Original scientific paper

SMART CITY INDICATORS AND THE CONCEPTUAL PROBLEMS OF MEASURING SMART CITIES

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Cite this article: Dusek, T. (2024). Smart city indicators and the conceptual problems of measuring smart cities. *Deturope*. 16(3), 172-184.

Abstract

As the popularity of smart city research is increasing, the measurement of smartness became also a popular research topic. This is in accordance with the demand of the planners and project financing institutions for the success indicators, and with the observable tendency of new indicators for describing the settlements from the point of view of the quality of life, liveability, creativity, environment, social capital, development and many other fashionable research aspects of modern urban societies. Analyses through such indicators run the risk of taking a mechanistic, technocratic, superficial approach to complex urban systems, ignoring the complex causal relationships between urban subsystems and the interpretative and statistical uncertainties behind the indicators. Moreover, these composite or complex indicators merge very different basic indicators, often with low data quality and validity. This paper focuses on the uncertainties of smart city indicators, which are often used to form composite indicators that moreover form the basis for comparisons of smartness of cities. The transformation of a multi-indicator system into a one-dimensional metric scale is a highly questionable practice. Composite indicators, despite their popularity, are methodologically and conceptually highly problematic analytical tools for researchers and normative targets for policy makers.

Keywords: smart city, composite indicators, proxy indicators, spatial level, decision support tools, monitoring

INTRODUCTION

One of the striking contemporary features of empirical data analysis is the substitution of basic, concrete and evident indicators of the observational units with complex or composite indicators. These composite indicators may contain only two or three basic indicators (like body mass index from the weight and height of a person), but the number of indicators amalgamated into one composite indicator can reach several hundreds, even thousands. Another contemporary feature of empirical data analysis is the frequent separation of statistical data and the concept or idea under study. To mention some common examples, researchers (or rather technocrats, bureaucrats) speak about the quality of research, and they use citation data; they think about the social capital, and they use the average number of Facebook connections; they speak about the quality of universities, and they use indicators such as the ratio of students and professors, revenues, number of publications, proportion of foreign professors and students.

Indicators describing smart cities are similar or the situation can even be worse in this field. Smart city research has become extremely popular over the last decade, with the emergence of meta-research and methodological studies that deal with smart city indicators themselves, as well as complex indicators derived from individual smart city indicators, in addition to applied research. This is in accordance with the demand of the planners and project financing institutions for the success indicators, and with the observable tendency of new indicators for describingsettlements from the point of view of the quality of life, liveability, creativity, environment, social capital, development and many other fashionable research aspects of modern societies. Today, the mere list of these indicators would take a very long time to read. Networked Society Index (by Ericson), IBM Smart City Assessment, Green City Index (Siemens), European Green Capital Award (European Commission), City Prosperity Index (UN-HABITAT), Global Power City Index, Spatially Adjusted Liveability Index (The Economist Intelligence Unit), Mercer's Quality of Living, Smart Cities ranking by the Vienna University of Technology, Innovation Cities Index (2thinknow), Arcadis Sustainable Cities Index, European Energy Award are some examples, and some of them have a connection to the concept of smart cities. According to a general overview about the performance indicators of world cities by Feenan et al. (2017, p. 8), more than 300 comparative city indices already existed worldwide about 10 years ago for measuring urban life.

The abundance of these indicators poses the risk of applying a mechanistic, technocratic, superficial approach to the concerned questions, instead of a more critical, inclusive evaluation. Moreover, these composite or complex indicators amalgamate very different basic indicators, often with a low data quality and validity. The very concept of smart city remains unclear due to the multiple definitions. Many of the proposed indicators (as will be demonstrated later) are but general, traditional measures of various characteristics of settlements, which have nothing to do with digitalisation or development, and are simply neutral indicators of urban conditions or a characteristic that depends on the size of the settlement. Moreover, some of the indicators used are not interpreted at the level of cities but at the national or regional level. Further conceptual difficulties arise from the comparability of indicators over time. This paper, after a short overview of the motivations for measuring smartness, focuses on the missing connection between the concept (smart city as the result of digitalisation) and the content (the meaning of the indicators). For illustrating some points, a typical example will be used, namely the smart city index (IESE Cities in Motion Index) of the University of Navarra.

MOTIVATIONS FOR MEASURING THE SMARTNESS OF CITIES

The growing importance of composite indicators is a general trend in descriptive statistics, originating in the 1960's. Several supporting factors have ontributed to this trend. Firstly, composite indicators are often used as a tool to evaluate and monitor the performance of government projects and systems (key words: evidence-based decisions, public accountability, transparency, visibility). The typical form of success indicators for projects funded by the government (more precisely, by some central, regional or local government organisation or agency) is as follows: this and this were the situation in period n-1 (before the project), and this was the situation in period n, after the intervention of local/central/international government, after the termination of the project. This is a mechanistic, measurement-oriented approach that ignores the complexity of processes, deadweight and displacement effects, autonomous processes and unobservable alternatives. The latter are described by Frederic Bastiat (2010) through numerous examples in his 1850 essay "What is Seen and What is Not Seen". Naturally, private companies also have to use success indicators, but that case is much simpler, because profit shows the effectiveness of the activity of the company.

In an ideal situation, every smart city project, as a public project financed by the taxpayers, would have a public and accessible cost-benefit analysis. In this case the task of the researcher would be easy, only a meta-analysis should be conducted, demonstrating which type of projects are the most successful and efficient. Defining success and effectiveness may prove to be difficult and problematic due to the nature of the project, as costs can be monetised, benefits of projects are difficult to measure, especially those that do not generate monetary revenues, but at least there would be some results. However, in reality, the source of the problem is that only the very general and mostly technical features of the projects are publicly accessible, the most interesting and detailed cost elements are treated as business secrets. A further problem is the time dimension, especially for projects using digital solutions closely linked to the smart city concept, where technical obsolescence can be very rapid: obsolescence is expected only a few years after the projects are operational, and the operating and maintenance costs of new digital solutions are difficult to estimate in advance. The only way to analyse efficiency is through unique data gathering about the individual projects, which is often impossible due to privacy issues. Therefore, for the analysis of urban performance, mostly some general data and some data about the digital solutions can be used, which are combined into a composite indicator or some composite sub-indicators.

A second factor contributing to the spread of composite indicators is the fact that the creation of composite indicators creates great publication opportunities, both in the scientific and in the popular news in mass media. A paper or a newspaper article with a ranking of observation units (e.g. countries, cities, companies, universities), the latter with a spectacular colour infographic, is easier to publish than a complex and technical verbal analysis of the causal links and technical details between the indicators.

The third factor supporting the construction of composite indicators is the widespread belief that more data means more information, and not only more information, but also more accurate and more precise information. And at the same time, this goes hand in hand with the belief, that it is more scientific to create a composite indicator than the mere display of the original one dimensional data. In fact, data quality aspects such as accuracy, validity, reliability, precision, consistency, usefulness are very important, and in the case of smart city indicators, relevance is of paramount importance. This will be demonstrated through several examples in the coming sections.

The fourth factor promoting the spread of composite indicators is technological, namely the digitalisation of data collection and processing, the availability of large databases, the spread of computers, which make it easy to construct composite indicators, to regroup and reweight basic indicators. Computers have a revolutionary impact on the practice of statistics. Seventy years ago, it was mainly only a theoretical possibility to create a composite indicator with one hundred indicators and two hundred observational units. Today the computational process requires practically zero time if the data are prepared and available for the researcher.

Finally, efforts to measure the smart city fit well with a quantifiable megatrend that pervades many layers of society and the economy, in which significant resources are used to rank and score phenomena and entities that were previously only considered qualitatively and based on expert experience: restaurants, hotels, films, books, songs, teachers, doctors, universities, hospitals and so on. This megatrend may have positive impacts, but at the same time tremendous dangers too (Power, 1997; Dahler-Larsen, 2012; Muller, 2018; Mau, 2019; Fourcade & Healy, 2024).

Relevant critiques of composite indicators pointed to the possible misinterpretations of the composite indicators, not their uselessness (see for example Espeland & Sauder, 2016; Bowen & Kreindler, 2008). These warnings however could not halt the general trend. Simple and deceptive composite indicators have had a great carrier when backed up by a powerful propaganda machine. For example, the UNDP Human Development Index (HDI) has become a well-known indicator, although it has inherent and intractable problems, for example the original underlying indicators would be necessary for interpreting the magnitude of the HDI (especially for countries with the same magnitude but with completely different basic indicator values), but due precisely to the aggregation of indicators, this original information is lost in the composite indicator. Similarly, university rankings have become a successful industry for profit oriented ranking institutions, leading to various noxious practices by the evaluated universities (O'Neil, 2015).

THE ELUSIVENESS OF THE SMART CITY CONCEPT

The smart city has become a key concept in urban planning and urban strategies, used by researchers, city managers, politicians and information technology companies (Józsa, 2020; Salnikova & Khanin, 2022). On every continent and in cities of all sizes, from megacities of tens of millions to mini-towns and villages of a few hundred inhabitants, more and more people are seeking to use more and more information technology applications, to become more digital and smarter and to involve as much external rather than local resources as possible in smart projects, in the spirit of rent seeking behaviour. In addition, the various projects have become a popular research topic, generously supported both by different levels of government and by the IT giants with a financial interest in smart city projects. Unusually for other academic subjects, the smart city theme has a very high proportion of corporate contributions (IBM, Cisco, SAP, ABB, Siemens, GE, etc.).

Among the historical antecedents of the smart city, Kitchin (2014) identifies a number of approaches, such as rational, modernist urban planning in the mid-twentieth century, cybernetics focused on surveys and monitoring in the seventies, and neoliberal entrepreneurial urban management and development in the eighties and nineties. Others refer to even earlier antecedents, going back to the late 19th century (Baji, 2017) or even to ancient planned cities. There are numerous definitions of the smart city concept itself (Klusáček et al., 2020), with many studies providing multiple definitions that include one or a combination of four elements:

- technology (the use of digitalisation, information technology for a positive purpose),
- qualities of city inhabitants (smart, responsible, informed),
- involvement of citizens in decision-making (local democracy),
- quality of life (good, environmentally friendly, energy efficient, transport efficient and so on).

There is no consensus on the concept of a smart city (Fernandez-Anez, 2016). Of the four categories above, the clearest and most tangible is the technological element, the use of digital solutions in the functioning, operation and management of cities. The adjective “smart” in this sense refers to technology, for example in the term “smart development” (Torre, 2022). According to Karvalics (2017, p. 14), the number of smart city ranking lists is outnumbered by the number of smart city definitions. And the existing definitions are not converging, but rather further diverging. In addition, supplementary adjective definitions are emerging, such as sustainable smart city, eco-sustainable smart city and so on. Kulcsár (2020) also points out that the relationship between the smart city and the other vaguely used, multi-defined concepts of the city (liveable city and the like) is not clarified. Egyed and Rácz (2020) indicate the relationship between local economic development strategies and smart specialisation, while Szép et al. (2021) analyse the relationship between the smart city and resilience. It is not my intention to list and classify the various definitions and to explore the connections between the various related concepts. Such lists can be found, for example, in Albino et al. (2015) or Ruhlandt (2018). The former work presents 23 definitions, the latter 19, selected from a large number of available options. In addition to presenting some definitions, Gere (2018) also discusses the relationship with various related concepts.

The widening of the meaning of measurement has made it possible to measure the smartness of cities

Measurement, in its traditional everyday meaning, is an operation (action, sequence of actions) in which some tangible property of an object is expressed numerically on a predetermined scale based on some convention. The result of such a measurement is the metric and the unit of measurement; the metric refers to the number of times and the quantity is the unit of measurement. This is what every young child encounters in everyday life and then in school, initially on a tangible and visible scale (for example, measuring the weight and height of the human body), and then expanding to microscopic and macroscopic scales. This traditional meaning does not change when the measurement is of a more complex characteristic and requires some more sophisticated technological aid, such as temperature, electric current, wavelength, air pressure, blood pressure, eye pressure, blood sugar. Also included in the traditional meaning of measurement are derived measurements in the sense that the relationship between more than one basic measurement is the result of the measurement: speed requires distance travelled and time, density requires mass and volume. These, although derived measurements, still refer to tangible, obvious phenomena.

By the end of the 19th century, the concept of measurement had expanded, the measurability of the physical and biological world had improved, but the basic meaning of measurement had not changed. Since then, the meaning has broadened and changed significantly: firstly, due to the extensive use of aggregates, then thanks to the psychometric and sociological surveys, it became common to describe non-observable concepts with one or many observable attributions, often without any strong connection between the non-observable concepts and the observable attributions. All this went hand in hand with an abstract, logical, epistemological discussion of measurement, divorced from empirical science, which began in the late 19th century and reached the stage where measurement was, in Norman Campbell's 1920 definition, "the process of assigning numbers to represent qualities" (Campbell, 1920, p. 267). Not only the qualities and properties measured have changed significantly, but also the units of observation: aggregated, complex, collective units of observation have emerged alongside the concrete and unambiguous natural units of observation (e.g. persons). Units of observation can be, for example, aggregated groups of different entities, such as countries, settlements, firms, institutions and others, whose delimitation is often arbitrary. Without these changes in the meaning and practice of measurement, it would not be possible to measure the smartness of cities (Dusek, 2024).

Several composite indicators have been proposed to measure the smartness of cities (see for example Giffinger, 2007; Zygiaris, 2013; Lazaroiu & Roscia, 2012; Lombardi et al., 2012; Carli et al., 2013; Nagy et al., 2018). Composite indicators are always based on basic or individual indicators. The number of basic indicators grouped into a composite indicator may be few (less than 10) or very large (more than 100). It is quite a common practice to use more than one hundred basic indicators, and to use them to create a main index and several sub-indices, such as economy, human capital, social cohesion, environment, public management, governance, urban planning, technology, transportation, education and so on. The surprising or strange feature of the basic indicators of composite smart city indicators is that a vast majority of them have nothing to do with information technology solutions, but they are very simple traditional indicators.

Inadequate basic indicators of Smart cities

This inadequate foundation, the lack of linkage between the concept and the basic indicator describing the concept, is a fairly common practice in the complex indicators for smart cities, and is very easily verifiable and demonstrable by empirical evidence, namely by a simple listing of the problematic basic indicators. For the sake of simplicity, I have chosen a welldocumented smart city index, but its characteristics can be generalised to other smart city indices, namely the Cities in Motion, provided by the University of Navarra yearly from 2014. In her 2016 article, Uszkai presented the position of the city of Vienna through various global composite indicators, including the Cities in Motion Index, but unfortunately, apart from the rankings, she did not discuss the content of the various indices, nor did she present the basic indicators on which they are based. This smart city index was the best performing index in a study by Lai and Cole (2023), which compared the following 9 smart city indices (the publisher of the index and the number of cities surveyed in brackets, specific indicators are not discussed):

- Cities in Motion Index (University of Navarra, 174),
- Digital City Index (Bloom Consulting, 136),
- Global E-Governance Survey (The Economic Policy Institute, 100),
- Global Innovation Index (World Intellectual Property Organization, 131),
- ICT Development Index (International Telecommunication Union, 176),
- Innovation Cities Index (2thinknow, 500),
- Smart City Government (Eden Strategy Institute, 235),
- Smart Cities Index (Easy Park Group, 500),
- Smart City Index (The IMD World Competitiveness Center, 118).

The history of the indicator will not be detailed, but as with other composite indicators published over several years, the indicators and the cities considered have changed several times due to data availability, content and other reasons. The indicator deals with major cities worldwide, the number of cities covered varies between 170 and 185 and the number of indicators considered between 80 and 120. The number of sub-indices is nine, as follows:

- Economy,
- Human capital,
- Social cohesion,
- Environment,
- Governance,
- Urban planning,
- International outreach,
- Technology,
- Mobility and transportation.

Previously there were 10 sub-indices, but community management has been merged into governance. The results are presented each year with spectacular infographics for the mass media, and there is a longer publication which describes the basic indicators and the sources of the data too.

The economic sub-index consists of 8 basic indicators (source of the data can be seen in the parentheses):

1. Labor productivity calculated as GDP per working population (Euromonitor).
2. Number of calendar days needed so a business can operate legally (World Bank).
3. The top positions in the ranking indicate a more favorable regulatory environment for creating and developing a local company (World Bank).
4. Number of headquarters of publicly traded companies (GaWC).
5. Percentage of people involved in total entrepreneurial activity (TEA) who are motivated by an opportunity for improvement, divided by the percentage of TEA motivated by need. Total entrepreneurial activity (TEA): new entrepreneurs or owners/managers of a new business (GEM).
6. Estimated annual GDP growth (Euromonitor).
7. Gross domestic product in millions of dollars (Euromonitor).
8. GDP per capita (Euromonitor).

None of the indicators are based on original empirical research conducted by the composite index creator. Each indicator has been imported from some other common source. Moreover, all indicators are very general, not related to the concept of smart city, either as a technological concept (digitalisation) or as a knowledge economy concept. They are traditional indicators used to measure economic development, economic administration and centrality in economic power, except for GDP growth, which is a rather volatile indicator from year to year.

As regards the other sub-indices, they include a number of additional indicators that have nothing to do with the smartness of cities. Such indicators include:

- Average rent prices for local households
- Number of museums
- Number of art galleries
- Carbon-dioxid emission
- Future climate

- Number of metro station
- Number of gas stations
- High-rise building
- Number of McDonalds restaurants
- Poverty ratios
- Road traffic deaths
- Deaths due to the cardiovascular diseases
- Ratio of female workers in public administration
- Ratio of deaths per 100000 inhabitants

In addition, there are also indicators for which it is even questionable whether their high or low value is favourable:

- Population density
- Road density
- Water consumption
- Ethnic plurality

Overall, the following conceptual problems can be identified when examining the basic indicators:

- Most indicators do not have any connection to smart technologies and digitalisation. They are unreliable and invalid, as a proxy (even a very distant proxy) for smartness. They can be useful for some reasons but entirely inappropriate indicators for smart cities.
- Some indicators are dependent on the size of the city (not proportion or ratio, but their absolute number. For example, the number of McDonalds restaurants, gas stations).
- Some indicators do not have any meaning at the level of settlements.
- Some indicators have an entirely different meaning for settlements of different size.
- Some indicators cannot be compared spatially due to the different method of measurement in different settlements.
- Several indicators cannot be measured adequately.
- Several indicators cannot be measured or are not measured at settlement level, only at country level (for example: Peace index).

- Some indicators are conceptually problematic: is a higher or lower value of the indicator advantageous?
- The value of most indicators is influenced by the administrative boundaries of cities, which can vary from country to country and can be arbitrary (to what extent are agglomerations a part of each metropolitan area?)

The common conceptual problems of multidimensional measures arise as well, such as the treatment of outliers, weighting, way of standardization. Finally, due to the very different phenomena (number of hospitals, number of crimes, number of McDonald's and so on) that are combined into one number or ranking, the effective interpretation of the results is difficult.

CONCLUSION

Indicators and composite indicators can provide valuable information, but they also have limitations. In the case of smart city indicators, as can be seen from the examples, there can be a clear breakpoint, a clear distinction between the concept and the content of the data. Therefore, the interpretation of the results (ranking of cities, sometimes with concrete benefits in addition to prestige) can be highly misleading. A notional solution to this problem is to rename the complex indicator of smart cities to some very general quality of life indicator. However, this is not an elegant and scientific solution. One step towards a substantive solution to the problem is to examine the original basic indicators of the composite indicators in terms of their linkage to digital technology. Only those indicators that are related to digitalisation are justified. Examples of other problems were also given, such as poor data quality, international and temporal comparability problems, different meanings of indicators for different sizes of settlements. Another solution to the problem is to return to individual indicators, rather than using complex indicators with uncertain content, merging many very different phenomena.

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