Increasing smart city competitiveness and sustainability through managing structural capital

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Abstract

Purpose – The purpose of this paper is to explore and discuss possible solutions to integrate the concepts of smart city (SC) and intellectual capital management, especially referring to structural capital. On the basis of this, the authors propose a theoretical framework that highlights the relevance of structural capital for strategic and operational planning of smarter cities.

Design/methodology/approach – Using a neuropsychological analogy, the authors assume that the development of SCs corresponds to the development of a sensorial or even a nervous system for cities based on their structural capital, and the development of city intellectual capital (CIC) corresponds to a further phase of the cities' mind development. The authors propose a practical framework that combines the concepts of city nervous system and city mind. It can be used as an instrument for project management. In this model, sensorial data – associated with the implementation of cities' sensorial systems – should naturally contribute with open data to the development of higher abstract functions that in turn supports the creation of CIC.

Findings – This paper highlights the interrelations between intellectual capital (IC) (especially its structural component) and SC and their synergic capability of improving both an SC's competitiveness and sustainability, and by this illustrates the benefits of combining both concepts in a common theoretical framework.

Research limitations/implications – Given the paper's theoretical nature, the empirical validation of the proposed framework is missing. This limitation will be addressed in forthcoming empirical research.

Originality/value – By proposing a framework that combines the concepts of SC and IC, the paper contributes to theory development regarding the strategic management of cities and the application of IC.

Keywords Strategic management, Intellectual capital management, Smart city, Knowledge management, Intellectual capital, Urban development

Paper type Research paper

1. Introduction

The concept of smart city (SC) has emerged recently and appears to be equated with a strategy to tackle the opportunities and challenges of increasing urbanization (Caragliu *et al.*, 2011; IDC Government Insights, 2013; EU Parliament, 2014). However, despite its worldwide dissemination, the concept's definition is still fuzzy and the theoretical background can be described as heterogeneous and vague (Dameri, 2013). An analysis of scientific and grey literature allows drawing boundaries and meanings of an SC, considering both the city itself and its "smartness" and the processes to transform a city into a smarter one.

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SC can be discussed from a top-down and a bottom-up approach:

- A top-down approach emphasizes a strategic vision of the city of the future. One that is driving both by the public and private efforts for creating better cities. Cities that are green, inclusive, and innovative metropolitan areas. This view highlights the idea of an SC as a better place to live and work in particular (Angelidou, 2015).
- A bottom-up approach starts from a framework that summarizes local policies and initiatives in an integrated programme. This view derives from the role of the EU and several national governments and intends on supporting and financing projects named as "smart" as well as on exploiting the role of local governments in defining integrated projects to gain funds in order to support their own local programs (Rossi, 2016; Anttiroiko, 2016).

An analysis of SC implementation has revealed that until now the bottom-up approach is prevailing. Indeed, smart programs emerge, in particular from individual initiatives driven by single actors or pools of actors which refer to both public and private initiatives and that often lack a formal direction. It seems that a real top-down approach is planned by only a few cities, the champion SCs like Amsterdam or Barcelona can be named in this context. Based on the analysis, it can be concluded that SC is a multi-faceted idea, one that is mainly attributable to the sum of implemented projects rather than to a strategic urban vision (Dameri *et al.*, 2016).

Despite the situation of a missing common SC definition (Dameri *et al.*, 2016; Albino *et al.*, 2015; Fernandez-Anez, 2016), it can be noted that an SC is a technology-based urban development path characterized by two fundamental aspects:

(1) A political/governance aspect assigned to programs and plans that aim at addressing the problems of urbanization, delivering a higher quality of life to citizens, and preserving the natural resources and the environment (Deakin, 2014; Dameri and Benevolo, 2015). In this sense, an SC is also a green city, or an inclusive one.

(2) An economic aspect looks at "smartness" as a means of supporting specific development paths. These are based on entrepreneurship (Kraus *et al.*, 2015) and considered as useful to attract investments, workers, and tourists (Hollands, 2008; Shichiyakh *et al.*, 2016). Despite the declared goals for environmental sustainability and quality of life, the economic development often emerges as the core motivation behind the cities' desire to become smart (Herrschel, 2013, Kraus *et al.*, 2015).

Over the time, an SC concept has emerged that is based on an urban area where participating governance manages technology and innovation to deliver benefits to its citizens in the form of environmental sustainability, social inclusiveness, quality of life, economic growth, and attractiveness. The specificity of an SC is largely based on innovation, research, knowledge, information, and communication, especially supported by information and communication technology (ICT) (Kraus *et al.*, 2015). In fact, ICT plays a pivotal role in both defining and implementing a so-called SC (Ishida, 2002; Su *et al.*, 2011).

The informational aspect of an SC has a complex architecture, as it involves several layers that are interconnected with each other (Kitchin, 2014):

- Public layer and private layer: local governments and public bodies should implement ICT infrastructures to enable the development of digital cities, whereas the solution vendors are the actors who realize the infrastructures concretely.
- Individual layer and collective layer: each citizen is involved in SCs, both in using smart apps to access data and as a producer of data and information. Local governments and public and private bodies are expected to collect, process, manage, and deliver data that are useful for both citizens and decision makers to better use and manage the crucial urban infrastructures and services.

- Infrastructural layer and intangible layer: ICT requires both the infrastructure and the software, data, and applications to achieve a twofold aim: first, to manage the natural resources (energy, water, waste treatment) and by this reduce pollution and consumption, and second, to manage the infrastructures and services aimed at improving efficiency and effectiveness for the benefit of citizens and enterprises.

From the analysis of all these SC aspects, the relationship between the latter and intellectual capital (IC) becomes evident. IC is a composed set of intangible elements and based on the virtuous cycle of knowledge accumulation (Rumelt, 1987). The IC approach has been extended to analyse territorial entities such as nations, regions, and cities as well (Bounfour and Edvinsson, 2012; Uziene, 2013). SC, understood as a territorial innovation system, is highly compatible with the idea of a territorial IC that is based on research, innovation, information, and communication, and one that requires managerial tools to govern the knowledge-based portfolio of intangible resources generated by SC initiatives (Dameri and Ricciardi, 2015). In this context, the structural capital, as a component of IC, is of particular relevance. Structural capital consists of the infrastructures, processes, routines, software, and databases that enable the functioning of organizations. Therefore, the ICT of an SC can be considered both as a stock and a producer of city structural capital, and thus helps in managing and preserving the knowledge that derives from different sources such as sensors.

The link between SC and IC is, therefore, a complex dynamic, considering the different aspects that are interconnected with each other. Almost all cited authors somewhat refer to some type of IC as a crucial component of SCs (e.g., Nam and Pardo, 2011; Neirotti *et al.*, 2014; Shapiro, 2006). However, it appears that to date no one has investigated SC as a new paradigm for initiating knowledge creation, sharing, and circulation and finally producing IC accumulation. One can argue that without this accumulation regime, no capital really exists. Therefore, it is crucial to understand if and how an SC's pool of initiatives not only initiate and integrate knowledge creation, sharing, and circulation but also knowledge sedimentation and accumulation into a set of intangible resources which in the end can form an economic capital (Grant, 1991; Collis and Montgomery, 1997). This aspect seems to be neglected in the SC literature.

With respect to a city's capability of driving its own development, an SC can be viewed as a reasoning entity capable of rational decision making and of rational choices covering an enlarged set of activities such as "smart" economy, people, government, mobility, environment, and quality of life (Giffinger *et al.*, 2007). Recent moves in this direction are even pointing to political issues such as "SC governance". In our work, we try to show that both concepts – "SC" and "city intellectual capital (CIC)" – consider cities as rational entities and, by this, emphasizing intellectual activities and whose results can be called CIC.

Against this backdrop, the purpose of this paper is to discuss the relationship between SC and IC and based on this suggest a theoretical methodology showing this relationship. Our work especially addresses the structural capital as the result of knowledge processing and accumulation through ICT. On the basis of a review of extant SC and IC literature, this paper tries to identify the shortcomings of SC Management and to show how the latter could benefit from the introduction of the IC concept to create and run competitive and sustainable cities.

The paper is organized as follows. Section 2 explores the embedding of IC in the SC literature. Section 3 develops the IC framework for SCs based on a theoretical methodology. Finally, Section 4 concludes the paper.

2. IC roots in the SC concept: a literature review

SC is a complex approach to metropolitan challenges and opportunities (Giffinger *et al.*, 2007). It is strongly based on innovative technologies, but especially on ICT that supports the pivotal role of data and information gathering, processing, and sharing (Ishida, 2002; Komninos, 2008). This specificity of an SC is an important way to produce and capitalize knowledge in intangible assets which in turn make SC's IC (Dameri and Ricciardi, 2015).

SC is a way to connect people, governments, enterprises, and universities with the aim of producing knowledge that delivers benefits to these different stakeholders. Falling back on the triple helix evolutionary model, some authors have identified a framework to understand how cities and other territorial innovation systems can generate IC and wealth, made possible through the synergies arising from the intelligence making cities smarter (Leydesdorff and Deakin, 2011; Lombardi *et al.*, 2012). Other authors have focused on the process of producing and sharing knowledge – and sometimes of capitalizing it – thanks to the use of ICT. Hall (2000) outlines the capability of SCs to develop knowledge through the use of sensors, transmission facilities, networking infrastructures, and integration instruments. These additional knowledge capabilities are considered as critical success factors to attract qualified workers and to encourage SC research. Hall's work is still immature and the topic is not thoroughly elaborated. This research stream is especially addressed by authors studying a city as an intelligent organism, focusing on its capabilities to learn and innovate (Ergazakis *et al.*, 2004), share data and information (Komninos, 2008), create and disseminate knowledge (Anthopoulos and Tougountzoglou, 2012), and invest in schooling and education. In this respect, Shapiro (2006) developed a mathematical model to investigate the link between city smartness and human capital (HC), defined as the number of highly educated inhabitants of a city. It is argued that HC could enable faster growth in productivity and therefore in urban gross domestic product. Shapiro's paper is the first one that explicitly linked SC IC (i.e. HC) with the creation of economic value, thereby suggesting a metric for its measurement.

SC aims not only at improving environment and quality of life but also at creating better social and economic conditions to compete with other cities worldwide in attracting the best people and companies. Indeed, some authors see in the large set of SC goals the intermediate steps to improve the quality of life and finally city attractiveness (Alawadhi *et al.*, 2012). An SC programme is sometimes compared with a strategy that translates and transfers a city's capabilities and competencies into a vibrant and attractive economic environment for companies and people (Paskaleva, 2009; Lombardi *et al.*, 2012). SC is also becoming a label, a brand distinguishing the best cities all over the world. For this reason, many cities are not only trying to become "smarter" but also to build their own brand to be recognized as an SC (Caragliu *et al.*, 2011; Nam and Pardo, 2011; Chourabi *et al.*, 2012). Hollands (2008) investigated the self-naming of an SC and the importance of an SC brand for supporting a so-called entrepreneurial city. Komninos (2011) based his studies on the implementation of electronic and digital applications in SCs and smart communities and on the embedding of data and information in the daily life of cities, in order to enhance innovation, education, and creativity. He stresses, however, the lack of integrated and people-oriented policies to exploit SC outcomes. It seems that urban strategies are often designed to increase a city's competitiveness but neglect the social aspects.

Moreover, Caragliu *et al.* (2011) included the concept of IC in their SC definition. They distinguish between HC (people education), social capital, and relational capital as drivers of urban growth, but they do not define these concepts. Their work focuses on the progressive clustering of urban HC as a primary effect of smarter cities, regarding some aspects such as better mobility, the use of ICT and the quality of life deriving also from environmental preservation.

Leydesdorff and Deakin (2011) explicitly refer to IC, but without providing any definition. Moreover, they attribute IC to universities participating in SC projects but do not specify an SC's IC. They consider IC as a driver of both efficiency in public service delivery and to sustain creativity, cultural development, and entrepreneurship. However, they do not explain how to do this. They especially recognize that the knowledge base of an SC development should be somewhat capitalized to produce relevant social and economic benefits in the long term.

Nam and Pardo (2011) in their most cited paper consider IC as an SC driver, outlining the importance of processes such as knowledge capital accumulation and investments to support knowledge development. They distinguish between public and private IC. Indeed, an SC resembles an ecosystem including both public IC, belonging to the city as a social subject, and private IC, belonging to organizations working inside the city's boundaries. Both forms of IC can be mobilized to produce economic and social returns. IC is one of the critical success factors to build a branding strategy to better compete with people, ideas, and capital and a city's smartness is increasingly becoming a major selling point.

Allwinkle and Cruickshank (2011) addressed the self-congratulatory nature of the SC label, sometimes conceptualized as a "magic potion" that is automatically capable of transforming and improving cities. The authors consider social capital as a fundamental component of an SC. Considered in a broad sense, social capital includes the norms, rules, values, expectations, and sanctions, but social capital is also supported by ICT in order to develop networked communities. These communities encourage the generation of shared knowledge and foster innovation, and not only technology innovation but also social and economic ones.

Chourabi *et al.* (2012) recalled several aspects already studied by other authors, but also stressed the twofold relation between IC and city attractiveness, that is, some city characteristics, such as social capital, HC, or organizational capital, can attract the best people and firms, and these characteristics are working inside an SC framework which in turn can develop an SC brand which attracts, even more, people and firms.

In sum, IC can be considered as a core component of an SC both as an output of implementing smart strategies and projects, and as a crucial input on becoming smarter. Indeed, the several processes involved in realizing an SC also produce knowledge that, when capitalized, can create a veritable SC IC, composed of structural capital, HC, and relational capital, even if the contents of these x-capitals are different in respect to the ones conceived for organizations (Dameri *et al.*, 2014). To our knowledge, no attention has been paid to define specific management best practices to introduce intellectual capital management (ICM) approaches to SC strategic planning, nor have performance instruments been designed to measure the IC value of an SC. This situation also applies to the role of SCs for supporting economic development or developing social benefits. We believe that ICM is a must-have practice to handle and manage IC in SCs to support the intentions regarding sustainability and competitiveness. Moreover, we argue that the development of structural capital that is supported by ICT is a fundamental prerequisite for backing these practices. In the following section, the development of such a framework will be outlined.

3. Methodology

The methodological framework presented below is based on a literature review and takes into account the following aspects of the relationship between SCs and IC:

(1) The concepts of "SC" and "CIC" are two faces of the same coin, that is, the city's capability to imagine its own development path and to realize it thanks to its own intellectual work (Vanolo, 2013).

(2) The concept of SC assumes implicitly that a city is an entity with reasoning skills, capable of rational behaviour, able to choose courses of action, pursue the objectives established in domains such as transports, communications, quality of life, and economy.

(3) We assume the city as a living and reasoning system distinct from its inhabitants: its reasoning capability and the results of such activity are not the mere sums of the corresponding activities of its inhabitants; instead, they are features of a distinct entity (the city) and we can speak, from this point of view, of the city rational and intellectual activity results and, in consequence, of CIC.

(4) On the other hand, forgetting for a moment the SC concept and assuming it makes sense to speak of a CIC, we are implicitly saying that a city is a thinking living system, capable of learning, capable of rational behaviour, capable of creating knowledge.

(5) Subjacent to both concepts (SC and CIC) it is implicitly assumed that there is one collective entity, formed by its inhabitants but distinct from them, capable of intelligent behaviour and having as one of its features the capability to create, organize, and store knowledge resulting and related by its activities.

(6) What distinguishes the two concepts is that in the concept of SC we are considering the behaviour and dynamics of the city (what must be done in order to have efficient and effective infrastructures) and when speaking of CIC we are referring to its identity and to the intellectual results of its smart or intelligent behaviour.

At this point, it would be useful to explicitly formulate a common framework or analytic referent, covering both these concepts, to be used in future city strategic planning and development work. One approach is to use biology and neuropsychology as natural sources of inspiration, observing what seems to happen in nature when similar problems are solved.

Following Matos *et al.* (2015), the process of city development, both from the point of view of its physical infrastructure and from the point of view of its IC, is the process to develop a living and thinking system. The concept of SC is based on the implementation of an urban sensorial system, collecting data from the city life, producing city structural capital (Filipponi *et al.*, 2010; Mitton *et al.*, 2012); the development of CIC is related to development of a reasoning capability and of problem-solving skills out of the material reality, similar to what is described by Damásio (2010) in relation to the development of mind and the self-manifestation in the human case. Convergence divergence zones and convergence divergence regions theory, described in Damásio (2010), seems relevant for modelling issues that occur in cities planning when a large number of sensorial systems, composed of thousands of sensors, are simultaneously developed in the context of SCs.

The neuropsychological paradigm is also inspiring in relation to the tasks of modelling the city reasoning, city learning, and city decision-making processes – a set of activities resulting in a specific form of IC: the CIC. These processes occur, for example, when the city legislative bodies discuss new laws or specify new institutions. These discussions and decisions are based on political groups' shared concepts and world representations, visions, or models.

The concept of mental model – or mental image – is a psychological concept, defined in Johnson-Laird (1983, 2010) and Damásio (2010). In this view, a mental model is an individual internal world representation used by individuals to reason about the world. This means that individuals do not reason directly over the signals collected by the sensorial systems, but on concepts that result from the processing of these signals by the brain. These concepts represent specific aspects of the world and can assume the form of spatial images, relations between objects, rules to process language, and reasoning rules (see Johnson-Laird, 1983, 2010; Damásio, 2010). In Kosslyn (1996), the problem of objective existence of these world representations and their role in human reasoning is discussed.

The concept of mental model seen as a set of internal world representations shared by specific groups of people is a social generalization of this concept (see, for instance, Hoffman *et al.*, 2014).

From these considerations, we propose the following framework for the development of models related to SC and CIC management projects:

- Cities are living, reasoning, and intelligent entities whose decision processes are based on data, collected by sensors that, collectively, form its sensorial system.
- City reasoning and decision processes act on world mental representations (city mental models) that represent specific aspects of the city dynamics and realities (social, economic, transportation, communications, ambient, quality of life) shared by the city decision process bodies (including the legislative and governance bodies).
- These representations are built and maintained by city technical, political, and cultural groups or organizations, through processes named Generation (of representations). All these generating processes consist of data captured through sensors and their work generates data at several levels of elaboration that are subsequently delivered to other processes and stored in data stores.

A model in such framework can be expressed by a graph or a network of graphs whose nodes are: Sensors, World Representations, Generators (of world representations), and Data Stores.

There is an edge between nodes A and B of such a graph when there is an information flow from A to B.

Sensor (S) – its function is to collect data on a single aspect of reality, characterized by a single variable which may have one or more components. Each sensor corresponds to a continuous flow of data (data stream) that will feed one or more decision-making processes. These data can be obtained directly from the outside world or from pre-existing data stores.

A sensor can collect physical data (temperature, air pollution level), quantitative or qualitative features related to city dynamics such as crowd formation, psychological features relevant for people mood in relation to political issues or health. For example, a sensor can capture the answers to a certain question belonging to questionnaire periodically applied. Another sensor can collect textual information generated randomly by citizens using their own mobile to report accidents, assaults, disorders, complaints, etc.; another example: selected texts of the daily press may be collected by one or more sensors that transmit these raw data to representation generators of political sentiments or public opinion. An SC is strongly based on sensors and data capturing, and on systematically collecting and processing data from social media and social networks; therefore, even if this aspect of capturing data existed before the SC vision, only with the SC implementation it assumes a pivotal role and has been implemented in real sensorial systems.

Representation (R) – it corresponds, in general, to a mathematical, pictographic, or verbal representation of some relevant aspect of reality related to city activity.

This representation must have a meaning for all involved and, being an abstraction, its characteristics must be as valid as possible of the real phenomena it represents.

The general idea is that the reasoning about the world from those involved in a specific management problem for which the representation is relevant is made thinking not in the world of sensor data, but in the world representation created by an abstraction process out of sensor data. The decisions about the world result from these reasoning processes, not from the direct observation of reality. Think, for example, about Christopher Columbus and his flawed – but ultimately successful – mental world representation, which in conjunction with the decisions of the Spanish catholic Kings led to the discovery of America.

Technically, a representation can be very complex or can assume the form of a single formula (for example: the law of gases relating pressure, volume, and temperature $PV = RT$) or complex decision rules to diagnostic illness of a human being or failure of a machine: a simulation system of weather in a certain region or the economy of that region. The general idea is that reality is replaced by its representation in the decision processes.

A valid representation, once operational, represents dynamic knowledge about reality, is IC. Any representation (of reality) results from a mathematical reasoning process followed by a validation process that involves data obtained by adequate sensors and its treatment by the suitable data analysis method, performed by another kind of component called Representation Generators. These data and processes are embedded in the structural component of the IC.

Historical examples of such concepts are ancient world maps – such as Piri Reis Map or Cantino Map, world cartographic representations constructed (generated) integrating all the geographic knowledge then available, based on data sensors as trip descriptions available from navigators or other sources. These maps were used not only as cultural and learning instruments but also as world representations used by rulers to take government decisions such as trip authorization and planning. These world representations were the precursors of modern Geo-Referenced Information Systems (GIS) that are much more accurate contemporaneous world representations.

Representation Generator (GR) – the representations result from the activity of some Representation Generators. For instance, a map is the result of some cartographic and drawing activity, combining data available about the world and its correspondence with geographic coordinates. These components receive sensor data and implement some specific statistical, optimization, or simulation tasks, transforming data into knowledge that represents some specific aspect of reality. This kind of component is an abstraction for some automatic data analysis processes that integrate human and other nervous systems and create or upgrade current representations. As an example, the construction of a visual image by the human vision system means that the conversion of light in chemical reactions whose resulting products are transformed in electrical signs on the optical nerve and the final construction and upgrading of images support for visual decision processes.

Memory (M) – stores sensor data or other information at several levels of abstraction resulting from the activity of other components of the system.

3.1 Example 1 – dynamic maps

To represent IC with a map, Kaplan and Norton (2004) have suggested giving a visual representation of the components of a corporation's strategy to leverage its intangible assets. The map depicts the interconnected role of different assets: HC; databases and information systems; responsive and high-quality processes; customer relationships and brands; innovation capabilities; and culture. This concept can be easily adapted to represent CIC in SCs, taking into consideration the pivotal role played by the geographical dimension of territorial systems. A visual representation can also help to understand how CIC can be used to create wealth and benefits for citizens (Marr *et al.*, 2004).

IC maps and their relations with geographic, sociological, and population variables are an important kind of reality representation. All kinds of reasoning and decision making involving geo-referenced knowledge can be made using maps. Before the digital era, distinct kinds of information could be mapped using clever labelling rules and symbols – such as simple words – to present visually the information that mattered. When that was not possible in a single map, specialized versions of the same map were produced (e.g. weather, terrain, roads, climate, resources, cities, etc.).

Today, the map of a city or region is updated in real time using the instantaneous content of specialized databases that can be geographically distributed and connected by the internet or other special networks, concentrating data from a large range of sensors (see Figure 1 for a schematic view of such a representation (dynamic map)). It may happen that a specific dynamic map can be enriched by inputs resulting from other representations of reality, for example, representations of city economy, environment, or transportation.

A dynamic map – integrating, for instance, data supplied by human sensors equipped with their smartphones or similar equipment – is a world representation especially suited

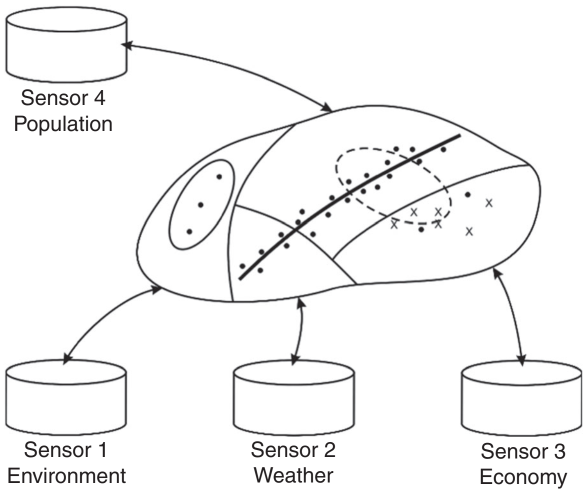


Figure 1.
A world representation (map) – city mental map – is dynamically updated by data supplied by sensors

to observe "online" the spatial and temporal emergence and evolution of social phenomena such as crowd emergence, development, behaviour and extinction, crime distribution or epidemic sources and spread. This example means in summary that sensorial systems developed in the context of an SC project must naturally be integrated with the processes related to CIC management through data stored in the corresponding databases, this (big) data being the source that feeds processes for creating new data at higher levels of abstraction.

3.2 Example 2 – modelling a CIC management system integrating sensors and data associated with the SC concept

Assuming CIC as a strategic planning factor for the formulation of policies, it makes sense to face the CIC management process and monitoring both in time and space as an important instrument for policy formulation and evaluation. This can be achieved by a systematic mapping of CIC relevant input variables.

It is not an easy task to obtain knowledge about real processes of CIC development and to validly acknowledge, as early as possible, its nature and potential future value. It requires a clear understanding of the spatial dimension of CIC to enhance the local endowment of knowledge and intellectual resources and the governance of processes to support IC management (Cappellin, 2003). Here, following Matos *et al.* (2015) and Matos and Vairinhos (2016), it is assumed that CIC is a function of some major players (MPs) behaviour – including decisions, attitudes, values, products, activities – that must be identified and characterized for each city. CIC is then resulting from the activity and interactions of these MPs (Teece, 2000). In its seminal paper about the cities of tomorrow, Hall (2000) well described the role of relations and networks in supporting a city's capability to face the challenges of the future. Moreover, thanks to the technological infrastructure embedded in the city's structural capital which represents a component of the CIC, an SC could be imagined as an aggregate of actors and systems interacting with each other.

Some MPs mean the same or approximately the same for all cities. Examples of generic players with similar meaning across the cities are:

- cultural players: universities, polytechnic schools, research institutes as well as cultural organizations or individuals characterized by a significant production of ideas;

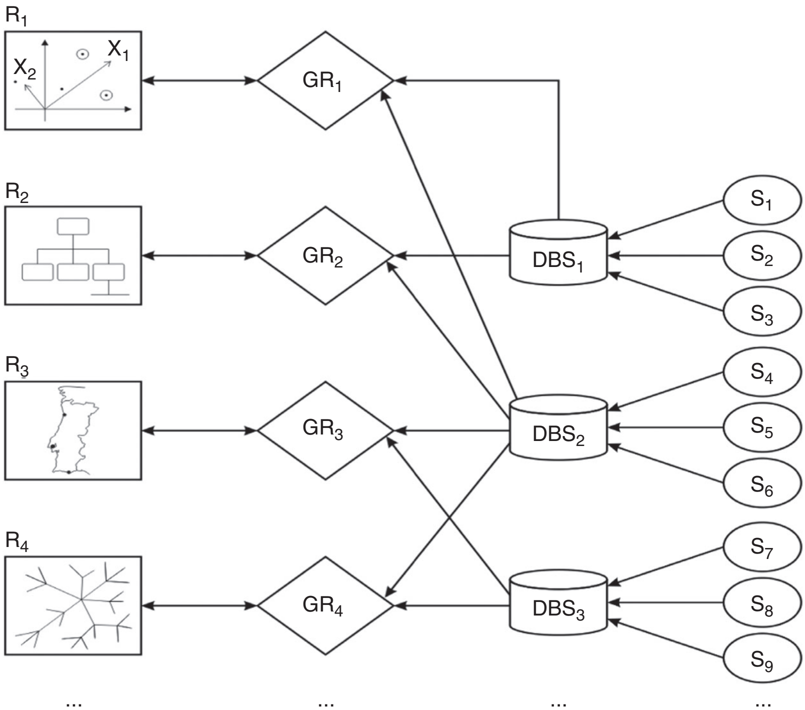
- political players: political parties and other political organizations having an influence on the formation of political attitudes of citizens;
- religious players: churches and other religious organizations with a significant impact on the religious attitudes of citizens; and
- economic players: commercial, agricultural, and industrial organizations or important and influential enterprises of the city or region.

Those players – by what they do, by its relationships, and by its importance – influence, and in some cases, determine the relevant city intangibles and their management, thus being natural sources of IC information.

One important source of information to be supplied by the identified players are the answers of MPs representatives to adequate questionnaires constructed having in mind the need to capture, in a fixed setup, the opinions, values, suggestions, facts, events of each player about distinct aspects related to the identification, creation and management of city intangibles, including CIC. The (big) data produced by these sensors must be openly accessed and combined with data generated by sensor systems developed and installed in the context of the SC concept.

These ideas are illustrated in Figure 2 with a hypothetical system to support the development and monitoring of a virtual CIC development.

If for this specific management problem, the decision process (including policy formulation) needs, at any moment, to know the spatial distribution of IC components and its relations with



Notes: R_1, R_2, R_3, and R_4 are world representations (mental models) needed for CIC management processes. Interaction with the system is thought through these representations

Figure 2.
World representations for CIC management processes

variables that could explain its occurrence – such as population distribution, income distribution, spatial distribution of cultural activities, quality of life, economic activity nature, location and level – then some of the following representations would be useful:

- R_1 – Biplots (or similar visualizations) that relate the components and nature of IC with MPs. This representation interacts with users and is generated and updated by a specialized statistical or data mining software called GR_1 – Representation Generator – that transforms the data collected by relevant sensors (S_1, S_2, S_3, S_4, S_5, S_6) stored in the memory components implemented by databases (DBS_1, DBS_2).
- R_2 – a decision tree that relates the attributes of IC with observed answers to questionnaires, supplied by specific players, and with geography, population, and official statistics.

These kinds of representations are created and updated by specific software (statistical software/data mining software) that receives its inputs from the databases (DBS_1, DBS_2) where relevant sensors (S_1, S_2, S_3, S_4, S_5, S_6) store its rough data.

- S_4 – corresponds to geographic data.
- S_5 – corresponds to population data.
- R_3 – a dynamic geographic map (see Example 1) where the spatial distribution of variables relevant to the decision process is posted according to the needs of policy makers and other decision-making processes. These maps are produced and updated by Geographic Information System generators (GR_3) using geo-referenced data collected by sensors (S_4, S_5, S_6) eventually combined with other information such as Opinion Polls (S_7), Press (S_8), and Citizens Opinion (S_9).
- R_4 – a Dynamic Semantic Net developed when concepts abstracted from Citizen Opinions (S_9), News (S_8), and Polls (S_7) are expressed through a graph of concepts and created and updated by a specialized Generator (GR_4) out of texts written or spoken and collected by specific sensors.
- R_1 – Representation 1 – expressed by dynamic Biplots.
- R_2 – Representation 2 – expressed by dynamic Decision Trees.
- R_3 – Representation 3 – dynamical map to display geographical distributions of variables.
- R_4 – Representation 4 – semantic map representing the public opinion, values, meanings, and its interrelations.
- GR_1 – statistical software/data mining package to create and update Biplots.
- GR_2 – statistical software/data mining package to create and update Decision Trees.
- GR_3 – statistical software – for example, GIS – to create and update the spatial distributions of relevant variables.
- GR_4 – statistical software to create and update Semantic Nets with concepts and its relations.
- DBS_1, DBS_2, DBS_3 – databases (memory) containing rough data (before analysis) collected by Sensors.
- S_1 – Sensor number 1 – to collect answers to questionnaire 1, directed to managers of firms.

- S_2 – Sensor number 2 – to collect answers to questionnaire 1, directed to managers of universities.
- $S_3, \ldots, S_9$ – specialized sensors to collect data from relevant sources.

3.3 Example 3 – modelling city attractiveness, competitiveness, and sustainability

City attractiveness is one of the main issues when facing the issues of survival and sustainability. Based on this observation, it is crucial, as observed and analysed by Matos *et al.* (2015), to have a model representing the processes of attraction (why they come?), stay (why they stay?), and leave (why they leave?) both from individuals and enterprises. Such a model must be able to predict future movements of these challenges based on a continuous monitoring of persons' and enterprises' "moods".

Sensors for economic, social, technology, and other variable conditioning what individuals and enterprises think are crucial (refer to Matos *et al.* (2015) for more details).

In sum, the experience with the SC concept has shown its utility and importance but also its limits and the need for theoretical developments and articulation with other concepts. CIC that deals with the intangibles determinants of city attractiveness, competitiveness, and sustainability can be an instrument of strategic city planning. The framework presented above, which stresses the structural capital dimension of CIC, is a move in this direction.

4. Conclusions

SCs are emerging all over the world and seem to be the outcome of urban strategies aiming at implementing better cities, with respect to aspects such as reducing pollution, improving public services, supporting more effective governance systems, and eventually increasing city competitiveness and attractiveness. An SC itself is an intellectual body, not only because it is strongly based on processes using data and information to produce knowledge about the city, but also because it is rooted in a reasoning system, where all the leading actors produce a living and reasoning system distinct from the ones of other cities and capable of showing a rational behaviour, of choosing courses of action, and of pursuing the objectives set in domains such as transports, communications, quality of life, and economy.

This cognitive nature of an SC is also a dynamic process of producing IC and using it for better and more informed decisions about the city's development path. The integration of SC strategies and IC endowment is considered a critical success factor to enhance the capability of cities to face the demanding challenges from urbanization and natural resource shortage.

The large use of sensors collecting data stored in large databases, the use of ad hoc software for data processing in urban areas, the implementation of infrastructures, and processes embedding data and information about the city produce a firm structural capital, understood as one of the supporting pillars and main components of CIC. Thus, the management of this structural capital has an important role to play in developing and maintaining SC competitiveness.

First, the present paper has the aim to show the relation between – at least, the corresponding relation – SC and IC and to base this dynamic relation on a city's capability of being itself a reasoning and thinking entity. Second, to root this capability in the technological infrastructure of an SC (the city's structural capital) that is strongly shaped by taking advantage of ICT, sensors, data collection, large databases, communication instruments such as social media, free apps available to citizens, and so on.

Moreover, this work suggests a theoretical model to map a city's capability to become smart by producing and (re-)using its own IC. This capability is especially shaped by the pivotal role of MPs responsible for creating an interconnected system of systems that is based on knowledge flow and sedimentation. We revisited the IC map to depict a CIC system (more precisely a city structural capital system) of SCs. This representation is the experimental outcome of a longitudinal analysis of scientific papers, grey literature, and several SC implementations in different European countries. The model identifies different representations, here understood as mental models, produced by an SC to understand and develop its own IC. This representation can be considered as robust as it is rooted in the more than ten years' old SC literature and experiences and at the same time is flexible enough to be adapted to present and future examples of SCs.

We are aware that this theoretical model requires empirical validation. This will be the next step of our research. To validate the proposed model, some champion SCs will be selected, their development path will be analysed, and the model tested. The focus will be on champion SCs because of two reasons: first, champion SCs were the first cities that started their own smart programme; therefore, they can offer the examination of a long-term development path and a certain level of IC creation until now; and second, champion SCs are characterized by the implementation of a large enough portfolio of initiatives, one that is not limited to a handful of pilot projects, and thus are mature enough for testing our model.

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