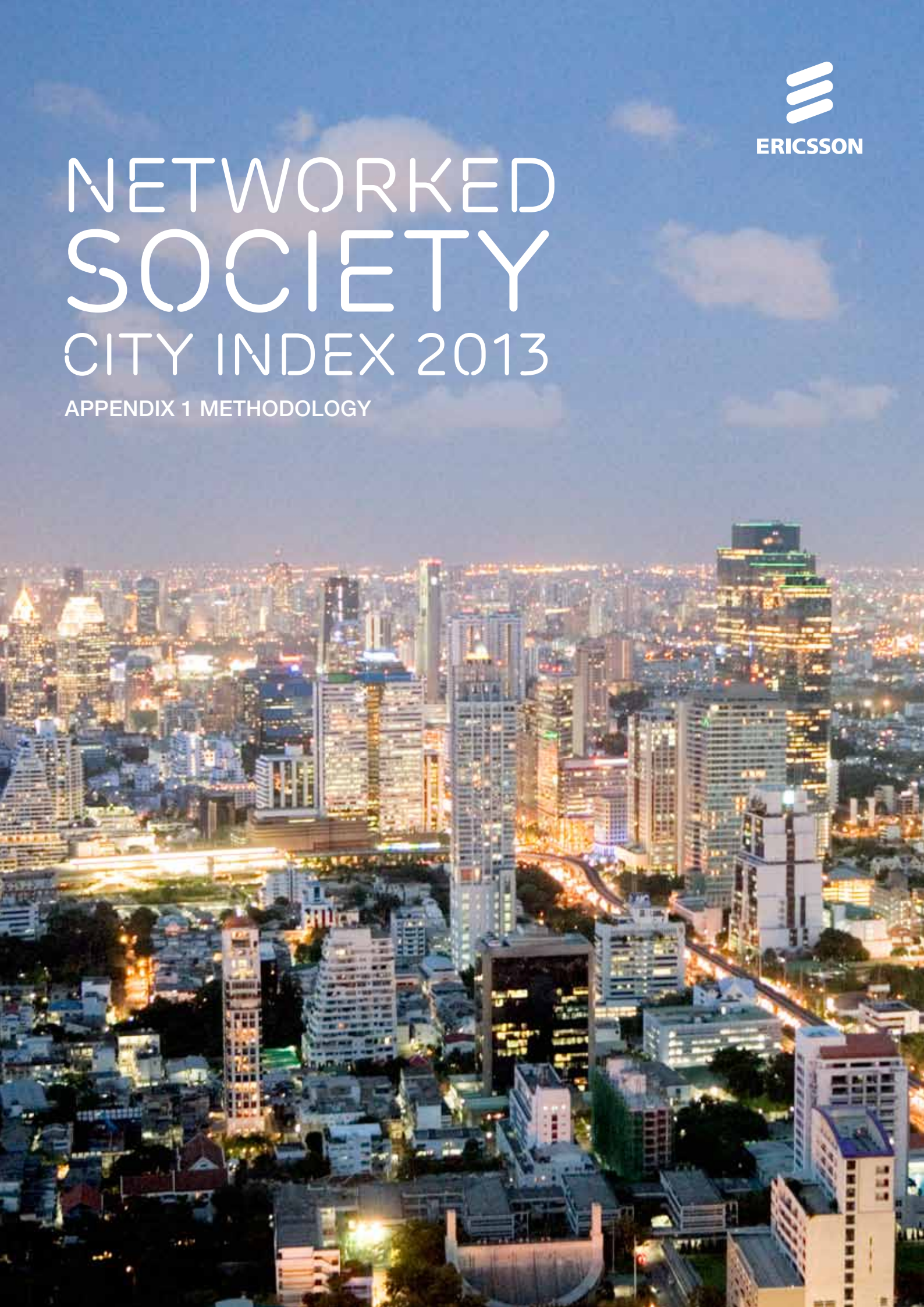
ERICSSON

NETWORKED SOCIETY CITY INDEX 2013

APPENDIX 1 METHODOLOGY



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INTRODUCTION

The aim of this section is to give an outline of how the index was created and the thought processes and conditions leading up to the chosen approach. Since the method used is affected by the requirements of the index, the methodology section will start by listing these and then continue with a description of the theoretical framework together with the rationale.

REQUIREMENTS ON THE INDICES AND THE METHOD USED

For background and purpose of the Networked Society Index please refere to the main report. Rather than offering a statistical approach, the methods used should be comprehensible for a wide set of people. This is especially important, because one of the main target groups is decision-makers. An important aspect is that policy makers should be able to see where the city is doing well and where the city needs improvement. The indices should serve as a tool to provide information on different perspectives that can be important for a society, and then be used as a catalyst for discussions regarding the different perspectives.

It's important to develop a theoretical framework and to discuss the rationale behind each indicator. The indicators should be selected so that the merged effect can be said to represent a meaningful composite indicator. The theoretical framework should in turn affect how the indicators are weighted and aggregated. It is also vital to include important immeasurable perspectives in the discussions.

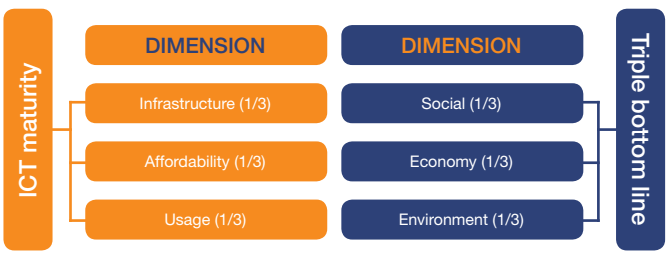
However, the most meaningful indicators are not always possible to measure or collect. When selecting the indicators, it is therefore necessary to be aware about the possibilities to collect the required data for cities all over the world. The realities in the cities can vary considerably, which is why different types of statistics may apply in different cases. The challenge is to find indicators that create a meaningful composite indicator, that data for these indicators are possible to collect, and that they are measured in such a way that they are comparable between all the cities.

When it is not possible to collect the data for a chosen indicator, different approaches of imputing values should be considered. The selected method of imputation should depend on the nature of the missing value. There is also a necessity to analyze the robustness of the indices and to evaluate the effect of excluding single indicators, rescaling them and analyzing the effect of different imputations.

Attempts should also be made to look at correlations of the composite indicator in relation to other published indicators. The composite indicators should also be transparent with a possibility of decomposing them to look at their underlying indicators or values.

INDEX CONSTRUCTION

A hierarchical model has been chosen to make the methods easier to understand. The top level aggregate represents the two perspectives in which we try to measure a city's performance level, both when concerning maturity in ICT and in triple bottom line (TBL). The top level aggregates are in turn divided into three sub-perspectives called dimensions. Dimensions deals with the social, economic and environmental perspectives. For the 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

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that are meaningful in terms of describing a city's performance. In some cases, different weighting is applied to provide a more meaningful composite measure. The TBL index is a geometric aggregate of the dimensions:

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

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, we have calculated a geometric aggregate. Geometric weights are applied and used to give an indicator a heavier weight and to create a more meaningful aggregate when indicators of different importance are used. To calculate an aggregate, each of its components is raised to the power of its weight and the product of the weighted components will be the calculated value. Generally, an arbitrary aggregate with n components is expressed as:

$$\text{Aggregate}_i = \prod_{j=1}^{n} \text{Component}_{ij}^{\text{weight}_j}$$

The formula above means that the aggregate of affordability is calculated by raising tariffs to its weight (2/3) and IP transit prices to its weight (1/3).

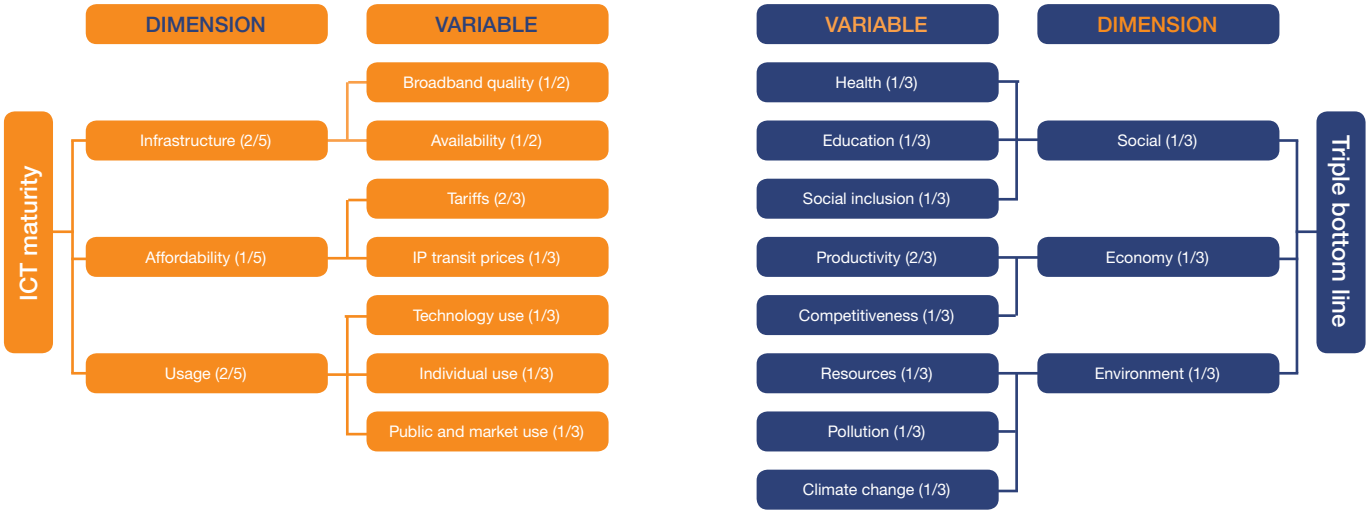
$$\text{Affordability} = (\text{Tariffs})^{2/3} \cdot (\text{IP transit prices})^{1/3}$$

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.

$$\text{Top aggregate} = \prod_{i=1}^{n} \text{Dimension}_i^{\text{weight}_i} = \prod_{i=1}^{n} \left(\prod_{j=1}^{m} \text{Variable}_{ij}^{\text{weight}_j} \right)^{\text{weight}_i}$$

An intuitive way to present a hierarchical structure is by using 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 numbers in parenthesis display the weight used in the aggregation. The branches show that the aggregate of the affordability dimension is composed of the tariffs and IP transit prices variables.

1 OECD, Handbook on constructing composite indicators (2005)



Normalization

To make the normalization as simple as possible and to not be forced to change the calculations when new cities are added, we have chosen to rescale the values so that the formula used has the property that the rescaled indicator only attains values between 1 and 100. The maximum and minimum values are chosen in such a way 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 or by using the theoretical maximum and minimum when they are close enough to the spread of the data to not heavily distort the rescaling. It's important to note that rescaling is sensitive to outliers where an extreme value affects the variance of the rescaled variable and therefore the impact on the aggregated value.

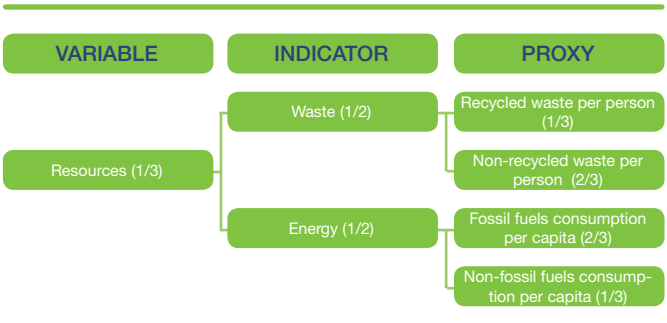
$$\text{Proxy}_{\text{Rescaled}} = \frac{\text{Observed} - \text{Min.}}{\text{Max} \quad \text{Min}} \cdot (100-1) + 1$$

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.

$$\text{Variable} = \prod_{i=1}^{n} \text{Indicator}_i^{\text{weight}_i} = \prod_{i=1}^{n} \left(\prod_{j=1}^{m} \text{Rescaled proxy}_{ij}^{\text{weight}_j} \right)^{\text{weight}_i}$$

The tree diagram below shows the hierarchical construction 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 waste indicator, recycled waste was considered to be better for the environment than non-recycled waste. The total waste per person was therefore divided into recycled and non-recycled waste, and cities with a high level of non-recycled waste were punished harder than those with a high recycling rate.



Handling Missing Data

When data is missing for a region, four different types of imputations will be 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 cities with missing data might be related to the value of other variables. For instance, a country with high GDP might be less likely to collect statistics of literacy rate at city level, whereas a country with low GDP might be more likely to collect the same statistic. Using the unconditional mean in such a case might result in an estimate of poor accuracy. In such a case, the relationship between the other variables and the indicator value should be used to impute the data. We will consider four types of imputation:

- **Hot deck imputation –** If we don't find data for the city we may use a larger region where the city is included, for example, a state or a country. This method should be used with care because data for cities may differ considerably from the value of the indicator 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 may, however, be possible to find older data. If the variable shows stability 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 –** If the indicator shows no clear relationship with other variables, this type of imputation can be used. However, this may create poor estimates of the actual value for the indicators in our indices. We will therefore avoid using 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 compared with simply using the unconditional mean or implicit modeling. For instance, many of the variables show a correlation with GDP, and this relation can be used when imputing the missing data to get a better estimate of the indicator.

DESCRIPTIONS OF ICT INDICATORS AND VARIABLE RATIONALE

ICT in many ways forms 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. ICT is setting the pace for a changing, competitive and dynamic global marketplace and representing an enabling platform for business and socioeconomic development. The effect of ICT innovations happens through applications such as business and socioeconomic development due to its role in introducing and diffusing the concepts of knowledge sharing, community development and equality.[2] [3]

The ICT maturity index aims to explain the readiness of cities to participate in the global information society and the degree to which a society is prepared to make use of an 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 that the available technology, a functioning market and a usage of ICT are important perspectives when measuring a city's ICT maturity. The indicators that have been chosen are selected to measure the performance the ICT infrastructure and individual's access to both basic and high technology have been obtained by discussions with ICT experts. To get a more meaningful composite index for ICT maturity, the perspectives of infrastructure and usage are considered to be of higher importance than affordability, and to highlight this these dimensions are weighted heavier than affordability.

A similar study has been performed by the International Telecommunication Union (ITU)[4] but there are some differences. In this index, we are interested in the ICT maturity of cities, while ITU focused on whole countries. Another difference is that with the ICT maturity index, the emphasis is on advanced technology solutions, like the quality of mobile and fixed broadband, through the application of leading technologies such as fiber and LTE, and by choosing not to include fixed telephony – as it has less of an impact on the new society.

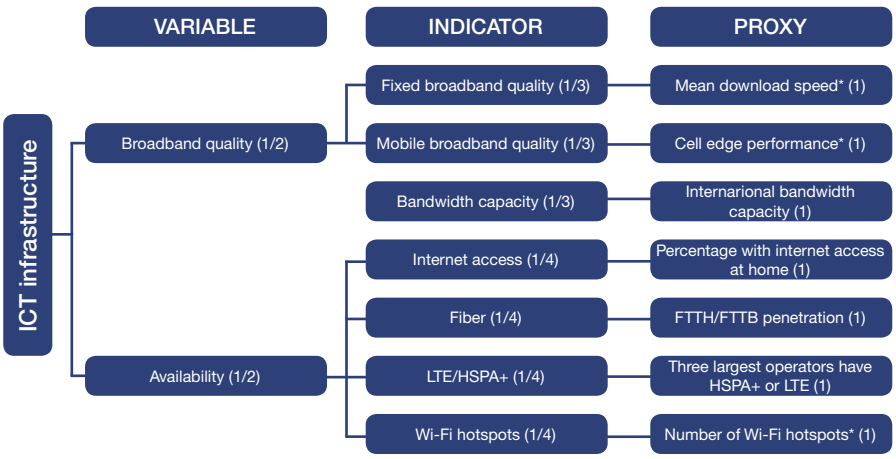
ICT Infrastructure

ICT infrastructure offers a range of technologies to assist cities in running efficiently, and the usage of ICT infrastructure allows cities to gain competitive advantages. The evolution of information technologies and systems continuously creates opportunities for governance, businesses and citizens. Therefore, it is necessary that cities have the basics – the infrastructure – in order, and it is also important that cities continually upgrade their ICT infrastructure.

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 regarding measuring a city's infrastructure.

2 ICT for City Management (2010)
3 Economic Impact of Broadband: An Empirical Study (2009)

4 Measuring the Information Society (2012)



BROADBAND QUALITY
Indicators: fixed broadband quality, mobile broadband quality and bandwidth capacity.

Proxies: fixed broadband mean download speed, mobile broadband call edge performance, and international bandwidth capacity.

Definitions: average download speed – May 1, 2013 to August 1, 2013.

Downlink speed – May 1, 2013 to August 1, 2013. Ninety percent probability of getting this speed in the city.

The data represents bandwidth connected across international borders to metropolitan areas as of mid-year. Domestic routes are omitted.

Variable rationale:
Measuring broadband quality is done by the international bandwidth capacity and by evaluating the broadband speed, which indicates what possibilities and online services that can, in practice, be used given the current infrastructure. Mobile broadband quality and fixed broadband quality are used as indicators to estimate how agile and advanced internet usage can be. The international bandwidth capacity indicates the possibilities of international communications and the possibilities to compete in the global market. Equal weighting of the indicators is considered to give a meaningful composition of the variable and is therefore used.

AVAILABILITY
Indicators: internet access, fiber penetration, LTE/HSPA+ and hotspots.

Proxies: household internet access. Percentage of households with access to fiber optic broadband, the three largest operators that have HSPA+ or LTE. The number of hotspots.

Definitions: the 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). This mainly includes fiber-to-the-home (FTTH) and fiber-to-the-building (FTTB), but sometimes even FTTX configurations such as fiber-to-the-curb.

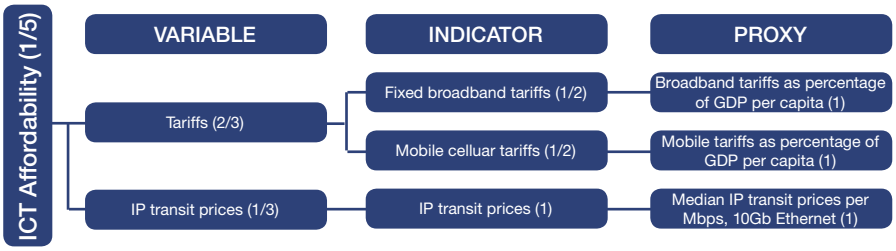
Number of the three largest operators that has LTE or HSPA+ (value range = 0-3).

Number of hotspots within a radius of 2 miles from a certain point in the city center.

Variable rationale:
The availability variable measures how well the infrastructure reaches the population: the technology level of communications and the diversity of technologies used in the city. Internet access is measured by the percentage of the population with internet access at home. The diversity in communications is measured by the 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, transact with banks or governments electronically, and shop online. Several studies show that these are all activities that we prefer to do at home in front of a larger screen rather than on a smartphone, proving that different ICT solutions demand different forms to access the internet. 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,

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)



the indicator for Wi-Fi hotspots captures internet availability for a wide set of devices. Wi-Fi hotspots can also provide a substitute where mobile broadband infrastructure and coverage are still undeveloped.

ICT Affordability

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

TARIFFS
Indicators: fixed broadband tariffs and mobile cellular tariffs.

Proxies: fixed broadband tariffs (residential monthly fee) as a percentage of the cities' GDP per capita. Mobile cellular tariffs (average of per minute on-net and off-net calls during peak hours) as a percentage of the cities' GDP per capita.

Definitions: the fixed-broadband sub-basket is calculated by the ITU on the basis of the price of the 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 Organisation for Economic Co-operation and Development (OECD) low-user basket. It gives the price of a standard monthly usage of mobile services, as determined by the OECD.

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

Variable rationale:
Tariffs are used to measure the cost of ICT connectivity, which is measured by broadband tariffs and mobile cellular tariffs. This in turn is divided to 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. The markets functioning are essential to price mechanism and therefore crucial to 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 ready and able to pay. For a society to be considered mature in ICT, prices must be set to enable penetration in all social and economic groups.

IP TRANSIT PRICES
Indicators: IP transit prices.

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

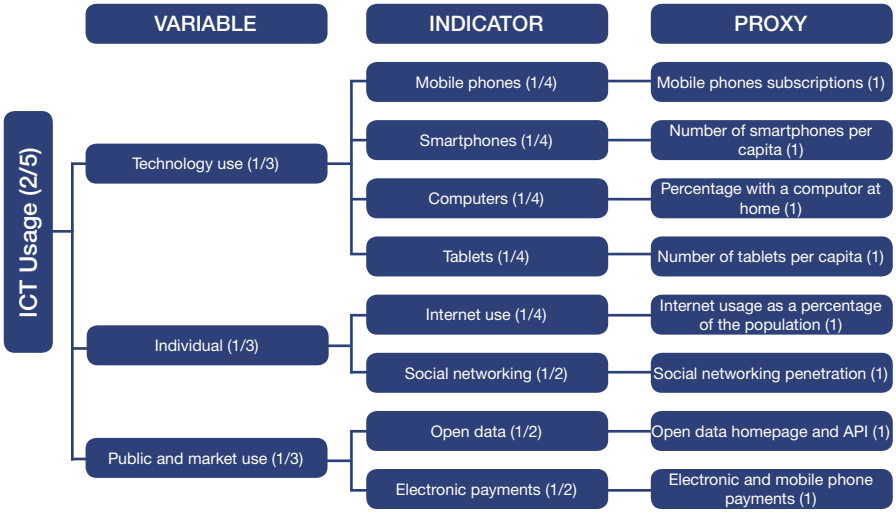
Definitions: monthly USD per Mbps prices for a full-port commit, excluding local access and installation fees.

Variable rationale:
IP transit prices complement the measurement of the market's function, and thereby the price a city dweller has to pay to be online. The spread of information relies on information being spread through network traffic; basic economic theory leads to the conclusion that if it costs more less will be spread. Thus, a lower price should lead to a higher flow of information and bigger potential for the city to maximize its development.

ICT Usage

The adoption of ICT and both basic and advanced usage of ICT is seen as an important aspect of ICT maturity. The ICT usage dimension strives to capture to what degree consumers and the private and public sectors are taking advantage of the available ICT

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



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, which 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 extending the types of activities and topics that are subject to collaborative behavior. Mobile devices, such as mobile phones, smartphones and tablets, are extending internet usage and the possibilities of new ICT services. The usage has a growing importance as a means for information exchange, social networking, democratic participation and economic activity. It is important to measure the technology adoption of the consumers since the usage level affects the incitements for both the public and private sector to use ICT as a method to reach the inhabitants of a city.

INDIVIDUAL USE
Indicators: internet use, social networking.

Proxies: internet usage as a percentage of the population, social networking penetration.

Definitions: the percentage of individuals using the internet indicator.

The percentage of the online population in the country that is using social networking multiplied by the percentage of the population in the city that is using the internet.

Variable rationale:
The internet use and social networking indicators describe a maturity of ICT usage above the most basic level. The internet is a focal point in ICT, and its usage is therefore used to measure the inhabitants' ICT usage.

PUBLIC AND MARKET USE
Indicators: open data, electronic payments.

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

Definitions: 0 = no API. 1 = the country (or state) has an open data homepage with an API. 2 = the city has an open data homepage with an API.

The percent of individuals using electronic payments or mobile phone payments. Based on country data and estimated for the urban population.

Variable rationale:
An open data page with an API is related to how advanced the public sector's level of technology is. It provides a possibility for programmers to write applications that can efficiently access data regarding the city. Electronic payments show the ICT maturity of both the business sector and consumers regarding the usage of ICT to efficiently exchange money.

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

Cities are growing fast, and their impact on global sustainable development will continue to increase. While each city has its unique preconditions and specificities, they all 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. Many global indexes are published every year by organizations such as the United Nations Development Programme (UNDP), the World Economic Forum and Freedom House that try to give an estimate of competitiveness, social development, environmental performance or a combination of the three on a national level. Measuring and comparing regional progress on a city level poses a great challenge. The main reason for this is because much of the basic data needed for such a comparison (for example, health and life expectancy, and civil and political rights) is aggregated on a national level in many countries. With the TBL index that has been created for this report, we try to reflect the views of each research field. It is important to state that we are not trying to come up with a new and better way to measure the TBL.

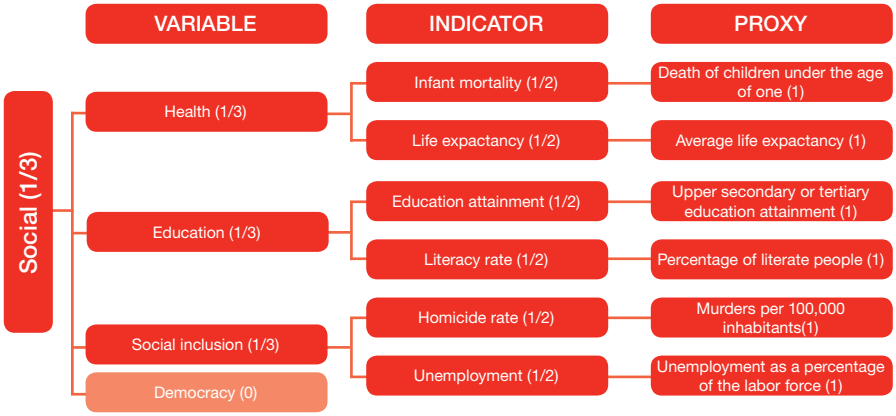
During the past couple of decades, ICT has become more evident in everyday urban life and in citizens' actions and behavior. ICT spurs economic development; it is positively correlated with GDP and growth, and therefore affects quality of life. Getting the sustainable city up and running relies in part on managing, utilizing and sharing various 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, which are important in achieving higher living standards and greater wellbeing.

Urban development has long been related to economic performance and physical structures that define a city's form and function. During the past few decades, there has been growing concern about communities' environmental sustainability, which has had significant implications for how many cities are managed. However, a city is so much more than its physical structures and economy. A city is composed of people and the places where they live. It is both a social environment as well as physical or economic environment. Communities therefore not only need to 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 regarding social dimension is a real challenge because necessary indicators and proxies not only need to be identified, but also connected to the territory of the city. The most important indicators for a society's performance are only available at a national level, and as social disparities between a whole country and a city are often major, the country data is unreliable and involves a large element of ambiguity. Furthermore, it is not easy to collect important data on social wellbeing, like democracy, at a city level. Democracy can be measured – for example, by the share of the population that participates in local elections. However, in some countries you have to register to vote, and in others there may only be one candidate, which makes it a complicated indicator to use when comparing cities. Since we currently lack sufficient data to create a variable for democracy that is a good reflection of reality, we have chosen to not include this variable in this year's index. The variable is kept in the hierarchy to display its importance to social development, and the ambition is to include this variable in the future. Compiling a list of variables that are representative of social sustainability is no straightforward task. Their



contextual dependency leads to different interpretations, and various aspects of social wellbeing 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 in 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, average life expectancy.

Definitions:
The number of deaths of children aged less than one year 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.[1]

1 http://www.kingsfund.org.uk/time-to-think-differently/trends/demography/life-expectancy

Domain rationale

Better health is central to human happiness and wellbeing. It also makes an important contribution to economic progress, as healthy people live longer and are more productive. They also invest more (save) in their future.[8] In rich and poor countries alike, the gross inequalities in people's health are not simply a product of their individual choices; they are also determined by the environment in which they find themselves. The health of a city's population is a solid indicator of wellbeing. When a city contributes to an enhancement of the physical and mental wellbeing 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 their economic development, general living conditions, social wellbeing, rates of illness, and the quality of the environment.[9] A high child mortality rate is also directly correlated to low environmental indicators, such as the level of wastewater treatment and sewerage and sanitation facilities.[10]

It is reasoned that measurements such as the infant mortality rate often become the principal focus of health policies, so that health strategies and health priorities are formulated with the proxy outcome measure in mind. Consequently, health policies tend to target the chosen outcome measure, while ignoring the rest of the population for which the outcome measure was supposed to be an indicator. Infant mortality may therefore decrease, as a result of it having become the principal focus of health policy, while population's health as a whole may remain static or even decline.

8 WHO
9 Infant mortality rate as an indicator of population health. D Reidpath, P Allotey. J Epidemiol Community Health 2003;57:344–346
10 UN Habitat, guidelines prosperity of cities

This creates the necessity to use other, more comprehensive measurements of a population's health – such as the average life expectancy – as a complementary proxy for health. Such measurements are intended to be sensitive to changes of health in 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 disability-adjusted life expectancy (DALE). However, it is not possible to collect such data on a city level.[11]

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. Proportion of total population.

The literacy rate is the total number of literate people 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 working 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.[12]

SOCIAL INCLUSION
Indicators: homicide rate and unemployment.

Proxies: murders per 100,000 of the population and the unemployment rate as a share of the labor force.

Definitions: reported murders are the number of murders reported to the police. In order 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 it comprises all people above a specified age, who during the reference period were:

without work; in other words, were not in paid employment or self-employment during the reference period

currently available for work; in other words, were available for paid employment or self-employment during the reference period

seeking work; in other words, had taken specific steps in a specified recent period to seek paid employment or self-employment.

Quality of life concerns the balance between material wellbeing, physical and mental health, family life, labor market participation and social participation. Safety and personal security are core elements for the wellbeing of individuals, and largely reflect the risks of people being physically assaulted or falling victim to other types of crime. One of the biggest impacts of crime on people's wellbeing appears to be through the feeling of vulnerability that it causes. Homicide rates (the number of murders per 100,000 inhabitants) only represent the most extreme form of contact crime, and therefore do not provide information about more typical safety conditions. They are, however, a more reliable measure of a country's safety level because, unlike other crimes, murders are nearly always reported to the police.[13]

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 therefore the possibility for an individual to earn a living; it is also important for social participation in all

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

urban spheres.[14] Income is an important means to achieving higher living standards, and therefore greater wellbeing. Higher economic wealth may also improve access to quality education, health care and housing.[15] However, economic indicators are included in the economical dimension of the index, and are therefore left out of the social dimension for statistical reasons.

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.[16]

ICT and health

Several research reports estimate a correlation between ICT and health. ICT maturity effects 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. [17] [18] [19] [20]

ICT and education

Improving the quality of education is a critical issue. ICT has long been regarded as an important tool to improve educational processes, with the potential to improve the quality of educational systems, extending educational opportunities and increasing individual access to education.[21] ICT can offer transformational tools which, when used appropriately, can promote the shift to a learner-cantered 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 is a potentially powerful tool for extending educational opportunities and increasing access to education. Groups traditionally excluded from education due to cultural or social reasons – such as ethnic minorities, girls and women, people with disabilities, the elderly, and others who for reasons of cost or because of time constraints are unable to enroll on campus – can gain access to it more easily through ICT development.

One of the most commonly cited reasons for using ICT in education has been to prepare students for a workplace where ICT, computers, the internet and related technologies, are becoming more and more ubiquitous. Technological literacy, or the ability to use ICT effectively and efficiently, is therefore seen as representing a competitive edge in an increasingly globalized job market.[22] [23] [24] [25] [26] [27] [28] [29] [30]

ICT and social inclusion

Estimates for 113 countries over a 20-year period show a positive link between ICT and GDP, as well as income, effecting city dwellers' quality of life.[31]

Technology adaptation and penetration are tools to create a more connected and safe 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, to integrate safety solutions across different stakeholder groups.[32]

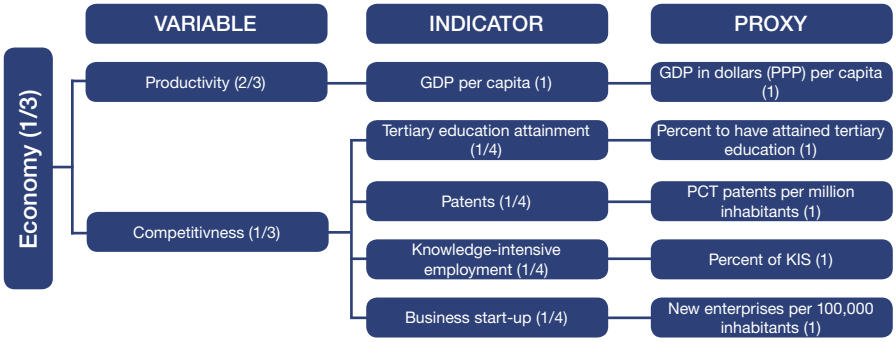
ICT has also made it possible to compare supply and demand in labor markets, with the result of a more efficient matchmaking between employees and employers. The internet has created a structural change in the employment advertising market, and affected the way individuals relate to the labor market 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 searches.[33]

Economic Dimension

Getting the sustainable city up and running is dependent on everyday urban life and the actions and behavior of the city's citizens and firms. In the new and global economic geography, 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.[34]

14 www.esri.ie/research/research_areas/social_cohesion_and_quality_of_life/
15 www.oecdbetterlifeindex.org/topics/life-satisfaction/
16 http://www.oecdbetterlifeindex.org/topics/life-satisfaction/
17 Fibre – The socio-economic benefits (PDF presentation) (2007)
18 Economic & Fiscal Impact of Introducing Broadband Networks and Services in Lebanon (2009)
19 Digital World Forum and the South/North Divide (2008)
20 Champion for Digital Inclusion (2009)
21 http://siteresources.worldbank.org/EDUCATION/Resources/278200-1290520949227/SABER_Report_Ch9.pdf

22 Champion for Digital Inclusion
23 Network developments in support of innovation and user needs (2009)
24 True Broadband – Exploring the economic impacts (2003)
25 Digital quality of life (2008)
26 Need for Speed: A new study confirms the positive effects of an increased broadband speed on GDP (2011)
27 Digital World Forum and the South/North Divide (2008)
28 Economic & Fiscal Impact of Introducing Broadband Networks and Services in Lebanon (2009)
29 Fibre – The socio-economic benefits
30 Towards A Connected World Socio-Economic Impact of Internet in Emerging Economies (2009)
31 www.ifpri.org/sites/default/files/pubs/pubs/ib/ib40.pdf
32 www.slideshare.net/PlanetInspired/the-case-of-safe-and-smart-cities
33 www.seek.com.au/content/media/EmploymentIndex/SEEK_AU_EI_Background.pdf
34 Krugman, Paul R.: "Geography and Trade" (1991)



Economic growth is considered the main driver for higher living standards. However, being a city does not automatically lead to prosperity – there are cases where cities do not develop into economic hotspots of their regions or countries. To succeed, a number of place-bound resources like human capital, institutions and technology must be used effectively. Economic growth is spurred and the standard of living can improve by increasing either the productivity or the amount of goods and services produced. In the past couple of decades, the ICT revolution has come to change how we regard the three factors of human capital, institutions and technology, but also how we view the economy as a whole. [35]

The performance of a city's economy and the prosperity of its citizens are positively correlated with GDP and economic growth. For example, there is a very strong correlation between the GDP/capita and how nations perform according to the UNDP's Human Development Index.[36]

Productivity and Competitiveness

PRODUCTIVITY
Indicator: GDP/capita.

Proxy: GDP in US dollars – purchasing power parity (PPP) per capita.

Definitions: GDP in current USD prices, current PPPs. Calculated by the GDP at current prices divided by the PPPs for GDP, which with this process of conversion eliminates the differences in price levels between countries. GDP is divided by the population.

Domain rationale

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 measurement of economic performance, even though these days it is also challenged as a measurement of economic success. The prosperity of nations is closely linked with the way the growth of their cities is shaped. People reside in cities, as do enterprises – which are responsible for a great share of the national GDP.[37] In Asia, it is estimated that more than 80 percent of the region's GDP is produced in urban areas.[38] The world's 600 largest metropolitan regions generate 60 percent of global GDP.[39]

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 a city's) standard of living.

During the elaboration of the index, other variables and/or indicators of productivity were also discussed. However, most of them can be regarded as subsets or components of GDP per capita, and other variables and indicators have therefore not been included.

35 Economic Impact of Broadband: An Empirical Study (2009)
36 UNDP: http://hdr.undp.org/en/statistics/

37 UN-Habitat, State of the World's Cities 2010/2011: Bridging the Urban Divide (2010)
38 Asian Development Bank
39 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 (percentage), Patent Cooperation Treaties (PCTs) per million inhabitants, share of KIS (percentage), 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: International Standard Classification of Education (ISCED) 5 tertiary-type programs, ISCED 6 advanced research.

KIS are computed as the ratio between employees in KIS and the total employment. KIS include the following sectors:
- information and communication
- financial and insurance
- real estate
- professional, scientific and technical
- public administration and defense; compulsory social security
- education
- human health and social work
- arts, entertainment and recreation.

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

Business start-ups are 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. Therefore, innovation leads to greater prosperity for the city and a 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.[40]

There is widespread recognition that tertiary education is a driver of economic growth and innovation and a precondition for positive economic development.[41] Many organizations, among them the OECD,[42] have pointed out that tertiary education contributes to social and economic development.[43] In one of its reports on this issue, the OECD highlights four major development contributions from higher education:

- the formation of human capital (primarily through teaching).
- the building of knowledge bases (primarily through research and knowledge development).
- the dissemination and use of knowledge (primarily through interactions with knowledge users).
- 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 education 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 with the aim of encouraging institutions to be more responsive to the needs of society and the economy.[44]

A city's climb up the value ladder goes hand in hand with an increase in the share of knowledge-intensive businesses. UNDP[45] 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 enrolment ratios in higher education became "leaders" in technology, with high levels of achievement in technology and knowledge-based industries.[46] On the subject of KIS, the OECD concludes the following: "From research and development to legal and marketing services, a wide range of knowledge-intensive service activities (KISAs) enables firms and public sector organisations to better innovate. KISAs are both sources and carriers of knowledge that influence and improve the performance of individual organisations, value chains and industry clusters across all sectors of the economy."[47]

The number of patents in a regional economy can be seen as one indicator (of many) 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

40 The Impact of Broadband on Growth and Productivity (2008)

41 Centre for Higher Education Transformation (CHET): Higher Education and Economic Development (2011)
42 OECD – Organisation for Economic Co-operation and Development
43 OECD: Tertiary Education for the Knowledge Society: OECD Thematic Review (2008)
44 Centre for Higher Education Transformation (CHET): Higher Education and Economic Development (2011)
45 UNDP – The United Nations Development Programme
46 European Commission: Knowledge intensive (business) services in Europe (2012)
47 OECD: Innovation and Knowledge-Intensive Service Activities (2006)

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.[48]

Business start-ups are a measure of a region's entrepreneurial climate. They are very important for job creation, and they add an increased dynamism to a city's economic activity.[49]

ICT and urban economies

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 its spillover effects to the rest of the economy. For this reason, ICT has been widely acknowledged to be an important driver of the economy. In that sense, ICT is compared to electricity and the railways and what they accomplished in terms of growth in the past. ICT plays a role in unlocking economic growth in other sectors. For example, investment in ICT capital increases labor productivity, even in sectors that have not traditionally used ICT.[50] [51] [52] [53] [54] [55] [56] [57] [58] [59] [60]

- 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, which describes the collective cooperation, primarily over 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 and, due to an expansion of the communications activity in a region or a city, it can also enhance competition in telecommunications, opening up scope for productivity gains and competitive gains for key industries.[61] Wide use of the available technologies shows that ICT adoption can be a key element for a region that wants to remain competitive.[62] [63] [64]

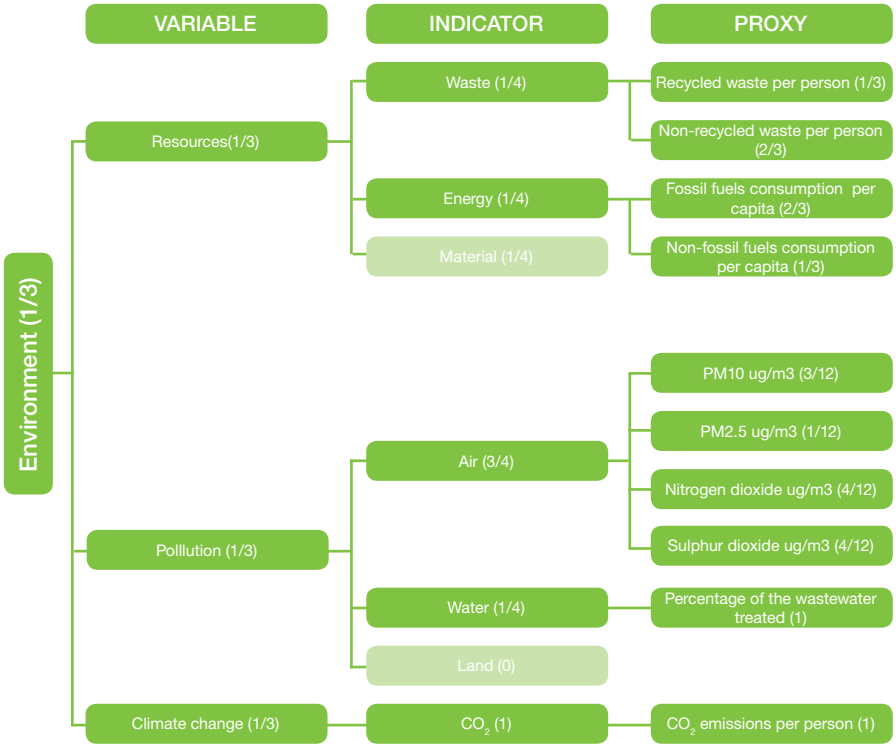
- ICT and improved economic performance
  A better economic performance relies in part on managing, utilizing and sharing various data that work together for urban development and that also take into account the balance between the three pillars of sustainability: environment, economy and society. ICT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

Environmental dimension – Overall rationale

Getting the sustainable city up and running is dependent on everyday urban life and the actions and behavior of the city's citizens and firms. More than half of the world's population lives in cities, and the urban share of the population will continue to rise. The performance of cities is therefore also a critical factor for the state of the global environment and climate. Cities are the key players for battling climate change, and they 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.[65] Most likely, ICT will also play a similarly important role in assisting growing cities to become more "climate smart."

The rapid increase in urban populations and urban production has been accompanied by an even more rapid 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 one of the key drivers of high levels of resource use and waste generation. A city's use of resources (in terms of energy and material) 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 in the reduction in the ozone layer).[66] These impacts vary significantly according to the type of city and its level of development. While a typically industrial city would have a large environmental impact locally and regionally, a more services-oriented city might have a clean environment locally, but produce a larger ecological footprint[67] globally.

48 World Intellectual Property Organization
49 Kaufmann Foundation: The Importance of Startups in Job Creation and Job Destruction (2010)
50 Need for Speed: A new study confirms the positive effects of an increased broadband speed on GDP (2011)
51 Measuring the Information Society, ITU (2012)
52 Measuring Broadband's Economic Impact (2005)
53 The Impact of Broadband on Growth and Productivity (2008)
54 Next G Productivity Impacts Study (2009)
55 Cities of opportunities (2012)
56 Megacities – our global urban future (2005)
57 Digital World Forum and the South/North Divide (2008)
58 Economic & Fiscal Impact of Introducing Broadband Networks and Services in Lebanon (2009)
59 Economic Impact of Broadband: An Empirical Study (2009)
60 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)
61 True Broadband – Exploring the Economic Impacts (2003)
62 http://www.ifpri.org/sites/default/files/pubs/pubs/ib/ib40.pdf
63 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)
64 Economic Impacts of Broadband (2009)
65 ICT for City Management (2010)
66 http://rsta.royalsocietypublishing.org/content/369/1942/1762.full.pdf
67 Wackernagel and Rees: Our Ecological Footprint: Reducing Human Impact on the Earth (1996)



An expanding number of large cities face significant energy, environmental and climate-related challenges now and in the future.[68] A growing number of cities are making climate change a focus of their policy initiatives, striving with transport issues as an area for attention to improve the sustainability of urban travel, in addition to the environmental, land-use, safety and accessibility objectives. To efficiently deal with these challenges, cities need to become more resource-efficient, consumer-focused and technology-driven.

Use of Resources, Pollution and Climate

During the elaboration of this year's index, a number of strategic issues have been raised. Many of them have concerned the environmental dimension of sustainability, where three main variables – the use of resources, pollution and climate – have finally been selected. The use of resources and pollution can be measured with some accuracy at city level, although there are some complications. While waste, for instance, can be measured, it is generally more difficult to do the same for resources. This partly depends on whether the city is viewed from a production or a consumption perspective. Including a city's supply chain in the calculations is highly complex. The climate impact of a city is also hard to define. While a city's use of energy and local CO2 emissions have an impact on the global climate, they are not enough to determine how climate-smart a city is. A more comprehensive measurement would also have to include the climate impact of the city beyond its borders. We have found that this is currently not possible. Since every city is part of a myriad of regional, national and global production and consumption chains, this approach currently becomes a mission impossible. It would need a clear definition of where the city's impact ends. It would also need a full overview of all value chains in which a city is included. What's more, it would need clear definitions of the climate impact of each individual factor. Additionally, comparable proxies for each city would need to be determined. And finally, 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 the inclusion of more indicators concerning climate.
There are similar issues concerning the other variables, where for example you could argue that waste and energy usage are insufficient to measure a city's use of resources. If use of material were included, it would give a better indication of the city's actual consumption. To get a better indication of a city's 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 these factors, but that we will try to include these variables in the future.

68 OECD Environmental Outlook to 2050: The Consequences of Inaction (2012)

RESOURCES
Indicators: waste, energy and material.

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

Definitions: recycling is a process to change materials (waste) into new products to prevent 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.

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

Primary energy consumption in gigajoules (GJs) 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 GJs 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.

Many of the world's cities are still materializing. Economic growth and a growing urban population increase the use of resources in the world's cities, and therefore also raise the environmental burden. Through economic growth, a larger part of the world's population can start to consume or increase their consumption; in other words, become more material-intensive. This leads to an increased strain on the Earth's resources and an upturn in the production of waste.

The growth of ICT-related services (such as in software development, on the internet, and in advertising and marketing) and of traditional services that have been transformed by the use of ICT (mostly financial services and commerce) contributes to a structural change in the economy away from material-intensive activities toward more service-based and information-intensive activities. ICT therefore 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.[69] However, it is hard to measure the materialization of cities, and it has therefore been left out of the index due to a lack of data.

The reason for including energy consumption in the index is that a large part of the consumed energy in cities might not be produced in the city, but in other regions and more rural areas in order to provide the city with energy. Consequently, the growing urban population and its increasing incomes and

69 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

POLLUTION
Indicators: air pollution, water pollution.

Proxies: nitrogen dioxide (NO2) levels, sulphur dioxide (SO2) levels, particulate matter (PM)10 levels, PM2.5 levels, energy consumption per capita and fossil fuels, wastewater treated.

NO2 comes from sources such as cars, trucks and electric power plants. NO2 and SO2 are the major precursors of acid rain, which has acidified soils, lakes and streams, accelerated the corrosion of buildings and monuments, and reduced visibility. High concentrations of NO2 and SO2 also affect human health.

SO2 comes from combustion of fuel containing sulphur – mostly coal and oil. NO2 and SO2 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 NO2 and SO2 also have a negative effect on human health.

Yearly average of PM10 ug/m3 (micrograms per cubic meter of air). 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.

Yearly average of PM2.5 ug/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 the percentage of the population connected to "public" wastewater treatment plants, and the degree of treatment. The definition can vary between countries and cities.

consumption place a strain on the world's energy resources and increase its 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.

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. [70] [71] [72]

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 rise is linked to increases in air pollution concentrations and urban population size, as well as improved data availability and the methods employed in gathering such data.[73]

In both developed and developing countries, the largest contributors to urban outdoor air pollution include transportation, small-scale manufacturers and other industries, the 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.

SO2 is one of a group of highly reactive gases known as "oxides of sulphur." The largest sources of SO2 emissions are from fossil fuel combustion at power plants (73 percent) and at other industrial facilities (20 percent). Smaller sources of SO2 emissions include industrial processes, such as extracting metal from ore, and the burning of high sulphur containing fuels by locomotives, large ships, and non-road equipment. SO2 is linked with a number of adverse effects on the respiratory system.

The most prominent sources of NO2 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 the 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 recommended maximum level of 20 µg/m3 (micrograms per cubic meter of air). 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 wastewater – 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, as there are severe problems involved in finding reliable data.

CLIMATE
Indicators: CO2.

Proxies: CO2 per capita.

Definitions: CO2 emissions per person. All energy production using combustion emits carbon dioxide. This includes motor vehicles, electricity production, heating, and on. Energy is also produced through the decomposition of organic matter in soils under oxidizing conditions. It excludes emissions from air transport, international aviation and shipping. In order to facilitate the comparison among cities/regions, the CO2 emissions are divided by the population. Note: all known greenhouse gases are not included.

Domain rationale:
Cities make up a large part of the world population and are great contributors to the world's climate change. In turn, they are also the areas most affected by the consequences if climate change is not controlled. CO2 is the main greenhouse gas emitted through human intervention.

70 www.cleanairtrust.org/nitrogendioxide.html
71 OECD Environmental Outlook to 2050: The Consequences of Inaction (2012)
72 Let's build cities for people (not cars) (2011)
73 www.who.int/mediacentre/news/releases/2011/air_pollution_20110926/en/index.html

ICT's effect on the environment and climate change

Information technology-based solutions could in many ways be the foundation on which citizen, economic productivity, and quality of life are maximized, while resource consumption and pollution are minimized. [74]

ICT and use of resources

Since more and more waste is being produced, recycling and the improvement of waste management have become alarming issues in cities and urban areas. Waste management is the collection, transport, processing or disposal, managing and monitoring of waste materials. Waste disposal and how it is facilitated 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 meeting). Other examples of technologies that help decrease consumption include online media replacing CDs and DVDs, e-commerce, e-paper and e-books and telecommuting. However, the impacts of a dematerialization process rely to a large extent on behavioral change. [75] [76] [77]

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 and increased recycling and reuse of materials here. For example, there are now ICT-supported systems on the market that can identify different kinds of waste (through smart labeling of waste bags, for example), and thereby increase the level of recycling. There are also smart trash cans that report over an e-mobile network when they are full and need to be emptied. ICT can also play a key role in making citizens better informed and increase public awareness – a key component in order to change behavioral patterns. One example is that in Estonia, 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 capability 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 enable process and product innovation. For example, access to electronic components and new fabrication technologies make it possible to design, develop and manufacture a variety of physical artifacts that previously required large-scale manufacturing equipment and investment. ICT therefore improves industrial processes along the value chain.[78] [79]

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 CO2 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 videoconferencing and web-based seminars.[80]

Buildings are another area where ICT could reduce CO2 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 introduced.[81]

ICT-enabled systemic effects could impact on economic and social parameters, such as attitudes, expectations and behaviors of individuals as consumers, citizens and businesses. The demand and supply of goods and services, organizational structures, production distribution and service processes, as well as governance in the private and public sector, could alter due to new technological solutions. ICT can therefore make a contribution to tackling climate change by eliminating the need for physical products or activities. ICT is already enabling the dematerialization of consumption. [82] [83] [84] [85] [86]

74 www.iisd.org/
75 Carbon Connections: Quantifying mobile's role in tackling climate change (2009)
76 Improving Quality of Life Through Telecommuting (2009)
77 Towards A Connected World – Socio-Economic Impact of Internet in Emerging Economies (2009)
78 ec.europa.eu/enterprise/sectors/ict/
79 thingtanklab.com/wp-content/uploads/2011/02/SSHRC_DigEcon_DDF.pdf
80 Intelligent Transportation Systems (2010)
81 www.greentouch.org, ITU
82 Carbon Connections: Quantifying mobile's role in tackling climate change (2009)
83 http://www.iisd.org/
84 The Green City Index (2010)
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Ericsson AB – Bahrain
Al-Moayyed House
Seef District
PO Box 11508 Manama
Kingdom of Bahrain
Telephone: +973 17 584 511

Ericsson AB – Jordan
Fountain Plaza, Sweifieh
PO Box 940302
Amman 11194
Jordan
Telephone: +962 (06) 5540787

Ericsson AB – Oman
Assrain House
Building 65, Al Khuwair
PO Box. 1945, PC 112 Ruwi
Oman
Telephone: +968 2463 6363

Ericsson AB – Kuwait
Telephone Equipment & Service
Behbehani Complex, Sharq City
PO Box 5979 Safat 130 60
Kuwait
Telephone: +965 246 54 65

Ericsson AB – Bahrain
Al-Moayyed House
Seef District
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PO Box 940302
Amman 11194
Jordan
Telephone: +962 (06) 5540787

Ericsson AB
SE-126 25 Stockholm, Sweden
Telephone +46 10 719 00 00
Fax +46 8 18 40 85
www.ericsson.com