in these neighbouring cities specifically, in Noida and Gurugram. Therefore, New Delhi cannot be considered in isolation. Similarly, Bengaluru is very well established in terms IT industry, it has a global presence, and is considered the Silicon Valley of India. Therefore, it does not represent several other cities of the country aspiring for the development of the IT industry. Mumbai is also another urban agglomeration having morphological and economic characteristics and is regarded as the financial capital of India. So, these cities might not represent the large number of cities aspiring to develop IT industrial economic activities. Therefore, these cities were considered in this study.

According to the Software Technology Park of India (STPI), the IT industry has a strong presence in the three considered cities. More than 200 IT companies (constituting both domestic and multinational) are located in Pune city and attracted huge investments from both domestic and foreign investors. Moreover, the lion’s share of the income generated from the IT industry in the Maharashtra province comes from the IT industry located in the city (Time of India, 2015). It is estimated that currently the city generates an estimated amount of more than 6000 million USD per year and employs about 150,000 employees. Similarly, about 100 IT industries are registered in Bhubaneswar generating 40 million USD through IT exports. It employs more than 17,000 employees. About 220 IT industries with more than 100,000 employees have been registered in Kolkata, which generates about 100 million USD per year. This indicates the significance of these three cities from the IT industry point of view.

The availability of adequate basic urban infrastructure that includes road transportation, electrical power, housing, other civic amenities, and IT industry-friendly policies are argued to be the major reasons for the establishment and growth of the IT industry in these cities. Moreover, the availability of skilled human resources in these cities significantly contributed to the development of the IT industry in these cities.

Therefore, an argument has emerged that urban infrastructure and human resources influence the growth of the IT industry. So, it is essential to understand and establish their interlinkage so appropriate policy interventions might be developed at the city level.

4. Research methods
A quantitative survey research method constituting data collection from the IT industry (different IT companies) through surveys and secondary statistical sources and inferential statistical analyses and empirical modelling was used in this study.

4.1. Survey and data collection
Data from primary sources were collected by conducting a survey among the IT companies in the three cities. The IT industrial survey was done to make the initial assessment of the urban infrastructures and human resources that significantly influence the establishment and growth of the IT industry in these cities as well as to understand the income generated from the IT industry.

Out of the estimated 531 IT companies situated in the three cities (only the active companies were considered), 80 companies (N = 80) (40 companies from Pune, 25 from Kolkata, and 15 from Bhubaneswar) were proportionately selected for the IT industry survey. The sample size was found to be within the range between 79 and 83 for a confidence level of 95% at a confidence interval of ±10% and a worst-case scenario of 50% variability (Baarttillet et al., 2001; Cochran, 1977). The sample size of 80 is found to be within the tolerable range and therefore is adequate. The companies for the survey were selected by using a systematic random sampling method. The
geographical location in the city, the size of the companies, the duration of the operation, and willingness to participate in the survey were considered while selecting the companies for the survey. An appropriate mix of large, medium and small companies in the public sector and private sector including multinationals were selected.

To conduct the survey, an IT industrial survey questionnaire was prepared. The questionnaire included three sections. The first section constituted questions related to the company profile such as what type of products the company produces or services provides, how much income is generated from the IT products and services per annum, and how many employees are working in the company. The second set of questions included the perception of the IT industry (concerned company) on the urban infrastructure challenges in the city, the human resource demands of the industry and their influence on the growth of the IT industry. Specifically, questions on the major infrastructural challenges and human resources, which significantly influence the growth of the IT industry were included. In this aspect, the questions were asked in two levels. With regard to infrastructural challenges, at the first level, questions were included on whether a particular infrastructure is a challenge in the city and does it influence the IT industry. If the answers are affirmative, then in the next level questions were asked which included the influence of the infrastructures on the IT industry. For example, with regard to road infrastructure, the first-level questions were: (1) whether the road infrastructure is a major challenge in the city, and (2) does it influence the growth of the IT industry in the city. If the answers were yes, then the second-level question was: what is the influence of road infrastructure on the growth of the IT industry. Similarly, in the third section, questions related to the challenge of human resources and its influence on the growth in the IT industry in the city were included. The surveys were conducted through a semi-structured interview process with the help of research assistants. The responses on the first level of questions were obtained on a categorical scale (Yes/No). The responses on the second level of questions, i.e., perceptions on the influence of infrastructure and human resources were obtained on a five-point Likert scale with 1 indicating very low, 2 indicating low, 3 indicating fair, 4 indicating high and 5 indicating very high.

Further, statistical data pertaining to income from the IT industry and supply of urban infrastructure at the city level were compiled from the published and unpublished reports, literature, and documents available at the city, and national levels. The statistical data on the income from the IT industry (considered as the measured variable of the growth of the IT industry-dependent variable) was obtained in terms of Million USD per year. The data on roads in a city were collected in terms of road length in Kilometres per year. The data on power (energy in terms of power generation in MW (megawatt)). Housing availability was collected in terms of the number of houses and the availability of built-up space of the IT industry was obtained in terms of square meters. The data on the human resource was obtained in terms of the total number of employees in the IT industry per year. These data were compiled over the period between 2004 and 2017.

4.2. Data analysis and modelling
The data were analyzed using both descriptive and inferential statistical methods. The perception indices (PIs) were used to evaluate the plausible influence of various urban infrastructures and human resources on the growth of the IT industry in cities of India. The PIs were calculated for the variables which received more than 50% affirmative responses on the level 1 questions. The mean Likert scale score was taken as the PI. The primary data collected were analysed city-wise and then on an aggregate basis to understand the similarities or variations and overall situation of the challenges of infrastructure and human resources among the three cities.

Further, inferential statistical methods such as correlation coefficient analysis, significance tests (t-tests) and regression analyses between income from the IT industry and the major urban infrastructure as well as human resources were conducted to examine the association between
the dependent and individual independent parameters. For this purpose, complied statistical data as obtained from various reports from the years 2004 to 2017 was used. However, data obtained with regards to Pune city only was used for these analyses and modelling as adequate data for Bhubaneswar and Kolkata were not available in a structured form. While analysing, the annual income from the IT industry was considered as a proxy for the growth of the industry. The annual income for the IT industry of the city was considered as the dependent variable and various influential urban infrastructures and human resources were taken as the independent variables.

A correlation coefficient of ≥0.5 was taken as the threshold for parameters to be considered as influential. Multi-collinearity analysis by using the Variance Inflation Factor (VIF) test was also conducted to determine the interdependency of the independent variables and their usefulness model development. Furthermore, the strength of the effect or relative influence of each independent variable on the income from the IT industry albeit growth of IT industry was assessed by determining both unstandardized and standardized Beta coefficients for each independent variable relating to the dependent variable (income for the IT industry). The unstandardized Beta coefficient associates the strength of the effect of each independent variable on the dependent variable implying that the more the absolute value of the Beta coefficient, the higher the effect. It also offers the degree of change in the outcome of the dependent variable for every 1-unit of change in the predictor variable (Ziglari, 2017). The standardized Beta coefficient offers the change in the dependent variable because of the change in independent variables in the same unit. Equation (1) was used to determine the unstandardized Beta ($\beta$) coefficient and equation (2) was used to determine the standardized Beta ($\beta'$) coefficient.

\[
\beta = \frac{Covariance(X_i, Y)}{Var(X_i)} \tag{1}
\]

\[
\beta' = \beta \frac{S_{X_i}}{S_{Y}} \tag{2}
\]

Where:

$\beta$ = Unstandardized beta coefficient

$\beta'$ = Standardized beta coefficient

$X_i$ = Independent variable

$Y$ = Dependent variable

$S_{X_i}$ = Standard deviation of independent variables.

$S_{Y_i}$ = Standard deviation of the dependent variable.

The combined understanding of the unstandardized, standardized beta coefficients ($\beta$ and $\beta'$) and coefficients of determination ($r^2$) was considered to evaluate the influence of the independent variables (urban infrastructure and human resource) on the dependent variable (income from IT industry; Ziglari, 2017).
Significance tests (t-test tests with p values for $\alpha \leq 0.05$) were done to establish significance between the independent variables (urban infrastructure and human resource) and dependent variable (income from IT industry) and the relationship between them as well as for testing the hypotheses.

Further, non-linear regression models between dependent variable-income from the IT industry and the major urban infrastructures and human resources were developed by using the relationships given in equations (3) and (4). The models were developed by considering the IT industry income generated and the availability of various infrastructures and human resources (estimated values as obtained from various literature and reports) over a period from the year 2004–2017. During the development of the models, extreme outliers were eliminated to enhance the robustness and accuracy of the models. The models were validated by checking the $r^2$, F, and p ($\alpha \leq 0.05$) values. The validated models were used to make sensitivity analyses to generate simulated scenarios that would predict the income from the IT industry under different scenarios of supply of urban infrastructure and human resources.

\[
Y = f(X^n) = a_0 + a_1X + a_2X^2 + \ldots + a_nX^n \quad (3)
\]

\[
Y = f(lnX) = a\ln X + c \quad (4)
\]

Where $X_i$ = independent variables; $Y$ = dependent variable; $a_n, \alpha = $ regression coefficients, $a_0$ and $c$ are constants

5. Results

The results and discussions are made under three aspects, such as the major urban infrastructure that influence the IT industry, the relative influence of each major urban infrastructure and human resources on the IT industry, and models and sensitivity analyses for predicting the growth of the IT industry under the impact of urban infrastructure and human resources.

5.1. Perception of IT industry in major urban infrastructures and human resources, which influence the IT industry in a city

Table 1 presents the perception of the IT industry on the different infrastructural and human resource challenges that influence the IT industry in the three cities and on an aggregate basis. The evaluations are made based on the PIs and p-values. A PI $\geq 3$ was considered fairly influential and PI $\geq 4$ was considered as highly influential. However, a PI $< 3$ was considered not influential. A p-value $\leq 0.05$ was considered statistically significant. It was found that the three cities present similar scenarios with marginal variations, indicating that the challenges faced by the IT industry in these three cities are more or less similar. Therefore, further evaluations were made on an aggregate basis. On the aggregate, human resource (PI = 4.39, p-value $\leq 0.05$) was found to be statistically significant and the most important influential parameter for the growth of the IT industry. Furthermore, houses (PI = 4.31, p-value $\leq 0.05$), road transportation (PI = 4.10, p-value $\leq 0.05$), and built-up office and industrial space (specifically for IT industry) (PI = 4.03, p-value $\leq 0.05$) are the major challenges and highly influence the growth of the IT industry. Also, electrical power (PI = 3.87, p-value $\leq 0.05$), is a moderate challenge and impact the growth of the IT industry fairly. The IT industry survey suggested that public transportation, parking, solid waste management, water supply, sanitation, entertainment facilities, commercial centres, health facilities, educational institutions, and organized open spaces do not impact the growth of the IT industry in the city significantly (Table 1). Thus, according to the perception of the IT industry, human resources, houses, built-up space for the IT industry, roads, and electrical power are critical for the
| Infrastructural facilities | Perception Index (PI) | SD   | Z test p-value | Rank |
|----------------------------|-----------------------|------|----------------|------|
|                            | Pune | Kolkata | Bhubaneswar | Overall |      |
| Road transportation        | 4.0  | 4.24    | 4.13        | 4.10    | 0.80 | 0.000† | 3    |
| Parking                    | 2.8  | 2.88    | 2.53        | 2.77    | 0.88 | 0.988  | 7    |
| Public transportation      | 2.93 | 3.00    | 2.73        | 2.91    | 0.93 | 0.799  | 6    |
| Housing                    | 4.3  | 4.4     | 4.2         | 4.31    | 0.81 | 0.000† | 2    |
| Power                      | 3.88 | 3.92    | 3.8         | 3.87    | 0.84 | 0.000† | 5    |
| Built of space for office and industries | 4.05 | 4.04 | 3.93 | 4.03 | 0.81 | 0.000† | 4    |
| Health facilities          | 2.6  | 2.44    | 2.27        | 2.48    | 0.79 | 0.998  | 12   |
| Water                      | 2.65 | 2.64    | 2.4         | 2.60    | 0.85 | 0.999  | 9    |
| Sanitation                 | 2.325| 2.36    | 2.53        | 2.37    | 0.77 | 0.995  | 14   |
| Solid waste                | 2.83 | 2.6     | 2.86        | 2.76    | 0.82 | 0.999  | 8    |
| Entertainment spaces       | 2.68 | 2.4     | 2.53        | 2.56    | 0.84 | 0.996  | 10   |
| Commercial centres         | 2.78 | 2.36    | 2.13        | 2.52    | 0.87 | 0.993  | 11   |
| Educational institutions   | 2.58 | 2.36    | 2.2         | 2.43    | 0.69 | 0.992  | 13   |
| Organized open spaces      | 2.2  | 2.36    | 2.0         | 2.21    | 0.85 | 0.999  | 15   |
| Human resources            | 4.4  | 4.44    | 4.27        | 4.39    | 0.70 | 0.000† | 1    |

N = 80

*- statistically significant
| Parameters                  | Correlation coefficients | VIF coefficients |
|-----------------------------|--------------------------|------------------|
|                             | Income from the IT      | R    | P    | H    | B    | E    | R    | P    | H    | B    | E    |
|                             | industry                |      |      |      |      |      |      |      |      |      |      |      |
| Income from the IT industry | 1                        |      |      |      |      |      | -4.38| 1.88 | 1.07 | 0.56 | 1.52 | 1.04 |
| Road (R)                    | 0.94                     | 1    |      |      |      |      | 1.88 | 1.29 | -1.01| -0.70| -0.66| -1.28|
| Electrical power (P)        | 0.83                     | 0.56 | 1    |      |      |      | 1.07 | -1.01| 1.53 | -0.71| -0.73| -0.20|
| Houses (H)                  | 0.81                     | 0.57 | 0.58 | 1    |      |      | 0.56 | -0.70| -0.71| 1.79 | -0.55| -0.31|
| Built-up space (B)          | 0.86                     | 0.47 | 0.49 | 0.51 | 1    |      | 1.52 | -0.66| -0.73| -0.55| 1.17 | -0.96|
| Human resources (E)         | 0.81                     | 0.62 | 0.43 | 0.49 | 0.55 | 1    | 1.04 | -1.29| -0.20| -0.31| -0.96| 1.67 |
growth of the IT industry in a city. Therefore, further analyses were made to examine the strength of the effects of each parameter and also to establish the linkage between these parameters with the IT industry.

The analyses of correlation coefficients between the income from the IT industry as the dependent variable and different urban infrastructures and human resources revealed that roads \((cc = 0.94)\), Built-up space \((cc = 0.86)\), electrical power \((cc = 0.83)\), houses \((cc = 0.81)\), and human resources \((cc = 0.81)\) are highly correlated with income from the IT industry (Table 2). Moreover, the low VIF coefficients (Table 2) suggest that these independent parameters do not show any significant co-linearity and are independent of each other.

Furthermore, the significant test (t-test) between the income from the IT industry and the four urban infrastructures such as road, electrical power, houses, and built-up space established statistical significance \((p \leq 0.05, \text{ for } \alpha < 0.05)\) between the dependent parameter income from the IT industry and the four mentioned urban infrastructures (Table 3). Similarly, the relationship between income from the IT industry and human resources is also statistically significant. The high \(r^2\) values (>0.80) show the validity of the relationships (Table 3). Therefore, based on the combined analyses of perceptions of people and IT industry, correlation coefficients, VIF test results, and significant tests, it can be ascertained that urban infrastructures such as houses, and built-up space of offices, roads, electrical power, and industries as well as human resource influence the growth of IT industry significantly. Consequently, the proposed hypotheses H1: Enhanced urban infrastructure (H11: Urban road, H12: Electrical power, H13: Houses and H14: Built-up space for offices and industry) enhance the growth of the IT industry and H2: Adequate human resource (knowledge workers) enhances the growth of the IT industry are established.

5.2. The relative influence of each major urban infrastructure and human resources on the IT industry

The relative effect of the four concerned urban infrastructures and human resources on the growth of the IT industry were examined by both unstandardized and standardized Beta tests. The relative influence of these parameters on the growth of the IT industry was established by simultaneous consideration of the unstandardized \((\beta)\), standardized beta \((\beta')\), and \(r^2\) values. The standardized and unstandardized beta and \(r^2\) values are presented in Table 4. It is found that with positive unstandardized beta values, the urban infrastructure (roads, electrical power, houses, built-up space) and human resources influence the income from the IT industry positively. In other words, an increase in these urban infrastructures and human resources will likely increase the income from the IT industry. The combined analyses of the two beta coefficients and \(r^2\) values suggest that Built-up space \((\beta = 1.55, \beta' = 55.87, r^2 = 0.83)\) is the most influential infrastructure followed by Houses \((\beta = 2.23, \beta' = 52.04, r^2 = 0.86)\). Roads influence fairly \((\beta = 0.98, \beta' = 0.94, r^2 = 0.95)\) and the influence of electrical power is relatively lesser among these urban infrastructures. Both the beta values and \(r^2\) for human resources \((\beta = 0.10, \beta' = 1.41, r^2 = 0.89)\) suggest that human resources have a fairly significant influence on the growth of the IT industry. The standardized beta values also show that 1 unit change in standard deviation in built-up space, houses, roads, electrical power, and human resources will incur changes in standard deviation units of 55.87, 52.04, 0.95, 0.027, and 1.41 in the income from IT industry, respectively.

5.3. Relationship between individual urban infrastructure and human resources, and growth of the IT industry

Non-linear empirical models between the five parameters (four urban infrastructures and human resources) and income from the IT industry were developed to establish the linkage between
As the intention was to find out how the individual independent variables (urban infrastructures and human resources) influence the dependent variable income from the IT industry, the regression modelling approach was found suitable and therefore used.

5.3.1. Road and income from the IT industry

The relationship between road and income from the IT industry is presented in Equation 5. It established a nonlinear parabolic (quadratic) relationship.

\[ Y = -6E + 0.05X_1^2 + 1.8158X_1 - 5546.9 \]
\[ r^2 = 0.95 \]  

where \( Y \) = Income from IT industry

\( X_1 \) = Road length in Kms

5.3.2. Power and income from the IT industry

Equation 6 presents the relationship between power and income from the IT industry. It shows a nonlinear parabolic (quadratic) relationship.

\[ Y = 0.0138X_2^2 - 5.4128X_2 + 133.37 \]
\[ r^2 = 0.89 \]  

Where \( Y \) = Income from IT industry

### Table 3. Statistical significance between income from IT industry and urban infrastructure and human resource

| Parameters       | r Square | t-stat | p* values significance | p** values significance | Significance | Hypotheses |
|------------------|----------|--------|-------------------------|-------------------------|--------------|------------|
| Road (R)         | 0.95     | 4.06   | 0.00019                 | 0.00039                 | Significant  | H11        |
| Electrical power (P) | 0.89     | -3.61  | 0.00156                 | 0.00312                 | Significant  | H12        |
| Houses (H)       | 0.86     | 61.59  | 1.008E-17               | 2.016E-17               | Significant  | H13        |
| Built-up space (B) | 0.83     | 44.99  | 5.865E-16               | 1.173E-15               | Significant  | H14        |
| Human resources (E) | 0.89     | 8.93   | 1.063E-06               | 2.127E-06               | Significant  | H2         |

[*-single-tailed; **- double tailed]

### Table 4. The relative influence of major infrastructure parameters and human resources on income from the IT industry

| Parameters       | Unstandardized Beta coefficient (β) | Standardized Beta coefficient (β') | R Square |
|------------------|-------------------------------------|------------------------------------|----------|
| Road (R)         | 0.98                                | 0.94                               | 0.95     |
| Power (P)        | 0.04                                | 0.027                              | 0.89     |
| Houses (H)       | 2.23                                | 52.04                              | 0.86     |
| Built-up space (B) | 1.55                               | 55.87                              | 0.83     |
| Human resources (E) | 0.10                              | 1.41                               | 0.89     |
5.3.3. Houses and income from the IT industry

The relationship between the availability of houses and income from the IT industry is presented in Equation 7. A non-linear logarithmic relationship between the two was observed.

\[ Y = 32643 \ln(X_3) - 434020 \]
\[ r^2 = 0.86 \]  

(7)

where \( Y \) = Income from IT industry
Equation 8 presents the relationship between built-up space and income from the IT industry. It shows a nonlinear logarithmic relationship.

\[ Y = 24601 \ln(X_4) - 326369 \]

\[ r^2 = 0.89 \]  

where \( Y \) = Income from IT industry

\( X_4 \) = Built-up space in sq. m.

5.4. Human resource and income from the IT industry

Human resource establishes a logarithm non-linear relationship with income from the IT industry. The relationship is presented in Equation 9.
\[ Y = 4674\ln(X_S) - 49353 \]
\[ r^2 = 0.83 \]

where \( Y \) = Income from IT industry
\( X_S \) = Built-up space in sq. m.

### 5.5. Sensitivity analyses, simulated scenarios, and hypothesis testing

The high \( r^2 \) values and \( p \) values <0.05 for \( \alpha < 0.5 \) established the validity of the models. These validated models were employed to make sensitivity analyses and generate simulated scenarios. For this purpose, simulated scenarios were created by increasing each urban infrastructure and human resources at differential increments ranging from 1% to 30% from the current (business as usual) scenario. Trend analyses of the simulated scenarios and comparison with the business as usual scenarios were done to assess the impact of the urban infrastructures and human resources on the growth of the IT industry. Figure 1(a-e) presents the trend of IT income in the city under different scenarios of growth of urban infrastructure and human resources. The model results (Figure 1(a-e)) evidenced positive albeit differential growth under different supplies of urban infrastructures and human resources. Although different simulated scenarios were developed by varying the parameters independently from 1.0% up to 30.0% at an increment of 1% each at a time, only 6 important scenarios (S1: 1%), (S2: 5%), (S3: 10%), (S4: 15%), (S5: 20%), (S6: 30%) and the business as usual scenario (BS) for income from IT industry were chosen for discussion and presented in Figure 2. Similarly, a change in income from the IT industry under these six simulated scenarios compared to the business as usual scenario is presented in Figure 3. As evidenced from Figure 2, a significant increase in houses, built-up space and electrical power will lead to a significant increase in income from the IT industry. Furthermore, it is found from Figure 3 that an increase of houses from 1% to 30% from the business as usual scenarios will increase the income from the IT industry from 5.04% to 133% followed by built-up space which will assist in increasing the income from 3.98% to 105.97%. Similarly, an increase in electrical power from 1% to 30% will enhance the income from the IT industry ranging between 22.85% to 101.22%. On the other hand, an increase of roads within the same range will marginally increase the income from the IT industry that would range between 1.0% to 22.35%. Furthermore, human resources will also contribute to the range of 0.73% to 19.26% under similar scenarios of enhancement. Thus, it is evidenced that the adequate availability of all the five parameters such as four urban infrastructures that include houses, built-up space, electrical power, and roads and human resources contributes positively to the growth of the IT industry, although to varying extents.

Furthermore, the evidence from these simulated scenarios in combination with the significance test (\( p \) values <0.05 for \( \alpha < 0.05 \)) and interlinkage between the urban infrastructures and human resources with income from the IT industry established the hypotheses that H1: Enhanced urban infrastructure (Urban road: H11, Electrical power: H12, Houses: H13 and built-up space for office space and industry: H14), and H2: Adequate human resource (knowledge workers) enhance the growth of IT industry.

### 6. Discussion and conclusion

The IT industry in developing nations such as India has become a vital part of the economy of the cities. However, the growth of the IT industry is also argued to be reliant on the availability of various urban infrastructures in a city. Although several studies have been conducted on the growth of the IT industry and arguments for policy initiatives for reinforcing urban infrastructures have been made to attract and establish IT industries in cities of developing countries such as India (Berry & Okulicz-Kozaryn, 2009; Das, 2019; Das & Sonar, 2013; Hollands, 2008; Navarro et al., 2017; Pradhan et al., 2018; Yigitcanlar et al., 2008), no direct linkage between urban infrastructure and growth of IT industry have been established thus far. Similar is the case for the relationship between human resources and the growth of the IT industry in a city. So, it was necessary to examine the linkage and
assess the impact of the several urban infrastructures and human resources on the IT industry in a city that would enable appropriate policy interventions, specifically for cities aspiring for IT industrial activities. This study has shown that what urban infrastructures and to what extent they would influence the growth of the IT industry in cities of developing countries. Furthermore, it established the linkage between human resources and the growth of the IT industry. Amongst the several urban infrastructures, the availability of adequate houses, and built-up spaces for offices and industry, urban roads, electrical power positively and significantly influence the growth of the IT industry albeit to differential extents. Houses and built-up space have a relatively higher influence than roads and electrical power. Human resources also influence fairly. While corroborating the findings of previous studies that urban infrastructures and human resources are crucial for the growth of IT industries in a city (Das, 2019; Das & Sonar, 2013; Pradhan et al., 2018; Yigitcanlar et al., 2007, 2008), it also substantiated the argument that urban economy and quality of urban space in terms of urban infrastructure are interlinked (Florida, 2002, 2005; Sassen, 1991, 2005), which could also contribute to transforming the cities to smart cities (Kumar et al., 2019; De Santis et al., 2014).

The major contribution of the study is that it established interlinkage among the urban infrastructures, human resources, and growth of the IT industry in cities of developing countries such as India. The empirical models that emerged from the interlinkages will enable assessing the impact of infrastructure on the growth of the IT industry quantitatively and assist in scenario analyses which could help in developing policy options. Thus, the findings of this study are envisaged to contribute to engendering appropriate policy options for prioritizing and developing relevant urban infrastructure to enable IT industry growth in similar aspiring cities of the developing world.

The scope of this study was limited to developing the association between relevant influential urban infrastructures and human resources independently with the growth of the IT industry in terms of income from the IT industry. However, the analysis of the combined effect of these urban infrastructures and human resources could offer more inclusive scenarios. Further, concurrently it is also acknowledged that urban infrastructure and human resources although are critical factors, several other important factors such as land availability, political and decision-making system, business environment, IT industry-friendly policy including taxation system, investment, the image of the city, etc., also influence the setting up of and growth of the IT industry in a city. Therefore, such aspects are considered as the further scope of this study. Despite the limitation, this study can contribute to engendering appropriate policy options for the development of urban infrastructure and human resources for the growth of the IT industry in the aspiring cities looking to strengthen their economy by encouraging setting up and growth of the IT industry in developing countries.

Funding
The author received no direct funding for this research.

Author details
Dilip Kumar Das
E-mail: dkd1267@gmail.com
ORCID ID: http://orcid.org/0000-0003-3071-6109
Civil Engineering, Sustainable Transportation Research Group, School of Engineering, Howard College, University of KwaZulu-Natal, Durban, South Africa.

Disclosure statement
No potential conflict of interest was reported by the author(s).

Author statement
Enhancement of the economy and reinforcing the infrastructure are essential for the development of Smart and Sustainable Cities in developing countries. Engendering the knowledge economy led by IT industries is argued to contribute significantly in this direction. The study is a part of a major project on smart and sustainable cities in developing countries. It examined what urban infrastructure influence the growth of the IT industry and to what extent. Also, it established the association between human resources and the IT industry growth. The models developed and consequent findings that emerged would assist the aspiring cities to evaluate the influence of urban infrastructures and human resources, which would enable them to take appropriate policy measures, develop strategies and prioritise relevant infrastructure to augment the knowledge economy through IT industries and consequently, would contribute to the development of smart and sustainable cities in developing countries.

Citation information
Cite this article as: Appraisal of the linkage among urban infrastructure and human resources and the growth of Information Technology (IT) industry in Indian cities, Dilip Kumar Das, Cogent Engineering (2022), 9: 2034263.
References

Abraham, G., van der Vyver, A. G., & Mario, M. (2015). Evaluating users’ perceptions of the digital doorway: A narrative analysis. Information Technology for Development, 21(1), 99–112. https://doi.org/10.1080/02681102.2013.841629

Alkemade, F., & Surr, R. A. A. (2012). Patterns of expectations for emerging sustainable technologies. Technological Forecasting and Social Change, 79(3), 448–456. https://doi.org/10.1016/j.techfore.2011.08.014

Asongu, S. A., & Le Roux, S. (2017). Enhancing ICT for inclusive human development in Sub-Saharan Africa. Technological Forecasting and Social Change, 118, 44–54. https://doi.org/10.1016/j.techfore.2017.01.026

Baartlett, J. E., Kottrlik, J. W., & Higgins, C. C. (2001). Organizational research: Determining appropriate sample size in survey research. Information Technology, Learning, and Performance Journal, 19(1), 43–50.

Bankole, F., & Mimbii, L. (2017). ICT infrastructure and its impact on national development: A research direction for Africa. The African Journal of Information Systems, 9(2), 77–101. https://digitalcommons.kennesaw.edu/ajis/vol9/iss2/1

Barcelona city. (2003). Barcelona City, Culture, the Motor of the Knowledge City: Strategic Plan of the Cultural Sector of Barcelona. Council of the Strategic Plan of the Cultural sector.

Baum, S., Yigticanlar, T., Horton, S., Velibeyoglu, K., & Gleeson, B. (2009). The role of community and lifestyle in the making of a knowledge city. Report. Griffith University.

Berry, B. J. L., & Okulicz-Kozaryn, A. (2009). Dissatisfaction with city life: A new look at some old questions. Cities, 26(3), 117–124. https://doi.org/10.1016/j.cities.2009.01.005

Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart cities in Europe. Journal of Urban Technology, 18(2), 65–82. https://doi.org/10.1080/10630732.2011.601117

Cochran, W. G. (1977). Sampling techniques (3rd ed.). John Wiley & Sons.

Colechia, A., & Schreyer, P. (2008). ICT Investment and economic growth in the 1990s: Is the United States a unique case? A comparative study of nine OECD countries. Review of Economic Dynamics, 5(2), 408–442. https://doi.org/10.1016/j.redy.2002.01.010

Das, D. (2016). Engendering image of creative cities by use of Information and Communication Technology in developing countries. Urban Planning. Urban Planning, 1(3), 1–12. https://doi.org/10.17645/ups.v1i3.686

Das, D. (2019). Exploring perspectives of the Information Technology industry in a South African city. Sustainability, 11(22), 6520. https://doi.org/10.3390/su11226520

Das, D., & Sonar, S. G. (2013). Perspective impacts of Information Technology industry in development of Pune city in India. Journal of New Generation Sciences, 1(3), 1–17.

Datta, A., & Agarwal, S. (2004). Telecommunication and economic growth: A panel data approach. Applied Economics, 36(15), 1649–1654. https://doi.org/10.1080/000368404200018552

De Santis, R., Fasano, A., Mignoni, N., & Villa, A., 2014. Smart city: Fact and fiction. https://mpra.ub.uni-muenchen.de/54536

De Silva, D. G., & McComb, R. P. (2012). Geographic concentration and high tech firm survival. Regional Science and Urban Economics, 42(4), 691–701. https://doi.org/10.1016/j.regsciurbeco.2012.03.001

Ergazakis, K., Metaxiotis, K., & Psarras, J. (2006). Knowledge cities: The answer to the needs of knowledge-based development. Journal of Information and Knowledge Management Systems, 36(1), 67–84. https://doi.org/10.1108/03055720610667381

Florida, R. (2002). The rise of the creative class and how it’s transforming work, leisure, community and everyday life. Basic Books.

Florida, R. (2005). The flight of the creative class: The new global competition for talent. Harper Collins.

Francis, K., Andoh-Baidoo, B. O., & Niki, K. (2014). KICT capacity as the investment and use of ICT: Exploring its antecedents in Africa. Information Technology for Development, 20(1), 51–59. https://doi.org/10.1080/02681102.2013.804199

Gifinger, R., Fertner, C., Kramar, H., Kolasek, R., Pichiermilanović, N., & Meijers, E. (2007). Smart cities: Ranking of European medium-sized cities. Vienna University of Technology. Retrieved October 13, 2017, from http://www.smart-cities.eu/

GlobeScan. (2007). Megacity challenges – A stakeholder perspective – A research project conducted by GlobeScan and MRC McLean Hazel and sponsored by Siemens. <http://w1.siemens.com/pres/en/events/megacities/green_cities.php>

Guma, P. K., & Monstadt, J. (2021). Smart city making? The spread of ICT-driven plans and infrastructures in Nairobi. Urban Geography, 42(3), 360–381. https://doi.org/10.1080/02723638.2020.1715050

Hartal, S., Rubin, O. D., & Molul, M. (2021). The mobility preferences of ICT knowledge workers: Do second-ranked cities have a chance of attracting them? Journal of Urban Affairs, 1–15. https://doi.org/10.1080/07352666.2020.1860676

Hollands, R. G. (2008). Will the real smart city please stand up? City analysis of urban trends, culture, theory. Policy Action, 12(3), 303–320. https://doi.org/10.1080/13608010802479126

Jalava, J., & Pohjola, M. (2008). The roles of electricity and ICT in economic growth: Case Finland. Explorations in Economic History, 45(3), 270–287. https://doi.org/10.1016/j.eeh.2007.11.001

Koutroumpis, P. (2009). The economic impact of broadband on growth: A simultaneous approach. Telecommunication Policy, 33(9), 471–485. https://doi.org/10.1016/j.telpol.2009.07.004

Kuada, J. (2015). Private enterprise-led economic development in Sub-Saharan Africa, the human side of growth. (J. Kuada, Eds.). Palgrave Macmillan.

Kumar, H., Singh, M. K., & Gupta, M. P. (2019). A policy framework for city eligibility analysis: TISM and fuzzy MICMAC-weighted approach to select a city for smart city transformation in India. Land Use Policy, 82(C), 375–390. https://doi.org/10.1016/j.landusepol.2018.12.025

Martinez, D., Rodriguez, J., & Torres, J. (2010). ICT-specific technological change and productivity growth in the US: 1980–2004. Information Economics Policy, 22(2), 121–129. https://doi.org/10.1016/j.infoecopol.2009.07.001

Mishra, V., & Bisht, S. S. (2013). Mobile banking in a developing economy: A customer-centric model for policy formulation. Telecommunication Policy, 37(6-7), 503–514. https://doi.org/10.1016/j.telpol.2012.10.004
Moussiopoulos, N., Achillas, C., Vlachokostas, C., Spyridi, D., & Nikolaou, K. (2010). Environmental, social and economic information management for the evaluation of sustainability in urban areas: A system of indicators for Thessaloniki, Greece. Cities, 27(5), 377–384. https://doi.org/10.1016/j.cities.2010.06.001

NASSCOM. (2016). The IT-BPM sector in India: Strategic review. https://community.nasscom.in/docs/DOC-1048

Navarro, J. L. A., Ruiz, V. R. L., & Peña, D. N. (2017). The effect of ICT use and capability on knowledge-based cities. Cities, 60, 272–280. https://doi.org/10.1016/j.cities.2016.09.010

Pradhan, R., Mallik, G., & Bogchi, T. P. (2018). Information communication technology (ICT) infrastructure and economic growth: A causality evinced by cross-country panel data. IIMB Management Review, 30(1), 91–103. https://doi.org/10.1016/j.iimb.2018.01.001

Sassen, S. (1991). The global city. Princeton, Princeton University Press.

Sassen, S. (2005). The global city– Introducing a concept. Brown Journal of World Affairs, XI(2), 27–43. https://www.jstor.org/stable/24590544?seq=1&cid=pdf-reference#references_tab_contents

Sassi, S., & Goaded, M. (2013). Financial development, ICT diffusion and economic growth: Lessons from MENA region. Telecommunication Policy, 37(4–5), 252–261. https://doi.org/10.1016/j.telpol.2012.12.004

SCM. (2015). Smart Cities Mission, Government of India, https://www.smartcities.gov.in.

Singh, I., & Kaur, N. (2017). Contribution of Information Technology in growth of Indian Economy. International Journal of Research -granthaalayah, 5(6), 1–9. https://doi.org/10.29121/granthaalayah.v5i6.1986

Szarek-Iwaniuk, P., & Seneta, A. (2020). Access to ICT in Poland and the co-creation of urban space in the process of modern social participation in a smart city—A case study. Sustainability, 12(5), 2136. https://doi.org/10.3390/su12052136

Tchamyou, V. S. (2017). The role of knowledge economy in African business. Journal of the Knowledge Economy, 8(4), 1189–1228. https://doi.org/10.1007/s13132-016-0417-1

The Times of India. (2015, July 27). Pune second only to Bengaluru in software exports. http://timesofindia.indiatimes.com/city/pune/Pune-second-only-to-Bengaluru-in-software-exports/articleshow/48230042.cms

Toader, E., Firtescu, B. N., Roman, A., & Anton, S. G. (2018). Impact of information and communication technology infrastructure on economic growth: An empirical assessment for the EU countries. Sustainability, 10 (10), 3750. https://doi.org/10.3390/su10103750

Van Winden, W., Berg, W., van Den, L., & Peter, P. (2007). European cities in the knowledge economy. Urban Studies, 44(3), 525–549. https://doi.org/10.1080/00420980601131886

Vu, M. K. (2011). ICT as a source of economic growth in the Information Age: Empirical evidence from the 1996-2005 period. Telecommunication Policy, 35(4), 357–372. https://doi.org/10.1016/j.telpol.2011.02.008

Vu, M. K. (2013). Information and communication technology (ICT) and Singapore’s economic growth. Information Economics Policy, 25(4), 284–300. https://doi.org/10.1016/j.infoecopol.2013.08.002

Yigitcanlar, T., Baum, S., Horton, S., & Carrillo, F. J. (2007). Attracting and retaining knowledge workers in knowledge cities. Journal of Knowledge Management, 11(5), 6–17. https://doi.org/10.1108/13673270710819762

Yigitcanlar, T., O’Connor, K., & Westerman, C. (2008). The making of knowledge cities: Melbourne’s knowledge-based urban development experience. Cities, 25(2), 63–72. https://doi.org/10.1016/j.cities.2008.01.001

Yigitcanlar, T., Veilbeyoglu, K., & Baum, S. (Eds.). (2008a). Knowledge-based urban development: Planning and applications in the information era. IGI Global.

Yigitcanlar, T., Veilbeyoglu, K., and Baum, S. (eds.). (2008b). Creative Urban Regions: Harnessing Urban Technologies to Support Knowledge City Initiatives. IGI Global, Hershey, PA. pp. 1–363.

Young, D., & Keil, R. (2010). Reconnecting the disconnected: The politics of infrastructure in the in-between city. Cities, 27(2), 87–95. https://doi.org/10.1016/j.cities.2009.10.002

Ziglar, L. (2017). Interpreting multiple regression results: β weights and structure coefficients. General Linear Model Journal, 43(2), 13–22. https://doi.org/10.31523/glmj.043002.002
