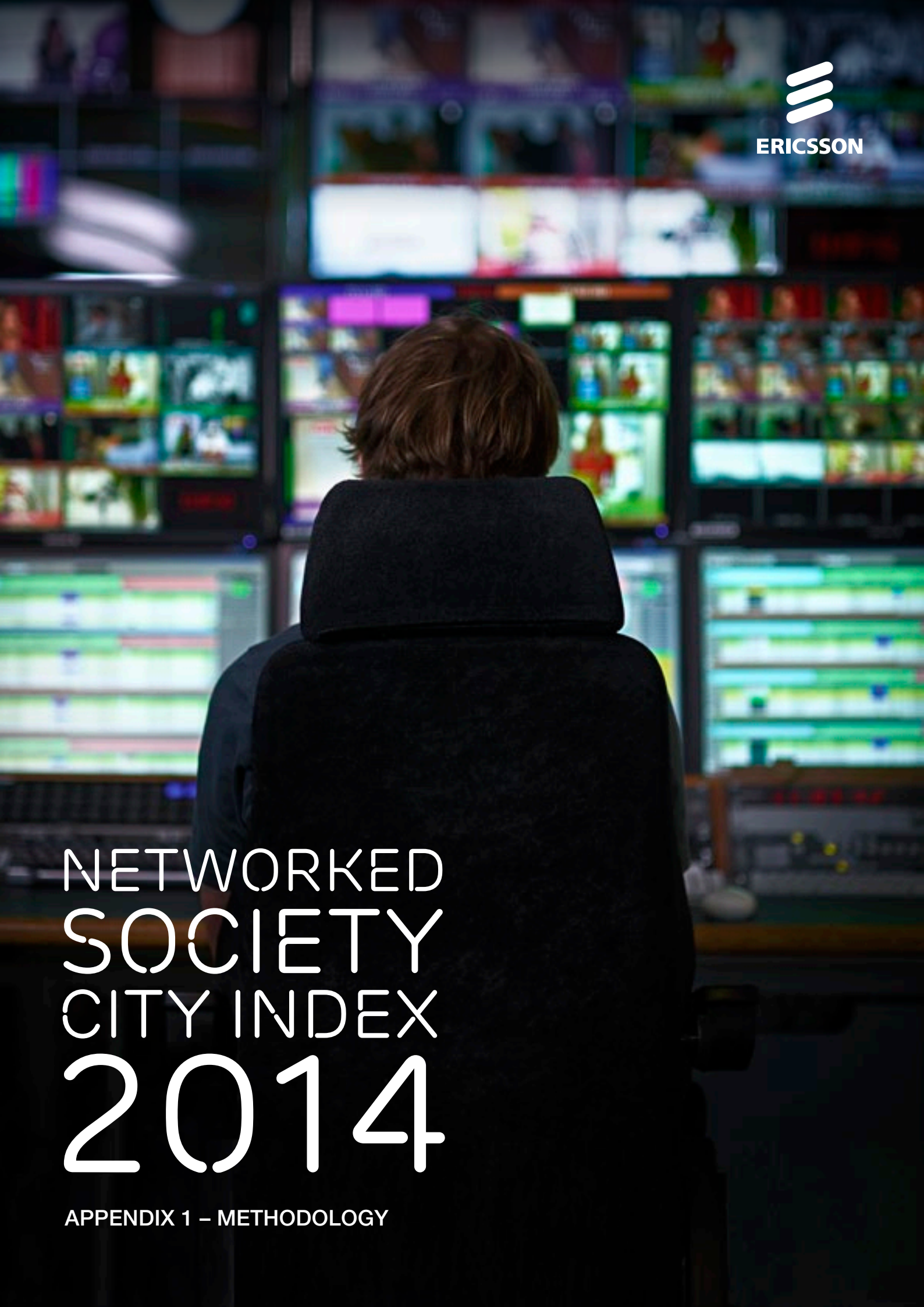


ERICSSON

NETWORKED SOCIETY CITY INDEX 2014

APPENDIX 1 – METHODOLOGY

CONTENTS

The Networked Society City Index compares cities' ICT maturity and their social, economic and environmental development (triple bottom line).

INTRODUCTION

This section outlines the way the index was created, along with the thought processes and circumstances behind the chosen approach. Because the method used is affected by the requirements of the index, this methodology section will start by listing these requirements before describing the theoretical framework and rationale.

REQUIREMENTS ON THE INDICES AND THE METHOD USED

It has always been a priority that the report and the methods used should be comprehensible for a broad audience. One of the main target groups comprises decision and policy makers: it is important that they should be able to see where a city is doing well and where it needs improvement. The indices should highlight different perspectives of importance for a society and act as a catalyst for discussions on these different perspectives.

It is important that a theoretical framework is put in place and that the rationale behind each indicator is discussed. The indicators should be selected so that the total effect represents a meaningful composite indicator. The theoretical framework should in turn influence the way the indicators are weighted and aggregated. Important immeasurable perspectives also have to be included in the discussions because some of the most meaningful indicators cannot always be measured.

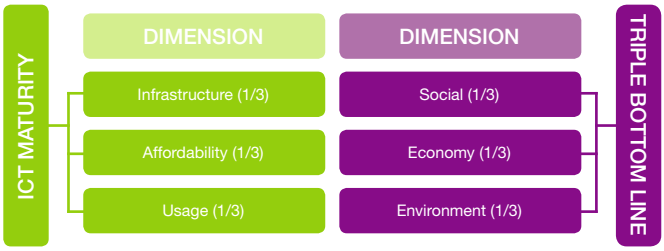
When selecting the indicators, it is important to consider the possibility of collecting the required data for cities all around the world, where circumstances can vary dramatically. The challenge is to find indicators that create a meaningful composite indicator, that are possible to collect and that they can be measured so they are comparable between all the cities.

When the data cannot be collected for a chosen indicator, different approaches of imputing values should be considered. The selected method of imputation depends on the nature of the missing value. The robustness of the indices also need to be assessed in such a case, along with evaluating the effect of excluding single indicators, rescaling them and analyzing the effect of different imputations.

The composite indicators should also be examined for possible correlation with other published indicators; they should also be transparent so that underlying indicators or values can be broken down and examined.

INDEX CONSTRUCTION

A hierarchical model has been chosen to make the methods easier to understand. The top-level aggregates represent the two perspectives from which we measure a city's performance, both regarding maturity in Information and Communications Technology (ICT) and the Triple Bottom Line (TBL). The top-level aggregates are in turn divided into three sub-perspectives called dimensions. For TBL, these dimensions are Social, Economic and Environment. For ICT these sub-perspectives are Infrastructure, Affordability and Usage.



Each dimension is described by a set of variables. The variables are created by aggregating a set of proxies that are meaningful in terms of describing a city's performance. Different weightings are applied in some cases to provide a more meaningful composite measure. The TBL index is a geometric aggregate of the dimensions:

$$TBL = (Social)^{1/3} \cdot (Economy)^{1/3} \cdot (Environment)^{1/3}$$

Aggregation

"In both linear and geometric aggregations, weights express trade-offs between indicators. A shortcoming in one dimension thus can be offset (compensated) by a surplus in another. This implies an inconsistency between how weights are conceived (usually they measure the importance of the associated variable) and the actual meaning when geometric or linear aggregations are used. In a linear aggregation, the compensability is constant, while with geometric

aggregations, compensability is lower for the composite indicators with low values. In terms of policy, if compensability is admitted (as in the case of pure economic indicators) a country with low scores on one indicator will need a much higher score on the others to improve its situation, when geometric aggregation is used. Thus in benchmarking exercises, countries with low scores prefer a linear rather than a geometric aggregation. On the other hand, the marginal utility from an increase in low absolute score would be much higher than in a high absolute score under geometric aggregation. Consequently, a country would be more interested in increasing those sectors/activities/alternatives with the lowest score in order to have the highest chance to improve its position in the ranking if the aggregation is geometric rather than linear."[1]

We have chosen geometrical aggregation to reward a city that is characterized by a balanced performance in several dimensions. Rather than letting the rate of substitution be linear, as would be the case in arithmetic aggregation, a geometric aggregate is therefore calculated. Geometric weights are applied and used to give an indicator a greater weighting and to create a more meaningful aggregate when indicators of different importance are being used. To calculate an aggregate, each of its components is raised to the power of its weight: the product of the weighted components will be the calculated value. Generally, for an arbitrary aggregate with n components, it is expressed as:

$$Aggregate_i = \prod_{j=1}^{n} Component_{i,j}^{\ weight_j}$$

The formula below means that the aggregate of affordability is calculated by raising tariffs to its weight n and IP transit prices to its weight (1/3).

$$Affordability = (Tariffs)^{2/3} \cdot (IP\ transit\ prices)^{1/3}$$

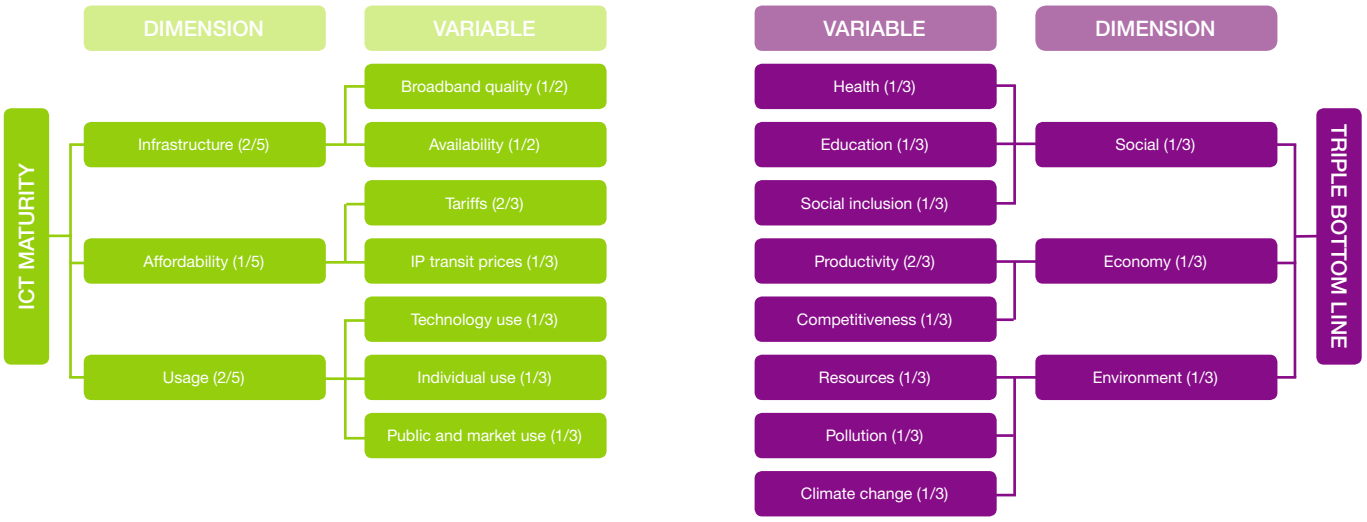
The index is constructed as a hierarchy where each step is the aggregate of the subordinated components. Variables are the aggregate of indicators used to measure the variable, dimensions are the aggregate of the variables used to estimate the performance in the dimension and the top-level aggregate (ICT maturity and TBL) is the aggregate of the dimensions used.

$$Top\ aggregate = \prod_{i=1}^{n} Dimension_i^{\ weight_i} =$$

$$= \prod_{i=1}^{n} \left(\prod_{j=1}^{m} Variable_{i,j}^{\ weight_j} \right)^{weig}$$

An intuitive way to present a hierarchical structure is with the help of a tree diagram. We have therefore presented the construction of the two models in the figure below. The root of each tree represents the top-level aggregate and the branches lead to the nodes that are aggregated to the top-level index. The number in parentheses displays the weight used in the aggregation. The branches show that the aggregate of the dimension Affordability is composed of the variables Tariffs and IP transit prices.

1. OECD, Handbook on constructing composite indicators (2005)



Normalization

To make normalization as simple as possible and not need to change the calculations when new cities are added, we have chosen to rescale the values so that the rescaled indicator only attains values between 1 and 100. The maximum and minimum values are chosen so that it is unlikely that a new city would fall outside the interval. This is done by adding 20 percent to the maximum and minimum values of the cities included in the index, or by using the theoretical maximum and minimum when they are close enough to the spread of the data not to heavily distort the rescaling. It is important to note rescaling is sensitive to outliers where an extreme value affects the variance of the rescaled variable and thus the impact on the aggregated value.

$$Proxy_{Rescaled} = \frac{Observed - Min}{Max - Min} \cdot (100 - 1) + 1$$

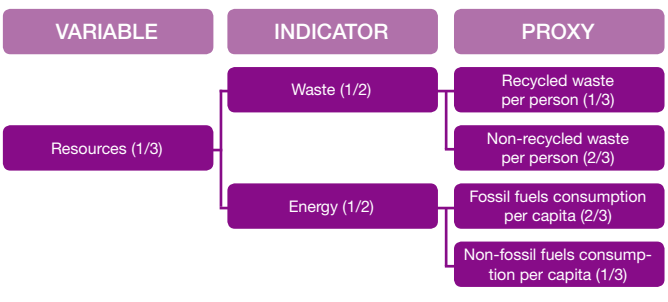
Variable construction

The variables are constructed in a similar fashion to the top aggregates. A variable is the aggregate of the subordinated indicators which in turn is the aggregate of the subordinated proxies. The proxies are the actual data points and are rescaled so that they have a value between 1 and 100 where higher equals better. For proxies that are considered to have an undesirable effect on the dimension, such as the effect of high carbon dioxide emissions on the environment, the values are reversed so that a low level of carbon dioxide emissions results in a larger rescaled value than a high level of emissions.

$$Variable = \prod_{i=1}^{n} Indicator_i^{weight_i} =$$

$$= \prod_{i=1}^{n} \left(\prod_{j=1}^{m} Rescaled\ proxy_{i,j}^{weight_j} \right)^{weight_i}$$

The tree diagram below shows the hierarchical construct of the variable resources. Equal weighting of the indicators was in this case considered to give a meaningful aggregate of the use of resources. For the indicator Waste, recycled waste was considered to be better for the environment than unrecycled waste. Total waste per person was therefore divided into recycled and unrecycled waste, and cities that had a high level of unrecycled waste were assessed harder than cities with a high recycle rate.



Handling missing data

When data is missing for a region, four different types of imputations are considered. The method selected will depend on the nature of the missing value and the indicator. The method of imputation should be used with care because the lack of data might be related to the value of other variables. For instance, a country with high GDP might be less likely to collect statistics on literacy at city level than a country with low GDP. Use of the unconditional mean in such a case might result in an inaccurate estimate. The relationship between the other variables and the indicator value should be used to impute the data in such a case. We will consider four types of imputation:

- **Hot-deck imputation**
  If we cannot find data for a city, we may use a larger region that includes the city, such as a state or country. This method should be used with care because data for cities may differ greatly from that for the larger region.

- **Cold-deck imputation**
  In many cases it may be difficult to find indicators from the same year for all of the cities. It might however be possible to find older data. If the variable is stable over time, the best estimate for the indicator might be obtained by using older data for the indicator rather than other types of imputation.

- **Unconditional mean**
  This type of imputation can be used if the indicator shows no clear relationship with other variables. However for the indicators in our indices, this may create poor estimates of the actual value. We will therefore avoid this method.

- **Regression imputation**
  When the indicator shows a relationship with other variables for the city for which we have data, we can use this relationship to get a better estimate of the indicator than simply using the unconditional mean or implicit modeling. For instance, many of the variables show a correlation with GDP and this relationship can be used when imputing the missing data to get a better estimate of the indicator.

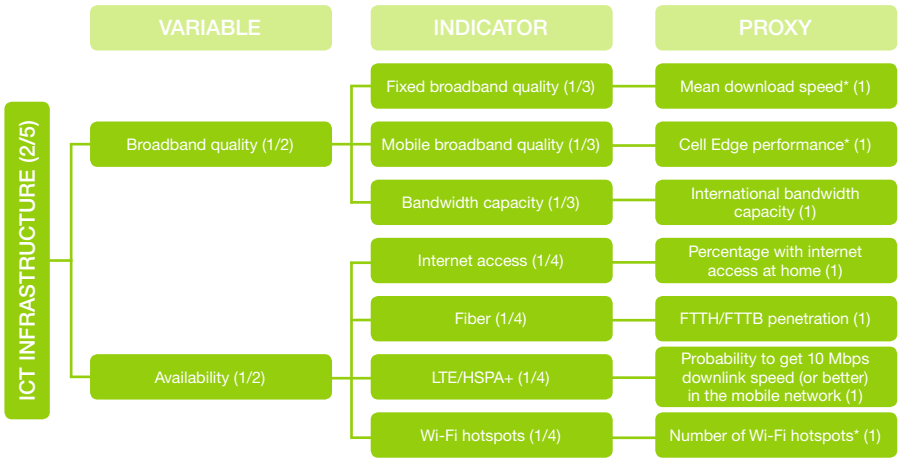
DESCRIPTIONS OF ICT INDICATORS AND VARIABLE RATIONALE

ICT is in many ways the essential basis for the everyday mechanics of a modern city. ICT affects quality of life and spurs economic development within the world's cities. Information and communication technology is setting the pace for a changing, competitive and dynamic global marketplace, providing a platform that enables business and socioeconomic development by introducing and spreading the concepts of knowledge sharing, community development and equality.[2, 3]

The ICT maturity index aims to describe the readiness of cities to participate in the global information society and the degree to which a society is prepared to make use of ICT infrastructure and digital content. The ICT index is built on three blocks: ICT Infrastructure, ICT Readiness and ICT Usage. These three dimensions are constructed to reflect the complexity of ICT maturity in a city, underlining the fact that the available technology, a functioning market and usage of ICT are important perspectives when measuring ICT maturity. The indicators to measure the performance of ICT infrastructure and individual access to both basic and high technology have been selected after discussions with ICT experts. To provide a more meaningful composite index for ICT maturity, the perspectives of Infrastructure and Usage are considered to be of greater importance than Affordability; to highlight this fact, these dimensions are weighted more heavily than Affordability.

A similar study has been performed by the ITU,[4] with some differences. In this index we are interested in the ICT maturity of cities while the ITU focused on countries. Another difference is that this index emphasizes more high-tech solutions such as the quality of mobile and fixed broadband through advanced fiber and LTE technologies, and chooses not to include fixed-line telephony which has been shown to have a decreasing impact on society.

2. ICT for City Management (2010);
3. Economic Impact of Broadband: An Empirical Study (2009)
4. Measuring the Information Society (2012)



ICT Infrastructure

ICT infrastructure offers a range of technologies to assist cities in operating efficiently, and the use of ICT infrastructure allows cities to gain competitive advantages. The continuous evolution of information technologies and systems creates opportunities for governments, businesses and citizens. Cities therefore require the basics – the infrastructure – and need to upgrade that infrastructure continuously.

The level of the ICT infrastructure is measured by two variables, broadband quality and availability, where equal weighting is considered to give a meaningful composite for measuring a city's infrastructure.

BROADBAND QUALITY

Indicators: Fixed broadband quality, Mobile broadband quality and Bandwidth capacity

Proxies: Fixed broadband means download speed, mobile broadband call edge performance and international bandwidth capacity.

Definitions: Average download speed. Source: Based on Speedtest.net results (2014)

Downlink speed May 1, 2014-July 29, 2014. 90 percent probability of getting this speed in the city. Source: Based on Ericsson's analysis of Speedtest.net results provided by Ookla (2014)

Data represent bandwidth connected across international borders to metropolitan areas as of mid-year. Domestic routes are omitted.

Variable rationale

Broadband quality is measured by assessing international bandwidth capacity and by evaluating the broadband speed; these indicate the possibilities and online services that in practice can be used given the current infrastructure. To capture both how agile and advanced the usage of internet could potentially be, mobile broadband quality and fixed broadband quality are both used as indicators. The international bandwidth capacity indicates the opportunities for international communications and potential to compete on the global market. The indicators are weighted equally to provide a meaningful composition of the variable.

AVAILABILITY

Indicators: Internet access, Fiber penetration, LTE/HSPA+ and Hotspots

Proxies: Household internet access. Percentage of households with access to fiber-optic broadband, probability of getting 10 Mbps downlink speed (or better) in the mobile network. Number of hotspots.

Definitions: Percentage of households with internet access at home. Access can be via a fixed or mobile network, irrespective of the device used.

Percentage of households with access to fiber-optic broadband. Fiber to the x (FTTX). It mainly includes FTTH and FTTB, but sometimes even configurations such as FTTC.

Probability of getting 10 Mbps downlink speed (or better) in the mobile network. Source: Based on Ericsson's analysis of Speedtest.net results provided by Ookla (2014)

Number of hotspots within a radius of 3km from a certain point in the city center.

Variable rationale

The Availability variable measures how well the infrastructure reaches the population, the technological level of communications and the diversity of technologies used in the city. Internet access is measured by percentage of population with internet access at home. The diversity in communications is measured by fiber penetration, market adoption of LTE/HSPA+ and the availability of Wi-Fi hotspots.

LTE/HSPA+ measures the competitiveness and quality of the leading mobile broadband technology and indicates the capabilities of the infrastructure to allow advanced mobile broadband services. Internet access in households enables people to work from home, interact electronically with banks or governments, and shop online. Several studies show that these are all ICT applications that we prefer to do at home on a larger screen rather than on a smartphone, showing that different ICT solutions demand different forms of internet access. Internet penetration is also positively correlated with business formation.[5, 6]

Since a majority of smartphones, tablets and computers have built-in support for Wi-Fi connectivity, the indicator for Wi-Fi hotspots captures the availability of internet access for a wide set of devices. Wi-Fi hotspots can also provide internet access in areas where mobile broadband infrastructure and coverage are still undeveloped.

5. Towards A Connected World Socio-Economic Impact of Internet in Emerging Economies (2009)
6. Network developments in support of innovation and user needs (2009)

ICT Affordability

The ICT Affordability dimension assesses the market and price level of ICT. The affordability perspective is important because it affects the spread of ICT. An ICT market function and price setting that make connectivity less dependent on an individual's income are seen as important signs of ICT maturity.

TARIFFS

Indicators: Fixed broadband tariffs and Mobile-cellular tariffs.

Proxies: Fixed broadband tariffs (residential monthly fee) as percentage of a city's GDP per capita. Mobile cellular tariffs (average per-minute call during peak hours) as percentage of a city's GDP per capita.

Definitions: The fixed-broadband sub-basket is calculated by the ITU on the basis of the price of a monthly subscription to an entry-level fixed-broadband plan.

The mobile-cellular telephony sub-basket is calculated by the ITU and is largely based on, but does not entirely follow, the 2009 methodology of the OECD low-user basket. It gives the price of a standard monthly usage of mobile services, as determined by OECD.

The mobile cellular tariff in the country is divided by the city's GDP per capita.

Variable rationale

Tariffs – for broadband and mobile-cellular services – are used to measure the cost of ICT connectivity. This in turn is divided by the city's GDP per capita to relate the price to the income levels of a city's inhabitants. The cost of accessing ICT is also an indicator of the level of competition in the internet and telephony sectors. An efficient market is essential for an efficient price mechanism and is therefore crucial for the availability of ICT.[7] Supply and demand in the market is decided by the quality of the product and the price that the customers are willing and able to pay. For a society to be considered mature in ICT, price setting has to allow penetration in all social and economic groups.

IP TRANSIT PRICES

Indicators: IP transit prices

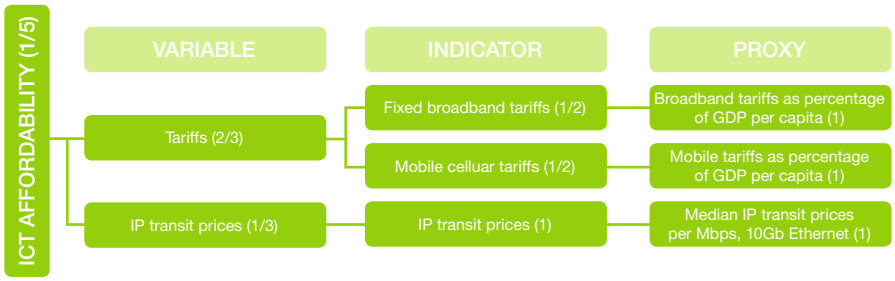
Proxies: Median IP transit prices per Mbps, 10 Gigabit Ethernet (10,000 Mbps)

Definitions: Monthly USD-per-Mbps prices, excluding local access and installation fees.

Variable rationale

IP transit prices complement the measurement of the market's function and thereby the price a resident has to pay to be online. The spread of information relies on network traffic, so basic economic theory leads to the conclusion that higher costs will mean less information being spread. A lower price should therefore lead to a greater flow of information and greater potential for the city to maximize its development.

7. Digital World Forum and the South/North Divide (2008)



ICT Usage

The adoption of ICT, and both basic and advanced use of such technologies, are seen as important aspects of ICT maturity. The ICT Usage dimension strives to capture the degree to which consumers as well as the private and public sectors are taking advantage of the available ICT infrastructure and technology. The dimension is a measure of the ability of a society to adapt to new technology and make effective use of ICT.

TECHNOLOGY USE

Indicators: Smartphones, Tablets, Mobile phones, Computers

Proxies: Smartphone penetration, Tablet penetration, Mobile phone subscriptions, Percentage of households with a computer at home

Definitions: Number of smartphones per capita.

Number of tablets per capita.

Mobile-cellular telephone subscriptions refer to the number of subscriptions to a public mobile-telephone service that provides access to the public switched telephone network using cellular technology.

A computer refers to a desktop or a laptop computer. It does not include equipment with some embedded computing abilities, such as mobile-cellular phones, personal digital assistants or TV sets.

Variable rationale

New technologies and solutions are enabling a rapid widening of cooperation, participation and knowledge sharing to previously excluded groups, as well as a deepening in terms of the types of activities and topics that are subject to collaborative behavior. Mobile devices, such as mobile phones, smartphones and tablets, are extending the scope of internet usage and the potential for new ICT services. Use of the internet is becoming increasing important as a means of information exchange, social networking, democratic participation and economic activity. It is important to measure consumers' adoption of technology because usage levels affect the incentives for both the public and private sectors to use ICT to reach the inhabitants of a city.

INDIVIDUAL USE

Indicators: Internet use, Social networking

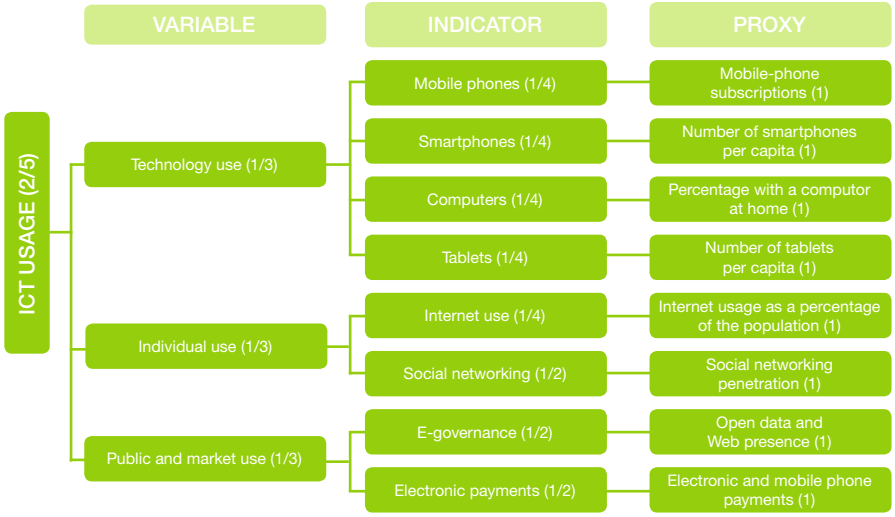
Proxies: Internet usage as percentage of population, social networking penetration

Definitions: The percentage of individuals using the internet.

Percentage of online population in the country using social networking multiplied by the percentage of the population in the city using the internet.

Variable rationale

The indicators Internet use and Social networking are used to describe ICT usage that has surpassed the most fundamental level of maturity. The internet is a focal point in ICT and its usage can therefore be used to measure the ICT usage of the inhabitants.



PUBLIC AND MARKET USE

Indicators: Open data and web presence, Electronic payments

Proxies: If the city (or country) has an open data homepage and if the page has an API. Electronic payments and mobile phone payments.

Definitions: Open data measures whether there is city data accessible through an API. It also measures if there is traffic data, geographical data, population data, city government financial information and environmental data accessible through an API.

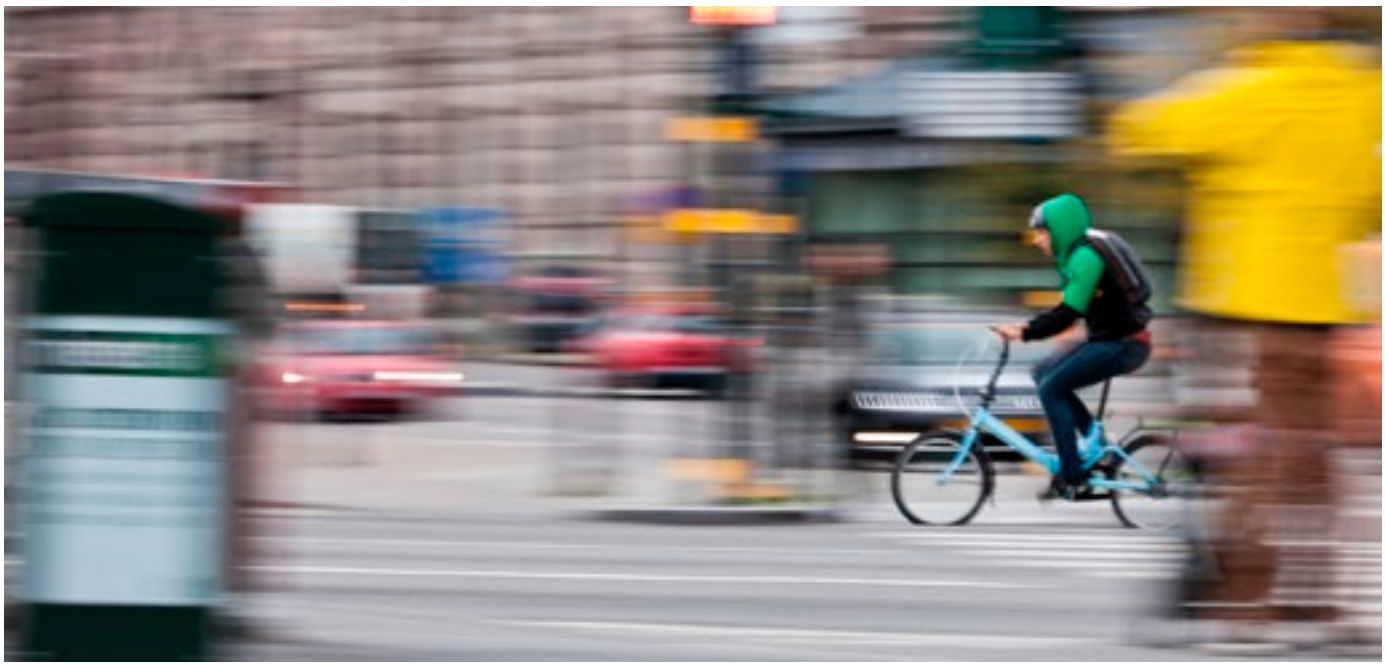
Web presence measures whether the city government has an official web page with basic (contact) information such as e-mail, phone numbers etc. This captures the first stage in a city's web presence development. We also measure if the city has forms for services such as ID cards or parking permits available for download (the second stage with services that enhance convenience for residents). Finally we measure whether people can apply online for services such as ID cards or parking permits (third stage, where people can rely completely on the website for certain services).

Percent of individuals using electronic payments or mobile phone payments. Based on national data and estimated for the urban population.

Variable rationale

An Open data page with an application programming interface (API) is related to the technology level of the public sector. It provides the ability for programmers to write applications that can efficiently access data regarding the city. A developed official city homepage, with e-services and essential contact information, is also related to the technology level of the public sector.

Electronic payments show the ICT maturity of both the business sector and consumers regarding the use of ICT for financial transactions.



DESCRIPTIONS OF TRIPLE BOTTOM LINE (TBL) INDICATORS AND VARIABLE RATIONALE

Cities are growing quickly and their impact on global sustainable development will continue to increase. While each city has its own unique circumstances, all cities share a common challenge: how to find a strategic policy approach that balances the three pillars of sustainability – environment, economy and society – at once?

It is difficult to measure and compare overall social, economic or environmental progress or to quantify "quality of life" on a city level, but it is possible to track individual indicators relevant to these broader concepts with a reasonable level of accuracy. There are many global indices published every year by organizations such as the UNDP, World Economic Forum and Freedom House that try to give an estimate of competitiveness, social development, environmental performance or a combination of all three on a national level. One challenge is to measure and compare regional progress on a city level, largely because much of the basic data needed for such a comparison (health and life expectancy, civil and political rights etc.) in many countries is aggregated on the national level. With the TBL index created in this report, we try to reflect the views of the respective research fields. It is important to state that we are not trying to come up with a new and better way to measure TBL.

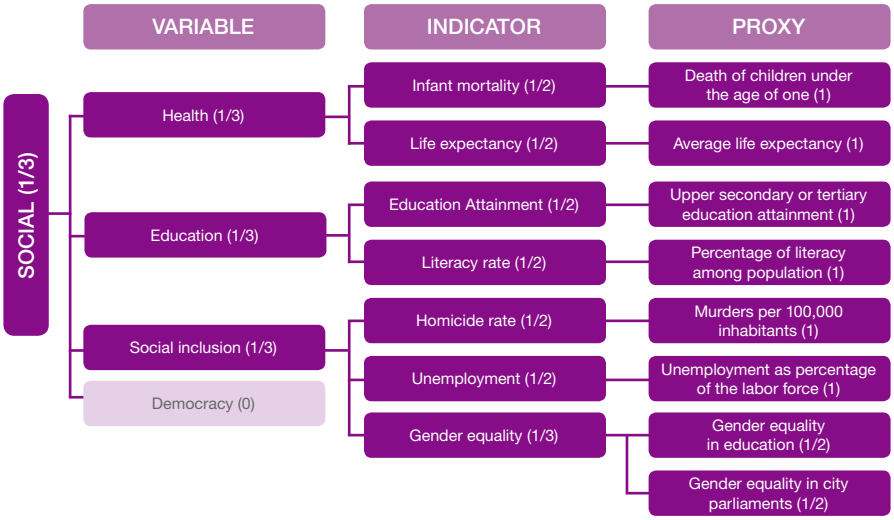
During recent decades, ICT has become more evident in everyday urban life and in people's actions and behavior. ICT spurs economic development: it is positively correlated with GDP and growth, and directly affects quality of life. Getting the sustainable city up and running relies in part on managing, utilizing and sharing the various forms of data that work together for urban development.

Social dimension

Hope for a better quality of life is fundamental, leading to urbanization trends in most parts of the world. For people seeking to improve their standard of living, cities provide opportunities for work, housing, health, education and leisure – all important factors in the quest for higher living standards and greater well-being.

Urban development has long been related to economic performance and physical structures that define the city's form and function. In recent decades, there has been growing concern about the environmental sustainability of the community, which has had significant implications for the management of many cities. However, a city is so much more than physical structures and an economy. A city is composed of people and the places where they live: it is a social, physical and economic environment. Communities therefore need not only be environmentally sustainable or economically vibrant: to be attractive and competitive, a city must also be socially sustainable.

Trying to measure how well a city performs in the social dimension is a real challenge, because the necessary indicators and proxies not only need to be identified, but also connected to the city itself. The most important indicators of societal performance are only available for the national level, but major social disparities between the national and city levels mean national data is often unreliable and ambiguous on the city level. Furthermore, important data on social well-being, such as democracy, is not easily collected on the city level. Democracy can be measured – for example, by the share of the population that participates in local elections – but in some countries, factors such as voter registration or a lack of alternative candidates can make it a complicating indicator when comparing cities. Because we currently lack sufficient data to create a variable for democracy that is a good reflection of reality, we have chosen not to include it in this year's index. The variable is kept in the hierarchy to display its importance for social development and the aim is to include it in the future.



Compiling a list of variables that are representative of social sustainability is not straightforward. The contextual dependency makes room for different interpretations and various aspects of social well-being are often closely interconnected, not only with each other but also with aspects such as culture. The index has been elaborated using variables according to various research and literature. The main variables chosen for this year's index are health, education and social inclusion.

Health, Education and Social inclusion

HEALTH

Indicators: Infant mortality rate and Average life expectancy

Proxies: Deaths of children under the age of one year, Average life expectancy

Definitions: The number of deaths of children aged less than one year of age that occurred in a given year, expressed per 1,000 live births.

Life expectancy is the average number of years that a person can be expected to live from birth, assuming that age-specific mortality levels remain constant.[8]

Domain rationale

Better health is central to human happiness and well-being. It also makes an important contribution to economic progress, as healthy populations live longer and are more productive. They also invest more (save) in their future.[9] In rich and poor countries alike, the gross inequalities in people's health are not simply a product of their individual choices, but are also determined by the environment in which they find themselves. The health of a city's population is a solid indicator of well-being. When a city contributes to the improved physical and mental well-being of its population, it is either directly or indirectly also spurring the overall development of the city.

In the past, the infant mortality rate was regarded as a highly sensitive measure of a population's health. This reflects the apparent association between the causes of infant mortality and other factors that are likely to influence the health status of whole populations such as economic development, general living conditions, social well-being, rates of illness and the quality of the environment.[10] High child mortality is also directly correlated to low environmental indicators such as the level of wastewater treatment, and sewerage and sanitation facilities.[11]

Measures such as the infant mortality rate often become the principal focus of health policy so that health strategies and priorities are formulated with the proxy outcome measure in mind. Consequently, health policies often target the chosen outcome measure, while ignoring the rest of the population for which the outcome measure was supposed to be an indicator. As a result, infant mortality may decrease as it becomes the principal focus of health policy, while the entire population's health may remain static or even degrade.

8. http://www.kingsfund.org.uk/time-to-think-differently/trends/demography/life-expectancy
9. WHO
10. Infant mortality rate as an indicator of population health. D Reidpath, P Allotey. J Epidemiol Community Health 2003;57:344–346
11. UN-Habitat, guidelines for prosperity of cities

This creates the necessity to use other, more comprehensive measures of a population's health, such as average life expectancy, as a complementary proxy for health. Such measures are intended to be sensitive to changes of health across the whole population, and account for the morbidity associated with non-fatal health outcomes as well as mortality. More complex proxies have been developed, such as the disability-adjusted life expectancy (DALE). However, data collection is not possible on a city level.[12]

EDUCATION

Indicators: Education attainment and Literacy rate

Proxies: Upper secondary or tertiary education attainment, Literacy rate

Definitions: Educational attainment is defined as the highest grade completed within the most advanced level attended in the educational system of the country where the education was received.

The literacy rate is the total number of literate persons in a given age group, expressed as a proportion of the total population in that age group. The adult literacy rate, used in this index, measures literacy among people aged 15 years and above.

Domain rationale

Cities are the centers of thought, action and information dissemination in the field of education. Urban areas, and the urban population, are growing and cities have an increasingly important role in education in order to promote sustainable development. Urban sustainability involves improving city dwellers' quality of life, all-inclusive equality and reducing poverty. Education is an increasingly important factor for inclusion in modern work life. Furthermore, a better informed society is better prepared to tackle current and future challenges concerning the environment and climate. It is also more competitive in the context of global economic competition. With that in view, education plays a crucial part in various aspects of urban social life and it is a solid indicator of the development level of a city's society.[13]

Quality of life is concerned with the balance between material well-being, physical and mental health, family life, labor market participation and social participation. Safety and personal security is a core element for the well-being of individuals, and largely reflects the risks

SOCIAL INCLUSION

Indicators: Homicide rate, Unemployment and Gender equality

Proxies: Murders per 100,000 population, unemployment rate as share of the labor force, gender equality in education and gender equality in city parliaments

Definitions: Reported murders are the number of murders reported to the police. To facilitate the comparison among cities/regions, the number of murders is divided by the population and multiplied by 100,000.

The unemployment rate is the ratio between the unemployed and the labor force and comprises all people above a specified age who, during the reference period, were:

a) without work, i.e. were not in paid employment or self-employment,
b) currently available for work, i.e. were available for paid employment or self-employment,
c) seeking work, i.e. had taken specific steps in a specified recent period to seek paid employment or self-employment.

Gender equality in education includes students enrolled in upper secondary and tertiary education. Number of women who study is divided by the number of men. If more women than men study it is calculated the other way around.

Gender equality in city parliaments refers to the percentage of women in the city councils, parliaments, legislative assemblies or similar bodies. If more women than men are members of the city parliament it is calculated the other way around.

of physical assault or other types of crime. One of the biggest impacts of crime on well-being appears to be through the feeling of vulnerability and insecurity that it creates. Homicide rates (the number of murders per 100,000 inhabitants) represent only the most extreme form of crime against the person and therefore do not provide information about more typical safety conditions. They are, however, a reliable measure of a country's safety level because, unlike other crimes, murders are almost always reported to the police.[14]

Social inclusion refers to the capacity of individuals and households to participate in economic and social life. Labor market participation is important, and sometimes essential, for social inclusion and a good quality of life. Employment not only provides an income and the resultant ability to earn a living, but is also important for social participation in all urban spheres.[15] Income is an important means to achieving higher living standards and greater well-being. Higher economic wealth may also improve access to better education, health care and housing.[16] However, economic indicators are included in the Economic

12. Infant mortality rate as an indicator of population health. D Reidpath, P Allotey. J Epidemiol Community Health 2003;57:344–346
13. UNESCO, Education for Sustainable Development. United Nations Decade 2005-2014
14. www.oecdbetterlifeindex.org/topics/safety/
15. www.esri.ie/research/research_areas/social_cohesion_and_quality_of_life/
16. www.oecdbetterlifeindex.org/topics/life-satisfaction/

dimension of the index and are therefore omitted from the social dimension for statistical reasons.

Gender equality is another important aspect of social inclusion. Gender equality relates to the productivity of labor and the extent to which economies get the most out of their human resources. Greater gender equality also improves the productivity of the next generation of workers because higher levels of female education and labor force participation have been found to be a major factor in investments in children's education and bringing about fertility decline.[17]

ICT and social development

ICT assists us in many areas of our lives. Large-scale deployment of communications technologies has produced major changes in the way individuals communicate for social purposes. ICT plays, and will play, an important role in many areas connected to social development, such as health care or interaction between citizens and government, improved access to education and housing, or increased safety and security in urban environments.[18]

- **ICT and health**
  Several research reports suggest a correlation between ICT and health. ICT maturity affects health indirectly through a positive correlation with economic development and directly through the improvement of efficiency and communication in health-care systems and the development of e-health services that improve access to health information.[19, 20, 21, 22]

- **ICT and education**
  Improving the quality of education is a critical issue. ICT has long been regarded as an important tool for improving educational processes, with the potential to improve the quality of educational systems, extend educational opportunities and increase individual access to education.[23] ICT can offer transformational tools that, when used appropriately, can promote the shift to a learner-centered environment. ICT can enhance the quality of education by increasing learner motivation and engagement, and by facilitating the achievement of basic skills. ICT has also been used to improve access to and the quality of teacher training.

  ICT provides powerful tools for extending educational opportunities and increasing access to education. Groups often excluded from education due to cultural or social reasons – such as ethnic minorities, girls and women, people with disabilities, and the elderly, as well as others who for reasons of cost or time constraints are unable to enroll on campus – can more easily get access to education using ICT.

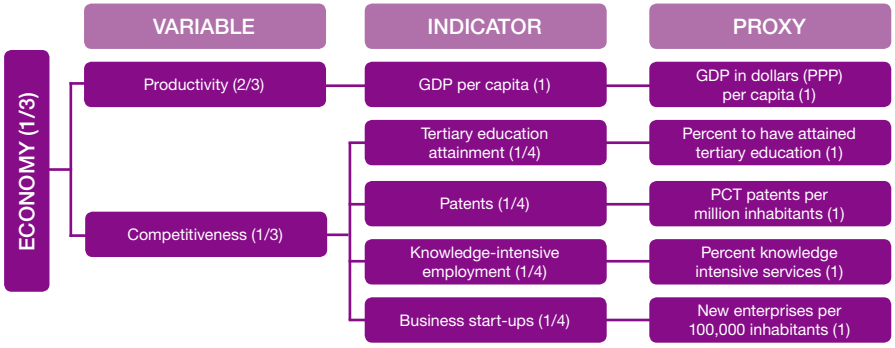
  One commonly cited reason for using ICT in education has been to prepare students for a workplace where ICT, computers, the internet and related technologies are becoming increasingly ubiquitous. Technological literacy, or the ability to use ICTs effectively and efficiently, is seen as providing a competitive edge in an increasingly globalized job market.[24, 25, 26, 27, 28, 29, 30, 31, 32]

- **ICT and social inclusion**
  Technology adaptation and penetration help create a more connected, safer city. ICT is used in a variety of areas such as advanced security and monitoring systems, recording criminal details, informing citizens about safety in a city, tracking devices and, not least, integrating safety solutions across different stakeholder groups.[33]

  ICT also has made it possible to compare supply and demand in labor markets, resulting in more efficient matchmaking between employees and employers. The internet has created a structural change in the employment advertising market, affecting the way individuals relate to the labor market and employment opportunities. Companies, government bodies and recruitment agencies are able to source candidates quickly and more efficiently online, and an increasing proportion of job seekers prefer the speed and convenience of internet-based job search.[34]

  While there is recognition of the potential of ICT as a tool for the promotion of gender equality and the empowerment of women, a gender divide has been identified, reflected in the lower numbers of women accessing and using ICT compared with men. This is true of rich and poor countries alike. Access to ICT can enable women and men to gain a stronger voice in their communities, their government and at the global level.[35, 36]

17. IDS working paper, volume 2013 No 417, Gender Equality and Economic Growth: Is there a Win-Win?
18. http://www.oecdbetterlifeindex.org/topics/life-satisfaction/
19. Fibre - The socio-economic benefits (presentation in PDF format) (2007)
20. Economic & Fiscal Impact of Introducing Broadband Networks and Services in Lebanon (2009)
21. Digital World Forum and the South/North Divide (2008)
22. Champion for Digital Inclusion (2009)
23. http://siteresources.worldbank.org/EDUCATION/Resources/278200-1290520949227/SABER_Report_Ch9.pdf
24. Champion for Digital Inclusion
25. Network developments in support of innovation and user needs (2009)
26. True Broadband - Exploring the economic impacts (2003)
27. Digital quality of life (2008)
28. Need for Speed: A new study confirms the positive effects of an increased broadband speed on GDP (2011)
29. Digital World Forum and the South/North Divide (2008)
30. Economic & Fiscal Impact of Introducing Broadband Networks and Services in Lebanon (2009)
31. Fibre - The socio-economic benefits
32. Towards A Connected World Socio-Economic Impact of Internet in Emerging Economies (2009)
33. www.slideshare.net/PlanetInspired/the-case-of-safe-and-smart-cities
34. www.seek.com.au/content/media/EmploymentIndex/SEEK_AU_EI_Background.pdf
35. http://www.un.org/womenwatch/daw/public/w2000-09.05-ict-e.pdf
36. IT&SOCIETY, VOLUME 1, ISSUE 7, SUMMER 2004, PP. 18-25. The global digital divide – within and between countries, Wenhong Chen, Barry Wellman



Economic dimension

In the new global economy, cities are engines of economic growth: their size and high population density combined with high accessibility create economies of scale that benefit economic activity, nourish innovation and foster a dynamic labor market.[37]

Economic growth is considered the main driver for higher living standards. However, being a city does not automatically lead to prosperity – some do not develop into economic hotspots. To succeed, some geographically fixed resources such as human capital, institutions and technology must be used effectively. Increasing either productivity or the quantity of goods and services produced can spur economic growth and improve the standard of living. In the past few decades, the ICT revolution has changed the way we see the economy as a whole.[38]

The performance of a city's economy and the prosperity of its residents are positively correlated with GDP and economic growth. For example, there is a very strong correlation between GDP per capita and national performance according to the UNDP's Human Development Index.[39]

Productivity and Competitiveness

PRODUCTIVITY

Indicator: GDP per capita

Proxy: GDP in USD (PPP) per capita (logarithm)

Definitions: GDP in USD current prices, current PPP. Calculated on the GDP at current prices divided by the purchasing power parity (PPP) for GDP, countering the differences in price levels between countries. GDP is divided by the population and transformed with the natural logarithm.

Domain rationale

Gross domestic product (GDP) is the market value of all officially recognized final goods and services produced within a country in a given period of time. GDP is a universally accepted measure of economic performance, although it is now being challenged as a measure of economic success. The prosperity of nations is closely linked with growth in their cities: they provide homes for people and bases for their enterprises, which are responsible for a large share of national GDP.[40] In Asia, it is estimated that more than 80 percent of regional GDP is produced in urban areas[41]. The 600 largest metropolitan regions of the world generate 60 percent of global GDP.[42]

It is important to note that GDP per capita is not a measure of personal income. However, GDP per capita correlates strongly with household income on the city level and is often considered an indicator of a country's or city's standard of living.

Other variables and indicators of productivity were also discussed during construction of the index. Most can be regarded, however, as subsets or components of GDP per capita and therefore have not been included.

We use the logarithm of GDP per capita to reflect the diminishing importance of income with increasing GDP. This is based on the studies and methods used in the Human Development Index (HDI) developed by the United Nations Development Programme (UNDP).

37. Krugman: "Geography and Trade" (1991)
38. Economic Impact of Broadband: An Empirical Study(2009
39. UNDP: http://hdr.undp.org/en/statistics/
40. UN-HABITAT, State of the World's Cities 2010/2011: Bridging the Urban Divide (2010).
41. Asian Development Bank
42. McKinsey Global Institute: Urban World – mapping the economic power of cities (2011)

COMPETITIVENESS

Indicators: Tertiary education attainment, Employment in knowledge-intensive services (KIS), Patents, Business start-ups

Proxies: Attained tertiary education (%), PCT patents per million inhabitants, Share of knowledge-intensive services (%), New enterprises per year per 100,000 inhabitants

Definitions: Educational attainment is defined as the highest grade completed within the most advanced level attended in the educational system of the country where the education was received. Tertiary education: ISCED 5 Tertiary programs, ISCED 6 Advanced Research.

Knowledge-intensive services (KIS) are computed as the ratio between employees in KIS and total employment. KIS includes the following sectors:

- Information and communication
- Financial and insurance activities
- Real estate activities
- Professional, scientific and technical activities
- Public administration and defense; compulsory social security
- Education
- Human health and social work activities
- Arts, entertainment and recreation

PCT (Patent Cooperation Treaty) patent applications per million inhabitants (fractional count; by inventor and priority year)

Business start-ups measured as the number of enterprises/establishment entries per year per capita

Domain rationale

Innovation is a driver of productivity growth, which in turn supports the growth of profits, wages and GDP. Innovation therefore leads to greater prosperity for a city and better quality of life for city dwellers. Innovation and productivity are connected through processes leading to improvements within existing firms and organizations. Process and organizational innovation lead to efficiency gains in production, creation of new goods and services, and to increased demand for firms' products.[43]

There is widespread recognition that tertiary education is a driver of economic growth and innovation, and a precondition for positive economic development.[44] The OECD[45] and other bodies have pointed out that tertiary education contributes to social and economic development.[46] In one reports on this issue, the OECD points to four major development contributions from higher education:

a) The formation of human capital (primarily through teaching).
b) The building of knowledge bases (primarily through research and knowledge development).
c) The dissemination and use of knowledge (primarily through interactions with knowledge users).
d) The maintenance of knowledge (primarily through inter-generational storage and transmission of knowledge).

Furthermore, universities and public research institutions play an important role in innovation and economic development. As participation in tertiary education expands in both industrialized and developing countries, tertiary institutions have assumed responsibility for a far wider range of occupational preparation than in the past. Substantial reforms are therefore taking place in tertiary education systems aimed at encouraging institutions to be more responsive to the needs of society and the economy.[47]

A city's climb up the value ladder goes hand in hand with an increase in the proportion of knowledge-intensive businesses. UNDP[48] work has shown that the level of achievement in technology critically depends upon the level of higher education in a given economy. Most countries with high enrollment ratios in higher education became "leaders" in technology, with high levels of achievement in technology and knowledge-based industries.[49] On knowledge-intensive services, the OECD concludes that: "From research and development to legal and marketing services, a wide range of knowledge-intensive services (KIS) enables firms and public sector organizations to better innovate. KIS are both sources and carriers of knowledge that influence, and improve the performance of individual organizations, value chains and industry clusters across all sectors of the economy."[50]

The number of patents in a regional economy can be seen as one indicator of a region's capacity to reinvent and take new ideas to the market. The patent system has evolved with a view to promote innovation and encourage economic development. It also promotes investment to commercialize and market new inventions. Furthermore, the system is designed to disseminate knowledge and information to the public through publication of patent applications and granted patents.[51]

The number of business start-ups is a measure of a region's entrepreneurial climate. They are important for job creation and add an increased dynamism to a city's economic activity.[52]

43. The Impact of Broadband on Growth and Productivity (2008)
44. Centre for Higher Education Transformation (CHET): Higher Education and Economic Development (2011)
45. OECD - Organization for Economic Co-operation and Development
46. OECD: Tertiary Education for the Knowledge Society: OECD Thematic Review (2008)
47. Centre for Higher Education Transformation (CHET): Higher Education and Economic Development (2011)
48. UNDP - The United Nations Development Programme
49. European Commission: Knowledge intensive (business) services in Europe (2012)
50. OECD: Innovation and Knowledge-Intensive Services Activities (2006)
51. World Intellectual Property Organization
52. Kaufmann Foundation: The Importance of startups in job creation and job destruction (2010)

ICT and urban economies

Estimates for 113 countries over a 20-year period show a positive link between ICT and GDP, as well as income, affecting city dwellers' quality of life.[53]

ICT contributes to productivity, innovation, trade and economic growth in both developed and emerging economies. The impact of ICT goes well beyond the ICT sector itself, because of the spillover effects to the rest of the economy. For this reason, ICT has been widely acknowledged as an important driver of the economy. In that sense, ICT is compared to power supply and the railways, and their historical contributions to growth. ICT is playing an enabling role and unlocking economic growth in other sectors. For example, investment in ICT capital increases labor productivity even in sectors that traditionally have not used such technologies.[54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64]

- **ICT and innovation**
  ICT is of major importance when it comes to connecting ideas, people and resources. While a company's innovative capability depends partly on its internal competencies such as R&D, it also depends on organizational strategy and innovation – processes in which ICT can play a central role. An example of how ICT has contributed to innovation is crowd financing, the collective cooperation, primarily via the internet, to support and finance ideas initiated by other people or organizations.

- **ICT and competitiveness**
  ICT has an influence on the number of new business formations. By expanding communications activity in a region or a city, it can also enhance competition in telecommunications, opening up the scope for productivity and competitive gains for key industries.[65] Wide use of the available technologies shows that ICT adoption can be a key element for a region that wants to remain competitive.[66, 67, 68]

- **ICT and improved economic performance**
  A better economic performance relies in part on managing, utilizing and sharing various data that work together for urban development and that also take into account the balance between the three pillars of sustainability: environment, economy and society. Here ICT already plays a very important role – a role that can be even larger in the future.

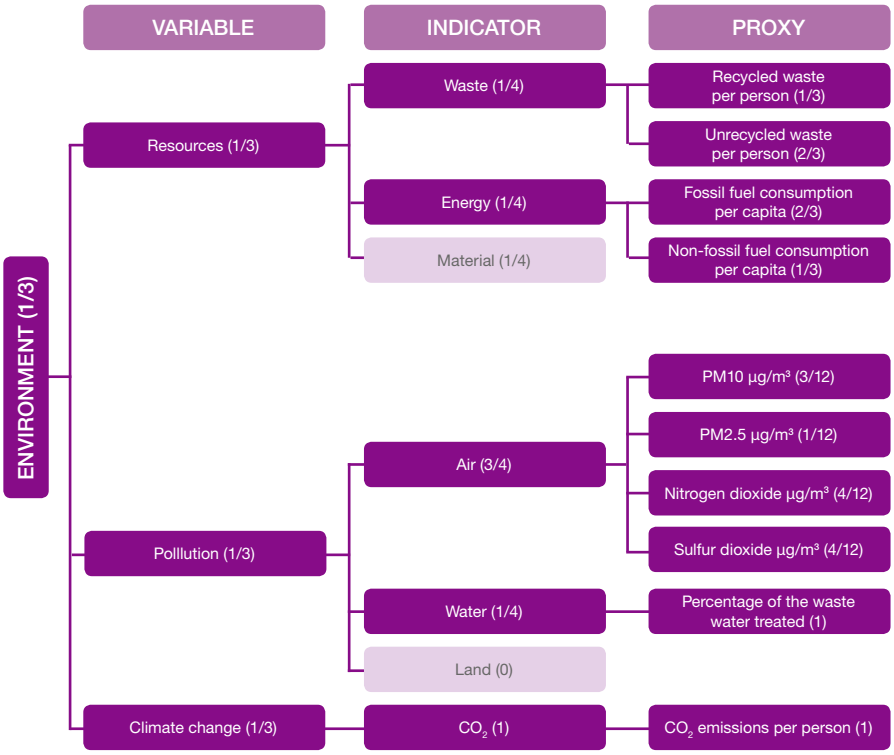
Environmental dimension – overall rationale

A sustainable city is dependent on the everyday actions and behavior of its people, organizations and enterprises. More than half of the world's population lives in cities and the urban share of population will continue to rise. As a result, the performance of cities is a critical factor for the state of the global environment and climate. Cities are key players for battling climate change, and also have the most to lose if climate change goes out of control. ICT already plays an important role when cities try to reduce their environmental impact through smarter technical infrastructure, recycling or measuring air pollution.[69] ICT is also expected to play a similarly important role to help growing cities become more "climate smart."

The rapid increase in urban population and urban production has been accompanied by an even faster increase in the use of fossil fuels, other mineral resources and in freshwater, fish and forestry products. Urbanization is also associated with increasing wealth, at least for a large proportion of the growing urban population, and increasing per-capita consumption levels. Urbanization can therefore be seen as a key driver of high levels of resource use and waste generation. A city's use of resources (in terms of energy and materials) and the waste it generates have serious ecological consequences locally, regionally (where resource and waste flows from urban centers shift to the wider region) and globally (for instance in regard to climate change and damage to the ozone layer).[70] A city's performance and impact vary depending on economic profile and current position in global value chains. While a typical industrial city would have a large local and regional environmental impact, a more services-oriented city might have a clean environment locally but produce a larger ecological footprint[71] globally.

Many large cities face significant energy, environmental and climate-related challenges now and in the future.[72] A growing number of these are making climate change a focus of their policy initiatives, working with transport issues as a way to improve the sustainability of urban travel, in addition to environmental, land-use, safety and accessibility objectives. To deal with these challenges efficiently, cities need to become more resource efficient, consumer-focused and technology-driven.

53. www.ifpri.org/sites/default/files/pubs/pubs/ib/ib40.pdf
54. Need for Speed: A new study confirms the positive effects of an increased broadband speed on GDP (2011)
55. Measuring the Information Society, ITU (2012).
56. Measuring broadband economic impact (2005)
58. Next G Productivity Impacts Study (2009)
59. Cities of opportunities (2012)
60. Megacities - our global urban future (2005)
61. Digital World Forum and the South/North Divide (2008)
62. Economic & Fiscal Impact of Introducing Broadband Networks and Services in Lebanon (2009)
63. Economic Impact of Broadband: An Empirical Study (2009)
64. A Single Market for an Information Society – Economic Analysis The Impact of e-Business on the Single Market: Trade Flows Between EU Member States (2009)
65. True Broadband - Exploring the economic impacts (2003)
66. http://www.ifpri.org/sites/default/files/pubs/pubs/ib/ib40.pdf
67. The impact of mobile phones (the report is a compilation of four articles: An econometric analysis of the impact of mobile, The impact of mobiles on agricultural productivity, A survey of usage of mobile in poor urban areas, The impact of mobiles in the SME sector) (2009) (Kari)
68. Economic Impacts of Broadband (2009)
69. ICT for City Management (2010)
70. http://rsta.royalsocietypublishing.org/content/369/1942/1762.full.pdf
71. Wackernagel and Rees: Our Ecological Footprint – reducing human impact on the Earth (1996)
72. OECD Environmental Outlook to 2050: The Consequences of Inaction (2012)



Use of resources, pollution and climate

During construction of this year's index, several strategic issues have been raised. Many have concerned the environmental dimension of sustainability, where three main variables – resource use, pollution and climate – have been selected. Resource use and pollution can be measured with some accuracy at city level, although there are some complications. While for instance waste can be measured, resources are often more difficult, partly depending on whether the city is viewed from a production or consumption perspective. Including a city's supply chain in the calculations is very complex. The climate impact of a city is also hard to define. While a city's use of energy and local CO_2 emissions do have an impact on the global climate, they are not large enough to determine how climate smart a city is. A more comprehensive measure would also have to include the climate impact of the city beyond its borders. This is not currently possible: because every city is part of a myriad of regional, national and global production and consumption chains, this approach becomes impossible. First, it would need a clear definition of where the city's impact ends. Second, it would need a full overview of all value chains of which the city is a part. Third, it would need clear definitions of the climate impact for each individual factor. Fourth, comparable proxies for each city would need to be determined. Fifth, it should be possible to find data for each city. However, bearing this in mind, and believing that such measurements will be easier to obtain in the future, we have decided to construct the index in a way that allows for inclusion of more indicators concerning climate.

There are similar issues concerning the other variables, where for example one could argue that waste and energy usage are not clear enough indicators of a city's use of resources. If use of materials were included, it would give a better indication of the city's actual consumption. To give a better indication of pollution levels in a city, we would want to include land pollution. We have included material and land pollution in the hierarchy for environment to indicate that we are currently unable to collect data for material and land pollution, but that we in future will try to include these variables.

Domain rationale

Economic growth and growing urban populations are increasing the use of resources in the world's cities and therefore increasing the environmental burden. Economic growth means more of the world's population can start to consume or to increase their consumption. This leads to increased pressure on natural resources and greater production of waste.

RESOURCES

Indicators: Waste, Energy and Material

Proxies: Recycled and unrecycled waste per person and recycling, energy consumption from fossil and non-fossil fuels, no data on material

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Definitions: Recycling is a process to change materials (waste) into new products to prevent the waste of potentially useful materials. Recycled waste is defined as waste that has been adequately disposed and recycled. It is measured in kilograms per person.

Unrecycled waste is defined as waste that not has been adequately disposed and recycled. It is measured in kilograms per person.

Primary energy consumption in GJ from fossil fuels per capita. Primary energy consumption refers to the direct use at the source, or supply to users without transformation, of crude energy – that is energy that has not been subjected to any conversion or transformation process.

Primary energy consumption in GJ from non-fossil fuels per capita. Primary energy consumption refers to the direct use at the source, or supply to users without transformation, of crude energy – that is energy that has not been subjected to any conversion or transformation process.

The growth of ICT-related services (such as software development, internet services, new advertising and marketing services), and of traditional services that have been transformed by the use of ICT (mostly financial services and commerce), contribute to a structural change in the economy away from material-intensive activities and towards more service-based and information-intensive activities. In this way, ICT speeds up structural change in the economy, and could contribute to improvements in relative resource efficiency and reduce the use of resources in relative terms.[73] However, the material intensity of cities is hard to measure and is therefore left out of the index due to lack of data.

The reason for including energy consumption in the index is that a large part of the energy consumed in cities might not be produced there but rather comes from other regions and more rural areas in order to provide the city with energy. In this way, the growing urban population with its increasing incomes and consumption stress the world's energy resources and increase the environmental burden. Energy consumption is divided into fossil fuels and non-fossil fuels in order to better capture the environmental burden of the city's consumption.

73. Dematerialising and Rematerialising: digital technologies and the environment. Frans Berkhout, Julia Hertin, 2004. SPRU-Science and Technology Policy Research, University of Sussex, Falmer, Brighton, East Sussex BN1 9RF, UK
74. www.cleanairtrust.org/nitrogendioxide.html
75. OECD Environmental Outlook to 2050: The Consequences of Inaction(2012)
76. Let's build cities for people (not cars) (2011)
77. www.who.int/mediacentre/news/releases/2011/air_pollution_20110926/en/index.html

POLLUTION

Indicators: Air pollution, Water pollution

Proxies: Nitrogen dioxide levels, Sulfur dioxide levels, PM10 levels, PM2.5 levels, Energy Consumption per capita and fossil fuels, Waste water treated

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Nitrogen dioxide (NO_2) comes from sources such as cars, trucks and electric power plants. Sulfur dioxide (SO_2) comes from burning fuels containing sulfur – mostly coal and oil. NO_2 and SO_2 are the major precursors of acid rain, which has acidified soils, lakes and streams, accelerated corrosion of buildings and monuments, and reduced visibility. High concentrations of NO_2 and SO_2 also have a negative effect on the human health.

Year average PM10 µg/m³. PM10 is defined as particles smaller than 10 micrometers in diameter and can be of both artificial and natural origin. High concentrations of PM10 can cause major concerns for human health.

Year average PM2.5 µg/m³. PM2.5 is defined as particles smaller than 2.5 micrometers in diameter and can be of both artificial and natural origin. High concentrations of PM2.5 can cause cardiovascular and other diseases when inhaled.

The percentage of the population connected to "public" sewerage networks and related treatment facilities, and percentage of the population connected to "public" wastewater treatment plants, and the degree of treatment. The definition can vary between countries and cities.

Domain rationale

Growing cities across the world face an increasing challenge of combining competitiveness and sustainable urban development. Urban and regional pollution is a significant environmental threat. Pollution threatens environmental sustainability and can have harmful effects on human health, not least in urban areas.[74, 75, 76]

The World Health Organization (WHO) estimates that more than 2 million people die every year as a result of air pollution and the number of deaths attributable to air pollution in cities has increased. This increase is linked to increases in air pollution concentrations and urban population size, as well as improved data availability and methods employed.[77]

In both developed and developing countries, the largest contributors to urban outdoor air pollution include transportation, small-scale manufacturers and other industries, burning of biomass and coal for cooking and heating, as well as coal-fired power plants. Industry, power generation and motor vehicles release pollutants that can lead to photochemical smog, haze and acidification. Solutions to outdoor air pollution problems in a city will differ depending on the relative contribution of pollution sources, its stage of development, as well as its local geography.

Sulfur dioxide (SO_2) is one of a group of highly reactive gases known as "oxides of sulfur." The largest sources of SO_2 emissions are from fossil fuel combustion at power plants (73 percent) and other industrial facilities (20 percent). Smaller sources of SO_2 emissions include industrial processes such as extracting metal from ore, and the burning of high-sulfur fuels by locomotives, large ships and non-road equipment. SO_2 is linked with multiple adverse effects on the respiratory system.

The most prominent sources of NO_2 are internal combustion engines, thermal power stations and, to a lesser extent, pulp mills. Butane gas heaters and stoves are also sources. The excess air required for complete combustion of fuels in these processes introduces nitrogen into the combustion reactions at high temperatures and produces nitrogen oxides (NOx). Limiting NOx production demands the precise control of the amount of air used in combustion. In households, kerosene heaters and gas heaters are sources of nitrogen dioxide.

The great majority of urban populations have an average annual exposure to PM10 particles in excess of the WHO Air Quality guideline which recommends a maximum level of 20 µg/m³. On average, only a few cities currently meet the WHO guideline values.

In the index, pollution is measured through air and water pollution. However, pollution is often referred to as emissions to air, land and water. Water pollution has been measured through treated waste water – since there is reason to believe that it is a solid enough indicator to measure how well a city manages its water usage. Emissions to land have not been included because of problems finding reliable data.

CLIMATE

Indicators: CO_2

Proxies: CO_2 per capita,

Definitions: CO_2 emissions per person. All energy production using combustion emits carbon dioxide. This includes driving vehicles, electricity production, heating and other activities. It is also produced through the decomposition of organic matter in soils under oxidizing conditions. It excludes emissions from air transport, international aviation and shipping. To facilitate the comparison among cities/regions, the CO_2 emissions are divided by the population. Note: Not all known greenhouse gases are included.

78. www.iisd.org/
79. Carbon Connections: Quantifying mobile's role in tackling climate change(2009)
80. Improving Quality of Life Through Telecommuting (2009)
81. Towards A Connected World: Socio-Economic Impact of Internet in Emerging Economies (2009)

Domain rationale
Cities account for a large proportion of the world population and are great contributors to global climate change. In turn they are will be among those most by the consequences if climate change is not controlled. CO_2 is the main greenhouse gas emitted due to human actions.

ICT's effect on environment and climate change
Information technology-based solutions could in many ways be the foundation on which economic productivity and quality of life are maximized while resource consumption and pollution are minimized.[78]

- **ICT and use of resources**
  With more waste being produced, recycling and improvement of waste management are becoming increasingly important for cities and urban areas. Waste management is the collection, transport, processing or disposal, management and monitoring of waste materials. Waste disposal is crucial in urban areas and ICT offers new technologies for optimizing waste disposal.

  ICT can also be used to decrease consumption. Dematerialization is the process by which an ICT product or service, such as videoconferencing, replaces a high carbon activity (travel) with a low carbon one (virtual meetings). Other examples of such technologies are online media replacing CDs and DVDs, e-commerce, e-paper and e-books, and telecommuting. However, the impacts of dematerialization processes rely to a large extent on behavioral change.[79, 80, 81]

- **ICT and waste management**
  ICT is already an important tool for waste management. Logistics play an important role in the waste management chain and ICT can contribute to smarter systems with increased recycling and reuse of materials. For example, ICT-supported systems on the market can identify different kinds of waste (through smart labelling of waste bags, for example) and increase the level of recycling. There are also smart trash cans that report over a mobile network when they are full and need to be emptied. ICT can also play a key role in making people more informed and increase public awareness – a key requirement when changing behavioral patterns. In Estonia, for example, smartphones can be used to document and report littering or waste being thrown in public places or parks on a public website.

- **ICT and energy**
  ICT increases the ability to generate and distribute electricity more efficiently than earlier technologies.

Through techniques such as smart electricity grids and smart metering, ICT could impact billions of commercial and residential subscribers worldwide, significantly reducing greenhouse gas emissions.

- **ICT and pollution**
  ICT could also decrease pollution through new technological solutions that enables process and product innovation. For example, access to electronic components and new fabrication technologies makes it possible to design, develop and manufacture a variety of physical artefacts that previously required large-scale manufacturing equipment and investment. ICT thus improves industrial processes along the value chain.[82, 83]

- **ICT and climate change**
  Transport, the second-leading greenhouse gas emitting sector after energy, could also benefit from more energy-efficient communications technology. ICT solutions can help reduce transport's CO_2 emissions through more intelligent transport systems and applications such as traffic management and parking optimization. ICT can also reduce the need for travel through advanced video conferencing and web-based seminars.[84]

  Buildings are another area where ICT could reduce CO_2 emissions and energy use. Smart building technologies built on ICT systems can make building design, construction and operation more energy efficient. For example, ICT management systems could run heating and cooling systems according to each occupant's needs, and software systems that automatically turn off PCs and monitors when users are absent could be used.[85]

ICT-enabled systemic effects could impact on economic and social parameters such as attitudes, expectations and behavior of individuals as consumers, residents and businesses. The demand and supply of goods and services, organizational structures, production distribution and service processes, and governance in private and public sectors could shift due to new technological solutions. ICT can therefore contribute to tackling climate change by eliminating the need for physical products or activities. The use of ICT in our consumption of products and services is already enabling dematerialization.

82. ec.europa.eu/enterprise/sectors/ict/
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