# Ontology based local spatial data Infrastructure for smart City Development

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## Abstract:

In the developing countries like India the vision of 100 smart cities is forming a multi dimensional digital platform to nurture, preserve and renew the strained urban fabric according to the increasing social and economical demand of population. India's cities are growing faster than its capacity to manage them. Therefore, city models with smarter approaches to city planning and management are critically needed.

Geospatial information forms the very foundation of all planned human activities, technologies that can decisively help in planning and informed decision making in knowledge-based policy driven and sustainable smart city development. To enable the sharing of geospatial technology at global, national or regional level spatial data infrastructure (SDI) denotes a framework of technologies, policies, and institutional arrangements that together facilitate the creation, exchange, and use of geospatial data and related information resources across an information-sharing community. Extracting meaningful geospatial information is a complex process because of the heterogeneity of spatial data, the rate of data generation, and the volume. Semantic technologies allow increasing interoperability, easing data integration and providing support to information retrieval and knowledge discovery tasks.

This paper starts with a unique concept of local spatial data infrastructure (LSDI) that share spatial information regarding global city indicators and provide access to updated information collated from different urban utility organizations. Finally an ontology-based web GIS system is developed using ESRI's ArcGIS server to share and analyze the updated information and ontology to improve the decision making in the context of Smart City.

**Key words:** Local Spatial Data Infrastructure, Semantics, Web GIS, Ontology, Spatial Data.

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## Introduction

Over the last two decades world is experiencing an evolution of extreme migration from rural to urban areas. Better educational facilities, employment options, healthcare/medical opportunities, sophisticated infrastructure, modern technology and the desire for better standards of living induce rural people to migrate to cities. This concentration of population inside the city boundaries better known as urbanization can yield positive effects if it takes place up to a desirable limit. Extensive urbanization or indiscriminate growth of cities may result in adverse effects.

Today, India is one of the fastest developing countries in the world but uncontrolled and unplanned social transformation from traditional rural societies to modern urban communities has strained India's urban systems to the point of breaking, creating massive slums with inadequate housing, sanitation, healthcare, education, basic life support services, security and environmental damages. This threatening rush of population to the urban areas disturbed the paramount harmony among the spatial, social and environmental aspects of a city and between their inhabitants. Undoubtedly India needs to work on several areas to manage its urbanization.

Since the arrival of new government in India, a new technical term, a modern buzz word "Smart City" is increasingly used by public authorities and private developers to address the urbanization and sustainability solutions. In the developing countries like India the vision of 100 smart cities is forming a multi dimensional digital platform to nurture, preserve and renew the strained urban fabric according to the increasing social and economical demand of population. But it is not possible to start from the scratch and build 100 new smart cities. So, instead of constructing 100 new smart cities, a lot of emphasis will be on strengthening the existing powers of Urban Local Bodies to make an existing city smart. Whatever the cities which are there, they will be impregnated with smart features and the new cities which will come up will be made smart. But the core problem is, India's cities are growing faster than the capability of existing technologies to manage them. Therefore multidimensional city models with smarter approaches of city planning and management is critically required to convert the most awaited dream of India to improve the quality of life for its 1.2 billion citizens and lay down the foundations for a truly prosperous future.

Geospatial technology emerged as the key solution in knowledge-based policy driven and sustainable smart city development. High precision geospatial data acquisition instruments, efficient geo-processing software, improved geo-visualization framework and simulators help to create the roadmap for planners and policymakers to examine how well a specific city plan is contributing to each and every aspect of sustainability. To enable the sharing of geospatial technology at global, national or regional level spatial data infrastructure (SDI) denotes a framework of technologies, policies, and institutional arrangements that together facilitate the creation, exchange, and use of geospatial data and related information resources across an information-sharing community.

## Semantic web & Ontology

The explosion of personal computers and major advances in the field of telecommunications were the triggers of the web as we know it today. In its first stage the web was meant to be a big working place where the programs and databases could share their knowledge and work together. But with the explosion of the media programs, video games, films, music, pictures, and so on, the web now is almost only used by the humans and not by the machines. Its main problem is that appeared in the WWW is that the information is written only for human consumption in most of the cases. The machines cannot understand what the meaning of what is online is. Semantic Web provides common formats for the interchange of data. The main purpose of the Semantic Web is driving the evolution of the current Web by enabling users and machines together to find, share, and combine information more easily. Semantic Web is generally built on the description of various concepts and relationships that can formally exist for an object or a community of objects. This description is called Ontology. The syntaxes usually used to represent description of concepts and relationships are generally triples based structures. These syntaxes are called "Resource Description Framework" syntaxes.

## Global City Indicators

The Global City Indicators Facility (GCIF) provides an established set of city indicators with a globally standardized methodology that allows for global comparability of city performance and knowledge sharing. The GCIF successfully developed an international standard on city metrics through the International Organization for Standardization (ISO) under the Technical

Committee TC268 on Sustainable Development of Communities [1]. The indicators are structured around 20 "themes" that measure a range of city services and quality of life factors.

**Table1. Global City Indicators**

| CITY SERVICES | QUALITY OF LIFE |
|---|---|
| Population<br>Education<br>Energy<br>Finance<br>Recreation<br>Fire Emergency<br>Response<br>Governance<br>Health<br>Safety<br>Solid Waste<br>Transportation<br>Urban Planning<br>Waste Water<br>Water | Civic Engagement<br>Culture<br>Economy<br>Environment<br>Shelter<br>Social Equity<br>Technology And<br>Innovation |

## Spatial data Infrastructure (SDI)

Spatial Data Infrastructure (SDI) is an initiative intended to create an environment in which all stakeholders can co-operate with each other and interact with technology, to better achieve their objectives at different political/administrative levels [2]. Over the past decade government organizations at provincial, regional, national and international levels, as well as non-governmental organizations and large companies, have been working on the implementation of Spatial Data Infrastructures (SDIs) – with the objective of easing access to spatial data for a wide range of users [2]. Esri has supported many SDI implementations at regional, national, and global scales across the world [3]. Many private and public organizations use Esri technology to create spatial data infrastructures (SDIs) to share geospatial data and resources and work collaboratively to address various challenges of smart development.

In this report we are developing local spatial data infrastructure for a city that contains separate layer corresponding to each city indicator in two broad categories of city services and quality of life. LSDI used by ESRI ArcGIS server to fetch and publish these layers on user specific WMS request. Further the concept is extended for machine understandable domain where a separate application is developed to generate and publish separate ontology services for specific layer.

## Multitier Semantic Web GIS Architecture

This paper extends the concept of multi-tier web architecture. We add an ontology server as an application server in the multi-tier approach. A basic multi-tier architecture follows a basic Client-server architecture in which the presentation, application processing and data access are logically separate processes. In web GIS, client or application sends an HTTP request to the web server. The web server forwards the request to the application server. The application server then responds to the request by forwarding it to the appropriate map server and manages the load amongst the map servers. The Map server then further synthesizes the request and performs the appropriate GIS function while retrieving the data from the data server [4].

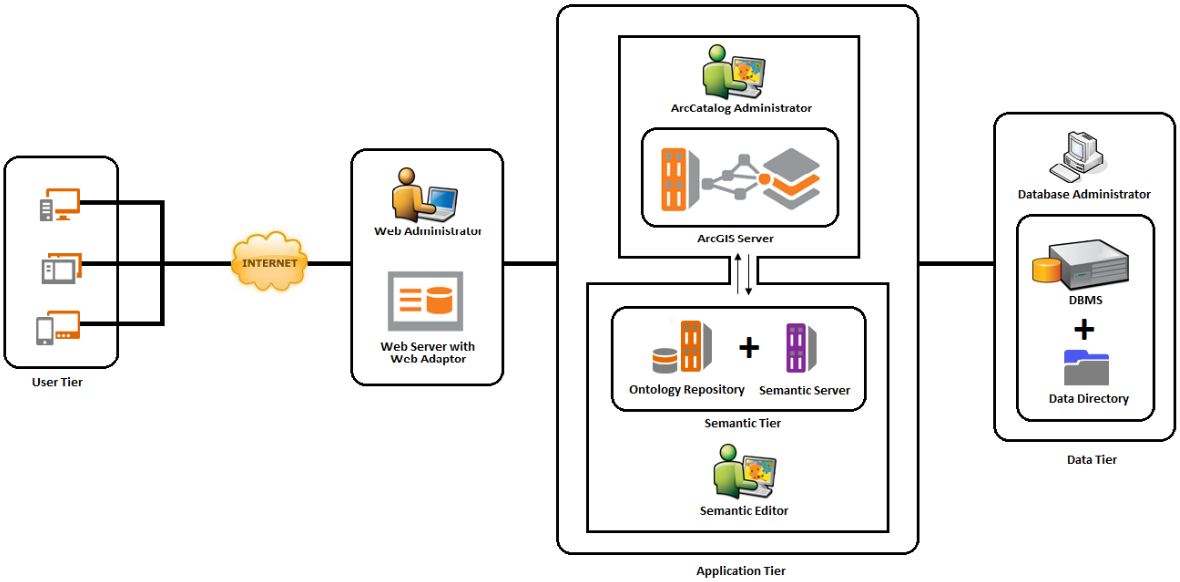



**Figure1. Multi-tier Semantic Web GIS Architecture.**

Components of a multi-tier approach summarized as follows:

- **Web server**—Hosts web applications, web services, ensures optional security benefits and load balancing to ArcGIS Server.
- **Web Adaptor**—Integrates ArcGIS Server with your enterprise web server, forwarding incoming requests to various GIS server machines.
- **ArcGIS server**— Hosts and runs services to fulfill requests issued for GIS web services. A GIS server can draw maps, run tools, serve imagery, synchronize databases, project geometry, search for data, and perform many other operations offered by ArcGIS.
- **Semantic Server**— Hosts semantic structure for integrated ontology-driven geospatial Information. Responsible for making the ontologies available to the user parallel to the request for GIS server. Semantic Server has three important components. Domain analysis is the first component that examines available knowledge set to generate user/machine required ontology. This ontology is computed in second phase which results meaningful triplets. That finally implemented in RDF and OWL. For all selected services RDF and OWL are stored in Ontology repository from where it will be delivered to users/machines for automated decision making.

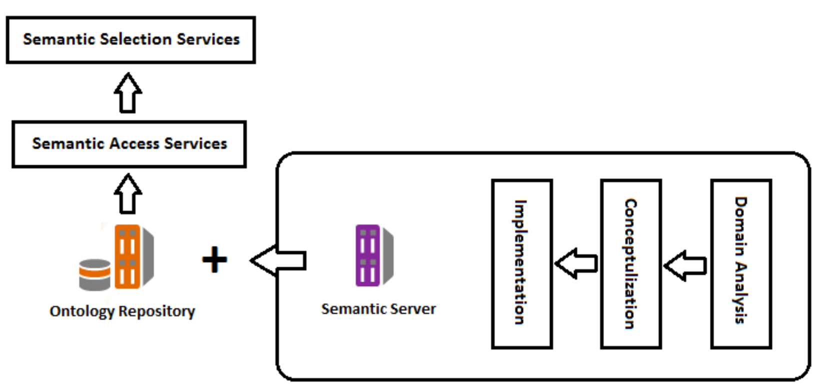



**Figure2. Detailed Semantic Server.**

The formal semantic has two kinds of structures, i.e., the specifications and the classes. The specifications are made by the editor and stored according to their distinguishing features (parts, functions, and attributes) and their semantic interrelations (is-a, part-of and whole-of relations) [5]. This structure provides information about the meaning of the available information. End users or application developer that wish to incorporate these classes in their development framework can make a dedicated request to web server through semantic selection services and access the information at different levels of detail depending on the ontology level by semantic access services .

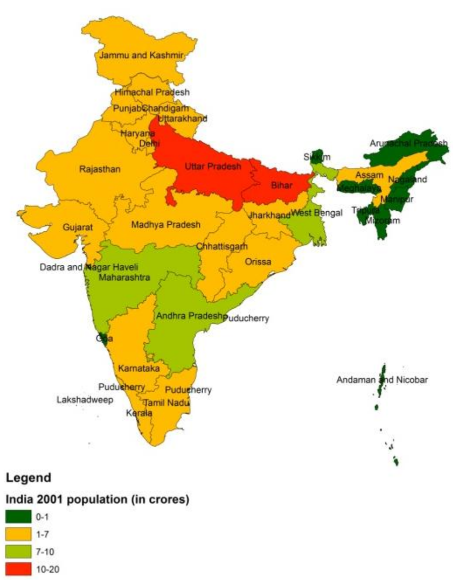
## System Implementation and Results

The objectives of the Global City Indicators are "to establish a policy-oriented urban indicators database for research, policy formulation, monitoring of the development impact of interventions in the urban sector, comparison of performance between cities, and improving the efficiency of urban service delivery." [6]. A city indicator is a measure of some property of a city. As we have mentioned earlier indicators are structured around 20 "themes" that measure a range of city services and quality of life factors. Let us take an example of "population theme". By this example we will understand how ArcGIS server in synchronization to semantic server generates user desired results. We assume that user make three request as follows.

1. Request for 2001 population of all Indian states.
2. Request for 2011 population of all Indian states.
3. Request for percentage increase in population from 2001-2011 for all Indian states.

These three requests are formulated as http request to web server where response is prepared in three categories for each incoming request. First is map, second is tabular output and third is RDF. One by one results for each request will be entertained and the results are generated. Generated results are as follows:

1. **Result for 1st Query:** Response for 2001 population of all Indian states.



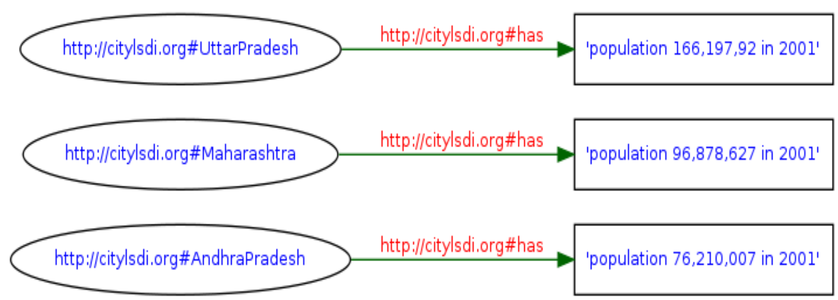
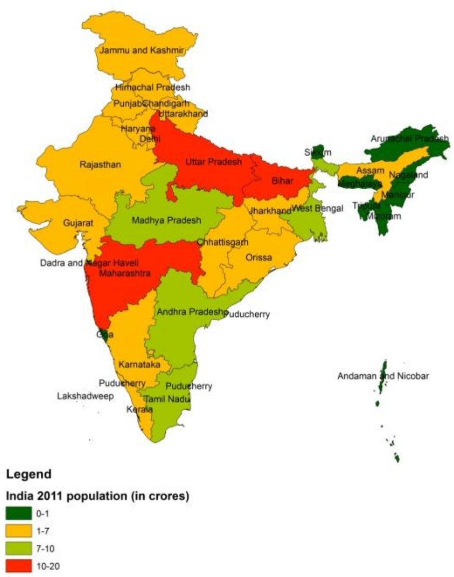




**Figure3. 2001 population of all Indian states.** **Figure4. Graph of the Data Model.**

RDF for 2001 population of all Indian states (Here only top three states are taken)

```
<rdf:RDF
   xmlns:Indicator="http://citylsdi.org#" >
 <rdf:Description rdf:about="http://citylsdi.org#AndhraPradesh">
   <Indicator:has>'population 76,210,007 in 2001'</Indicator:has>
 </rdf:Description>
<rdf:Description rdf:about="http://citylsdi.org#Maharashtra">
   <Indicator:has>'population 96,878,627 in 2001'</Indicator:has>
 </rdf:Description>
<rdf:Description rdf:about="http://citylsdi.org#UttarPradesh">
   <Indicator:has>'population 166,197,92 in 2001'</Indicator:has>
 </rdf:Description>
</rdf:RDF>
```

2. **Result for 2nd Query:** Response for 2011 population of all Indian states.



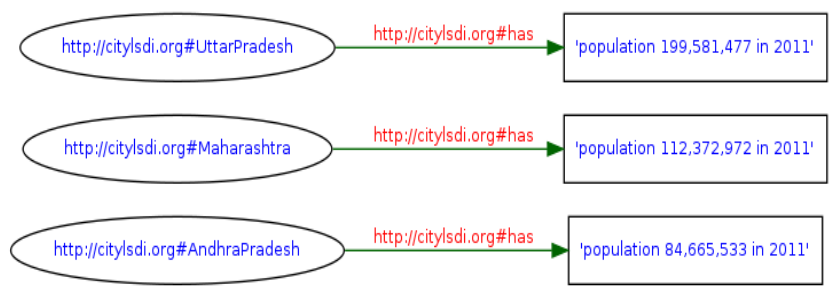




**Figure5. 2011 population of all Indian states.**

**Figure6. Graph of the Data Model.**

RDF for 2011 population of all Indian states (Here only top three states are taken)

```
<rdf:RDF
      xmlns:Indicator="http://citylsdi.org#" >
 <rdf:Description rdf:about="http://citylsdi.org#AndhraPradesh">
   <Indicator:has>'population 84,665,533 in 2011'</Indicator:has>
 </rdf:Description>
<rdf:Description rdf:about="http://citylsdi.org#Maharashtra">
   <Indicator:has>'population 112,372,972 in 2011'</Indicator:has>
 </rdf:Description>
<rdf:Description rdf:about="http://citylsdi.org#UttarPradesh">
   <Indicator:has>'population 199,581,477 in 2011'</Indicator:has>
 </rdf:Description>
</rdf:RDF>
```

3. **Result for 1st Query:** Response for percentage increase in population from 2001-2011 for all Indian states.

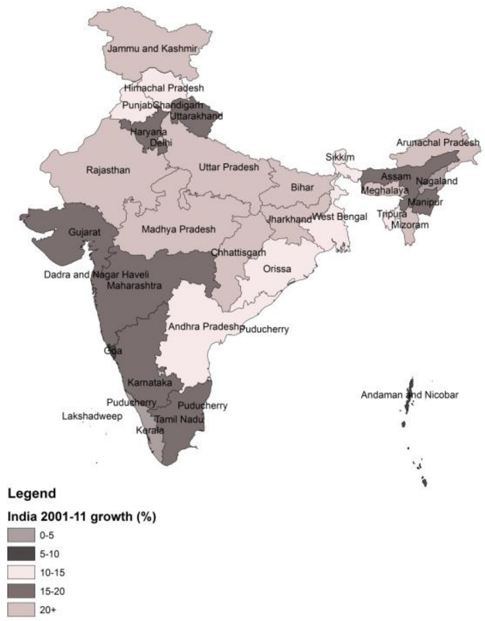




**Figure7. 2001-2011 population growth of all Indian states.** **Figure8. Graph of the Data Model.**

RDF for Population growth from 2001 -2011 for Indian states (Here only top three states are taken)

```
<rdf:RDF
  xmlns:Indicator="http://citylsdi.org#" >
<rdf:Description rdf:about="http://citylsdi.org#AndhraPradesh">
   <Indicator:has>'population 84,665,533 in 2011'</Indicator:has>
   <Indicator:has>'population 76,210,007 in 2001'</Indicator:has>
   <Indicator:grew>'1.1% from 2001 to 2011'</Indicator:grew>
  </rdf:Description>
<rdf:Description rdf:about="http://citylsdi.org#Maharashtra">
   <Indicator:has>'population 112,372,972 in 2011'</Indicator:has>
<Indicator:has>'population 166,197,92 in 2001'</Indicator:has>
<Indicator:grew>'1.5% from 2001 to 2011'</Indicator:grew>
  </rdf:Description>
<rdf:Description rdf:about="http://citylsdi.org#UttarPradesh">
   <Indicator:has>'population 199,581,477 in 2011'</Indicator:has>
  <Indicator:has>'population 166,197,92 in 2001'</Indicator:has>
 <Indicator:grew>'1.9% from 2001 to 2011'</Indicator:grew>
  </rdf:Description>
</rdf:RDF>
```

## Discussion

Indian government is working on a “flexible” PPP (public-private partnership) model to realize its ambitious project to develop 100 smart cities. So smart city development will not be a responsibility of a single department, rather it will be executed in the collaborative efforts of all existing government departments, private organization and people. SDI provides a basis for spatial data discovery, evaluation, and application for decision makers and providers within all levels of government, the commercial sector, the non-profit sector, academia and by citizens in general [7]. By using local SDI, each organization has access to spatial information of other organizations and can design drilling paths to have the least possible collision with other underground facilities [8]. Whenever we discuss the concept of collaboration and try to keep all the developing communities on the same platform we face the challenge of ambiguity. This implies that different perspectives are possible in understanding the concept and that concrete SDI initiatives can mean quite different things to different people. Moreover, different perspectives may bring conflicts between different requirements, interests and values. Their multi-facetted nature makes SDIs complex beyond technicalities or just being ‘difficult’ [9].So an ontology enriched semantic web-based system is installed and all organizations related to urban development share their information on the web. This system is a coordinated smart city development project which makes it possible for different departments, companies and independent developers to organize communicate and share their spatial, attribute and temporal information. When comprehensive and complete information from resources, services and facilities are accessible, the responsible organizations in urban utility management can make the best and most appropriate decisions. More over semantic heterogeneity as one of the most important constraints against both spatial and attribute data interoperability is discussed and RDF is applied as the best solution to overcome ambiguity.

## Conclusion

This paper presents the concept of local spatial data infrastructures, including the semantics as the best solution to overcome ambiguity; which help to build understanding about the importance of the relationships among various organizations of SDIs to support the interactions and partnerships of the spatial data for smart city development. The purpose of this paper is to present an extended SDI to save time, effort and money in accessing spatial and attribute data and using it responsibly to avoid unnecessary duplication in the smart city datasets by promoting semantic interoperability. Developed SDI shares global city indicator as an important spatial and non – spatial data set for smart city development project simultaneously semantics is maintained for these indicators that ensure interoperability among various organizations and users share SDI for the common aim of development.

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