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Circular City and Cultural Heritage Interplay

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Indice/Index

A BIG DATA DASHBOARD ARCHITECTURE FOR A COMPUTABLE INTELLIGENT CITY

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Abstract

This paper aims to sketch the principles and design of advanced smart city research from the perspective of digital big data, against the background of the emerging "New Urban World". This study takes its starting point in the need for up-to-date and knowledge-based decision support systems for modern cities, and sketches the cornerstones of an "Urban Dashboard" for modern urban policy analysis.

Keywords: trading zone, integrated conservation, sustainable development

UN'ARCHITETTURA PER LA GESTIONE DI BIG DATA PER CITTA' INTELLIGENTI E COMPUTABILI

Sommario

Il paper ha l'obiettivo di disegnare i principi e costruire una metodologia di ricerca avanzata per lo sviluppo di smart city, che includa strumenti per la gestione di big data digitali, nella prospettiva del "Nuovo Mondo Urbano" emergente. Questo studio si inserisce nel settore di ricerca scientifica su sistemi avanzati di supporto alla decisione per la gestione delle città moderne, che siano costantemente aggiornati e basati sulla conoscenza, e disegna una metodologia per la costruzione di un sistema di analisi e gestione dei dati urbani ("Urban Dashboard") a supporto delle moderne politiche urbane.

Parole chiave: zona commerciale, conservazione integrata, sviluppo sostenibile

1. Intelligent cities in the "New Urban World"

Contemporary cities are facing unprecedented challenges. The world population is – despite ageing processes in many developed countries – still rapidly increasing in size. The accommodation of several billions of additional inhabitants on our planet calls for new settlement systems and new perspectives for human habitat. Urbanization is one of the most obvious responses to the global population rise. At present, already more than one half of the world population lives in urban areas (with a share of up to 70 to 80% in OECD countries), and this trend is expected to continue in the decades to come. The emerging 'urban century" puts a high stress on the economic, social, technological, cultural, health, safety and environmental capabilities of large cities. Urban vitality and sustainable urban living are one of the great challenges of the emerging "New Urban World" (Kourtit, 2015).

Against this background, recently a New Urban Agenda was formulated at the HABITAT III conference in Quito (October 2016): «This New Urban Agenda acknowledges that culture and cultural diversity are sources of enrichment for humankind and provides an important contribution to the sustainable development of cities, human settlements, and citizens, empowering them to play an active and unique role in development initiatives; and further recognizes that culture should be taken into account in the promotion and implementation of new sustainable consumption and production patterns that contribute to the responsible use of resources and address the adverse impact of climate change» (p .2).

In the light of the critical importance of urban areas for sustainable development, a new fashion word has in the past years been introduced, viz. "smart" (or "intelligent") cities. A smart city aims to improve its performance (social, economic, environmental, technological, etc.) – relative to other cities, by using advanced knowledge and cognitive principles – mainly through access to and use of digital technology, for strategic urban policy and city management. A smart city is not an endpoint in itself: it is a learning and inclusive city, with the involvement of stakeholders and citizens, in which education and employability are cornerstones with the aim to improve its performance (the XXQ-principle, based on a maximization of urban quality; Nijkamp, 2008). In the "urban century" smart cities are seen as the spearheads of balanced and competitive development of our world, mainly through the presence and effective use of agglomeration advantages of all kind (scale benefits, economies of density, proximity and connectivity advantages). In this concise paper we will sketch the principles, architecture and applicability of the smart or intelligent city concept, with a particular view to the relevance of big data in the context of urban dashboards as decision support tools.

2. Aims and scope

Cities in the "New Urban World" deserve profound policy research attention. Modern cities are new magnets for people and businesses, and house nowadays the majority of the people in many countries. They face many challenges (e.g., transport, energy, amenities, land use, climate change, poverty, housing) which call for appropriate and informed policy responses. There is a great variety of interest groups and stakeholders, with a broad diversity of objectives and information needs. Data systems may vary from individual to aggregate information, with different degrees of accuracy. There is however, no systematic architecture for transforming unstructured urban data into a coherent and measurable data system that is suitable for policy making and policy analysis. The current wave of "big data" (e.g., from personal mobile devices, social media, sensorization of urban space) offers not only a challenge, but also an unprecedented and innovative opportunity for balanced and effective city governance. To meet this new challenging opportunity, modern cities need to develop advanced expertise on complex city dynamics, urban informatics and analytics, smart urbanity and cyber civil participation (Batty, 2013). Against this background, the proposal put forward in this inception note has the following aim: design, test and implementation of a cognitive data-driven and stakeholder-oriented dashboard, as one of the cornerstones of an intelligent C-i-TY Lab for complex policy support, that acts as an operational and measurable navigation tool for informed, effective and sustainable urban governance in a data-rich environment.

Information on a city can be extremely diverse, ranging from aggregate indicators (number of people, length of streets, size of urban parks) to detailed or disaggregate indicators (number of accidents or crimes on a given day, air quality near urban ring roads, influx of illegal immigrants). Some information may be structurally available, but other types of information only on an ad-hoc or unstructured basis. Some data may be based on empirically verified information, other data may be uncoordinated and unverified (e.g. social media data), even though the contents of such data may be highly interesting. In a smart city, some data may thus be used for strategic urban performance management regarding long-range critical urban domains (e.g., environmental quality, labour market, mobility, education) or for specific policy fields belonging to the competence of institutional divisions in the city government (e.g., land use, traffic, social security).

However, city governance does not only need a long-term horizon, but also a short-term response mechanism (e.g., crowd management in case of big manifestations). These data have to be instantly available and the policy response or management intervention should be immediate and on the spot (e.g., traffic management, crowd control, security control). The previous observations have also far-reaching implications for urban dashboards: there is not a one-size-fits-all dashboard; on the contrary, there are multiple fit-for purpose dashboards.

Thus, professional data management is essential for any “computable intelligent city”. In the new data-rich era, there is a need for up-to-date information systems (including “big data”) which play a critical role in a knowledge-based urban governance context. Against this background, the current plan to build an urban decision support system, with a collection of fit-for-purpose policy dashboards, has to be considered and assessed.

This ambitious task needs both a solid conceptual framework, supported by urban planning analytics, geo-science metrics, and big data expertise, and an empirical testing, for instance, through an experimentation on the basis of appropriate pilot studies, for designing and operationalizing the cornerstones of the C-i-TY Lab sketched out in the present note.

3. Urban policy in motion

Cities all over the world – in both developing and developed countries, display complex evolutionary patterns. Some cities show wave-like fluctuations, others show a steady rise. Over the past decades, we have observed a particularly rapid increase in population size of large urban agglomerations (e.g. Mumbai, Sao Paulo, Shanghai). The result of this dynamics in population demography has been that globally more than half of the world population is living in urban areas (the “New Urban World”; Kourtit, 2015). In the “urban century”, cities are both sources of hope and despair; they are faced with both positive and negative challenges.

The urban policy responses to such challenges are varied and show different degrees of success. The performance of cities does not only depend on economic and geographical factors, but also on institutional and cultural backgrounds. Cities have turned into open, complex and multilevel organisms, with a great diversity among stakeholders with different aspirations.

The governance of such complex urban entities is fraught with many problems, and has not always led to satisfactory outcomes. In recent years, a new concept, coined “smart city”, has come to the fore. This concept regards the city as a multi-faceted material and immaterial phenomenon, which is increasingly determined by access to and use of digital technology. The city tends to become a “cognitive engine” (Batty, 2013), in which an intelligent use of big amounts of relevant data is a key for success.

In the past years, we have seen interesting recent smart initiatives in e.g. transportation and mobility planning, service provision in the public sector, safety management etc. In this context, “big data” supported by digital technology turn cities into powerful cognitive machines, which most likely will be able to cope effectively with energy scarcity, high mobility, environmental sustainability, and safety in public spaces. Consequently, urban structures and spatial interaction patterns will drastically change, leading to new urban systems connected by virtual and physical infrastructures which form the backbone of smart or intelligent cities.

In this so-called i-city a fusion of heterogeneous information from different policy domains is a key for governance success. For instance, mobility, environment, safety and poverty would have to be looked at simultaneously from the perspective of integrated data treatment. The pervasive use of modern ICT is promising and allows in principle to produce holistic synergy in such a “big data” environment at any spatial level of an urban systems network (Kourtit and Nijkamp, 2017).

Introduction of such “big data” systems will have far-reaching impacts on traditional ways of urban modelling, characterized by equilibrium models, activity-based models, discrete choice models, complex spatial systems analyses and agent-based models. In the new stream of “big data” analysis there is more scope for an avalanche of spatially and temporally disaggregated longitudinal, statistical data with a high degree of granularity, which will need sophisticated data science techniques.

This new approach calls also for new decision support tools in a multi-stakeholder setting, for both strategic urban policy and daily management of a complex city system. We observe recent tendencies towards more participatory or interactive modes of urban planning, while on the other hand there is also a new emerging trend to design operational navigation tools for urban policy. A recent phenomenon in this field is the emergence of urban dashboards. The aim of the present note is to lay the foundation for an operational and computable i-city dashboard, in which the notion of a smart city - governed by digital data systems - is used as a stepping stone to attain the high ambitions of an i-city in the “urban century”.

An i-city dashboard is not a technical instrument per se, but functions as a decision-support tool in a broader policy environment, in which multiple stakeholders, conflicting objectives (through the use of advanced multi-criteria analysis) and “complex big data” play a critical role. Hence, the name C-i-TY Lab for our experimental approach.

4. Characteristics/design principles of smart city policy

The rising complexity of modern urban agglomerations – which abandon their isolated island position and move into strategic hubs in an open network society and in a globalizing space-economy, and the unprecedented and pervasive use of ICT (Neal, 2012), which turns cities into complex data machines with an ever increasing information wealth - prompt unforeseen challenges to urban policy-making bodies and stakeholders. To cope with the new emerging tasks of modern city governance, due attention has to be given to the following elements of and tasks involved with smart city planning:

- geographic representation of city morphology, characterized by spatial and socio-economic externalities from density, proximity and connectivity in the urban space;
- Ranging from "street-level" attributes to collective data representations at the meso-level of a city ("geoscience");
- focus on smart people and smart specialization, driven by hierarchical "cognitive ladder" principles (from education and training via knowledge and expertise to creativity and innovation in urban areas for all actors in the city area) ("smartness");
- stimulation of an ICT habitus, in particular digital technology access and use, including fine-grained geo-science statistical information and accessible software for decision support and city management ("intelligence");
- involvement of local actors/agents through the use of multi-modal social media platforms, collecting and storing the avalanche of publicly available personal information from many modalities and sources, and leading to systematics in the acquisition of and transmission of big data, which allows the use of sophisticated urban analytics and data metrics ("urban informatics");
- development of an open-access data warehouse at city level, based on sound digital data infrastructure principles and public access conditions for data providers and users in a participatory city democracy ("warehousing");
- design of an interactive, spatially disaggregated, multi-temporal and open-access 3-D/4-D dashboard for a "computable intelligent city", to be used by urban stakeholders employing tailor-made city KPIs (Key Performance Indicators); this would lead to an operational C-i-TY Lab as an information hub for pro-active urban policy in a dynamic city environment ("performance assessment").

It goes without saying that urban data systems are not only heterogeneous, but also show a high variability in accuracy and reliability. "Perfect information" does not exist, and therefore strict data control is a sine qua non for information to be used in a city dashboard or a decision support system.

5. The urban arena

The modern city is not an oasis of social relaxation and democratic tranquility, but an arena of socio-economic and political forces in which maximization of urban performance, sustainability, competitiveness and citizens" satisfaction play a key role. Depending on local conditions in cities and priorities of stakeholders and inhabitants, the following – illustrative and non-exhaustive – policy domains or themes may be mentioned in the management and strategic development of a computable intelligent city:

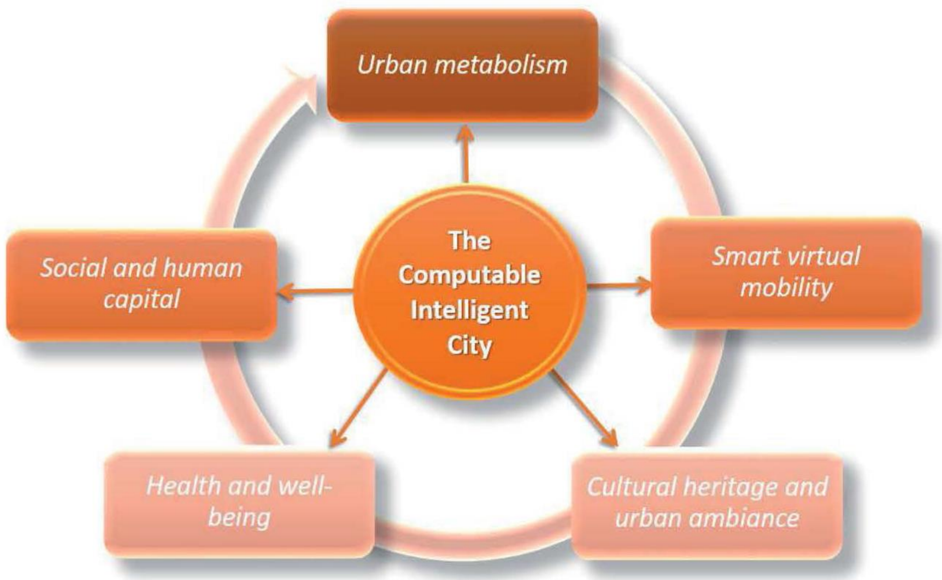
1. *urban metabolism*: circular economy, climate neutrality, bio-based economy, smart energy grids, etc., as a support for urban sustainability;
2. *smart virtual mobility*: substitution or reduction of physical flows, virtual connectivity,

cyber behavior, ICT education etc., as a vehicle for environmentally-benign mobility;

3. *cultural heritage and urban ambiance*: e-tourism, tele-visits, electronic appreciation platforms (e.g., TripAdvisor, Foursquare, Twitter, Spotify), smart communication devices, digital information equipment etc., as a means for supporting urban culture;
4. *health and well-being*: tele-medical services, urban happiness initiatives and research, cognitive and perceptional GIS (3-D/4-D) images, city gaming with target groups, etc., as a contributor to human health;
5. *social and human capital*: virtual interaction, cognitive communication, opinion formation, social mobilization including political participation scenarios, digital training center, etc., as tools for a social network city.

These domains/themes characterizing the manifold aspects of a complex urban arena can be incorporated in the following illustrative, conceptual urban force field, called the urban arena (Fig. 1).

Fig. 1 - The Urban Arena of the Computable Intelligent City



Source: Kourtit and Nijkamp (2017)

Clearly, this picture of an urban arena is mainly illustrative. But it serves to understand the need for a broad information perspective on modern cities: cities in a digital world are data producing machines, and simultaneously they need an avalanche of information to keep city complexity under control.

6. C-i-TY Lab: principles and design

The approach adopted in the present document is not aimed at developing an isolated technical instrument, but to lay the conceptual and methodological foundation for a coherent and integrative architecture for strategic urban policy and daily urban management in a dynamic and complex environment characterized by multiple interest groups and ever-changing data needs and opportunities in a modern city.

The principles and design of the C-i-TY Lab, in a broad context, are sketched in Figure 2 in a modular and cascade fashion, with a particular view to the development of an urban dashboard (Fig. 2).

Fig. 2 - Modular Architecture of C-i-TY Lab & Smart Dashboard

Source: Kourtit and Nijkamp (2017)

The building blocks of this architectural design, for a comprehensive decision support system meant for a computable intelligent city, will now very concisely be described. It goes without saying that this modular design is not only valid for the city as a whole, but also for specific policy domains in the city, such as transportation, housing construction, safety etc. It should be noted that the left-hand side of Figure 2 is more oriented towards methodological issues, and the right-hand side more towards applied methods.

1. City Mission and Position:
   - urban strategic objectives;
   - long-range trend analysis;
   - mapping of urban arena.
2. Performance Management through urban indicators:
   - needs and targets;
   - functioning of city system;
   - relevance for XXQ in the city.
3. Policy KPIs for testing urban performance:
   - definition and specification;
   - state of affairs;
   - measurability and accountability.
4. Pentagon Model for critical success conditions:
   - critical Success Factors (CSFs) in policy arena;
   - data organisation and systematics;
   - steering wheel information.
5. Big Data Metrics for analysing urban complex pictures:
   - time scales;
   - spatial scales;
   - individual-aggregate data;
   - policy domains and information;
   - complex data structure.
6. Information Cascade for systematic micro-meso-macro data analytics:
   - bottom-up;
   - stepwise selection;
   - conceptual needs and insights;
   - systemic approach.
7. Hierarchical Filters for transition from complexity to simplicity:
   - from “Big” Data to “Small” information;
   - multivariate analysis/data metrics;
   - redundancy vs. relevance of urban data;
   - data mining.
8. I-City Dashboard for interaction with stakeholders:
   - mechanism;
   - specification requirements;
   - alignment with Pentagon conditions;
   - feedback and learning tools.
9. Navigation System for dedicated strategic policy choices:
   - multi-tasking in multi-stakeholder setting;
   - selective choice of indicators;

- KPI monitoring;
- comprehensive vs. manageable data knowledge.

10. Multi-Criteria Analysis for transparent trade-offs:
    - fundamentals;
    - dashboard connection;
    - interactive techniques;
    - policy and stakeholders' priorities.
11. Stakeholders/Actors for balanced decisions in conflict management:
    - classification;
    - distinct objectives and conflicting preferences;
    - priority schemes.
12. Policy Priority Actions for putting the city on course:
    - choices;
    - implementation;
    - timing;
    - feedback mechanisms.

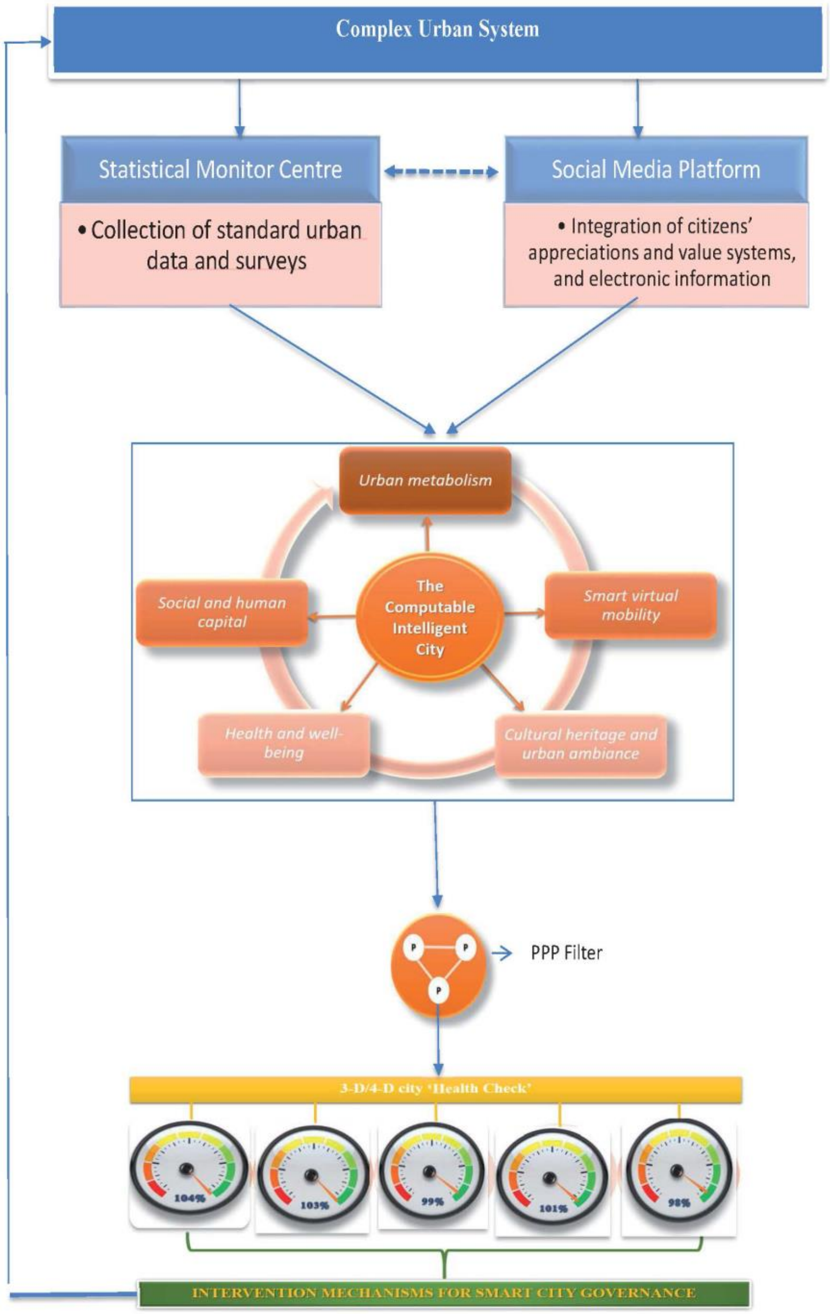
The previous brief mapping of a comprehensive decision support system for a smart city, from the perspective of a "data-rich" environment, has assigned a central position to the smart city dashboard. This will be further outlined in the next section.

7. The Smart i-City Dashboard

An Urban Dashboard is a smart, interactive navigation tool for providing informed and structured guidance to urban governance with a view to achieving the highest performance of a sustainable city, sometimes measured along the 3 well-known PPP dimensions (People, Planet and Profit). In general, many more relevant dimensions are included in urban preference schemes, as is also demonstrated in the previously mentioned XXQ-principle. Its overall architecture - supporting on a balanced trade-off of Society, Environment and Economy - can be sketched in the context of a complex urban system (Fig.3). The systematics of the data handling activities is next sketched in the cascade structure in Figure 4. The Urban Dashboard supports the strategy for achieving a Computable Intelligent City. It is incorporated in a broader C-i-TY Lab strategy which forms the integrating cognitive and data-driven framework for smart city governance in a complex data setting. The Urban Dashboard may provide a systematic monitoring of the emerging state of the urban economy based on a selected set of appropriate CSFs and the related KPIs. Normally, the maximum number of KPIs that can simultaneously be handled in a systematic and deliberate way does not exceed 5. Consequently, we will assume 5 "performance meters" for 5 CSFs in our Dashboard. This holds also for management Dashboards dealing with real-time decision issues in cities. Should in a data-rich environment many more relevant indicators exist, then multivariate methods may be helpful to reduce dimensionality and collinearity. Figure 3 provides a systematic sketch which puts the different components in perspective.

The smart i-city Dashboard is thus based on a broad range of KPI indicators which are seen as relevant policy objectives in a smart city context. In this way, stakeholders have five critical components "health-checks" to monitor the evolution of the city system and to use policy handles to keep the city, or specific domains, on course (Fig. 3).

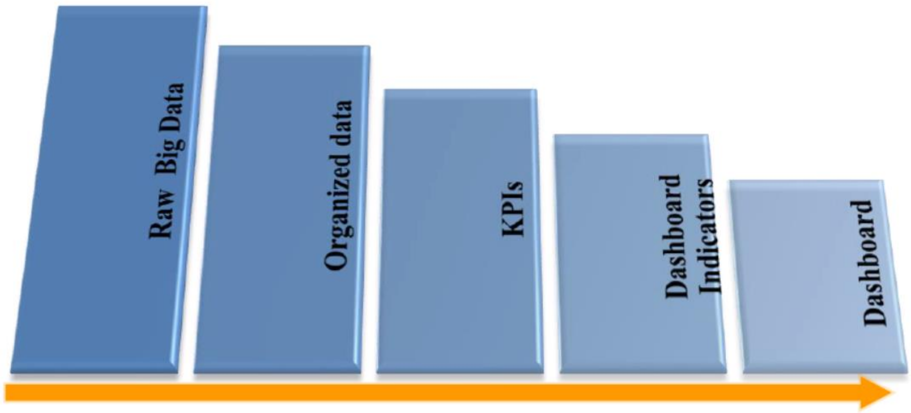
Fig. 3 - A sketch of the Smart i-City Dashboard



Source: Kourtit and Nijkamp (2017)

Figure 4 provides a systematic structure for filtering the data in a transparent cascade form, so that out of the chaos an ordered data system can be created that can be used as a transparent input for the i-city Dashboard (Fig. 4).

Fig. 4 - Cascade structure of complex data for a Smart i-City Dashboard



Source: Kourtit and Nijkamp (2017)

Finally, it should be noted that Figures 3 and 4 are only components of the broader modular architecture sketched in Figure 2. Indeed, a Dashboard is not merely a technical instrument, but part of an integrated decision support system for governing and managing a "smart big data city". It deserves to be further designed, refined and tested in a modern cognitive policy-analytical context of cities.

8. Ways forward

The above sketch of the principles and applicability of a smart i-city Dashboard needs of course a careful conceptualization, a multi-stakeholder contextualization, an evidence-based operationalization and a broad policy-based acceptation. From this perspective, a smart i-city Dashboard may need complementary attributes in order to meet real-world requirements. We mention here several desiderata for a user-friendly extension of the above mentioned cornerstones of smart i-city Dashboard:

- a broadly supported acceptability of the relevance, transparency and reliability of the data used as well as of the solidity of the data system as a whole;
- a professional client-oriented visualization of data handling in a multi-actor context;
- a clear labeling of KPIs and underlying indicators with a view to user of stakeholder interests;
- an advanced use of modern data mining techniques and multivariate methods, explained in a user-friendly and understandable way;
- use of common sense learning methods as a complement to advanced statistical methods (such as machine learning);

- search for a balance between demand-oriented data needs and supply-based information systems (e.g. social media);
- interpretation of big data as part of the public domain accessible to all citizens and stakeholders;
- involvement of citizens' participation in the operation of living labs for smart urban big data storage and analysis;
- orientation of multivariate data towards the interest of multiple classes of stakeholders;
- extension of big data towards further policy usage, e.g. in the form of urban scenarios;
- pedagogical training of stakeholders and citizens in using urban Dashboards;
- articulation of the specific significance of data for policy interests or domains.

A smart i-city Dashboard does not lead to a final endpoint decision, but opens up roads for alternative visions and strategies. It seems realistic to develop smart i-city Dashboards in cooperation with a multiplicity of interested stakeholders, not as a blueprint plan but as a learning tool for a quantum jump in the performance of cities through the use of "big data".

References

Batty M. (2013), *The New Science of Cities*. MIT Press, Cambridge.

Kourtit K. (2015), "The 'New Urban World' - Economic-Geographical Studies on the Performance of Urban Systems". PhD Dissertation. Adam Mickiewicz University, Poznan, Poland.

Kourtit K., Nijkamp P. (2017), "Big Data Dashboards as Smart Decision Support Tools for i-Cities – An Experiment on Stockholm". *Land Use Policy*, vol. 71, pp. 24-35.

Neal Z. (2012), *The Connected City: How Networks are Shaping the Modern Metropolis (The Metropolis and Modern Life)*. Routledge, New York.

Nijkamp P. (2008), "XXQ factors for sustainable urban development: A systems economics view". *Romanian Journal of Regional Science*, vol. 2, no. 1.

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