Paper presented at CITIES4PEOPLE: SMART CITIES AND DATA ANALYTICS, International Kick-Off Venue of M-i-City Centre April 18-20, 2018, JADS, s'Hertogenbosch, The Netherlands

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Knowledge Society, Territorial Intelligence, Smart Cities, Knowledge Infrastructure

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Abstract
The concepts of smart cities and territorial intelligence cannot be understood without examining their links with the knowledge society. In this kind of society, knowledge must be considered as a capital shared not only with experts, but also with citizens, within the target of sustainable development. After studying those concepts, the scope is to examine how human knowledge and artificial intelligence can be combined in geographic knowledge systems, essentially based on machine-processable knowledge and the concept of rules. Several geospatial rules are detailed in order to distinguish several categories implying locational issues. Then, a general structure for geographic knowledge base systems is given together with some fundamental elements for an infrastructure in which human collective intelligence is a key-element. To conclude this paper, a research agenda is given to integrate urban and regional management into the knowledge society.

Key-words: Knowledge society, Smart Cities, Territorial Intelligence, Geographic Knowledge Systems, geospatial rules.

1 – Introduction

Nowadays, the concepts of knowledge society, smart cities and territorial intelligence are mainstream. But what are their relationships? How knowledge can impulse the development of territories? What could be the respective roles of human collective intelligence and artificial intelligence (Batty, 2018), or more precisely of machine-processable knowledge engineering?

From millennia, knowledge is used in various domains, not only to understand the nature, but also to construct man-made artifacts such as tools, but also social organizations.

But now, the problem is not only to accumulate knowledge (knowledge as a capital!), but rather to use it in automatic reasoning systems. In other words, the challenge is to deal with machine-processable knowledge, *i.e.* not only to consider knowledge written with sentences which can be transformed through some computer languages. And the *nec plus ultra* is to consider declarative knowledge in contrast with procedural knowledge included as algorithms into computer programs.

This text will be organized as follows. First, the concepts of knowledge and knowledge society will be examined, followed by those regarding territorial intelligence and smart cities in order to sketch the characteristics of geographic knowledge systems and infrastructures.

2 – About knowledge and the knowledge society

After trying to define knowledge, let us examine the main visions for the knowledge society.

2.1 Knowledge definitions and categories

Various definitions of the word "knowledge" have been provided trying to distinguish knowledge from information.

The Oxford dictionary gives various meaning of knowledge: (*i*) facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject; the sum of what is known; philosophy true, justified belief; certain understanding, as opposed to opinion; (*ii*) Awareness or familiarity gained by experience of a fact or situation. For Davenport *et al.*, (1998), knowledge is "information combined with experience, context, interpretation, and reflection. It is a high-value form of information that is ready to apply to decisions and actions."

Moreover, Makhfi (2001) distinguishes seven models of knowledge:

- **Diagnostic models** (Complaint ==> Possible Cause(s)): "Our city has these symptoms. What is the problem?"
- **Explorative models** (Problem Description ==> Possible Alternatives): "Ok, I know the problem. What are our options?"
- **Selective models** (Alternatives ==> Best Option): "Now we know the options. Which one is the best for us?"
- **Analytic models** (Option ==> Fitness): " We selected one option. How good and suitable is it for our objective?"
- **Instructive models** (Problem Statement ==> Solution Instruction): "How can we achieve that?"
- **Constructive models** (Problem Statement ==> Design Solution): "We have to design a policy such as...".
- **Hybrid models**: by chaining some of the previous models.

But, to this list, we must add locational models in order to answer the question "where to?" and decisional models implying several stakeholders – those models being developed later in §4.

After having presented different categories of knowledge, let us examine the computer perspective.

2.2. From a computing point of view

In computing, usually four words are commonly used, data, information, knowledge and wisdom. Data correspond to raw values (numbers, strings of characters), information to data with its semantics, knowledge to information used to solve a problem, and wisdom is when knowledge is used (Ackoff, 1989). For instance "Red" and "George Washington" as strings of characters are data. If I say the traffic light of the George Washington Avenue is red, this is information. If I say "When the light is red, I stop", this is knowledge; and finally as "I am arriving to the red traffic light, I do stop", this is wisdom. As a conclusion, from a computing point of view, when using knowledge, there is wisdom, and moreover if everybody uses knowledge, we reach to a global wisdom, or a knowledge society (Figure 1).

According to Gurteen (1998), the cake metaphor can help understand the differences between those concepts: "data" corresponds to molecular components of the cake; "information" to the ingredients; "knowledge" to the recipe (how to make the cake); and finally "wisdom" corresponds to know why and for whom to make the cake.

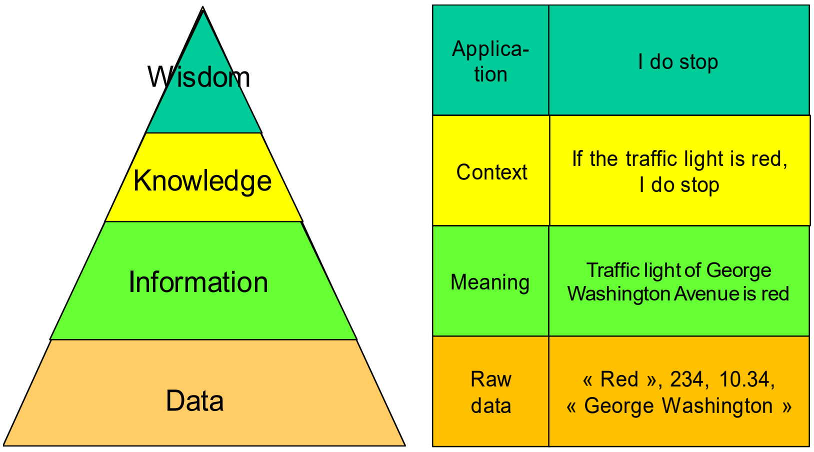

Figure 1. Data, information, knowledge and wisdom in the computing perspective.

2.3. Knowledge society

According to UNESCO (2015), "the idea of the information society is based on technological breakthroughs. The concept of knowledge societies encompasses much broader social, ethical and political dimensions. In emerging knowledge societies, there is also a virtuous circle in which the progress of knowledge and technological innovation produces more knowledge in the long term. We are witnessing an acceleration of knowledge production. The new technology revolution marks the entrance of information and knowledge in a cumulative logic, which Castells (1996) describes as the application of such knowledge to knowledge generation and information processing/communication devices, in a cumulative feedback loop between innovation and the uses of innovation."

Moreover, according to Afgan and Carvalho (2010), "the development of the Knowledge Society is focused on the following objectives:

- To inspire and enable individuals to develop their capability to the highest potential level throughout life, so they can grow intellectually, be well equipped for work, can contribute effectively to society and enjoy active personal fulfillment;
- To increase knowledge and understanding for their application at local, regional, national level;
- To play a major role in shaping a democratic, civilized and intellectual society;
- To promote the exchange of ideas for the development of the knowledge society and merge joint activities devoted to the future development of life support systems;
- To learn, evaluate, assess and validate economic, environmental, social and technological advancement to produce benefits based on the knowledge society."

Based on these considerations concerning the whole society, what could be told regarding the impact of knowledge, and especially geographic knowledge for smart cities and territorial intelligence?

3 – Smart cities and territorial intelligence

Many definitions have been proposed to define both smart cities and territorial intelligence. They all have in common the integration of sustainable development. Even though those two concepts came from different disciplines, their main differences can be stated: as "Smart City" focuses on cities, "Territorial Intelligence" concerns larger spaces including regions and countries.

3.1. Smart cities

Dr. Carlo Ratti, director of the MIT Senseable City Lab, claims that an intelligent or smart city is technological, interconnected, clean, attractive, comforting, efficient, open, collaborative, creative, digital and green. The European Union considers six components : economy, mobility, environmental, people, living, governance to shape a Smart City.

Boyd Cohen[1] (2012) has given a more sophisticated definition of a smart city with this circular diagram or wheel (Figure 2). And this wheel has been inspired by the work of many others. In this diagram, one can see that Information and Communication Technologies (ICT) appear several times especially under the title "Smart Government".

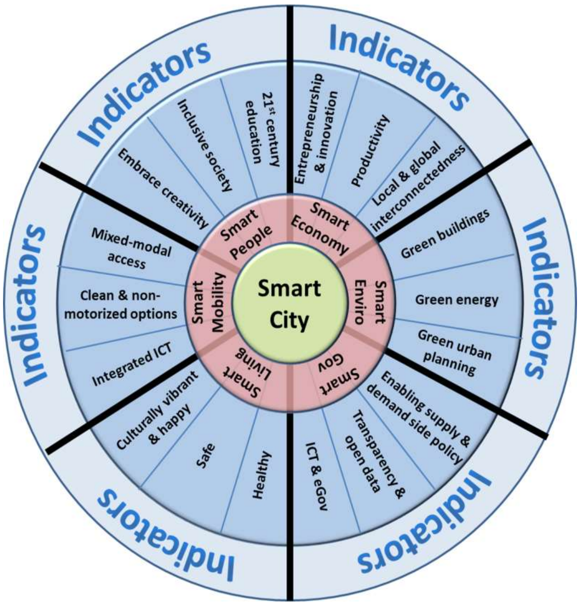

Figure 2. Definition of a Smart City according to Boyd Cohen.

This latter definition was extended by Mathew (2013) illustrated Figure 3 as a form of a diamond connecting Smart Governance, Smart Citizens, Smart Healthcare, Smart Energy, Smart Buildings, Smart Technology, Smart Infrastructures and Smart Mobility.

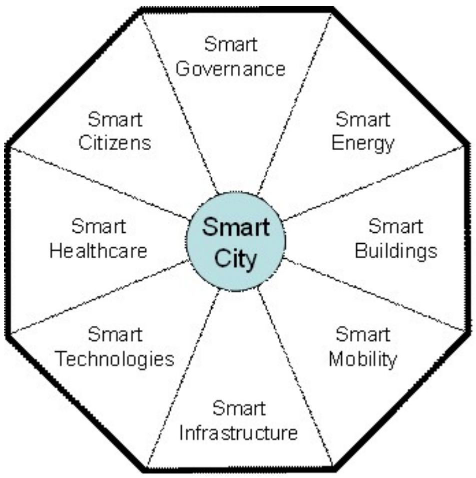

Figure 3. The Smart City components according to Mathew's diamond (2013).

1 http://www.fastcoexist.com/1680538/what-exactly-is-a-smart-city

In addition, let me mention another interesting definition emphasizing participation: according to Deutsche Telecom[2], "a Smart City is an ecosystem characterized by a partially digitized set of processes and striving to its self-awareness and efficiency, through ICT and a higher degree of participation from its citizens, authorities and businesses". Moreover according to Kourtit-Nijkamp (2012, 2018), "Smart cities are the result of knowledge-intensive and creative strategies aiming at enhancing the socio-economic, ecological, logistic and competitive performance of cities. Such smart cities are based on a promising mix of human capital (*e.g.* skilled labor force), infrastructural capital (*e.g.* high-tech communication facilities), and social capital (e.g. intense and open network linkages) and entrepreneurial capital (*e.g.* creative and risk-taking business activities". Notice that the last definition stresses the importance of knowledge in a smart city. For other definitions and analysis, please refer to Albino *et al.* (2015) for a very comprehensive review.

Another interesting point of view is given by Fernandez-Anez (2016) in which she compares 32 definitions from a stakeholder point of view. In conclusion, she proposes the following definition: "A Smart City is a system that enhances human and social capital wisely using and interacting with natural and economic resources via technology-based solutions and innovation to address public issues and efficiently achieve sustainable development and a high quality of life on the basis of a multi-stakeholder, municipally based partnership". This definition can be seen much closer to territorial intelligence.

3.2. Territorial intelligence

Considering now territorial intelligence, also several definitions can be quoted. According to Bertacchini *et al.* (2007), "Territorial Intelligence can be compared with the territoriality which results from the phenomenon of appropriation of resources of a territory; it consists in know-how transmissions between categories of local actors of different cultures." In the other hand, Girardot (2008) defines Territorial intelligence as "the science having for object the sustainable development of territories and having for subjects the territorial communities." This definition was extended later Girardot (2010) by specifying that territorial intelligence innovations must include:

- use of multidisciplinary knowledge,
- dynamic vision of territories,
- involvement of communities and practitioners,
- sharing, co-constructing and cooperating,
- and participatory territorial governance.

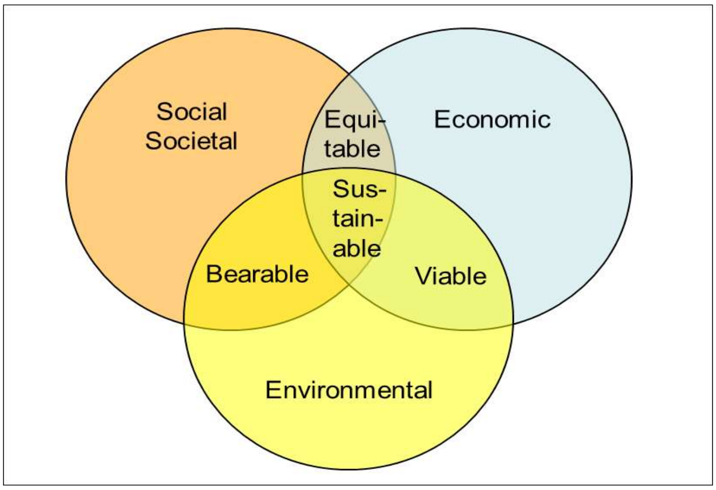

Figure 4. The three pillars for territorial intelligence (Girardot 2008).

2 Cited by http://www.cisco.com/assets/global/RO/events/2015/ciscoconnect/pdf/santal/ Cisco-Introductory-EP.pdf

Territorial intelligence consists of a set of scientific methodologies, analysis tools and measurement systems that mobilize the stakeholders of a determined territory. The territorial intelligence approach entails coordinating all stakeholders to bring about actions favoring the collective good (citizens, companies, etc.) through an interaction of the three concepts of sustainable development: economy, society and environment (Figure 4).

For my part, let me propose the following definitions, "Territorial intelligence can be defined as a territory (maybe a city) which is planned and managed by the cross-fertilization of human collective intelligence and artificial intelligence for its sustainable development".

Another expression is also in use, "geospatial intelligence" with a similar meaning. For Bacastow (2014), "Geospatial Intelligence is actionable knowledge, a process, and a profession. It is the ability to describe, understand, and interpret so as to anticipate the human impact of an event or action within a spatiotemporal environment. It is also the ability to identify, collect, store, and manipulate data to create geospatial knowledge through critical thinking, geospatial reasoning, and analytical techniques. Finally, it is the ability to ethically collect, develop, and present knowledge in a way that is appropriate to the decision-making environment."

Regarding knowledge for those domains, the first step is to ask people to give their "narrative knowledge" *i.e.* with words, and then to formalize it and to encode it for reasoning. A nice example is given by Chang *et al.* (2009).

And now the question (Laurini, 2017a) is "how artificial intelligence and especially knowledge engineering can help not only local decision-makers to plan a city but also lay citizens to give their opinion about the future of their city?" A preliminary study can be found in Bertacchini (2016).

4 – Geographic knowledge for smart cities

Various categories of knowledge exist and Afgan and Carvalho (2010) distinguish three categories, namely economic knowledge, environmental knowledge and social knowledge, in which we must add geographic knowledge (GK) which is orthogonal to the previous one, whereas temporal knowledge is already included.

According to Golledge (2002), Geographic Knowledge is useful for two fundamental reasons: (1) to establish where things are and (2) to remember where things are to help us in the process of making decisions and solving social and environmental problems. However, some questions and tasks that the discipline must face as we move further into the 21st century include:

- How can geographic knowledge contribute to the comprehension and solution of problems involved in society-space relations?
- What future role can geographic knowledge play in establishing global international, national, regional, and local policy?
- What geographic knowledge can we create to enhance understanding of global societies, cultures, economies, and political and information structures?

Bearing all that in mind, concerning territorial intelligence, let me propose the following definition: "geographic knowledge corresponds to information potentially useful to explain, manage, monitor, understand the past, plan a territory and innovate". Let me develop.

a/ Geographic Knowledge to Explain. It corresponds more or less to Gollege's definition. Synonyms can be to understand, to explore, to assess the context and to detect problems. Existing books and monographs can help a lot from an historical point of view. Techniques such as geographic text mining (Salaberry 2013) and, when databases are existing, spatial data mining can be the sources of this kind of geographic knowledge. An extension of this category is to consider knowledge to reconstitute the past landscape or to simulate future evolution.

b/ Geographic Knowledge to Manage. One of the goals of local authorities is to manage the territory under their jurisdiction. The management could range from street and engineering network repairs to school and other public services such as waste collection. The knowledge they have to use is essentially coming from laws, by-laws and best practices. In other words, knowledge is known in some natural language and must be transformed to become machine-processable. Often, here can knowledge be seen as an extension to business intelligence applied to local authorities?

c/ Geographic Knowledge to Monitor. This kind of knowledge can be seen as an extension of the previous one, but its nature is totally different. Indeed, local authorities in order to reduce pollution or regulate traffic, install sensors as previously explained to get raw data which are transformed into knowledge by real time data mining.

d/ Geographic Knowledge to Plan. In my understanding, this is the ultimate goal of geographic knowledge engineering, to plan smart cities or territories. It means to design scenarios of evolution, study alternatives and take citizen's opinions into account within the scope of sustainable development.

e/ Geographic Knowledge to Understand the Past. This is another usage of knowledge, for instance in archeology or in history. By examining excavation findings, already-known ancient knowledge can be used to understand, but also the findings can suggest novel theories, for instance for commercial exchange.

f/ Geographic Knowledge to Innovate. This kind of knowledge is important for the future of the smart cities; it will be essentially based on technological and sociological watches.

5 – Back to knowledge models

In this section, we will develop first what it is meant by additional models about location and decision making, and then what big data can offer to those models.

5.1. Locational models

As previously told, the role of locational models is to deal with the question "where to?" Indeed for any public policy, the problem of identifying and selecting the more suitable places is important. Several aspects must be rapidly examined from a geometric point of view:

- **Point selection**: for instance, to choose the location for new pollution sensors, speed cameras and cameras of video-surveillance;
- **Small area selection**: for instance location for bike rental stations or bottle banks; in this categories, we can include well-oriented sloppy roofs for photovoltaic panels, and flat roofs for vegetable gardens;
- **Bigger area selection**: for hospitals, fire stations, schools, bus terminal, waste disposal site, soccer stadium, etc.;
- **Line identification and network selection**: for bus lanes, bike paths, bridges, roads, powerlines, new metroline, waste collection, etc.;
- **Tessellation selection**: for instance for splitting a territory for polling sectors, medical sectors, etc.

Those models have in common to deal with places by combining several criteria; for instance the criteria to position an hospital are very different from those for determining polling sectors.

5.2. Multi-criteria multi-actor decisional models

In the literature, several models have been proposed, some of them only on multi-criteria decision-making (for instance Triantaphyllou, 2000), others on multi-actor models usually including multi-criteria aspects (Macharis *et al*. 2012) since stakeholders may have different criteria to optimize. In addition, some authors include multi-round negotiations (Howlett, 2007). Indeed, in local policy-making, usually several groups exist with different objectives and sometimes those objectives are very conflictual. Among stakeholders, let us mention:

- the local elected officers,
- the State government which can have different visions,
- some NIMBY groups (Not in My Backyard),
- environmentalists,
- some companies,
- some local people, associations, etc.

Figure 5 illustrates an example facing some vacant land, some actors will advocate for a new recreation park whereas other for a commercial mall, etc. Sometimes the conflicts can be very strong and anyhow a consensus must be found or some arbitration must close down the debate.

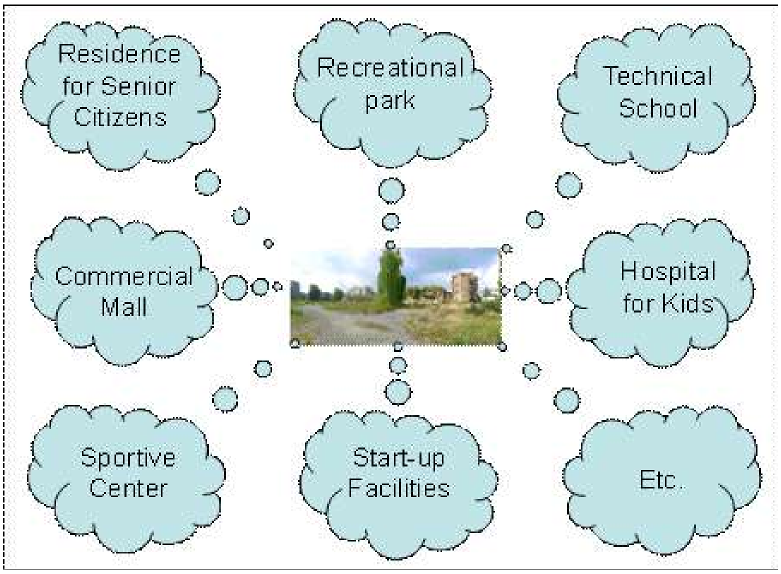

Figure 5. Facing a vacant land, various stakeholders can have different visions.

5.3. Big data and models

According to Snijders *et al*. (2013), Big Data is a loosely defined term used to describe data sets so large and complex that they become awkward to work with using standard statistical software. Now, with telecommunications and sensors, cities can get lots of data, from which characteristics, regularities or patterns may be discovered through sets of algorithms generally named Big Data Analytics. Among those characteristics, novel knowledge chunks can be discovered.

According to Mitchell (2014), Big Data Analytics has several characteristics; among them, let's mention the necessity to use cloud computing, the importance of "big data lakes", predictive analysis, new data models and deep learning. Even if the development of those technologies are outside the goal of this article, let me only explain the following; in the past, we first designed a data base model and then populated it; but now we do have a "data lake", *i.e.* without any a priori model. The challenge of big data analytics is so more complex to be achieved. As a consequence, a sort of virtuous circle can be defined as depicted in Figure 6: throughout the smart city, lots of sensors (including user-generated) can measure data which can generate knowledge about the smart city. By accumulating knowledge, it is expected to design new micro-theories regarding cities (Batty 2013).

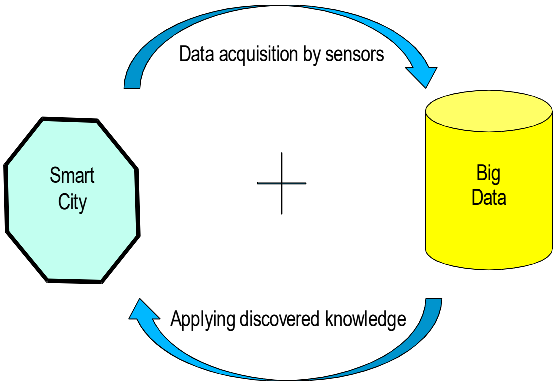

Figure 6. The Smart City/Big Data virtuous circle.

Knowledge discovery or harvesting can be made by means of different techniques, among them data mining, and in our case spatial data mining (Shekhar *et al*. 2005).

Back to the different models of knowledge, what Big Data can provide? My feeling is that big data can be very useful to diagnostic, analytic, constructive and locational models, whereas this technology will apparently bring nothing to selective or decisional models unless some additional information is stored besides data, maybe as metadata.

Anyhow, the knowledge chunks which can be more effective and machine-processable are by using rules, and especially geospatial rules.

6 – About geospatial rules

Rules constitute a very important component of knowledge. In artificial intelligence, the representation of rules is based on several mathematical theories, such as classical logics. Moreover, according to Graham (2006) and Morgan (2008), business rules should be considered as first-class citizens in computer science. In this section, first, generalities about geospatial rules will be examined, and then some preliminary element to get them machine-processable will be given.

6.1. Generalities about geospatial rules

Consider some examples of knowledge chunks in smart cities, some of them coming from physical laws, administrative regulations or best practices (Laurini *et al.* 2016):

- if a lane is narrow, make it one way, except if it is a cul-de-sac (dead end);
- when planning a metro, move underground networks;
- no parking, no business;
- each building must be connected to utility networks (water, electricity, gaz, telephone, Internet, etc.);
- council flats must be connected to urban heating systems;
- if a cross-road is dangerous, install traffic lights;
- in city centers, transform streets into pedestrian precincts;
- when a commercial mall is planned in the neighborhood of a city, shops located in the city

center will be in jeopardy;
- if the number of car parking lots is insufficient, encourage using buses or bikes;
- at the vicinity of an airport, limit building heights (see Figure 7 for an example):
- when a big plant is closing, unemployment will increase;
- at the vicinity of an historic building (listed monument), no modifications of building are allowed (See Figure 8);
- every lamppost can be considered as holder of sensors (temperature, pollution, noise, etc.);
- when defining a new industrial area, unemployment will diminish;
- when a road is wide and buses are running, provide a bus lane;
- if a recreational park is inside a city, provide bike lanes coming to this park;
- in France, it is forbidden to open a new tobacconist shop within 500 meters from an existing one;
- if there is one or several rivers crossing a city, design systems to mitigate floods;
- if a sloping roof is well-oriented, envisage solar panels;
- if a roof is plat, envisage either urban farming or a landing place for air mobility;
- in a city with many hills, consider cable-cars linking them.

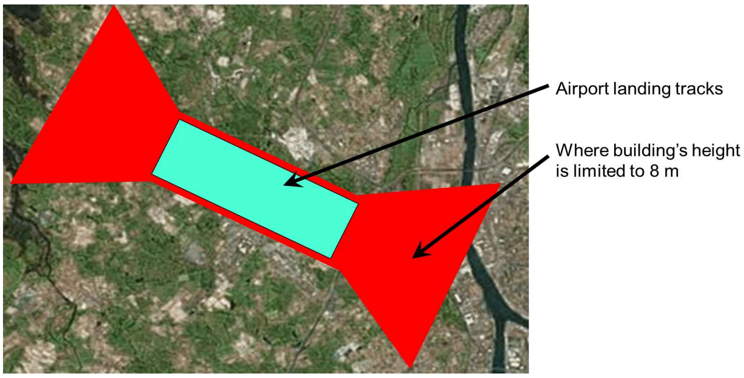

Figure 7. Limitation of building heights at the vicinity of an airport.

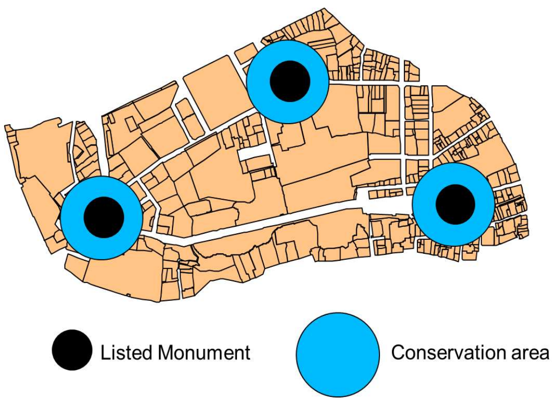

Figure 8. At the vicinity of listed monuments.

In Figure 9, an example of planning rules is given.

Unless business rules which are encoded with logic, those geospatial rules need to integrate computational geometry, topology, operation research (especially for looking for optimum) and differential equations (at level of instructive models when flows are considered).

Generally, the implementation of rules is based on two grammatical structures IF-THEN-Fact and IF-THEN-Action (Ross 2011). The first serves above all to involve new facts, that is, for us, new objects, attribute values, new relationships between geographic objects. And the second is to involve new actions. But who will be in charge of such new actions? In some cases, the computer itself may run procedures; in others, particularly in regulatory contexts, a decision maker (for example, the Mayor of a municipality) must himself initiate the action. Another interpretation could be that the choice of alternatives of an action, for example when a law, in some well-defined contexts, opens many perspectives.

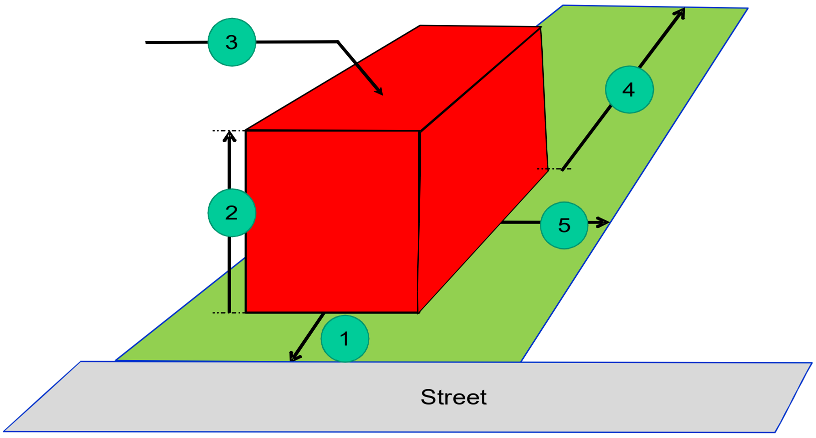

Figure 9. Example of a set of planning rules concerning buildings. 1 – minimum distance to street; 2 – maximal height; 3 – Volume of the building; 4 – minimum backyard distance; 5 – minimum distance to neighbor.

A special case concerns sets of rules related to the same factors-dependent conditions modeled according to trees or decision tables.

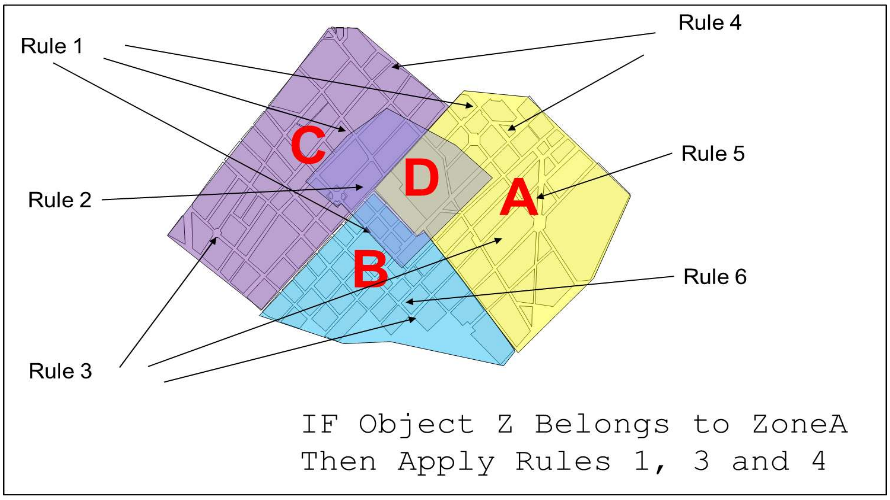

Figure 10. A decision map for located rules.

In Laurini (2017a and 2017b), concerning geoprocessing, new other types of rules can be distinguished:

- **co-location rules** the meaning of which is “if something here, then another thing nearby”;
- **IF-THEN-Zone**, for the creation of a zone from scratch, for instance the administrative creation of a recreational park;

- **Metarules** such as "IF some conditions hold, THEN apply *RuleC*";
- among the latter a special case is **located rules** such as "IF in the place *A*, THEN apply *RuleB*", meaning that when we are in the place *A*, the *RuleB* holds;
- **bi-location rules** such as "IF something holds in place *P*, then something else in place *Q*"; in other domains, this rule is similar to the well-known butterfly effect.

Classically, factor-dependent rules can be organized as decision trees and decision tables. The previous category leads to decision maps (Figure 10).

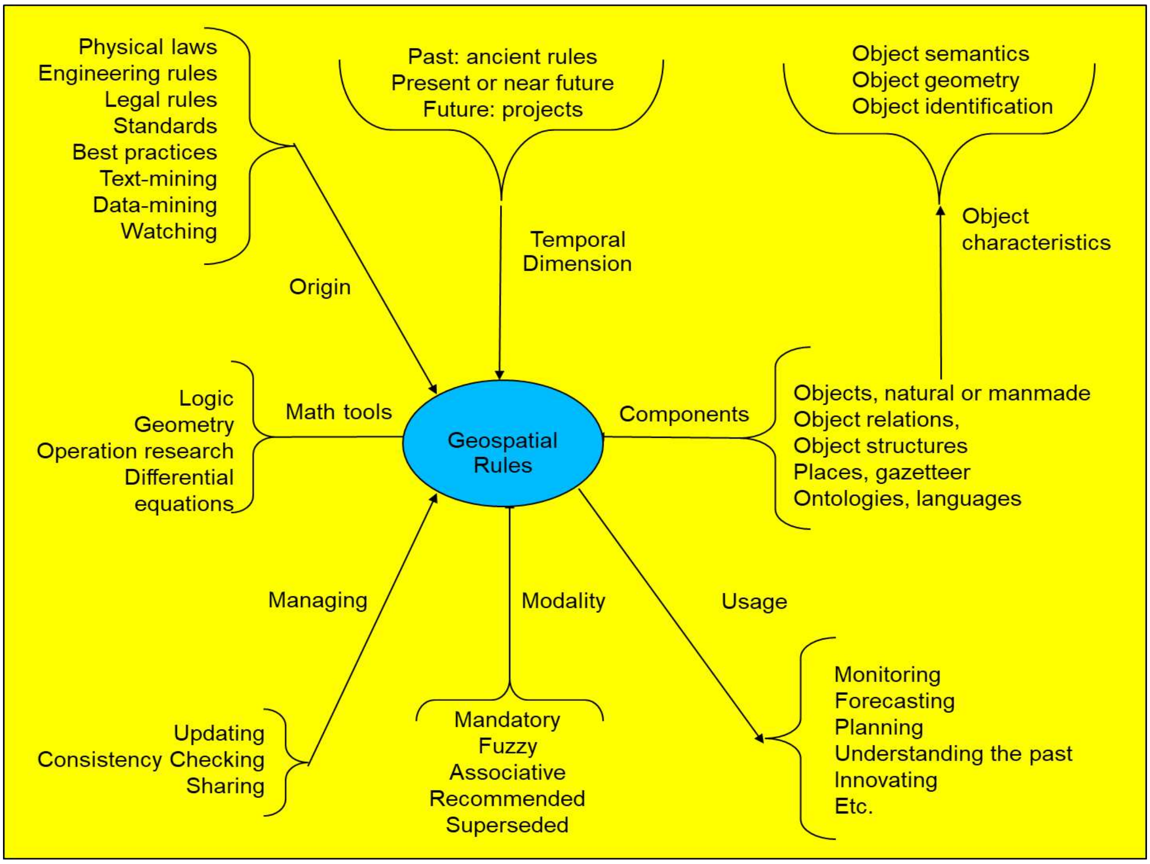

Figure 11. Geospatial rules and their context

Another aspect in geospatial rules is the possibility of being superseded. Indeed, consider a rule such as "in the Northern hemisphere, the Norther we go, the colder" is generally true, but in some place, it can be warmer. Also consider administrative laws which can assign exemptions in a few places.

In Figure 11, geospatial rules are presented together with their context, *i.e.*, their origin, the mathematic tools to model them, their components (objects, relation, structure, places, gazetteer and ontologies), their modalities, their usage and their management. Concerning geographic objects, it is necessary to consider their semantics (linked to ontology), their geometry and their identification (linked to gazetteer).

But the situation is a little bit more complex since several stakeholders can have different rules as illustrated in Figure 8. A possibility is to look for a consensus when the context is not too conflictual. But, what could be the consensus is a boxing match.

6.2. Languages for rule encoding

Several languages to model rules exist. For instance, Boley *et al.* (2010) suggested several XML extensions to model rules. The simplest of these is as follows:

```
<Implies>
     <if>
          <..>
     </if>
     <then>
          <..>
     </then>
</Implies>
```

But in Varadharajulu *et al*. (2016), an example of rule encoding is given concerning road naming in Australia in order to automate the process. Rules are defined using the language SWRL (see https://www.w3.org/Submission/SWRL/ for details).

The main problem is that those languages are overall based on logics, and it is very difficult to integrate aspects coming from computational geometry or operation research. In (Laurini, 2017a), a mathematical language for rule encoding is proposed, but not yet a computer language, essentially because it will depend upon the structuring of geographic knowledge base and system in use.

In (Laurini 2017a), a mathematical language for geospatial rules is given with the following notations:

- **antecedents** will be represented as a context with quantifiers ("∀" or "∃") followed by the symbol ":" and some Boolean expressions to model conditions;
- the symbol "⇒" when the implication is mandatory;
- and **consequents** (as acts or actions); if there are many, they will parenthesized by "{" and "}", and each separated by ";".

For instance, the example given Figure 8 (listed monuments) can be encoded as follows (conservation area of 100 m):

$$\begin{gathered}\forall\, T \in \text{Earth},\ \forall\, B \in \text{PROJECT},\ \exists\, M \in \text{Geo-Objects},\\ \Omega\text{-Type}\ (B) = \text{“Building”},\\ \Omega\text{-Type}\ (M) = \text{“Listed\_Monument”},\\ \text{Inside (Geom } (B), T\text{), Inside (Geom } (M), T\text{):}\\ \text{Disjoint (Geom(}B\text{), Union (Buffer (Geom } (M)\text{, 100)))}\\ \Rightarrow\\ \text{State } (B) = \text{“LM\_Approuved”}\end{gathered}$$

6.3. Chaining rules

A very important functionality is the possibility to chain rules. Consider for instance the case of an architect submitting a projected building for getting the building permit. The local authority's planning officers must examine several standards and official statements to accept the project. In other words, there will be the combination of several rules, such as the height of the building, the proximity to an airport or to a listed monument (Figures 7, 8 and 9). Whether it is a commercial or a residential building, several additional rules must be considered. So, depending of the location and the characteristics, some rules do not apply, but those applied must provide always a positive answer to get the permit. A solution could be to state rules which do not apply as valid.

7 – Geographic knowledge systems and infrastructure

Concerning only geographic knowledge, what could be the differences between a system and an infrastructure? Sometimes, it seems that some authors confuse them. According to the Merriam-Webster dictionary, an infrastructure is defined as "the underlying foundation or basic framework (as of a system or organization)", whereas for Von Bertalanffy (1973) a system is defined as a complexes of elements standing in interactions. In other terms, infrastructure corresponds to the basic and common aspects on which a system can be built.

Let us examine those concepts more in details.

7.1. Geographic Knowledge Infrastructure

Now, regarding urban and regional knowledge, an infrastructure can be proposed based on machine-processable knowledge and human collective intelligence.

It is necessary to distinguish several cases, data infrastructure, information infrastructure and knowledge infrastructure. Regarding spatial data infrastructures, several works have done, among them, the more important seems to be the European initiative INSPIRE[3] which is based on the following principles:

- "Data should be collected only once and kept where it can be maintained most effectively.
- It should be possible to combine seamless spatial information from different sources across Europe and share it with many users and applications.
- It should be possible for information collected at one level/scale to be shared with all levels/scales; detailed for thorough investigations, general for strategic purposes.
- Geographic information needed for good governance at all levels should be readily and transparently available.
- Easy to find what geographic information is available, how it can be used to meet a particular need, and under which conditions it can be acquired and used."

From those principles, it appears that data and information are mixed in this infrastructure. However, regarding spatial information infrastructures, according to Onsrud *et al.* (200'), "spatial information infrastructures and geolibraries span a broad range of technical, social and institutional issues". Finally the boundary between data infrastructures and information infrastructure is not so clear-cut.

However, several authors have advocated the design of knowledge infrastructures (Edwards *et al.* 2013), but few have directly worked on spatial, geospatial or geographic infrastructures (Markus (2002), Dangermond, (2010), Ivanova *et al.* (2017), etc. More precisely, for Stock *et al.* (2012), "a geospatial knowledge infrastructure consists of a set of interoperable components, including software, information, hardware, procedures and standards, that work together to support advanced discovery and creation of geoscientific resources, including publications, data sets and web services". In addition, Duckman *et al.* (2017) define a spatial knowledge infrastructure as "a network of data, analytics, expertise and policies that assist people, whether individually or in collaboration, to integrate in real time spatial knowledge into everyday decision-making and problem solving".

Anyhow, the basic element lays on a Data Infrastructure. Of course, not yet machine-processable

3https://inspire.ec.europa.eu/

knowledge must be considered, essentially when ultimately decisions must be made, as depicted in Figure 12.

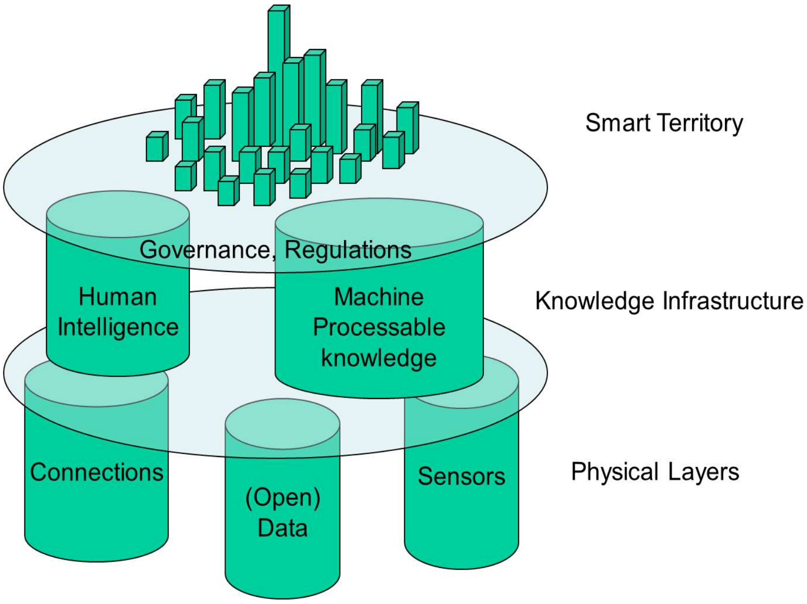

Figure 12. Proposition of a knowledge infrastructure.

For our part, in continuity with the previous definition, let's define a geographic knowledge infrastructure as a "computer repository necessary to store, access and share geographic knowledge, potentially useful to explain, manage, monitor and plan a territory".

A best practice seems that such an infrastructure can be shared by several stakeholders, administrations and companies, whereas a geographic knowledge system belongs to only one of them.

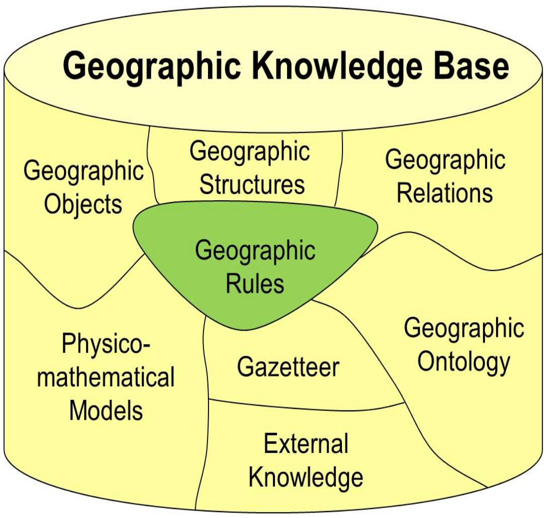

Figure 13. Contents of a geographic knowledge base

7.2. Geographic knowledge systems

In consequence of what has been previously said, any geographic knowledge base (Figure 13) will consist of a set of geographic objects, a set of geographic relations, an ontology, a gazetteer, a set of geographic structures, a set of physico-mathematical models and a set of rules; in addition, external knowledge can also be very useful. For more details, please refer to Laurini (2017a) and Laurini-Favetta (2017). Remember that a gazetteer is storing placenames, and ontologies the description of all types and classes of geographic objects. By external knowledge, we mean two things: (*i*) neighboring knowledge to ensure reasoning continuity, and (*ii*) knowledge coming from outside for both technological and sociological watches which will be the background for innovation.

The general structure is illustrated in Figure 14. The core consists in a geographic inference engine working with the geographic knowledge base together with an input and an output. In input, there is the description of geographic projects such as:

- Where to put a new airport, a new hospital, a new stadium, etc.?
- Is this new construction project compliant with planning rules?
- What is the best mode or the best way to get from A to B?
- Where and what are the priorities?
- How to organize a plan for green spaces in a city?
- How to reorganize common transportation?
- How to transform slums into more modern houses?

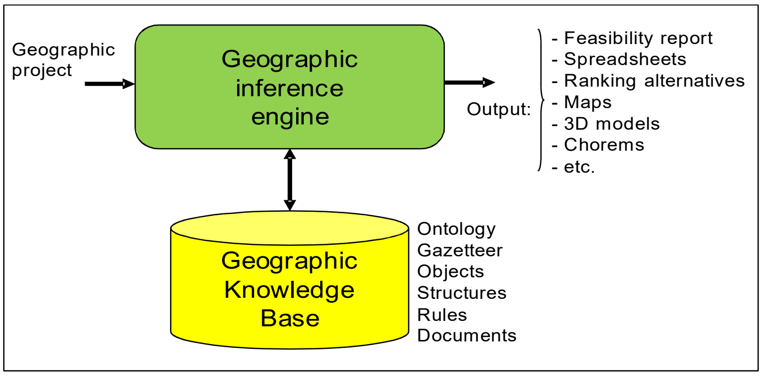

Figure 14. General architecture of a geographic reasoning system.

As output, the more common seems to be a feasibility report consisting in textual or cartographic issues. Among textual issues, let us mention, essentially explanations regarding the possible achievement of the project, comparison and ranking of alternatives. In the cartographic issues, maps can be good candidates and sometimes, chorems can be an elegant way to summarize visually the results (Del Fatto *et al*. 2007). Don't forget to add 3D mock-ups which can be also a very efficient way to represent novel projects though 3D-printing.

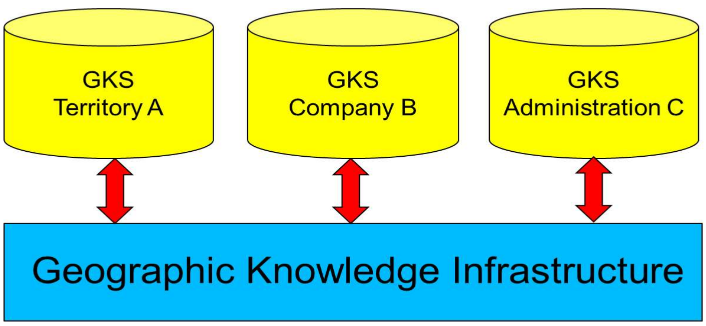

Figure 15. Interrelations between GK systems and a GK infrastructure

7.3. Interrelations

So, a GK infrastructure can be the foundation of several GK systems as exemplified in Figure 15. The GKI will include very general rules, ontologies, documents, services, methodologies and sets of data which can be shared by any GK system. In the other sense, when necessary, some knowledge chunks or bunches will be transmitted to the GKI.

8 – About smart citizens and the knowledge society.

In this infrastructure, human intelligence is one the key-element. In Figure 2, Boyd Cohen speaks about "Smart People" and Mathew (Figure 3) about "Smart Citizens". Let us take the expression "smart citizens"; what do we mean by this expression? If there are smart citizens, what about non-smart citizens? This is a delicate question.

In a lot of papers regarding smart cities, people are cited as smart people or smart citizens. Similarly in papers relative to participation, people are mentioned, stating that smart citizens must be a key-point in smart city development. However, few definitions exist. According to Shankhar[4], "A smart citizen is one who has civic sense and respects the law". What is civic sense? Is this definition rightly covering the subject? Those are important questions to be solved.

Suppose we use the following definition: a "smart citizen" is a citizen who can imagine and act for the general interest. A NIMBY acts for his/her own interest, not for a global interest. A colleague told me that, for a politician, the general interest is what could help him being reelected. For instance, consider the phrase "think globally, act locally"; according to Wikipedia[5], it can be generally attributed to the Scots town planner and social activist Patrick Geddes. So, this phrase can be used to define a smart citizen. But if we take only this definition, few people can enter into this category; a larger definition must be developed. Of course, everything must be done, mainly by education to help any lay people become a smart citizen, in other words to enter into the knowledge society.

Another aspect is to be aware that some stakeholders can have different visions and strong power relationships. The capacity of negotiations and the skill to solve conflicts and overall accept solutions partially against his/her own interest, can also be viewed as desired characteristics of a future smart citizen.

9 – Conclusion and research agenda

Presently, as the philosopher Michel Serres said, knowledge must be considered as an infrastructure (quoted by Lévy, 1994). And for smart cities, knowledge must be considered as one of the basic infrastructure. Secondly, knowledge must also be considered as a common good *i.e.* which refers to what is shared and beneficial for all or most members of a given community.

In this paper, overall some 2D or 2.5D knowledge chunks were presented; but obviously, temporal and tridimensional chunks can be exhibited, for instance for sensor-based regulation or building design. Concerning buildings, with the emergence of BIM (Building Information modeling), applicable standards will be transformed into 3D rules.

Now that more than 50 % of the world population, we can claim that a huge component of the knowledge society will be embedded in cities. However, due to their characteristics, urban

4 http://www.thehindu.com/features/homes-and-gardens/why-smart-cities-need-smart-citizens/article8625075.ece

5 https://en.wikipedia.org/wiki/Think_globally,_act_locally.

knowledge has some peculiarities that were analyzed in this text. In conjunction with actor knowledge and knowledge coming from big data, knowledge bases must be constructed so that some aspects of automatic reasoning for spatial planning must be integrated. And the first step is to transform knowledge chunks into machine-processable knowledge, and in particular, into rules.

In order to integrate cities and territories into the knowledge society, several steps must be considered:
1 – identification of knowledge chunks, including rules, and their characteristics,
2 – clarify the differences between a GK system and a GK infrastructure,
3 – identification of 2D and 3D rule semantics,
4 – identifying a collection of examples and simple applications for early prototyping,
5 – definition of a language for geospatial rules,
6 – structuring and populating knowledge bases,
7 – design of a language for modeling projects and scenarios as input,
8 – integrating building rules with BIM,
9 – identifying output representations (geovisualization) suitable for all stakeholders,
10 – definition of a language for project and scenario modeling
11 – primary specifications of a geographic inference engine,
12 – implementation and execution of the engine,
13 – integration of narrative and visual knowledge,
14 – assessment of the result and possible modifications of the language or the engine,
15 – definition of real-life examples,
16 – acceptability by stakeholders.

Surely, some additional steps should be surely considered for constructing a fully-operational knowledge infrastructure for smart cities.

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