**Measuring multidimensional topics: the case of the Italian Smart Cities**

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**Abstract**

The definition of a measurement system of smartness comparable at territorial and dynamic level is a very complex goal since there is not yet a shared, operational and empirically testable description of Smart City/Community. Despite the unquestionable glamour of this topic, the measurement aspects of smartness are often mistreated in favour of the dissemination of best practices and projects at local level. Until now, nearly all the experiments to measure smartness at local level have produced rankings based on economic, social, environmental and technological infrastructures as outputs.

In more details, the outputs represented by city rankings are often highly heterogeneous regarding methodology and objectives. A more elaborated procedure is therefore necessary to focus on the specific profile of a city with its strengths and weaknesses. In this framework, introducing the use of multidimensional analyses could result particularly useful to better identify indicators that provide real contributions to the measurement of smartness. Consequently, the passage to cluster analysis represents one of the possibilities out of a wider range of procedures for investigating rankings in a more robust way. Clusters, which show specific patterns of cities, are useful to overcome the superficial character deriving both from the mere rank obtained and the random comparison between best and worst cities. In order to compare the degree of smartness for different local contexts, it is also necessary to find a convergence towards a shared measurement system that includes specific local aspects. This system cannot ignore the starting situation of single territories, given both the heterogeneity of the different socio-economic frameworks and also some detailed features that have to be examined in depth. This paper intends to carry out a theoretical and empirical experiment in order to verify whether some of the above mentioned methodological innovations can produce improvements in the measurement of the Italian Smart Cities with regard to previous experiences.

**Keywords**: Italian Smart Cities; multidimensional analyses; smartness; measurement system.

## 1. Introduction

During the last decades, cities have become increasingly central in economic, environmental, social and development-related processes, representing a real focal point of political and economic strategies. Within this framework, the strong correspondence between urban environment and Information and Communication Technology (ICT) has become evident and it is a necessary though not sufficient condition to address local challenges, also in terms of smart sustainable development.

Since 1990 the term “Smart City” has been increasingly used in conjunction with the liberalisation of telecommunications and the development of services provided through the Internet. However, this definition is likely to remain too general and unshared. The term Smart City has recently become synonymous with cities characterised by an extensive and intelligent use of digital technologies that enable an efficient use of information, even if intelligent cities imply much more than this, as clearly illustrated in the relevant literature.

The process of transforming a city into a Smart City is complex and multidimensional, as is measuring progress towards that goal. The smart city transformation affects many aspects of a city operations, including government, buildings, mobility, energy, environment and services. In addition to the complexity involved in coordinating and connecting all the issues illustrated above, initial goals can change over time as planners and developers work to achieve more and better results.

## 2. Theoretical background and some methodological shortcomings

The concept of Smart City at the moment has not any shared definition[1]. In the beginning, the label "smart" was used to describe a digital city; later it evolved in a social inclusive city or, even more extensively, in a city offering a better quality of life through the intelligent use of technological innovations.

One of the most used operational definition is that of Giffinger et al. (2007) through which it is possible to evaluate the smartness degree of 70 medium-sized European cities. It includes not only digital data and information but also (*i*) "smart mobility", (*ii*) "smart environment", (*iii*) "smart governance" (*iv*) "smart economy", (*v*) "smart people", (*vi*) "smart living". These six dimensions, in turn broken down into 31 major factors and 74 indicators, set the concept of Smart City within the neoclassical theory of regional and urban development. Furthermore, they have the merit to be the first methodological attempt to measure the degree of smartness underlining the driving forces behind it.

In order to monitor the convergence of a city towards a Smart City it is first of all necessary to define exactly what is a city (Province; Metropolitan Area; Travel To Work Areas (TTWA); Provincial Capital; Municipality) and which indicators have to be selected for a city "to be smart".

In addition to the question of the territorial level, another element of potential instability is represented by the definition of a precise territorial analysis unit. If, on the one hand, no measurement can be made without it, on the other hand the very nature of Smart Cities as urban areas leads back to more undefined boundaries that are fuzzier than the administrative borders of a specific territory.

While the measurement-oriented literature focused on the concept of city with the aim of working out an operational definition, in present debates the community is increasingly becoming the main topic of discussion. This concept recalls dialogue, cooperation among actors, interaction among stakeholders, participation in decisional processes; it therefore stretches onto the governance framework of a territory in which smartness refers to the process rather than the result, whereby the expected result is measured in terms of increase in the community well-being levels.

Notwithstanding this, taking into account both the dimensional component and the statistical information useful to measure smartness from an operational point of view, it can be advisable to consider the provincial capital when referring to the concept of city. Identifying the measurement system is even more difficult since there is no unique and shared definition of Smart City as already stated; for this reason, the boundaries of a selection of indicators valid for any situation are not easily identified. The appeal of smartness applied at the local context is unquestioned and contributed in creating various multidimensional definitions. The measurement issue, however, has not followed the same accelerating path and has remained marginal with respect to the dissemination of many heterogeneous local practices.

A classification of cities according to their level of smartness was carried out for the first time on the basis of Giffinger's definition. Although this classification became an important reference in the debate about Smart Cities, by the authors' own admission (Giffinger and Gudrum 2010) it presents a number of limitations such as not being able to measure properly all the indicators, also due to the fact that a significant number of them (35%) were available only at national level.

Moreover, from the analysis of the main measurement experiences of Smartness[2] some limits to the existing methodologies can be derived (see Table 1).

From the limits described in Table 1, a conceptual shortcoming defined as the "original sin" can be derived. This concept is used within this paper to indicate the need to reflect on the correctness of the existence of a rigid, unique system dedicated to the measurement of smartness. Many studies use a traditional approach to the benchmarking of city smartness.

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[1] For a survey of literature see De Santis, Fasano, Mignolli, Villa (2014).
[2] see De Santis, Fasano, Mignolli, Villa (2014).

Preliminary results, however, show for example that cities in Europe and Italy are characterised by relevant infrastructural and cultural differences and, therefore, that no smart city model can be considered universal.

**Table 1 – Main critical aspects of measurement experiences**

| Aspects | Critical elements |
|---|---|
| ***Experiences*** | high heterogeneity in measurement practices; comparisons not always possible; existence of specific type of smartness |
| ***Methodology*** | unclearness; non-disseminated; non-shared |
| ***Data*** | lack at local level; difficulties in collection; information not always updated |
| ***Indicators*** | highly correlated; lack of information for international comparisons |
| ***Output*** | ranking; lack of dynamic analyses |

Source: Our elaborations, 2014

Moreover, despite the unquestionable glamour of this topic, the measurement aspects of smartness are often mistreated in favour of the dissemination of best practices and projects at local level. Until now, with very few exceptions, all the experiments to measure smartness at local level have used "top-down functionalist models" of smart cities based on infrastructures. This kind of measurements are indeed very useful to produce rankings based on economic, social, environmental and technological soft and hard infrastructure as outputs. They make it, however, very difficult to overcome purely quantitative data.

Furthermore, all measurements are also affected by other methodological limits such as the lack of control on the presence of possible correlations among the indicators identifying smartness, restrictions in providing the dynamics of obviously evolutionary concepts, practical and economic obstacles in collecting data at city level and the fact that the output is necessarily a ranking.

## 4. The case of the Italian Smart Cities

To verify whether the previously underlined methodological limits can bias the smartness measurement system, a case study taken among those presented in paragraph 3[3] was analysed more in depth.

In particular, two assumptions need to be tested:

1. the smartness dimensions are correlated;
2. using the same dimensions for heterogeneous territorial contexts could bias the smartness measurement.

The case study (CS1) has been selected for some features relevant in order to implement a measurement system of smart communities such as:

1. the six dimensions are those reported by Giffinger (2007);
2. the indicators composing the dimensions represent a broad set of variables selected in order to avoid missing data and outliers[4];
3. the reference years are often very different, however the indicators have a limited time variability;
4. the territorial level is the municipality (103 provincial Capital in 2012) for the majority of the selected indicators (33 are at provincial level, attributed to the municipality);
5. the data sources are reliable and in many cases official.

[3] For a detailed description see De Santis, Fasano, Mignolli, Villa (2014).

[4] While constructing this index, using statistical techniques those variables showing a limited variability of the event measured were excluded in favour of more heterogeneous variables for a total of 89 variables/indicators, some of which are synthetic indicators.

The synthetic indicators relative to the six dimensions were taken from CS1, they were calculated as simple mean of the transformed values of elementary indicators.
The indexes were aggregated following different methodologies in order to test robustness with respect to the aggregation methodology.
In particular, two methods were used: mean of standardised values and mean of relative indexes.
From a preliminary analysis the final result is neutral with respect to the selected method. Thus the method of relative indexes was preferred because more suitable to the data characteristics.
To test the first assumption a correlation matrix for the six dimensions was built.
The dimensions are positively and highly correlated and statistically significant. The dimension *Economy* is more correlated with *Living*, *Mobility* and *Government* (the correlations are all over 0.5). On the contrary, the correlation between *Economy* and *Environment* and *Economy* and *People* is weaker (see Table 2).

**Table 2 - Correlation Matrix between the six dimensions**

| | Economy ECN | Environment ENV | Governance GOV | Living LIV | Mobility MOB | People PEO |
|---|---|---|---|---|---|---|
| ***ECN*** | 1.000 | 0.259 | 0.522 | 0.636 | 0.532 | 0.398 |
| ***ENV*** | 0.259 | 1.000 | 0.416 | 0.390 | 0.272 | 0.555 |
| ***GOV*** | 0.522 | 0.416 | 1.000 | 0.467 | 0.635 | 0.580 |
| ***LIV*** | 0.636 | 0.390 | 0.467 | 1.000 | 0.553 | 0.512 |
| ***MOB*** | 0.532 | 0.272 | 0.635 | 0.553 | 1.000 | 0.431 |
| ***PEO*** | 0.398 | 0.555 | 0.580 | 0.512 | 0.431 | 1.000 |

Source: Our elaborations, 2015

Interestingly enough, high correlation should not be an obstacle for the effectiveness of the analysis and of the instrument from a descriptive point of view (i.e. the variety of dimensions offers a better description of the event); from the point of view of policy-making, it could however be inefficient or even bias the analysis.
The lower correlations of *Environment* with the other dimensions suggests a sort of polarisation of smartness on two macro-dimensions. This preliminary evidence, if assessed, could help verifying the second assumption (using the same dimensions for heterogeneous territorial context could bias the smartness measurement).

**Table 3 – Principal Component Analysis: eigenvalues and explained variance**

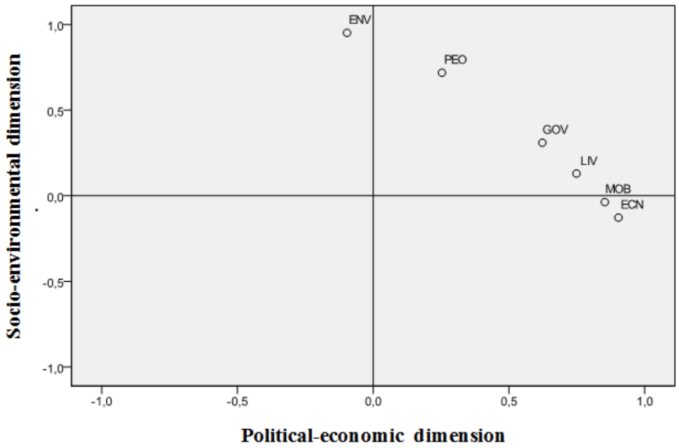
| Component | Eigenvalue | % of Explained Variance | Cumulative % of Explained Variance |
|---|---|---|---|
| ***1*** | 3.406 | 56.773 | 56.773 |
| ***2*** | 0.920 | 15.331 | 72.104 |
| ***3*** | 0.603 | 10.046 | 82.149 |
| ***4*** | 0.413 | 6.881 | 89.030 |
| ***5*** | 0.395 | 6.576 | 95.607 |
| ***6*** | 0.264 | 4.393 | 100.000 |

Source: Our elaborations, 2015

To deepen this assumption, Principal Component Analysis - PCA was used; this confirmed that the six dimensions cooperate in measuring smartness. Using the eigenvalue method or the screen plot as criterions, PCA highlighted a single component as the most significant (eigenvalue > 1; about 57% of

total explained variance; see Table 3). This result suggests that the idea of smartness as a multidimensional issue is correct and that the six dimensions are suitable to measure it.
In order to improve the performance of the model, the second component was also considered, increasing the explained variance to 72% of total explained variance (see Table 3).
Rotating the solution and determining a different group of linear combination of the PCA components with the same explanatory power allows to find a result that can be interpreted more easily (correlation coefficients among variables and components with values either high or close to zero).
The rotation method used is *Oblimin* which allows to obtain variables near to 0 for all components except one. The method proved efficient since the correlation obtained is 0.45.

**Figure 1 - The six dimension correlation on the first two components**




Source: Our elaborations, 2015

With this transformation (see Figure 1) smartness is polarised along two dimensions that can be defined “political-economic” (GOV, LIV, MOB, ECN) and “socio-environmental” (ENV, PEO). The analysis highlights the presence of territorial contexts smarter in the features linked to *Economy*, *Mobility*, *Life quality* and *Governance* and of others smarter in environmental aspects and in social and human capital.
As a consequence, smartness is reached by the combination of the six dimensions; furthermore the combinations of indicators determining smartness differ according to the various territories.
This result seems to confirm the second assumption and underlines the presence of a very important problem, i.e. whether the idea itself of a single and standardised measurement system of smartness is correct or not (“original sin”).

## 5. Conclusions

The definition of a measurement system of smartness comparable at territorial and dynamic level is undoubtedly a very complex goal. At present an operational, common and empirically testable definition of Smart City/Community does not even exist. Moreover, outputs represented by city rankings are often highly heterogeneous regarding both methodology and objectives; a more detailed procedure is therefore necessary to focus on the specific profile of a city with its strengths and weaknesses.
Within this framework, introducing principal component analyses results particularly useful to better identify indicators that give real contributions to the measurement of smartness, also in order to redefine the dimensions. As a matter of fact, the high correlation among dimensions should not be an

obstacle for the effectiveness of the analysis and of the instrument from a descriptive point of view, though from the point of view of policy-making it could be inefficient or even bias the results.
Moreover, in this paper a sort of renewed "original sin" is highlighted: it is related to the idea of a too standardised "Measurement System" for quantifying smartness at local level.
Once the results of previous measurement experiments are analysed more in depth, this preliminary empirical exercise shows at least two indicator combinations towards smartness.
In order to compare the degree of smartness for different local contexts it is necessary to find a convergence towards a shared measurement system. This system, however, has to be implemented so as to be able to include specific territorial aspects (if necessary). In addition, the system cannot ignore the starting situation of single territories, given both the heterogeneity of the different socio-economic frameworks and also certain detailed features that have to be examined in depth (also exploiting both Administrative and Big Data).
From the starting point put in evidence in this paper, passing to cluster analysis is one of the possibilities out of a wider range of procedures for investigating a measurement system of smartness in a more robust way.
Clusters, which show specific patterns of cities, are useful to overcome both the superficial character derived both from the mere rank obtained and the random comparison between best and worst cities. For city stakeholders these more substantial findings can allow to focus on the specific strengths and weaknesses of similar cities. It is not reasonable to follow best practice strategies randomly, but it is necessary to concentrate on cluster membership.
In this way best practice examples of other cities can be interpreted with regard to their specific profiles, thus making it easier to adopt them in a more effective way. Last but not least, according to these preliminary conclusions, it is also possible to imagine a dynamic framework in which smart cities could transit from a group - cluster to another as a consequence of policy effectiveness.

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