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Dealing with smartness at local level: experiments and lessons learned

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Abstract. The smart city issue is becoming central in the social and political debate. From the measurement point of view, in the related literature, however, there are mainly papers focusing on specific and heterogeneous local projects. Moreover, the outcomes of these papers are mostly rankings based on peculiar and often non standardised methodologies.

In this framework, the present paper carries out a research aimed at i) defining properly the concept of smart city ii) analysing and comparing the existing methodologies to measure a multidimensional concept as smartness at local level is, iii) deriving policy implications in order to improve citizens' quality of life through the smart city instrument.

A review of the existing theoretical and empirical literature stresses the steady evolution of the meaning of the smart city concept at local level, integrating technological and digital innovation with territorial and social aspects. Starting from a pilot database derived from other related studies, a principal component analysis is run in order to verify whether some methodological innovations can produce improvements in the measurement of Italian Cities smartness with regard to previous experiences. More specifically, findings suggest that cluster analysis is one of the possibilities for investigating a measurement system of smartness in a more robust way. Through this alternative approach to rankings, 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, contributing to overcoming the mere distinction between best and worst realities. According to the preliminary conclusions it is also possible to imagine a dynamic framework in which smart cities could transit from a cluster to another as a consequence of policy effectiveness at local level.

The possibility to implement this kind of innovative analysis of smartness at local level is obviously strictly linked to the availability of "smart" data such as administrative or big data, so as to converge towards a measurement system including specific local aspects.

Key words: Smart city, urban development, human capital, transport infrastructure, ICTs.

JEL Code: A13, L90, O18, R12

* Any error or mistake remains the authors sole responsibility.

1. Introduction

During the last decades the role of cities in the economic, environmental, social and development-related processes has become increasingly central, becoming a real focal point of the political and economic strategies. As a consequence, the strong correspondence between urban environment and Information and Communication Technology (ICT) has become evident and it constitutes one of the necessary conditions to address local challenges, also in terms of smart sustainable development.

Within this framework, 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, its definition is likely to remain too general and unshared. 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. However 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 transformation of a city into a smart city affects many aspects, 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.

This paper aims at critically analysing the main features related to Smart Cities such as terminological issues, the heterogeneous theoretical background and the methodological limits of the existing measurement experiences.

The work is organised as following: in the second and third paragraphs surveys of definitions and theoretical background are presented; in the fourth paragraph the methodological limits of the main measurement experiences of smartness are analysed; in the fifth paragraph an empirical exercise on Italian cities smartness measurement is carried out. Conclusions follow.

2. Defining Smart Cities: a literature review

The concept of Smart City was created in the nineties in parallel to the liberalisation process of telecommunications and the development of internet services. While this expression is considered increasingly strategic to meet the needs related to the irreversible urban agglomeration growth, it risks remaining too general and without an operational definition since there is no shared definition of Smart City[1] at the moment and this concept is used with different meanings in different contexts. In the beginning, the label "smart" was used to describe a digital city; afterwards it evolved in a social inclusive city or, in a broader sense, 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. This definition 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 6 dimensions 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 the related literature the definitions are highly heterogeneous (Table 1). Dirks and Keeling (2009) consider Smart Cities as an organic integration of IT systems, while Kanter and Litow (2009) assimilate them to an organism with an artificial nervous system, allowing the city to perform in intelligent and coordinated ways. In Harrison et al. (2010), a Smart City is rich in highly technological tools, enabling the "intelligent" and "interconnected" city to receive and provide data. Interconnection implies that data are integrated on a platform and communicated in real time to the citizens. The intelligence refers to the presence of processes optimising the use of information. These two characteristics of the city can facilitate the decision-making process especially for business activities. Toppeta (2010) highlights smartness as the improvement of sustainability and liveable level of the city, while Washburn et al. (2010) identify Smart Cities as a collection of smart technologies applied to some strategic infrastructures and services.

These technologies consist in very innovative hardware and software of new generations integrated in network so as to provide Information Technology (IT) systems and real time data.

More recent studies (Nijkamp et al. 2011), eventually, focus on the interrelationships among the components of Smart Cities (as defined by Giffinger 2007), including human and social relations that link intellectual capital, health and governance through an approach based on the "Triple Helix Model" (Etzkowitz and Lydesdorff 2000; Lombardi et al. 2012).

1. De Santis, Fasano, Mignolli, Villa (2014a).

Table 1 - Main definitions of a Smart City

Years	Authors	Definitions
2000	Hall R.E.	«A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens».
2007	Giffinger R. et al.	«A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens».
	EU Strategic Energy Technology Plan (SET)	«[...] a city that makes a conscious effort to innovatively employ information and communication technologies (ICT) to support a more inclusive, diverse and sustainable urban environment».
2009	Lombardi et al.	«A smart city therefore has smart inhabitants in terms of their educational grade. In addition, the term is referred to the relation between the city government administration and its citizens. Good governance or smart governance is often referred to as the use of new channels of communication for the citizens, e.g. "e-governance" or "e-democracy».
	Harrison C. et al.	«A city connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city».
2010	Toppeta D.	«A city combining ICT and Web 2.0 technology with other organizational, design and planning efforts to dematerialize and speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity, in order to improve sustainability and liveability».

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Table 1 (continued)

Years	Authors	Definitions
2010	Washburn D. et al.	«The use of Smart Computing technologies to make the critical infrastructure components and services of a city - which include city administration, education, healthcare, public safety, real estate, transportation, and utilities - more intelligent, interconnected, and efficient».
2011	Nijkamp P. et al.	«… the city is called "smart" when investments in human and social capital and traditional and modern communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance. Furthermore, cities can become "smart" if universities and industry support government's investment in the development of such infrastructures.»
2013	Giovannella C.	«A Smart City should be a city well performing in a forward-looking way in six smart characteristics (also called soft factors: smart economy, smart mobility, smart environment, smart people, smart living, smart governance), built on the smart combination of endowments and activities of self-decisive, independent and aware citizens».

Source: *De Santis, Fasano, Mignolli, Villa, 2014b*

From another point of view, assuming social innovation as a target, Smart Cities are those that create the conditions of governance, infrastructure and technology to produce Social Innovation, so as to solve social problems related to growth, to inclusion and to quality of life through listening and involving different local actors: citizens, businesses and associations.

The concept of Smart City has been progressively changing its meaning and the related interconnection with the different dimensions of living. It is also worth underlining that the various definitions can assume different meanings also in relationship with the stakeholders (institutions, academic world, civil society, enterprises, as suggested by the Triple helix theory). In more detail, also the different roles simultaneously assumed by a single actor take on importance (i.e. a citizen can be a student, a parent, a volunteer or a car driver). The existence of a single definition for Smart Cities can therefore be considered fiction. What is a fact is that the features of a Smart City are very articulated. For this reason, starting from a shared definition becomes a priority in order to keep using this concept.

Smart City is still a fuzzy concept which is not used consistently within the literature (Tranos and Gertner, 2012). Smart, indeed, is often used interchangeably with intelligent, wired and digital. One of the main criticisms is "*the disjuncture between image and reality [...] the real difference between a city actually being intelligent, and it simply lauding a smart label*" (Hollands 2008: 305). Recently, the only fact that can be detected is a convergence towards some common points in many definitions. For example, the fact that smart is more than digital - despite the cross-sectional role of ICT - or the importance given to environmental sustainability represent elements that put the Smart City issue in a broader vision, including very recent analysis to measure well-being beyond GDP.

The complex theoretical background of the concept of Smart Cities justifies and explains the huge and complicated literature related to this issue.

The first references in the related literature focused on the very tight connection between innovation and territory. As suggested by Auci and Mundula (2012), the first theory concerning this one-to-one relationship dates back to the mid-1970s and is the paradigm of "Industrial districts" (Bagnasco, 1977).

This idea later evolved into the theory of "Industrial clusters" (Porter, 1990), focusing on industries geographically concentrated and inter-connected, producing positive consequences due to their "tight local inter-connections".

Afterword, the theories concerning Smart Cities evolved in correspondence with the diffusion of technological and digital innovations and with a changing focus from the national to the regional-local level.

As a matter of fact, a review of the related literature highlights a transition from a shared knowledge at a global level (Lundvall, 1992 and Nelson, 1992) to its application within a local framework through studies on "Learning Regions", "Regional Innovation Systems" and "Local Innovation Systems" (Cooke et al., 2004), allowing many experts to rediscover the central role of the regional scale and of specific and regional resources in fostering the innovation capability and competitiveness of firms and regions.

As anticipated before, the growing interest for this topic led to the formulation of other theories behind the Smart City paradigm combining the social context with the involved actors; among these two of them are of particular interest, the model of the "Triple Helix" (Etzkowitz and Lydesdorff, 2000) and the model of the "Three Ts - Technology, Talent and Tolerance" of economic development (Florida, 2002).

The first examines the changing nature of knowledge-based innovation systems in the light of the dynamic interconnections between University, Industry and Government at local level. This model is structured in three different versions: 1. an "etatistic" model of relations, which does not allow bottom-up initiatives in terms of innovations; 2. a "laissez-faire" model of relations, which tends to reduce the role of the State; 3. the Triple Helix model of relations, which represents a tri-lateral network with overlapping institutional spheres.

The second model of the "Three Ts" underlines the importance of social cohesion and social capital to make Talent and Technology productive in terms of innovations; at local level the simultaneous presence of all Three Ts ensures an economic success. In more details, this model elements can be described as: 1. Technology, as a core component to drive economic growth; 2. Talent, as the presence of creative people; 3. Tolerance, as integration of new ideas and different people.

On the trail of these two theories various authors (Shapiro, 2003; Glaeser, 2005; Glaeser and Redlick, 2008) included a fourth actor represented by the Civil Society, since they acknowledged the fundamental role of human and social capital as inputs for sustainable urban development (Ambrosetti, 2012). The entrance of this fourth actor triggered a scientific debate on the proper definition of the concept of Civil Society, given the huge variety of stakeholders involved, each one characterised by a possible different role within the social context (citizens, students, tourists, researchers, cultural associations, schools, municipalities, etc.).

Other contributions emphasised the role of creativity in urban development (Gabe, 2006; Markusen, 2006; Fusco Girard et al., 2009) or of the importance of environmental sustainability. The concept of sustainability also included the social aspect: "*Today we see a growing number of cities emerging as strategic territories that contribute to articulate a new global political economy*" (Sassen, 2006). However, if on the one hand technological innovation and economic development facilitated trade globalisation, on the other hand they also created social inequality and deep changes affecting the work-life balance of citizens. As a result, new forms of "participatory democracy and active citizenship" are required at local level, thus further differentiating and complicating the number of actors involved in the process (Paci, 2008).

Therefore, also from a sociological point of view, the focus on the local dimension represented by the city and the improvement of liveability finds its advocated solution in the growing request for cities characterised by increasing smartness (De Santis, Fasano, Mignolli, Villa, 2014b).

The welfare of citizens assumes an important role for the achievement of better quality of life especially in terms of human well-being.

The scientific debate emphasises a critique of the inappropriate use of Gross Domestic Product (GDP) as a measure of national well-being and suggests to integrate the economic aspects with indicators that promote truly sustainable development by improving the quality of human life.

Within this framework, Caragliu *et al.* (2009) measure the effects of some relevant variables of urban growth through the GDP of a city using indicators derived from the Urban Audit dataset, while Nijkamp *et al.* (2011) focus on the interrelationships among Smart Cities components, including human and social relations, intellectual capital, health and governance. Finally, Auci and Mundula (2012) use an empirical model based on the concept of output maximising in order to measure smartness at local level; the outcome of their research is the construction of a ranking of European cities that find a weighting term in technical inefficiency.

Very recently, Lombardi *et al.* (2013) offer a deep analysis of the interrelations between Smart City components, finding a full list of indicators available at urban level, identified and selected from literature review.

In the light of the above, the existence of a single Smart City theoretical framework cannot be identified. This paradigm has to be analysed within a complex set of visions based on the necessity to create a new social dimension especially at local level.

Social innovation for example is one of the possible outcomes of the Smart City framework. It draws the attention on the different sectors and areas at city level generating flows of knowledge vertically and horizontally. It includes issues related to environment, society and politics referred to social enterprises, design, public policies, social evolutions and in general all the features related to community development.

As a matter of fact, at the moment the theoretical and empirical literature on Smart Cities still remains heterogeneous and inconclusive especially from an economic perspective. The only common element in most papers is that the Giffinger framework is quite often taken as a starting point for the analyses.

3. Definitions and measurement experiences: some major problems

There is no shared definition of Smart City at the moment which allows to build a measurement system. In the beginning, the label "smart" was used to describe a digital city; afterwards 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.

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 and which indicators have to be selected for a city "to be smart" (Province; Metropolitan Area; Travel To Work Areas (TTWA); Provincial Capital; Municipality).

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 less focalised 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.

Thanks to Giffingers' definition a classification of cities according to their level of smartness was carried out for the first time. 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 related to, for example, the fact of not being able to measure all the indicators properly, rather than to the fact that a significant number of indicators (35%) were available only at national level.

Moreover, from the analysis of the main measurement experiences of Smartness[2] some limits of the existing methodologies can be derived. They affect different aspects: experiences show high heterogeneity in measurement practices, not always possible comparisons and the existence of specific types of smartness; the methodology is characterised by unclearness, is not disseminated and not shared; data are lacking at local level, difficult to collect and not always updated; indicators are highly correlated and lacking of information for international comparisons; finally, as far as output is concerned, this consists mainly in ranking with consequent lack of dynamic analyses.

A conceptual shortcoming adds to the limits described above; it can be defined as the "original sin" and affects all these measurement experiences. 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. The 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.

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, in fact, are very useful to pro-

2. De Santis, Fasano, Mignolli, Villa (2014b).

duce rankings based on economic, social, environmental and technological soft and hard infrastructure as outputs. They make it, however, very difficult to overcome the 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. An empirical exercise

A case study taken among those presented in paragraph[3] was analysed more in depth to verify whether the methodological limits underlined previously could bias the smartness measurement system.

In particular, two assumptions were intended to be tested:

i) the smartness dimensions are correlated;

ii) using the same dimensions for heterogeneous territorial context can 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 dimensions are those six 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 year is not homogeneous, however the indicators have a limited time variability;
4. the territorial level is the municipality (or a more disaggregated level) for the majority of the selected indicators (33 are at provincial level);
5. the data sources are reliable and in many cases official.

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

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.

From CS1 the synthetic indicators relative to the six dimensions were taken, they were calculated as simple average of the transformed values of elementary indicators. Indexes were aggregated following different methodologies in order to test their 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 hypothesis 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, while high correlation might 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 phenomenon); it could however be inefficient or even bias the analysis from a prescriptive point of view.

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 hypothesis (using the same dimensions for heterogeneous territorial context could bias the smartness measurement).

Table 3 - PCA analysis

Component	Initial Eigenvalue		
	Total	% of Variance	Cumulative %
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 confirm this assumption, Principal Component Analysis - PCA was used; this established that the six dimensions cooperate in measuring smartness. Using the eigenvalue methods or the screen plot as criterions, PCA evidenced a single component as the most significant (eigenvalue > 1; about 57% of total explained variance). This result suggests that the idea of smartness as a multi-dimensional issue is correct and that the six dimensions are suitable to measure it.

In order to improve the performance of the model also the second component was considered, increasing the explained variance to 72% of the total variance (Table 3).

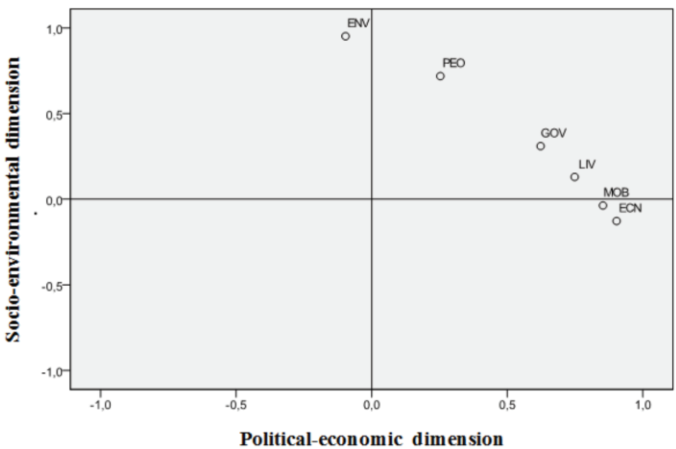
Rotating the solution and determining a different group of linear combination of PCA components with the same explanatory power allows to find a result easy to be interpreted (correlation coefficients among variables and components with values either high or close to zero).

The rotation method used is Oblimin which allows to obtain variables nearly 0 for all components except one. The method proved efficient since the correlation obtained is 0.45.

With this transformation (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 that are 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 thanks to the combination of the six dimensions; furthermore the combinations of indicators determining smartness differ according to the various territories.

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



Source: Our elaborations, 2015

This result seems to confirm the second hypothesis and underline 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. Preliminary 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 methodology and objectives; a more elaborated procedure is therefore necessary for focusing on the specific profile of a city with its strengths and weaknesses.

In this framework, introducing principal component analyses results particularly useful to better identify the indicators that give real contributions to the measurement of smartness, in order also to redefine the dimensions. In 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; from a policy making point of view, it could however be inefficient or even bias the analysis.

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.

This very preliminary empirical exercise shows at least two indicator combinations towards smartness once the results of previous measurement experiments are analysed more in depth.

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 (if necessary) specific territorial aspects. This 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.

From the starting point put in evidence in this paper, passing to a 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 aspect indicated by 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 the effectiveness of sound policies.

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