The Future of Spatial Data Infrastructures: Capacity-building for the Emergence of Municipal SDIs

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Abstract

Our paper suggests a realistic and sustainable pathway that will enable the emergence of comprehensive municipal information infrastructures, which in turn will support higher-level integration for spatial planning and decision-making at the regional, state, national and international scale. First of all, we propose to target our efforts to the primary *locus* of spatial change, i.e. the municipality, hence we call the strategy the *City Knowledge* approach (Carrera, 2004). We believe that the creation of sustainable Spatial Data Infrastructures – where data are plentiful and readily available in what we term a "Plan-Ready" scenario – can be achieved by investing time and effort in the creation of comprehensive municipal information systems (Carrera and Hoyt, 2006). The City Knowledge approach is founded on the premise that urban change falls almost entirely under municipal jurisdiction, and specifically under the purview of individual municipal departments. This paper therefore proposes to "grow" this knowledge from the middle-out, integrating a top-down approach to standardization (Craglia and Signoretta, 2000; Nedović-Budić and Pinto, 2000), with a bottom-up approach to neighborhood-scale 'atomic' data accrual (Ferreira, 1999; Talen, 1999). We believe that a web-services approach (Singh, 2004) would provide the technical mechanisms whereby towns will be enabled to accrue and maintain their municipal information in an inexpensive, efficient and sustainable manner.

The "middle-out" approach combines the benefits of top-down and bottom-up initiatives, while largely avoiding their respective pitfalls. Thus, instead of proposing a top-down solution to municipal data management, this paper suggests a distributed scheme whereby each department would be in charge of the upkeep of its own urban data, leveraging the power of Geographic Information Systems (GIS) as the platform for intra- and inter-departmental sharing of information. The novelty in this approach – as exemplified by the concept of the "birth certificate" which captures piecemeal "urban change" within a geospatial infrastructure – lies in its pragmatic, yet systematic pursuit of exhaustive, fine-grained, department-level datasets for each physical structure and dynamic activity in the urban realm, and in the identification of the implementation tools available to municipal governments, as well as of the technical and administrative mechanisms for capturing permanent as well as ephemeral change when it is directly or indirectly caused by official municipal acts.

Keywords: Municipal information system, urban data management, spatial data infrastructure, capacity building

1. PREAMBLE

Every single day, municipal governments make maintenance, management, planning and policy decisions that affect the inhabitants of the city or town as well as its coffers. Invariably, to support these decisions, a great deal of time is spent gathering information by scouring the archives of the various departments and by leveraging personal contacts with those who are the "institutional memory" of the department (Ghose and Huxhold, 2002, 5; Nedović-Budić, 2000, 82). Meanwhile, administrative data are gathered by city offices incessantly for specific purposes, most often connected with revenue-generation (taxes, fees, etc.) or regulatory compliance (permits, licenses, etc.) (ICMA, 2002). Yet these data are more often treated as "documentation" supporting a specific act or deliberation rather than as "information" that can be reused over and over in other contexts to support other municipal tasks (Masser and Wilson, 1984).

The diminishing cost of computer hardware and software has led to a proliferation of homegrown GIS initiatives that address specific needs of municipalities. Increasingly, there have been attempts to harness the richness and diversity of such independent activities to reduce wasteful redundancy and duplication and to maximize the synergistic potential of a coordinated approach to geospatial information management (Klosterman, 2001). Top-down initiatives emanating from the national level (National Research Council (NRC), 1993) have led to the creation of Spatial Data Infrastructures (SDIs) (Nedović-Budić et al., 2004) which in turn frequently include provisions for a core set of so-called "framework data" (Tulloch and Fuld, 2001). Simultaneously, bottom-up efforts are looking at the role of neighborhoods in the development of a finer-grained spatial data infrastructure (Talen, 1999) through Community Statistical Systems (CSS) and the like. Citizen groups, with the aid of academia, are producing the neighborhood-level equivalent of national framework data, through such efforts as the National Neighborhood Indicator Partnership (NNIP) (Sawicki and Flynn, 1996) that tries to consolidate indicators of urban well-being using public administrative data sources (Coulton et al., 1997). Meanwhile, technical standards that allow the exchange of spatial data are also being developed primarily by the Federal Geographic Data Committee (FGDC) of the National Spatial Data Infrastructure (NSDI).

Current trends indicate a move toward the development of local geographic information strategies (Craglia and Signoretta, 2000; Tulloch and Fuld, 2001) to capture the finer grain of urban data that community statistical systems require (Ferreira, 2002). There begins to be also a discussion about the importance of supporting the development and maintenance of local databases (Nedović-Budić, 2000, 87) so that distributed municipal information systems can be assembled without redundancies from a series of networked systems, connected via the World Wide Web (Kelly and Tuxen, 2003), and developed in a coordinated manner (Keating et al., 2003), based on agreed-upon structures, processes and policies (Nedović-Budić and Pinto, 1999, 56-59) for the creation, archival, maintenance, updating, removal and sharing of urban data.

As Keating *et al.* (2003, 5) put it, a first challenge "lies in striking a balance in the degree of centralization of data storage, administration, and procedural control while serving the needs of the community […]". Moreover, according to the University Consortium for Geographic Information Science (UCGIS),

> *"As the variety of geospatial information and data resources increases each year, the demand for understanding and building sustainable information and knowledge structures remains a critical research challenge for the geo-spatial information community."* (Shuler, 2003)

So the problem today is not the availability or capability of technology for planning, but rather the availability of "good" fine-grained, up-to-date data that are maintained by the administratively responsible agencies, and are loosely-coupled as federated databases that connect to a service-oriented architecture (Singh, 2004). What's also missing is an active pursuit of the creation of systematic, maintainable storehouses of urban knowledge that are accumulated in the course of performing urban services, and are sufficiently cross-referenceable (by entity type, time, and place) to be useful for higher level urban management, planning and policymaking. According to the established "Communicative Action" paradigm (Innes, 1998), the way forward is to embed in the planning community – and in municipal administration in general – an innate appreciation for the value and importance of information at every level of urban maintenance, management and planning. This shift of mindset would enable a sea-change to take place in how cities collect and organize information (Carrera, 2004).

This paper, as its title implies, addresses directly the aforementioned research priority of the UCGIS. It specifically focuses on the organizational, institutional, technical, logistical and financial mechanisms whereby appropriate local authorities could systematically build up a comprehensive set of fundamental datasets and map layers. The gradual, but systematic compilation of all the disparate datasets accumulated by a wide variety of government and non-government organizations is what we term the *City Knowledge* approach. The authors draw upon their experience with GIS-related projects in Italy, UK, and US to illustrate how recent improvements in geospatial technologies and location-aware computing make it practical to address City Knowledge issues at a level of spatial granularity that (finally) matches the needs of urban planning and management. In this context, this paper introduces the "birth certificate"mechanism that would allow municipalities to record change as it happens and to delegate such recordkeeping to the "agents of change" who actually generate the physical change to the urban lansdscape in the real world.

Comforted by the latest developments in the definition of "core" framework datasets (Nedović-Budić et al., 2004; Harris, 1999, 330; Tulloch and Fuld, 2001), and by the current trends among researchers toward a "local" approach to the creation of comprehensive municipal information systems (Craglia and Signoretta, 2000), using smaller and smaller jurisdictions to allocate responsibility over specific data layers (Nedović-Budić and Pinto, 2000, 468), we are confident that our City Knowledge approach will prove to be a valid contribution to the creation of emergent, comprehensive, updatable municipal information infrastructures.

2. THE CITY KNOWLEDGE APPROACH

The fundamental goal of City Knowledge is to bring about a paradigmatic shift in the mindset of municipalities whereby they will begin to treat information as a primary infrastructure, parallel to other physical and/or administrative infrastructures such as transportation, water, sewers and education. We are actively engaged in the process of causing such a shift to take place department by department within local governments in the U.S., U.K. and Italy.

City Knowledge relies on a set of basic premises as well as on a number of fundamental principles extracted from the academic literature. In a nutshell, the premises of the City Knowledge approach are the following:

1. Municipalities are the *locus* of urban change;
2. Municipalities are composed of two fundamental elements: structures and activities;
3. Urban data are either already "out there" (the so-called "backlog") or will be produced in the future by changes to either structures or activities;
4. Top-down and bottom-up approaches to urban data management have pros and cons, but do not seem to produce sustainable urban information systems;
5. Space is the "glue" that can connect disparate urban datasets;

6. Governments only have a few tools at their disposal to manage and control change[1]

A prior paper (Carrera and Hewitt, 2006) discusses these premises in detail. Each section in that paper is also accompanied by illustrative examples of how these fundamental propositions applied in the London Borough of Merton. On the basis of such premises, we have identified practical mechanisms that can at least facilitate the attainment of such positive traits (Carrera, 2004). Once the primary paradigm shift has taken place toward an information-conscious *modus operandi* in all municipal operations, City Knowledge can begin to emerge, based on the following foundations:

1. Distinct informational jurisdictions
2. Distributed, atomic data acquisition and organization
3. Sustainable update mechanisms
4. Institutional and/or voluntary sharing of information
5. Interagency coordination

The key to the emergence of a body of municipal knowledge greater than the sum of its parts is the so-called "middle-out approach" to the development of City Knowledge

An exhaustive discussion of these principles can be found in Carrera (2004).

In this paper, we focus specifically on items 2 and 3 in the above list. We introduce a very powerful mechanism for distributed, atomic data acquisition and organization which we call the "birth certificate", which is an example of how a careful combination of the limited government tools available to municipal governments (see footnote 1) can bring about the necessary changes in municipal processes, which in turn will facilitate the emergence of comprehensive information infrastructures that can be sustainably updated in perpetuity. Moreover we suggest delegating the upkeep of geospatial information to "change agents" in order to move toward more sustainable and cost-effective municipal information infrastructures. Finally, we forecast that, in the foreseeable future, web-service technologies will enable most municipalities to engage in the systematic accumulation of city knowledge for their own direct benefit. To facilitate the illustration of our main points, each section of this paper is accompanied by specific examples of a "real world" implementation, related to the management and maintenance of a typical municipal infrastructure: a town's road network.

3. ENABLING THE EMERGENCE OF SUSTAINABLE INFORMATION INFRASTRUCTURES

It is safe to assume that most contemporary scholars and practitioners will agree that it makes sense for physical assets, such as roads, which require periodic maintenance by municipal departments, to be properly represented on computer systems as geo-spatial virtual assets capturing all the salient characteristics of the real things. Using roads as our running example, we will now focus on how such a parallel, virtual representation of the real roads ought to be created and maintained, leaving out some of the technical implementation details to which many scholarly papers are usually devoted, and focusing instead on the enabling technologies and on the pragmatic procedures that can make these parallel universes emerge over time. Although this paper focuses on tangible assets (what we call "structures"), many of the principles described herein could also apply to "activities", such as traffic or economic development, that

[1] Schuster *et al*, (1997) suggest 5 tools: (1) Ownership and operation; (2) Regulation; (3) Incentives/Disincentives; (4) Education and Information; (5) Rights; Carrera and Hewitt (2006) propose a sixth tool: (6) Mitigation and compensation.

fall under the management or planning purview of a municipality (Carrera and Hewitt, 2006; Carrera, 2004).

Our "middle-out" philosophy suggests that municipal information infrastructures will be built around the "real assets", based on clear informational jurisdictions. In the case of roads, we have been collaborating with some municipal Departments of Public Works (DPW) or Highway Departments, which are the primary entities in charge of the upkeep of the physical road assets, and have therefore entrusted them with the simultaneous upkeep of the "virtual" road assets as well. Typically, a DPW will begin creating a geo-spatial representation of its roads by mapping the existing network and gathering basic information about each road. This process, which we call "catching up with the backlog" (Carrera and Hewitt, 2006; Carrera, 2004), may be conducted by DPW staff, by other municipal departments (such as the GIS or IT department) or by external consultants.

In this paper we have purposely chosen to avoid delving in the devilish details of metadata, ontologies and topologies. Nevertheless, the concept of "birth certificate" could be seen as a fundamental nucleus of metadata that can act as an everpresent building block for more elaborate meta-descriptions of municipal geo-spatial urban elements. Moreover, the City Knowledge approach allows for a vertical convergence on ontolological issues through the top-down consensus developed in the course of "interagency coordination" (item 5 in above list - covered in more detail in Carrera, 2004). Additionally, our approach encourages municipal departments to develop "atomized" topological representations of urban elements, based on local needs as well as on wider standards and practices in that arena, without having to wait for an ideal top-down solution from the higher echelons of municipal, state or federal government. We assume that a consensus solution will eventually emerge from the self-correcting scrutiny of a hierarchy of actors, and we expect that it will be relatively simple for municipalities to reconfigure our "atomic" urban elements to conform to evolving top-down standards.

Regardless of the initial geo-spatial representation of existing assets, to make a municipal spatial data infrastructure sustainable over time, the really important issue is how to maintain the information up-to-date, a process that we call "intercepting future change". The trick is to clearly identify the mechanisms that generate change in the real world and to tap into these processes to maintain the virtual world consistent with the changes in the real one. A good portion of this paper is dedicated to this important aspect, which alone can guarantee that a spatial data infrastructure (SDI) will be reliably re-usable over time and across departments and disciplines. Since we believe that practically <u>all</u> change is filtered through municipal administrative processes, our focus has been on the development of mechanisms to intercept change at the local level, by tweaking the existing bureaucratic procedures already in place in most of our cities and towns. We use the example of roads to exemplify how existing procedures could be amended to continually provide the information needed to maintain our municipal information infrastructure up-to-date.

The key steps in the implementation of sustainable update mechanisms are:

1. Establishing a "birth certificate" for each new "real" asset;
2. Delegating the update of geo-spatial datasets to those who effect the "real" changes;
3. Enabling the upkeep of the "virtual" assets through widely-available, easy-to-use technologies;

4. THE "BIRTH CERTIFICATE" CONCEPT

A very fundamental tenet of City Knowledge is the attribution of clear "informational jurisdictions" over the "birth and death" of the "structures" that make up our urban environment, as well as over the "actions" that occur within it (Carrera, 2004; Nedović-Budić and Pinto, 1999, 58). One should not confuse the concept of informational jurisdiction with some form of *exclusive* responsibility over the maintenance and management of these city elements by a single entity or department. Nor, should our informational jurisdictions be mistaken for an assignment of complete "ownership" over all information that pertains to a specific item.

In the domain of physical structures, the definition of clear jurisdictions that we propose refers solely to the "parental authority" over the certification and formalization of the birth and death of these objects within the municipal administration. The notion here is that the physical assets that make up the "public" part of a city – roads, buildings, trees, parks – have an "administrative existence" that begins and ends with official bureaucratic acts that always accompany operative government actions in the real world. In Massachusetts, most new roads are constructed by developers within residential or commercial subdivisions. Very rarely is a local road actually built by the town itself. In fact, practically all road creation happens in the private sector, although most privately-built roads eventually get absorbed into the municipal public road network, whereby a town becomes the official maintainer of the asset. Thus, the administrative birth of a road could be treated in a manner that is not too dissimilar to how our own birth is also "tracked" by an official administrative act – namely our birth certificate – when we are physically born into the world, and by a subsequent "adoption" certificate when the road passes from private to public hands.

Regardless of whether the original paternity is public or private, though, we think that the parents of an asset should be in charge of recording its birth information into a municipal information system set up for such a task. In the case of a typical new Massachusetts road, we believe that it should be up to the developer to create a new GIS object (centerline, road polygon and even right-of-way buffers), as well as to populate the attribute-set with fundamental and permanent metadata about the newly created road. Only later, would the town take ownership of both the real asset as well as of its virtual representation (geometry as well as attribute data). This is how we deal with human births (and deaths), which are entirely private events that the public is simply notified about, so that public rights and duties can be bestowed upon the newborn (and later removed upon death). In fact, a lot of private property that the public cares about – generally for regulatory or taxing purposes – such as land, buildings and cars, already receives a treatment that is similar to that of human birth and death certification. Unfortunately, many urban assets that are directly under public management or maintenance do not receive the same treatment, since they are not subject to taxation or direct regulatory oversight.

The birth certificate for a new municipal asset, would start simply with the assignment of a label or code to the new asset (in our case the road) to identify it unambiguously vis-à-vis all other assets of the same type (i.e. other roads) in the city. This process parallels what happens in our own lives when we are immediately attributed our "given name" by our parents so that (among other things) we can be quickly tagged with a bracelet to avoid being "switched at birth" in the nursery room. In the case of roads, private developers (or contractors hired by the town) will generally have "informational birthrights" over new streets and it would thus be their responsibility to create the corresponding GIS elements, as well as to provide an initial set of data attributes to attach to such geographic entity on a municipal geographic information system, using standards specified by the municipality The following section of this paper illustrates some of the creative ways in which a municipality can actually induce developers and other “agents of change” into providing “birth certificates” and other data updates. Developers and contractors know every minute detail about the new road they just built, and they possess precise engineering (CAD) drawings about all of its construction specs, therefore they are best suited to provide the initial geographic representation of the road for the emergent municipal infrastructure. In concert with the town’s departments, the developer/contractor should also assign a unique name and/or code to identify each segment of the new road from that moment on. In addition to “naming the child”, as we humans do at birth, the “road birth certificate” may contain a few additional immutable parameters, such as the name of the parent(s) – i.e. the constructor and/or developer – the date of birth (i.e. the date of completion of the road), and perhaps some additional descriptive pieces of information, such as details about the surface of the road, dimensions, etc. These birth records are a necessary foundation to city knowledge although they are not sufficient, by themselves, to support all of the desirable re-use capabilities that were discussed elsewhere (Carrera, 2004).

To induce the birth parents to produce such geospatial birth certificates, the town will need to employ the six tools (see footnote 1) in a creative and coordinate manner, as explained in the next section. In some Massachusetts towns, we have already successfully experimented with the use of the disincentive tool by adjusting municipal regulations so that the fees associated with the submission of subdivision plans will get higher for developers who choose to turn in the old-fashioned paper plans, while reducing the fees for those who submit the plans in GIS format (as an incentive).

Once a town accepts a newly constructed private (subdivision) road, an “adoption certificate” should be issued which will augment (e.g. with the date of adoption) and update (e.g. with final information about topcoating, etc.) the dataset that accompanies that road since birth. After the town has accepted a private road, it becomes part of the municipal network and the town becomes responsible for all subsequent surface repairs, as well as for the cleaning of catch basins, the painting of lines, the upkeep of signs and guardrails, the landscaping along the shoulders, the plowing of snow and for other typical road maintenance activities, which ought to be tracked by the town from that point on. In this scheme, we recommend that the town should also simultaneously take over the upkeep of the corresponding information, though it may try to delegate this function to outsiders as explained in the next section.

Despite the longevity of roads, even <u>they</u> occasionally become abandoned (in whole or in part) and they therefore officially cease to exist in terms of public maintenance or management responsibility. Therefore, a department needs to be given “deathrights” over the recordkeeping related to the removal of the road from public care. Just as we have “death certificates” that formalize our passing from this life, some department (like the DPW) needs to have the authority to remove the road symbol from the road layer in the municipal GIS, so that everyone will know that the road no longer exists. A record of its existence ought to be kept for historical reasons, but it would otherwise disappear from current maps and databases.

Establishing birth, adoption and death certificates for assets that are subject to municipal maintenance, management or planning – regardless of whether they are eventually owned and operated by public or private entities – would not only reflect how human beings manage their own personal birth, adoption and death information, but would more importantly guarantee the long-term reliability of a municipal information infrastructure. The next section explains how this recordkeeping can become commonplace in the management of municipal information.

5. DELEGATING DATA UPKEEP TO THE "AGENTS of CHANGE"

The assignment of very clear jurisdictions over birth rights and death rights (as well as adoption rights) for each element of the municipal infrastructure is a *conditio sine qua non* for a comprehensive municipal information system to function properly over the long run. Just as in the world of human beings, the original paternity over a physical asset is fairly straightforward. Whoever builds, creates or installs the asset is responsible for its birth certificate. Whoever adopts it, accepts maintenance responsibility for it, *in loco parentis*. Whoever has jurisdiction over it when it ceases to exist is in charge of its removal from the record books – though traces of its existence may be kept for historical purposes.

But outside of these major events in the existence of an urban element, a variety of information may be collected and attached to these items. It happens to all of us after our own birth: schools attach grades to our personal records; the department of motorvehicles keeps track of our driving record; the IRS knows all about our financial affairs; credit companies rate our creditworthiness; our employers track our performance and salary; and so on. The prerequisite for the unequivocal attribution of all these disparate records is that each person needs to be uniquely and unequivocally identified. In the USA, the social security number has become the de-facto identifier of citizens and residents. A national ID number plays the same role in other countries. First and Last names are in fact typically insufficient to differentiate among individuals.

Once the "parents" of an object have uniquely named it (and coded it), other interested parties (municipal departments, other government agencies as well as private entities) will hopefully also use the same given name/code as their internal identifier when they manage their own – possibly proprietary – information about that asset. This convergence of the naming conventions about each urban element will implicitly foster greater interoperability whenever data is willingly exchanged between different public and/or private entities. Essential data about the physical artifact will be under the jurisdiction of the public entity that is in charge of its management or upkeep. In the case of roads, the DPW will have jurisdiction over the maintenance of both the real road as well as of its virtual representation on geospatial databases. All other accessory information about the asset will be maintained by those who need it, as is typically done with human beings.

Having informational jurisdiction over roads does not mean that the DPW should actually be directly responsible for updating the GIS or datasets every time a change occurs. It is quite preferable for a town to delegate such updating activities to outside entities, such as contractors, especially when the latter are the actual agents of change. In the same manner in which the DPW is in charge of real roads, yet it subcontracts their plowing, resurfacing and line painting, the DPW should also include the upkeep of the information that accompanies such activities in the same maintenance contracts. *In short, those who are most closely associated with real change to the asset should also be in charge of recording such changes in the municipal information system.*

Thus, either the actual maintenance of the asset is carried out by internal municipal staff, in which case the same municipal staff will also be in charge of updating the computerized recordset, or, if the maintenance is outsourced, so should be the upkeep of the related information. For example, if the DPW is in charge of installing traffic signs, its own personnel should maintain the respective GIS layers and related datasets. If, however, the DPW hires outside contractors to install guardrails, it should also include in the official bid and contract the provision whereby the contractor will need to provide acceptable GIS geometries and data records according to municipal standards. Until the required information is inserted in the municipal information system and validated by DPW personnel, the contract is not fulfilled and payments are withheld, just as they would be if the real guardrail was incompletely or incorrectly installed.

From the moment the road is born into the municipality (e.g. from the moment it appears on a shared web-GIS system), until its "official death", different departments will be able to attach assorted pieces of information to this road, by creating relational databases that can link to the road through its unique code assigned at birth. For instance, the town's traffic engineer may attach traffic volume information to each road segment via the codes that the DPW maintains about the physical roads. The ability to link up information to an object may depend on permissions granted by those who have jurisdiction over it. Overall accords about "read" and "modify" rights might also be agreed upon and propagated in a top-down fashion by a committee that coordinates the creation of the City Knowledge system in a town. In general, linking ought to be universally permissible to those who want to attach their own datasets to geographical representations of publicly-owned properties. Beyond the sharing of mere codes and spatial locations, selected portions of municipal datasets may also be made directly accessible to outsiders, through a system of permissions. Authorized users could be granted "field-level" permissions that would specify exactly which fields in which database are accessible to whom, for reading, writing or modifying.

Although several scholars have recently discussed similar concepts (Craglia et al., 2004, 61; Reeve and Petch, 1999, 155-156), the primary novelty of our approach lies simply in the renewed focus on information and space. In this *information aware* context, we can then be more overt about assigning jurisdictions over the accrual and updating of the data. In the simplest situations, our proposal gives primacy to the spatial aspects and therefore assigns the jurisdiction to the front-line offices that are actually interacting with the physical world and are doing the hands-on installation or "creation" of the object in the real world. Next in line for jurisdiction over updates – in case no municipal department is directly involved in the birth of the object – would be the department that last authorizes the creation/installation of the structures, or the department that is in charge of managing the activities.

The main departure from currently popular practices is the attribution of a special importance to the exact place of birth and death of administrative objects, so that appropriate jurisdictions can be drawn up using consensus approaches based on the locus of such administrative events. The politics of such a consensus approach would surely be quite intriguing and potentially detrimental to the success of this aspect of the City Knowledge approach, yet there will be plenty of uncontested jurisdictions that are unequivocally already under the sphere of influence of a specific office or department. Our pragmatic, middle-out strategy suggests that we should start organizing urban data within these clear-cut, *de facto* domains before we get into the more controversial ones.

4. ENABLING CITY KNOWLEDGE TO EMERGE VIA WEB-SERVICES

The two concepts discussed in the preceding pages – birth certificates and delegating information maintenance to the "agents of change" – are conceptually related and quite intuitively straightforward, yet they are not in widespread usage in cities and towns as part of a strategic approach to treat information as an infrastructure. Under other guises, these concepts appear here and there in individual departments' operations, often as a consequence of the acquisition of commercial software applications that specialize in the recordkeeping associated with specific departmental functions, such as work orders, pavement maintenance, or the like. Yet, to the best of our knowledge, no city has instituted a town-wide approach akin to what is described above, and at the same time made it possible for the various departments to easily and freely share information with each other and with the outside world.

Most city-wide solutions have been entrusted to professional consultancies or software vendors charged with finding an “enterprise solution” for the whole town. We are skeptical about the efficacy and sustainability of these top-down, silver-bullet approaches, though we appreciate their well-intentioned desire to surpass the pervasive application-oriented stovepipes, information islands and specialized information silos that permeate the municipal landscape nowadays.

We foresee a future in which comprehensive municipal information systems will gradually emerge as a federated web of loosely-coupled, yet compatible building blocks catering to the day-to-day needs of individual municipal departments. We are spearheading the creation and adoption of modular solutions that adhere to open standards of interoperability, which we hope will spread freely (Godin, 2001) to even the smallest towns via the internet, eventually reaching a tipping point (Gladwell, 2000). We firmly believe that a web-services approach will in the end become commonplace in the management and maintenance of municipal information infrastructures, dramatically lowering the barriers to entry for cash-strapped municipalities. A new business model will need to be developed that harnesses the powers of the “long-tail” (Anderson, 2006) both in terms of municipal data collection as well as with regards to the provision of for-profit information services.

In short, we think that recent tools (like Google Earth and YouTube) have heralded a new era of democratization of the tools of production and we can imagine how collective intelligence techniques – like crowdsourcing, wiki content, collaborative filtering, reputation management, and others – borrowed from other Web 2.0 businesses, such as del.icio.us, Flickr, Wikipedia, Amazon, SlashDot or Ebay, will metamorphose into equally effective and innovative mechanisms that will foster an explosion of geoinformation solutions. We suspect that the nature of these bottom-up tools will reinforce our credence in the centrality of municipalities in the geospatial ecosystem (Lessig, 2007). A new era will be upon us before long wherein old-school approaches to urban information systems will be supplanted by novel, engaging, flexible, robust and reliable federated systems, wherein commercial interests will shift their focus from software-system solutions to information-content services.

To support these middle-out efforts, both *City Lab* at WPI and the Urban Information Systems (UIS) group in the Department of Urban Studies and Planning (DUSP) at MIT are developing online systems that exploit the web-services approach to make information available to municipalities in an inexpensive (often free), efficient and intuitive manner. In particular, *City Lab*’s urban information tool, nicknamed LOUIS (Local Online Urban Information System), is an open-source, AJAX-based geographic information system derived from OLIVER (On LIne data ViewER), a set of mapping services and tools developed by the Massachusetts state authority for GIS (MassGIS) that supports the web mapping service (WMS) and web feature service (WFS) protocols of the Open Geospatial Consortium (OGC). A tool like LOUIS would enable municipalities to successfully harvest their various “data plots”, by distributing the onus of creating and maintaining data inventories to the department or division that has the clearest ‘paternity’ over them. A primary duty of the ‘parent department’ (or division) will consist in the institution of formal ‘birth certificates’ to clearly identify each urban element with its ‘baptismal name’, i.e. a unique code that allows other datasets to refer to the same physical object unequivocally from that moment on (Carrera and Hewitt, 2006).

The UIS group at MIT is developing, through a Brookings-funded project, “intelligent middleware” approaches for sharing data within a metropolitan area in a manner that is intended to be more effective, scalable, and sustainable than the traditional 'data center' approach (Ferreira and Singh, 2007). The proposed tools and methods provide mechanisms for accumulating and utilizing local knowledge about neighborhood-scale land use, ownership, and market potential. The basic idea is to codify local knowledge in ways that can be isolated from both the official datasets and from the definition of maps and reports that generate the desired analyses and community indicators. The local knowledge is codified as 'business rules' that produce virtual tables (called *façades*) when applied to the read-only official data (called *basetables*). Reports and Thematic maps that use these façades can be defined and saved as if the façades were permanent tables. However, authorized users can change the façade rules online independently from running the maps and reports or choosing alternative basetables. The system is implemented using web services and open source software on a Linux server with access control for users and groups at the level of individual façades and reports. Use of web services with XML messaging and Open Geospatial Consortium protocols enables distributed access from a variety of desktop applications including MS-Excel, Google maps, Google Earth, ArcGIS, and ordinary browsers.

These systems demonstrate how spatial tools can be used to index and correlate a number of datasets – residing even on separate servers – thanks to a common underlying geographic reference platform and thanks also to the emerging standards for interoperable geospatial services. Gradually, such systems will support extensive facilities for the online creation, removal, modification, updating, downloading, viewing and printing of municipal geospatial information through distributed web-services. The underlying schemas, metadata, ontologies, attribute sets and formats will track the developing geospatial standards, while allowing maximum freedom and flexibility in developing customized client applications. Provided that datasets about municipal structures and activities can be connected to geographic elements via unique IDs, we think that independently created geospatial data can be shared and re-used through the use of customizable filters, “façades” and other middleware (Ferreira and Singh, 2007). We also think that after an initial period of anarchy, it seems reasonable to expect that reputation-moderated peer-production, together with folksonomies and other Web 2.0 innovations will steer the whole City Knowledge movement towards some convergence. Towns will benefit from extremely rich and fine-grained datasets, with little or no investment, while professional consultants will earn their fees by conducting second-order analyses based on the accumulated storehouse of city knowledge, while software developers will profit by selling web-services instead of enterprise systems to the private and public entities who actually benefit the most from the data thus accumulated.

5. CONCLUDING REMARKS

A revolution is coming in the field of urban and geospatial information systems. Our bet is that it will be focused around fine-grained data, collected more or less for free through peer-production or through contractual obligations, predominantly by non-municipal personnel. Detailed information about urban change will be channeled into web-based municipal information systems and archived in secure servers via a series of mechanisms managed and validated by individual municipal departments exploiting the five or six tools at their disposal. Such cumulative, always-up-to-date municipal knowledge could then be accessible to multiple users for multiple purposes, within or without the municipal firewall, via permissions granted by the "parent" department.

Web 2.0 tools and techniques will be adapted to the municipal realm to exploit the characteristics of the "Long Tail" that apply to urban information, such as the fact that over 80% of the world's municipalities have less than 10,000 inhabitants and that the vast majority of urban change is authorized by a small minority of municipal departments. There will be a move away from top-down standardization to facilitate the free flow of information, forcing municipalities to become moderators and validators of crowdsourced and outsourced urban data, vetted through sophisticated reputation-management systems. Software companies that are investing in the creation of one-size-fits-all "enterprise solutions" for municipalities will see their market monopolies erode when new, agile, and recombinant software modules will begin to spread by word-of-mouth. This "viral" diffusion will in turn allow "domain experts" (Rosenberg, 2007) with a clear understanding of frontline municipal operations to acquire the capacity to mashup modular applications to suit the specific needs of niche users (like themselves). In the process, de facto standards for information interchange will spontaneously emerge, based on the foundation laid out by the Open Geospatial Consortium.

Proprietary solutions that are not modular and do not adhere to open interoperability standards will be shunned by users that have grown up with the freedom and flexibility of products like Google, del.icio.us, Myspace and the like. The new market leaders in Municipal Information Systems will adopt novel business models to make a profit without charging municipal governments a dime. Web services will be the new currency and the private sector will fund the creation of these systems due to the irresistible value proposition represented by "plan-ready" information.

The future of Spatial Data Infrastructures therefore lies in creating capacity at the municipal level so that these Municipal SDIs can emerge and spread from the middle out, gradually filling in the tassels of the greater (regional, national) spatial puzzle. Spurred by the government's judicious combination of the few, yet powerful, tools at its disposal, individuals as well as corporations will contribute to – as well as benefit from – the emergence of Municipal Spatial Data Infrastructures and towns will be able to use their "plan-ready" City Knowledge to become more effective and efficient in providing maintenance, management and planning services to their citizens.

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