Modeling for Making Smart City KPIs a User-friendly Tool for Smart City Design[*]

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Abstract. This paper highlights the importance of smart city governance and smart city monitoring frameworks for the success of smart city strategies. It then stresses how smart city monitoring frameworks are not always used and available, hampering the success of smart city strategies. That is due to several factors included the lack of data tools. Finally, the paper argues that the modeling scholars can support the adoption of smart city monitoring frameworks through their work simplifying smart city data tools.

Keywords: Smart city lifecycle, Governance, Monitoring, Modeling

1 The lifecycle of smart cities

1.1 The Evolution of Smart Cities

The concept of smart city and smart community goes back to 1997 when the California Institute for Smart Communities developed a "Smart Communities Guidebook" in which smart community was defined as following:

"A smart community is simply that: a community in which government, business, and residents understand the potential of information technology, and make a conscious decision to use that technology to transform life and work in their region in significant and positive ways." [1]

Since then, the definition of smart city has evolved between an approach majorly focused on the use of technology and another one towards a more collaborative approach among different disciplines trying to make the entire concept less technology centric. The latter has driven the attention on the concept of smart city. In fact, on the technology side, the advent of the Internet of Things has provided the technological tools for simply implementing the definition by the California Institute for Smart Communities. On the socio-economics side, the continuous demographic push on cities and their increasing economic importance have pushed city administrations to re-think the purpose of the city and the services provided to citizens, businesses and other city stakeholders. The combination of the possibilities offered by technology and the increasing socio-economic importance of cities have brought the concept of the smart city to the top of the political agenda and challenged the business community to explore how to transform smart cities into a business opportunity.

Put aside the socio-economic and political aspects of smart cities, the IoT has become an important technological framework for smart city development. The IoT transforms spaces into connected and intelligent ones. The data are gathered, exchanged, analyzed and actions are taken based on that analysis. The data gathered is a combination of different data. If cities are systems of systems, the IoT is the technological framework able to make that system of systems works smoothly and to be beneficial for citizens and businesses.

In practice, many smart city projects evolve much more organically. Several cities have started experimenting with the applications of IoT in their services, initially, focusing on a specific application. There have been then several smart parking projects, intelligent lighting projects, smart public safety solutions and so on. But that was only the first step. As per any IoT solution, the user appreciates the value of the IoT project outcome – the beauty of the data gathered and the value of its analysis – and wants then to explore more. In that way, the smart parking projects expanded into environmental monitoring solutions and/or public safety solutions and moving further to more complex projects.

1.2   Introducing the Smart City Strategy Lifecycle

The evolution of smart city projects requires an overall smart city strategy that needs to be managed. The smart city strategy does not have a conclusion, but it evolves continuously based on achievements, issues and new city needs. Therefore, it is important to see smart city strategies with a lifecycle approach. The smart city lifecycle can be structured in key 5 phases as shown in Figure 1.
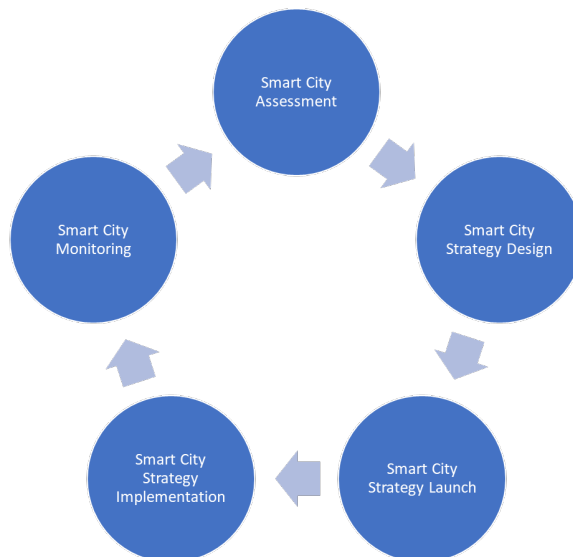

Fig. 1. Smart City Strategy Lifecycle

Smart City Assessment. This phase looks at the need of the city, as well as its level of digital maturity. The digital maturity can be addressed in a variety of ways through the monitoring framework illustrated previously This phase needs to be very inclusive of all the city stakeholders: businesses, academia, public organizations and citizens' groups. The output of the smart city assessment is then used in the next phase.

Smart City Strategy Design. Based on the smart city assessment, a smart city strategy document is produced. This document contains overall objectives, projects to implement, and resources to use. The strategy document should also include a monitoring framework. We will explore that more extensively later in the report.

Smart City Strategy Launch. It is important to find a wide city consensus on the strategy and communicate the strategy to the city stakeholders. The inclusiveness of the city as an all in the process is a key factor of success.

Smart City Strategy Implementation. The smart city strategy document contains an implementation roadmap. Therefore, the length of this phase really depends on the decisions in the roadmap. The roadmap could include both short-term and long-term projects.

Smart City Monitoring. This phase makes the monitoring framework established in the Smart City Strategy Design phase in operation. That framework should assess the evolution of the smart city strategy implementation. The output of the smart city monitoring can enable another cycle, starting with the assessment. The repetition of the cycle can also be established in the smart city strategy.

1.3   The importance of Smart City Monitoring Frameworks

The monitoring phase is particularly important because it defines the level of "smartness" of a city, therefore, the level of success of a smart city strategy. There is not one way of running the monitoring phase. A monitoring framework is affected by the specific city context, but there are quite few organizations proposing monitoring frameworks.

The monitoring phase is based on a set of Key Performance Indicators (KPIs) that assesses different dimensions of a smart city. The types of indicators depend on the organization proposing a monitoring system for smart city. This article considers three approaches: the ITU Smart and Sustainable Cities KPIs, the Digital Cities Challenge Framework, and the CITYKeys Indicators.

CityKeys Monitoring Framework

The CITYKeys Indicators, results of an EU Horizon 2020 project, provided a monitoring framework based on the two levels of KPIs: KPIs for individual smart city projects and overall KPIs for the smart city.

"A smart city is a city that efficiently mobilizes and uses available resources (including but not limited to social and cultural capital, financial capital, natural resources, information and technology) for efficiently:

1) improving the quality of life of its inhabitants, commuting workers and students, and other visitors [people]

2) significantly improving its resource efficiency, decreasing its pressure on the environment and increasing resiliency [planet]

3) building an innovation-driven and green economy [prosperity]

4) fostering a well-developed local democracy [governance].

A smart city project is a project that

1) has a significant impact in supporting a city to become a smart city along the four axes of sustainability mentioned above

2) actively engages citizens and other stakeholders

3) uses innovative approaches

4) is integrated, combining multiple sectors." [2]

The indicators used for the two levels are related and based on the framework showed in Figure 2.

Theme	Sub-theme
People	Health, Safety, Access to services, Education, Diversity & Social Cohesion, Quality of Housing
Planet	Energy and mitigation, Materials water and land, Climate resilience, Pollution and waste, ecosystem
Prosperity	Employment, Equity, Green Economy, Economic Performance, Innovation, Attractiveness and competitiveness
Governance	Organisation, Community involvement, Multi-level governance
Propagation	Scalability, Replicability

Fig. 2. Structure of the CityKeys Monitoring Framework [2]

Digital Cities Challenge

CITYKey Monitoring Framework was an inspiration for the one used in the EU-funded Digital Cities Challenge (DCC) project [3]. The DCC project run for almost two years with the intent of driving digital transformation strategies in cities. The large majority of the cities were small-sized ones located in areas with economic growth issues. The raison d'etre of the project was that digital transformation strategy design and implementation could drive economic growth. The project encouraged cities to adopt a data-driven decision making using a monitoring framework. That framework had different dimensions as shown in the picture below.
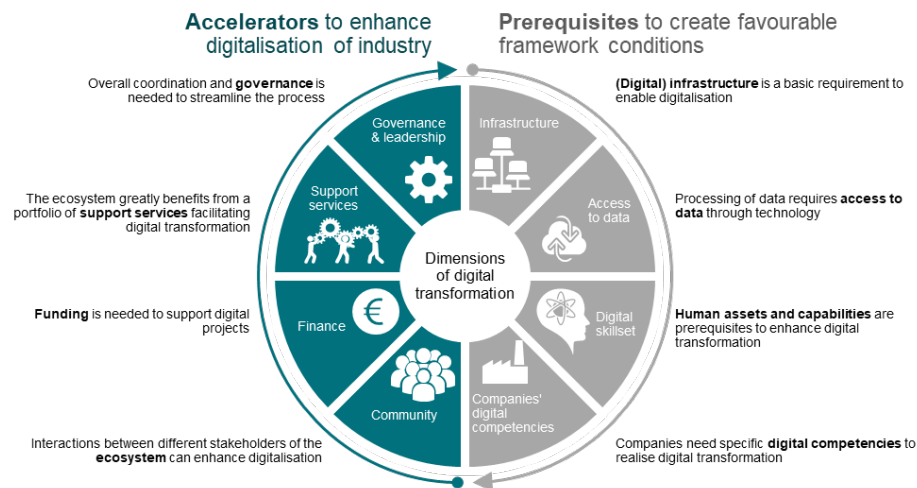
Fig. 3. Digital Cities Challenge Monitoring Framework [3]

The monitoring framework should also have been used to assess the smart city lifecycle based on the strategy designed. The project also encouraged the creation of smart city governance models. The approach was based on three components: the strategy ownership, the steering group, the operational agent.

The project was completed in July 2019 with almost 40 European cities with a digital transformation strategy, a monitoring framework and in-development smart city governance models. The results of some of those cities have been used in this work.

United 4 Smart Sustainable Cities (U4SSC) KPIs [6]

The U4SSC is a UN initiative and coordinated by the International Telecommunications Unit (ITU) to achieve the Sustainable Development Goal number 11: "Make cities and human settlements inclusive, safe, resilient and sustainable" [6]. The U4SSC has developed a set of KPIs to monitor the development and the success of smart sustainable cities. The KPIs are structured in three groups: Environment, Society & Culture, Economy. Over 50 cities worldwide are already implementing these KPIs, including Dubai, Singapore, Manizales, Montevideo, Maldonado, Foshan, Wuxi, Guangshan, Kairouan, Pully, Moscow, Valencia and Rimini.

1.4 The Models of Smart City Governance

A smart city monitoring framework is an essential tool for managing the smart city lifecycle. It enables to assess the development of the smart city strategy and to update the strategy considering that. To do that, an organizational structure that manage the entire smart city lifecycle is necessary. That organization is often referred to as smart governance. This chapter will explore what a smart governance is with an emphasis on the models of smart governance currently used in cities.

The debate in academia and in the public sector on what smart city governance entails continues to be animated by different positions. For the purpose of this paper, the term "smart city governance" refers to an organizational entity and its processes in charge of governing a smart city strategy.

The smart city governance can be structured in the components illustrated in Figure 4.
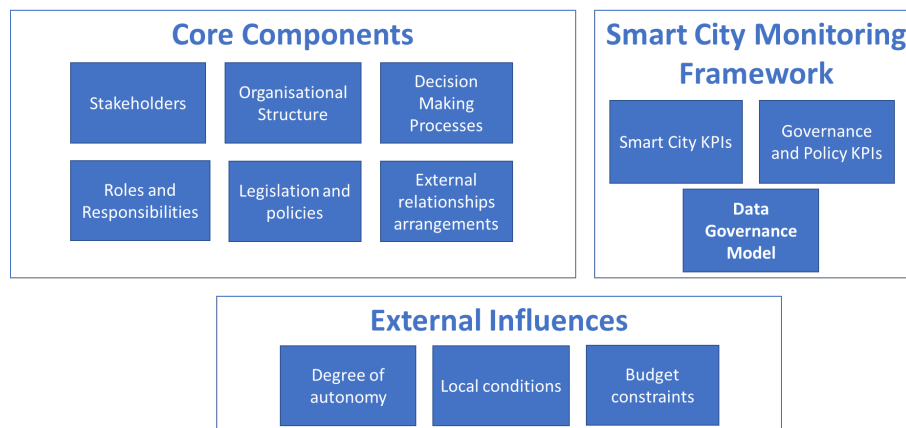

Fig. 4. Components of Smart City Governance Framework (Elaboration on [4])

Within a smart city monitoring framework there are three key areas to consider: governance and policy KPIs, smart city KPIs and data governance model. The data governance model essentially gathers all the data needed to manage and govern smart cities. That includes machine-generated data, but also socio-economic data and administrative data. The governance and policy KPIs refer to indicators measuring if and how the smart city strategy objectives have been achieved. The smart city KPIs refer to the performance of the various solutions in place. It is important to think about this framework as a live system that continuously monitor the progress of projects and the overall strategies.

2 Modeling for Smart City Monitoring Framework

2.1 The City Struggle with Governance and Monitoring

Smart city governance and smart city monitoring framework are widely recognized as an essential elements of successful smart city strategies. However, they are also the most common missing points in stories of smart cities. Roland and Berger [5], in their annual analysis of smart cities, found that "a small and growing number of cities have comprehensive smart strategies." And, the ones in the small group scored highly due to "factors such as robust system of performance monitoring."

The experience of the EU-funded Digital Cities Challenge reveled similar problems. The project gathered more than 40 European cities, most of them with economic growth problems, and work with them to build digital transformation strategies for the cities and the local economy. After two years of work, much progress was made by the cities, but two issues strongly affected robust and sustainable development: the lack of a solid governance structure and the lack of a robust smart city monitoring framework.

The creation of a governance structure requires alignments among city stakeholders and careful balance in the decision-making process for cities. Therefore, defining that and implementing that is not always easy and immediate. It should be driven by a strong commitment of the local policy makers.

Certainly, the use of a smart city monitoring framework requires a similar commitment, but there are another three key factors that, if addressed, can facilitate the adoption of such frameworks. These three factors influenced each other and are:

Evidence-based policy culture. At the level of smart city local stakeholders, the culture of evidence-based decision making is not always present. Decisions are often not supported using data.

Data. The lack of data hampers the possibility of evidence-based decision making. At local level, there are difficulties in gathering, organizing, and using smart city data and other administrative data. The structure of city data is too often based on several silos.

Tools. The inability of using data is also due to the absence of smart city data visualization and analysis tools. Existing tools can be unaffordable for local authorities. Local authority personnel need to be formed for using those tools. Sometimes, local authorities have serious budget issues to purchase tools and train personnel.

2.2   Modeling for Evidence-based Smart City Strategies

Addressing the three factors hampering the adoption of smart city monitoring frameworks require a collaboration among public, private, and academic stakeholders. The community of modeling scholars can give a major contribution to that challenge.

- Developing ideas on how to organise, orchestrate and model smart city data enabling local authorities to see their city through the eyes of connected devices and the data they produce.
- Abstracting the complexity of technologies, creating easy-to-use tools that enable local authorities to reflect on the city and its future.
- Developing tools for enabling scalability, better performance, risk assessment, and strategy design.

These three steps should aim at simplifying the use of smart city data by local authorities and smart city governance organisations. That simplification should favour the

development of an evidence-based policy making process in smart cities and support the governance of smart city lifecycles.

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