# Structuring indicators for the development of a smart city plan

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## Abstract

This policy brief examines the indicators for the development of a Smart Cities Plan and presents a new model (MODIS) for its implementation covering transport and mobility, urban planning, governance, information and communication technology, quality of life, creative economy and environment. The model comprises 20 indicators and 74 sub-indicators and can be applied comparatively between cities in different chronological periods and analytical categories.

## Smart Cities concept

According to World Development Indicators (WDI), issued by the World Bank, the proportion of the urban population reached 53.857% in 2015 and this number was expected to reach 60% by 2030. It has been suggested that this number would increase significantly in developing countries such as China. However, it is widely appreciated that rapid urbanization has generated many problems, such as lack of energy, environmental pollution, traffic congestion, social inequality, unavailability or shortage of public service and loss of land. These problems cause cities to become disorderly and disorganized, hindering their sustainable growth (SHEN *et al*, 2018).

The idea of a smart city is a motivator for the development of policies that contribute to a better society and, consequently, to improving the quality of life of citizens. It can be emphasized that the basis of a smart city is the combination of human capital, social capital and an information communication technology infrastructure, in order to generate economic development, improve the well-being and quality of life for its citizens (GUIMARÃES *et al*, 2020).

The implementation of a Smart Cities plan has two different perspectives: one as an objective for urban development projects while the other is concerned with the support of specific development policies. In the current context, the smart city concept has taken this endogenous model to another dimension: one that is based on the knowledge economy and using the integration of information and communications technologies as the main instrument for economic growth (BARBA-SÁNCHEZ *et al,* 2019).

Smart Cities is not a strictly defined concept (SOLANAS *et al.,* 2014), but is a term commonly used to refer to the convergence of technology and city (YIGITCANLAR *et al.,* 2018). Although it is often confused with other similar but more specific terms such as information cities' or 'virtual cities', Smart Cities aims to cover all of these whilst including that most important and often missing component, the people who live within them (ALBINO et al, 2015).

Smart cities are built on complex and intelligent frameworks of ubiquitous digital networks, connecting citizens, governments, and objects that simultaneously send and receive data. Generally, smart city proposals comprise four main attributes: sustainability, quality of life, urbanization and intelligence, with some sub-attributes of these being more closely related than others (SILVIA; Khan; HAN, 2018).

## Smart City models

Modeling the complex implementation of a smart city plan is challenging and there are several components that vary at different levels from one model to another according to their focus (MOHANTY et al, 2016). These components constitute several domains of the city where the meaning of the label 'Smart' has different connotations in each (OSMAN, 2019). Today, conurbations and districts large and small are proposing Smart City models, as the way to develop an interconnected, attractive, safe, comfortable and sustainable community (LAZAROIU; ROSCIA, 2012). A brief survey of ten such city models reveals the conceptual aspects between sustainable cities and smart cities and the indicators and strategies for implementing proposals for them. These models and their respective attributes are summarized in Table 1.

Smart Cities models have at their core the integration between the municipal management areas and information technology, this being a fundamental pillar for the economic, social and environmentally sustainable growth that are essential foundations

*Table 1. Summary incidence of categories in international models for Smart Cities*

| Smart Cities Council | Connected Smart Cities | Easy Park | Cities in Motion | Grow Smarter | Barcelona Smart Cities | European Comission | Smart Cities - India | Smart Cieis Plan - Australia | United Smart Cities |
|---|---|---|---|---|---|---|---|---|---|
| Mobility | Mobility and Accessibility | Transport and Mobility | Mobility | Urban Mobility | Urban Mobility | Smart Mobility | Transport | Mobility | Urban Mobility |
| Environment | Environment<br>Energy | Environment | Environment | Environment<br>Infrastructure | Environmental Sustainability<br>Infrastructure | Smart Environment | Solid Waste | Environment | |
| Housing | Urbanisation | - | Urban planning | | Urban platform | Smart home | Constructions | Planning and Infrastructure | Const Infrastructure. Urban Development |
| Economy | Economy<br>Entrepreneurship | Economic Innovation | Economy<br>Human capital International Disclosure | - | Economy | | | | Financial Institutions |
| Governance | Governance | Governance | Governance | - | Governance<br>Legislation | Intelligent Governance | | Governance | |
| | Technology and innovation | Digitalization | Technology | - | Innovation<br>Technology | | Wi-fi | Business Value Capture Solution Technologies | |
| | Security<br>Health<br>Education | Quality of life<br>Expert Opinion | Social Cohesion | - | Population Participation<br>Health<br>Education | Smart Community | Health<br>Education | | Security<br>Infrastructure for Health |

*Source:* Authors, 2020

permeating them. The participation of the population in the development of the city is recurrent as is the accessibility to information. Cited often, all of them lead to decreased economic inequality and orderly urban growth

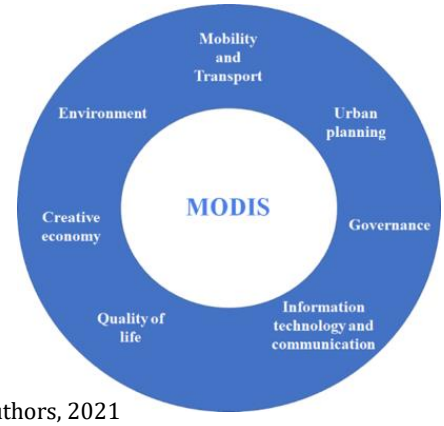
## MODIS - A new Smart City paradigm

Smart Cities can be seen as cloud-based entities that receive, manage and analyze data transforming it into intelligence that, ultimately, helps to improve the way we live, travel and work. They are in fact cities based on silicon technology or, in short, they are 'Silicon Islands' where a complex network of interconnected sensors, devices, and software collect and analyze mass quantities of data from a wide variety of industries, from urban planning to the collection and disposal of waste.

Our overview has led us to develop a new model for planning and implementing Smart Cities using practical performance indicators for a metropolitan capital that covers not only technological aspects, but also a wide range of components directly related to the management of a city. Using the idea of a Silicon Island Model, MODIS adopts an analytical approach based on an active local innovation system permeated by initiatives such as meetups and hackathons, incubation and acceleration of startups, angel investment, venture capital funds and actions promoting a high density of startups per inhabitant. MODIS encompasses the attributes of Smart City fit for purpose in a modern society today.

MODIS is more easily visualized as a circle of categories (Figure 1) that were identified as having the highest incidence of importance in the models analyzed the survey. Additional, indicators and sub indicators were also selected, analyzed individually and those that best contributed to the analysis of a Smart City plan were selected and validated from the literature. Table 2 presents the structure of MODIS which can be thought of as a map depicting the locations for the collection of data from the sub-indicators and indicators in the various principal component axes. It is then possible to evaluate of the quality of municipal services by stratifying from the micro detail through to the comprehensive macro-overview via these levels of indicator and axes. The model is constructed in such a way that it can be applied in different periods of time with data collected by different chronologies.

*Figure 1. Categories for the deployment of Smart Cities*




*Source:* Authors, 2021

*Table 2. Silicon Island Model (MODIS) map*

| Ind. | Sub indicators | Source |
|---|---|---|
| **TRANSPORT AND MOBILITY** | | |
| Public transport | Proportion of the Bus / Automobile Fleet | Detran |
| | Annual number of public transport trips per capita | (ISO 37120: 18.3) |
| | Integrated fare system offer for public transport | PMF |
| | Percentage of people satisfied with public transport services | PMF |
| Traffic | Congestion level | (Waze Satisfaction Index) |
| | % of traffic lights connected to real-time traffic management system | PMF |
| | Proportion of Cars/Population | Detran / IBGE |
| Other Modals | Miles of bike paths per 100,000 | (ISO 37120: 18.7) |
| | Number of shared bikes per capita | Rappi |
| | Number of cars belonging to sharing services in relation to the population | Detran |
| | Proportion of Commercial Vehicles / Automobiles | Detran |
| | Movement by air | ANAC |
| | Freight distribution using e-cargo bikes in the city center | Rappi, Uber e IFood |
| **MEIO AMBIENTE** | | |
| Waste Generation | Total water consumption per capita (liters / day) | (ISO 37120: 21.5) |
| | Total collection of municipal solid waste per capita (in kg) | (ISO 37120: 16.3) |
| | Average Age vehicle fleet | Detran |
| | % of solid waste from the city that is recycled | (ISO 37120: 16.2) |
| | % sewage treatment (volume) | Casan |
| Energy Efficiency | % of total energy derived from renewable sources | (ISO 37120: 7.4) |
| | Total residential energy use per capita (in kWh/year) | (ISO 37120: 7.1) |
| | Consumption by GDP (kWH / GDP) | Celesc / IBGE |
| **URBAN PLANNING** | | |
| Urbanism | % of the population in low and medium density | PMF / IBGE |
| | Green areas per 100,000 (in m2) | (ISO 37120: 19.1) |
| | % urban water/sewage service (coverage) | Casan |

| Ind. | Sub indicators | Source |
|---|---|---|
| Buildings | Number of LEED or BREAM sustainability-certified buildings in the city | SECOVI |
| | % regular/irregular buildings | MPSC / IPUF |
| **CREATIVE ECONOMY** | | |
| Entrepreneurship and Innovation | Growth in the Number of Technology Companies | ACATE |
| | Number of Technology Parks and/or Research Center | ACATE |
| | % of PIB of TI / PIB of City | ACATE / IBGE |
| | Number of Blockchain transactions per city | ACATE |
| Productivity and Income | GDP growth per capita | IBGE |
| | Average Income per capita | IBGE |
| | Labour productivity calculated as GDP per working population (in thousands) | IBGE |
| Local and Global Connections | Number of Participants in Fairs and Events | ABIH / FECOMERCIO |
| | Number of hotels per capita | ABIH / FECOMERCIO |
| | Number of arrival flights (air routes) in a city | ANAC |
| | Number of McDonald's restaurants per city | McDonalds |
| | Classification of cities according to the number of photos taken | Google |
| Human Capital | Proportion of the population with complete higher education | IBGE |
| | International movement of higher education students. | UNESCO |
| | Number of universities in the city among the top 500 | MEC |
| | % of jobs in the ICT sector | ACATE |
| **QUALITY OF LIFE** | | |
| Health | Suicide rate by cities | Ministry of Health |
| | Average life expectancy | (ISO 37120: 12.1) |
| | Doctors / inhabitants | Ministry of Health |
| | Infant mortality | IBGE |
| Education | % of Students with Personal Computer | IBGE |
| | % of Illiterate | IBGE |
| | Dropout Rate (High School) | IBGE |

| Ind. | Sub indicators | Source |
|---|---|---|
| Safety | Feminicide rate | Ministry of Justice |
| | Violent crime rate per 100.000 inhabitants | (ISO 37120: 14.5) |
| | Traffic Deaths | Detran |
| | Police officers / inhabitants | Ministry of Justice |
| Social | Gini Index | IBGE |
| | Proportion of workers in public administration | PMF |
| | % of people working full-time | (ISO 37120: 5.4) |
| **GOVERNANCE** | | |
| Digital Government | % of gov services that can be accessed by citizens via web or mobile phone | PMF |
| | No services integrated in operations center, using real-time data. | PMF |
| | Local government site traffic as a percentage of the population | PMF |
| Transparency and Services | Number of calendar days required for a company to operate legally. | PMF |
| | Has Open Data Policy | PMF |
| | International Transparency Ranking Score | Transparência Internacional |
| Public Spending | Independence of Public Sector Jobs | PMF / Caged |
| | % Payroll and Personnel Expenses | TCE/SC |
| | % of Public Indebtedness | TCE/SC |
| | % Public Investment | TCE/SC |
| **INFORMATION TECHNOLOGY AND COMMUNICATION** | | |
| Infrastructure | Average 4G download speed (in Mbps), adjusted to the Internet speed of each city (Mbps) | ANATEL |
| | 4.5G coverage | ANATEL |
| | Free Wi-Fi hotspots, adjusted for the city area | ANATEL |
| Users | % high-speed broadband | ANATEL |
| | Percentage of people who own a smartphone | ANATEL / IBGE |
| | Users registered with Gmail in the city | Google |
| | Number of LinkedIn users in the city. This is part of the social media variable | LinkedIn |

*Source:* Authors, 2022

## Summary

The applicability of MODIS allows a diagnosis of how much a city fits into the concept of Smart Cities. From this structured approach it becomes possible to perform an evolutionary analysis and design incremental improvements for each indicator in detail. In turn, it becomes possible to identify the main deficiencies in urban development, and, consequently, guide the direction of actions that public and private managers can make to develop cities that are smarter, environmentally sustainable with a better standard of health and well-being.

From another perspective, a comparative analysis can be performed between different municipalities that is especially useful for analyzing localities that are recognized a reference or beacons of good practice in certain areas. For example, the category of Governance can be analyzed individually between two or three municipalities, considering one of them as a reference to be achieved. Similarly, another category such as Transportation and Mobility can be analyzed for other different municipalities in order to obtain the best performance in relation to the generalized model for the implementation of Smart Cities. As a means of making a comparative analysis, MODIS can identify which municipalities stand out in certain segments, stimulating in-depth research on their quality, causal parameters and opportunities for adoption into public policies or reasons why they have fostered the success of a region.

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