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Citation	International Journal for Housing Science and Its Applications. International Association for Housing Science . Vol. 41 (2017) No: 2, pages 113-125
Date	2017
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Int. Journal for Housing Science, Vol.41, No.2 pp. 113-125, 2017
Published in the United States

CITYkeys SMART CITY PERFORMANCE MEASUREMENT SYSTEM

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ABSTRACT

Cities are tackling their economic, social and environmental challenges through smart city solutions. To demonstrate that these solutions achieve the desired impact, an indicator-based assessment system is needed. This paper presents the process of developing CITYkeys performance measurement system for target setting and monitoring. This European smart city indicator framework was developed by analyzing cities' needs, existing indicators and gaps.

Keywords: Smart city, Indicator, KPI, Performance measurement, Indicator framework, CITYkeys

0146-6518/02/113-125, 2017

Introduction

Cities are areas of creativity and economic growth: the potential for exchanges, optimization and new solutions is unique and enormous. Yet, the current transition to low carbon, resource-efficient and climate resilient cities with uptake of innovative solutions providing growth is progressing slowly [1-3]. As the European Union (EU) has set its climate and energy targets for 2020 and 2030 [4], there is an urgent need to develop smart solutions to overcome barriers and to address these challenges [5]. Innovative approaches are needed to tackle problems related to overcrowding and jamming of infrastructures, energy consumption, resource management and environmental protection [6]. The development of smart city solutions is highly relevant and expected to contribute to meeting the 20-20-20 targets established in the European 2020 Strategy and, beyond that, the European 2050 objectives.

Many definitions for smart cities have been developed in the past years, some with more emphasis on ICT technologies, others stressing collaborative methods and citizen engagement [7-10]. The various definitions share the idea that innovative methods, processes, digital solutions and/or technologies are enablers for a more sustainable urban environment.

There is a strong need for new, efficient, and user-friendly technologies and services, particularly in the areas of energy, transport, and ICT with interoperable and integrated approaches [11]: 'smart' solutions, i.e. both highly efficient and sustainable on the one hand, as well as generating economic prosperity and social wellbeing on the other hand. This is best achieved by mobilizing all city's resources and coordinating its stakeholders using new technologies and forward looking joined-up policies [6].

Innovative and smart solutions for cities are already available but their uptake is low, one of the reasons being that often the impacts of the smart city solutions cannot be objectively verified and because of lack of evidence that these solutions can also be applied in other contexts and cities [12]. In response, some cities and countries have developed their smart city strategies [e.g. 13-16].

The European Commission has developed under Horizon 2020 Research Programme two parallel approaches to support the implementation of smart urban technologies: large scale "vertical demonstration" of technology in cities and communities ("lighthouse projects") and "horizontal activities" to address specific challenges including performance monitoring [17]. This paper presents the results of the CITYkeys project that addressed one of these horizontal challenges, namely "Metrics & Indicators".

CITYkeys project developed a performance assessment framework for smart cities. The aim was to speed up the transition to smarter cities by facilitating and enabling stakeholders in projects and cities to learn from each other, create trust in solutions, and monitor progress, by means of a common and transparent performance measurement framework. The CITYkeys framework allows monitoring and comparing the implementation of smart city solutions. The CITYkeys concept is summarized in Fig. 1.

This paper presents the process of developing the holistic CITYkeys smart city performance system which comprised of the following main steps:

- Specification of the European cities' needs on smart city performance measurement
- Compilation of currently existing indicators and gaps definition
- Building of new indicators to fill the gaps
- Definition of CITYkeys indicator framework and indicators
- Study of the available data for the KPIs calculation
- Development of a prototype system for the data collection, processing and KPIs visualization

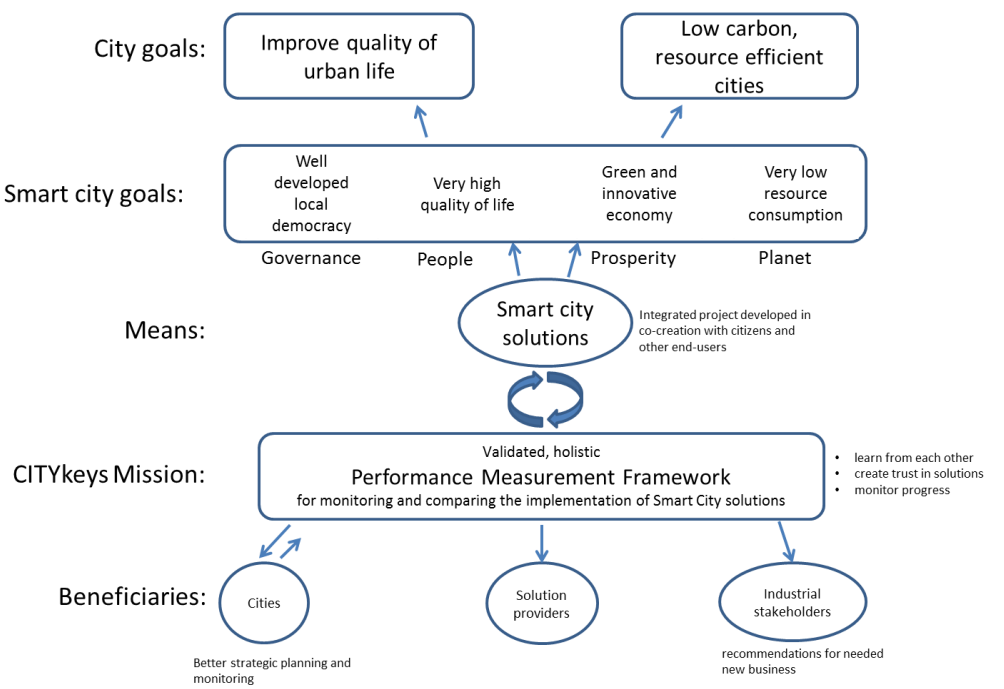

Fig. 1. CITYkeys goals.

Methodology

Input from cities was collected though a comprehensive questionnaire involving 20 European cities of different sizes [18]. The questions were divided to two levels of smart city development − project level and city level − and included questions related to smart city priorities, the need for a smart city framework, the uses of performance measurement in a city, the desired properties of a measurement tool and the practices of collecting and opening datasets.

The availability of indicators was checked via the analysis of 43 existing sustainable and smart urban performance measurement frameworks. Those ranged from sectoral to holistic and integrated frameworks that either assess the performance of projects or that of a whole city. The full list is included in [19].

The new CITYkeys indicator framework [20] was designed with active participation of five cities: Rotterdam, Tampere, Vienna, Zagreb and Zaragoza. Around 30 other European cities as well as a number of associations, companies and standardization bodies were actively involved in commenting on the indicator selection and indicator descriptions. Their responses were gathered in webinars and in written comments. Starting from a long list of indicators, we worked gradually towards the final selection. Scoring the indicators on compliance with the criteria of relevance, completeness, availability, measurability, familiarity, non-redundancy and independence [21] helped to come up with a total number of indicators considered manageable by the cities involved in the process (~100). During the discussions also new indicators were suggested.

The feasibility and usefulness of the CITYkeys indicators were tested in the five cities' case studies for both smart city project performance assessment and the evaluation of smartness at city level [22]. Gathering the data and doing the interviews for the qualitative indicators was done by the staff of the city administration in some cases supported by the researchers. In addition to the five project partner cities' case studies, the final validation of the indicators and the prototype tool was done by collecting feedback from a network of 50 testers varying from cities to project consortia and industrial stakeholders mainly from Europe but also beyond.

Cities' needs and gaps regarding smart city performance measurement

Cities' needs on smart city performance measurement

The development of the Key Performance Indicators (KPIs) for the CITYkeys performance measurement system started from the identification of cities' needs on smart city performance measurement.

In both planning and implementing smart city solutions, performance measurement is considered to be a key component of the development process [18]. Nevertheless, and although they would like to do so, many cities haven't yet widely adopted or implemented such performance measurement systems.

The areas in which cities mostly need indicators to measure their smart city performance include in order of importance: energy, greenhouse gas emissions, transportation, digital infrastructure and e-services, resource management, citizen participation, competitiveness, economy, environment, quality of life and research and knowledge creation. On the smart city project level, the areas in which cities mostly need indicators to measure performance include: greenhouse gas emissions, energy, transportation, digital infrastructure and e-services, environment, quality of life,

research and knowledge creation, resource management, innovation, urban planning and social inclusion.

Existing smart city KPIs and gaps

The next step was to analyze what indicators are already available to measure smart or sustainable urban performance. The analysis of existing indicator frameworks revealed that there are only few indicator frameworks available that assess smart city performance in a holistic manner. No framework enabled to make the connection between the impacts of smart city projects and impacts on the level of the city.

An analysis of the gap between the expressed needs of the cities and the indicators included in existing frameworks revealed that indicators are completely lacking at city level for multilevel governance. At project level indicators are missing for the themes of education, employment, scalability and replicability. [19]

CITYkeys performance measurement system

Indicator framework

Based on the analyses presented in Chapter 3, a comprehensive indicator framework was structured according to the themes of key smart city policy goals under which the indicators are presented in a harmonized and balanced way (See Fig. 2). [20]

The CITYkeys performance measurement framework enables project and city level assessments. The framework is structured according to the categories of People, Planet, Prosperity, Governance and Propagation. It contains both output indicators (e.g. number of open data sets) that enable measuring the progress on short term and impact indicators (e.g. reduced energy consumption) that can be either estimated in the beginning of a project through simulation or monitored on a longer time scale (after the implementation of the project).

Fig. 2. CITYkeys smart city project KPI framework structure with number of indicators.

The indicator selection for project and city level assessments is quite similar with minor differences, enabling to some extent the evaluation of impacts of projects on city scale. Both frameworks contain around 90 KPIs (Key Performance Indicators). These have been described using the template presented in Table 1.

Table 1. Template used for KPI descriptions.

Name of the indicator	Type of project for which the indicator is relevant (ICT, built environment, transport)
Description & justification	
Definition	
Calculation	
Strengths and weaknesses	
Data requirements	
Expected data source	
Expected availability	
Collection interval	
Expected reliability	
Expected accessibility	
References	

The table contains all the needed information to be able to describe an indicator as well as potential data availability, sources, reliability and accessibility. Around half of the indicators are quantitative and the other half qualitative. The latter ones are described and assessed on a five level Likert scale through for example interviews. All indicator descriptions are available in [20].

Data availability

The availability of data needed for the calculation of the quantitative city level KPIs was analyzed after defining the datasets needed by the KPIs [23]. The analysis of availability of those datasets in the five CITYkeys partner cities considered available data sources, their reliability, formats, level of confidentiality and data access methods. In addition potential privacy issues were screened.

Based on the results of this analysis [23] on average 72% of the needed (quantitative) datasets are available in the five CITYkeys partner cities and the availability rates vary between 52% and 82%. On average 44% originate from public sources (e.g. as reports) and 5% are confidential. Typical sources of data for city KPIs include statistical sources or data provided by outsourced or otherwise external companies (e.g. energy or water company). For qualitative indicators the needed data is available and the feasibility depends on the availability of an assessor. For project indicators the data coverage is project specific and the data is typically not readily available or collected in a systematic way.

Most of the project and city KPIs were also tested in several case studies with each having a different aim and focus. The data availability and successful implementation of most of the project KPIs (73/101 = 72%) and city KPIs (62/76=82%) were validated. The average KPI data availability rates in a European city are expected to be over 70% (around 25% as open data) for quantitative city KPIs and close to 100% for all the qualitative ones. [22]

Open data availability and quality

Data can be called open data if it fulfils the following three requirements: 1) it is available and is in readable form, 2) it is published with a license which allows re-use and redistribution, and 3) it is published with equal terms for every user. [24]

On average 15% of the needed data is available as open data in the five CITYkeys partner cities. Cities have up to 300 open datasets on their portals but only very small part of it provides the required data for calculating CITYkeys smart city indicators. The number of open data sets in the five partner cities' portals are as follows: 16, 103, 111, 144, 292. It is however important to highlight that quality and reliability are often more important for the usability of the data than is quantity. [23]

The quality of all open data available in the five cities' portals was rated using the 5-star rating scale [25]:

1. Data is published in any format under an open license
2. Data is in structured format
3. Data is in open format
4. Data is in linked data format containing URIs
5. Data is linked to other data respectively

The average open data quality ratings in the five partner cities varied between 2,17 and 2,96. In simple terms, this means that most of the data is published in structured format (e.g. Excel), but not everything in open format (e.g. CSV). Excel is not an easily machine readable format even though it can be read after some conversions. Almost half of the datasets are spatial enabling the calculation of indicators also for geographically restricted areas. [23]

Prototype platform

Together with the KPI framework a prototype web based tool of the performance measurement system was also developed. The tool integrates data input, calculation methodologies, and result visualization in an intuitive and user-friendly interface [26].

The end-users of the tool (i.e. cities) were actively involved in all stages of the tool development. Based on the feedback, improvements were made before implementing the final tool prototype. Also small refinements in KPIs and their definitions were made based on the testing case studies. This approach ensured the strong involvement of the end-users of the tool in its design.

The KPI calculation tool has both manual and automatic input modes [26]. In the manual mode cities input in a web-interface first general project or city information and then assess each KPIs by inputting their assessment values. All needed information to assess the KPIs is available on the interface. In the automatic mode the datasets needed by KPIs are read from cities own databases or platforms, and CITYkeys services automatically calculate the KPI values which are regularly updated when the raw datasets are updated by the city. Cities can also insert KPI values to the KPIs tool or connect it with other platforms through RESTful APIs.

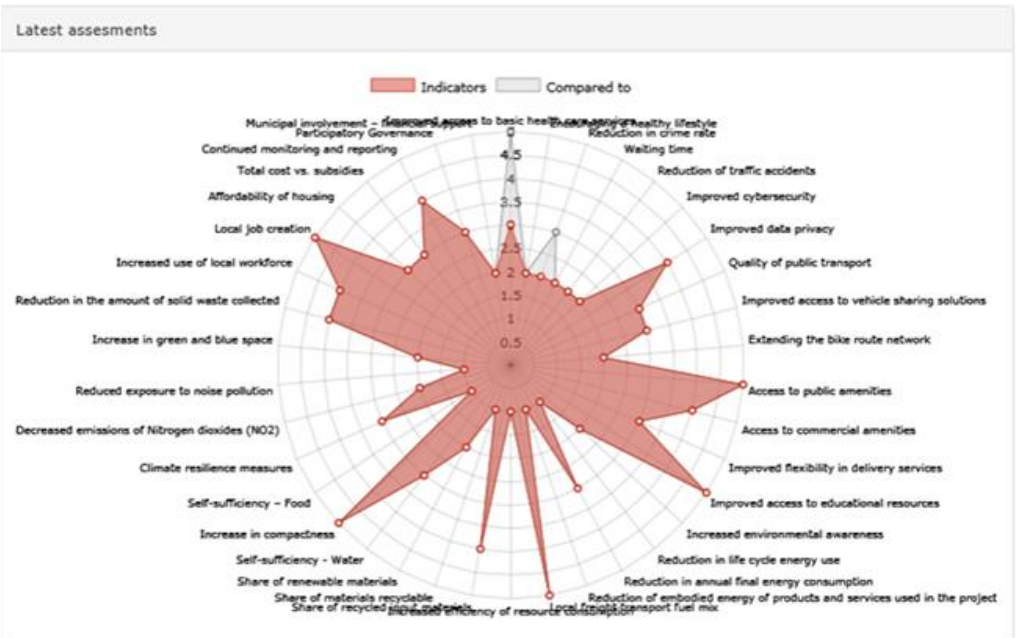

Fig. 3. Visualisation of assessment results in spider diagram.

All the project KPIs are evaluated on a five level scale with qualitative assessment scales or numerical target values. The overall assessment results can be visualized and compared through spider and trend diagrams (see Fig. 3 and 4).

Fig. 4. Visualisation of assessment results in trend diagram.

However, since not all the KPIs are relevant in all contexts and the main objective of the framework is not benchmarking, not all the KPIs need to be assessed. Instead of comparing to each other, which often doesn't even make sense because of cities' differences, cities seem to be more interested in using the indicators to set own targets, learn and monitor progress. The main target groups identified are cities' strategic and operative level management and project managers or urban planners.

Discussion

Due to the wide definition of "smart city projects" as used by the European cities involved in the project, the CITYkeys indicator framework includes a large number of project indicators. Only part of these are generally applicable; many indicators serve to assess projects in a specific sector. That means that on the one hand for the assessment of a specific project not all indicators need to be used, but that on the other hand comparability between projects of different kinds is limited. However, it might be expected that with a growing number of integrated projects, that is, projects combining for instance transport and energy, a larger number of indicators can be used.

Similarly, as cities stress the sustainability aspect of smart city projects, the CITYkeys indicator framework has a number of indicators in common with sustainable city indicator sets. Still, its focus on innovative approaches makes CITYkeys stand out as a distinct product. The overlap with sustainability indicators has been used by aligning as much as possible to standard indicator definitions, e.g. from the ISO 37120 standard [27].

The number of indicators that allow making a quantitative link between the result on project level and the result on city level is very limited. In fact it concerns "Planet" indicators on (reduction of) energy consumption, emissions of CO_2 and air pollutants, and generation of renewable energy. For other aspects of the framework, differences in data definition between the CITYkeys indicators on project and city level hamper direct comparison. To align smart city projects better to city ambitions it would be good to extend the exploration on the possibilities to define indicators that enable to link project impacts to city ambitions.

The main barrier in data collection within a city organization is not the data availability or lack of expertise, but rather the localization and accessibility of the needed data. The localization of the data within or outside the often scattered city organization dealing with the wide topic of a smart city has proved to be often a so burdensome task that it sometimes leads to giving up the whole KPI evaluation process due to the time needed.

The development of cities' centralized data management, storing and publishing practices would help a lot in the localization and exploitation of the currently vast amount of available city data.

As a later step, the standardization of (open) data set formats would further improve the data exploitation possibilities. In addition, these steps would greatly improve the efficiency of city processes including management, coordination and reporting of smart city activities.

CITYkeys RESTful APIs are a good and easy way to open CITYkeys data for other developers. In future, linked data would probably be a good way to integrate different types of open datasets in different URLs.

Conclusions

The research presented in this paper developed and validated a performance evaluation framework, including KPI definition, guidelines for data collection, a performance system prototype and testing in case cities. The indicators were selected according to the identified cities' needs and using as much as possible already existing indicators for which cities already have data collection procedures in place. The framework provides a common and transparent methodology for European smart city performance monitoring and allows to some extent the comparison of smart city solutions across European cities.

While there is a huge amount of indicator systems available to measure urban sustainability or performance on specific sectors, holistic indicator systems for smart city (project) performance measurement have been lacking until now. One reason for this might be that the concept of smart cities is not yet well established and that it covers issues that are rather difficult to measure. In CITYkeys philosophy a smart city must be sustainable and therefore typical sustainability impact categories and KPIs can be found in the framework. The difference between smart and sustainable cities is that smart cities use innovative and integrated methods – either technological or collaborative – to achieve the sustainability impacts. Hence, it is key to have in a smart city performance measurement framework both concrete output indicators that measure the implementation of certain measures (e.g. number of smart meters installed) and impact indicators that measure the progress towards the overall targets (e.g. GHG emission reduction). Also, both quantitative and qualitative indicators are needed to capture the concept of smart city in its full extent.

The co-development of the CITYkeys framework with its main target group, i.e. cities, is expected to ensure its usability in practice. During the project at least 50 end-users (cities, smart city project consortia or industrial stakeholders) have started the process of implementing the framework and/or tool in their context. In addition, some policy actors have already adopted CITYkeys framework or KPIs in their work (e.g. ETSI standardization body and the European Innovation Partnership for Smart Cities and Communities).

Acknowledgments

The work has been co-funded by the European Commission within the H2020 Programme (Grant Agreement no: 646440). Acknowledgments are due to all project partners: City of Tampere, City of Zaragoza, City of Wien, City of Zagreb, City of Rotterdam, TNO - Netherlands Organisation for Applied Scientific Research, AIT Austrian Institute of Technology GmbH; EUROCITIES ASBL and VTT Technical Research Centre of Finland Ltd.

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