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Geographic Information System: A Conceptual Enterprise Model for Bangalore Metropolitan City

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ABSTRACT
Geographical Information System (GIS) is an effective tool for planning and management of a metropolitan city. In developing countries like India, metropolitan governments, planning authorities and parastatals (viz. Water Supply Board, Transport Corporation etc.) have executed GIS projects independently. In recent years, many municipalities in the World have switched from stand-alone GIS systems to integrated approaches that share resources and applications. Enterprise GIS is an organization-wide approach, integrates spatial data and technology across the different departments of an organization coupling centralized management with decentralized use. Geographic Information System projects have been implemented in Bangalore City by the different stakeholders independently, without much common resources and integration. This calls for integrating both spatial and non-spatial data of all the stakeholders for effective planning, governance and management. This paper presents experiences of GIS implementation in Bangalore City and suggests a conceptual Enterprise GIS Model for Bangalore.

***Key Words*: Enterprise GIS, Integration, Metropolitan City Planning, Spatial**

I. INTRODUCTION
Geographic Information System (GIS) has been in use in local government since many years for isolated application such as tax collection, town planning etc. Enterprise GIS is considered to be the highest level of GIS development, which involves a large scale data, provides an information and operational framework for major portions of the activities and applications within an organization or consortium of organizations. The term 'enterprise' refers to looking at the entire organization as a single entity. An Enterprise GIS approach will provide a framework for integration of the requirements of all the departments of municipal governments including collection of data, sharing of information, collaborating and conducting cross-departmental analysis. The Enterprise GIS (EGIS) also, extends both vertically to state and central governments and horizontally to other organizations, stakeholders and parastatals (ESRI, 2003).

II. BACKGROUND OF BANGALORE
Bangalore is the third largest metropolitan city with a population of over 9.5 million (2011 provisional figures of Census of India) rose from 5.7 million in 2001. The City is an Information Technology (IT) hub and is also called as Silicon City of India. The City Government was called Bangalore Mahanagara Palike (BMP), with 100 wards, had an area 226 sq.km. It was renamed as Bruhat Bangalore Mahanagara Palike (BBMP) in 2007, by increasing its area to 800sq.kms and wards to 147 wards. The Bangalore Development Authority (BDA) is a statutory Planning Authority, has a Local Planning Area (LPA) namely Bangalore Metropolitan Area (BMA), with an extent of 1279 sq.kms. The Bangalore Metropolitan Regional Development Authority (BMRDA) was established in 1985 having its jurisdiction of Bangalore Urban, Rural and Ramanagaram districts. Bangalore Metropolitan region Development Authority (BMRDA) was set up for the purpose of planning, coordinating and supervising the proper and orderly development of the area within the Bangalore Metropolitan Region (BMR) with Local Planning Areas to the extent of 8005 sq.km.

III. INITIATION OF GIS IN BANGALORE
The BMRDA engaged Indian Resource Information and Management Technologies (INRIMT), Hyderabad for preparation of structure plan for metropolitan region in 1994. The satellite photography was procured from the Indian Remote Sensing (IRS) Programme, available through National Remote Sensing Agency (NRSA), which has influenced the urban planning in Bangalore for the first time. The INRIMT constructed the base map 1:250,000 scale from Survey of India topographic sheets including the boundaries of BMR. The overlays for different variables including topography, drainage, water bodies, ground cover, annual rainfall, geology and mineral, ground water table, and transportation network, water supply, sewerage and electricity lines etc are some of the prominent features. The BMRDA set up a GIS centre by hiring a consultant to support the System and installed hardware and software along with the technical personnel. Similarly, Bangalore Development Authority also initiated Integrated Urban Environmental Improvement Project (IUEIP), which covered neighbourhoods in four layouts in 1998 for over a

period of 3 years. The GIS was initiated for water distribution system in Bangalore Water Supply and Sewerage Board (BWSSB) for by engaging the French consultants, Strategie-Conceptions-Erudes (SCE) in 1999 and implemented in 2001. Bangalore Mahanagara Palike (BMP) also initiated GIS project in a selected wards on a pilot basis in 2002. The details of the Implementation of GIS of BMP, BWSSB, BDA and BMRDA are as follows:

3.1 Bangalore Mahanagara Palike (BMP)

A pilot GIS project was initiated in two wards of BMP in 2002 covering two layers viz. property and road as shown in figure 1 and figure-2, by the Indian Space Research Organization (ISRO).

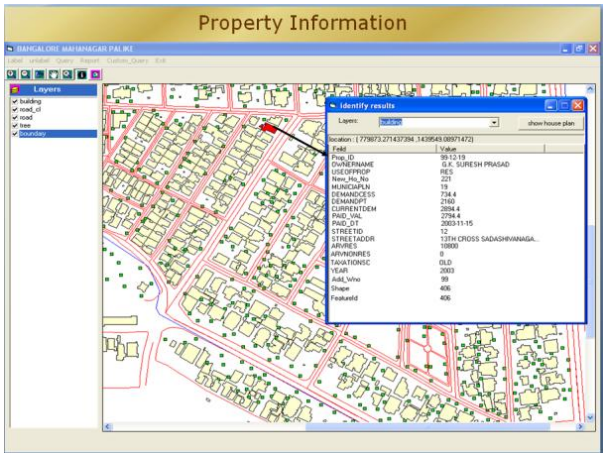

Fig.1: Property Information of BMP Ward No-99

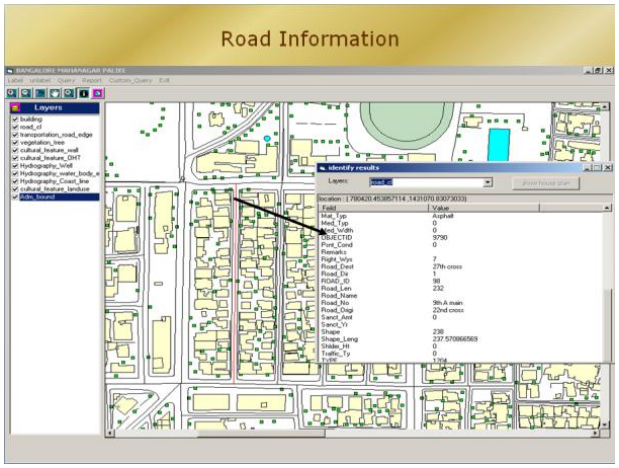

Fig.2: Road Information of BBMP Ward No: 60
(Source: BBMP, Bangalore)

The objective was to develop customized GIS software and the Management Information System (MIS). In 2004, the Karnataka State Remote Sensing Applications Centre (KSRSAC) conducted another pilot project for BMP in Ward No.64 by capturing 15 features namely roads, properties, storm water drain, cross drainage works, streetlights, trees, public taps, location of water tanks, public taps and bore-wells etc., covering four important departments namely Revenue, Health, Horticulture and Engineering Departments. Quick Bird satellite image of 0.6m spatial resolution captured in 2004 and the image was used for creating the base map. In the pilot project, tasks of physical surveying, collection of attributes of various layers, digital photographing, data validation at the field and linking attribute and spatial data were carried-out.

Later, BMP extended the geo-database model, spatial data for 29 wards of BMP involving KSRSAC as coordinating agency with the support from the National Remote Sensing Agency (NRSA). The data model is represented in the fig.5. However, only 29 wards were covered out of 100 wards of BMP in the first phase of the project. As of now, the data validation is completed in few wards. Further, BMP GIS model excluded Solid Waste Management, Emergency Services, Crime, Education, Health Services, Election, Property Management, Poverty Management, Housing etc. which are of utmost importance for urban governance.

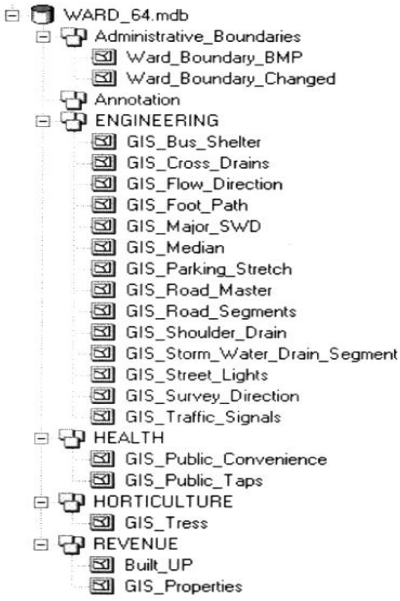

Fig. 3: Geo-database Model Adopted by BMP

3.2 Bangalore Water Supply and Sewerage Board

The Bangalore Water Supply and Sewerage Board (BWSSB) has implemented GIS for its water supply and sanitary services in the year 2001.The base map was prepared using aerial photographs supplied by NRSA. The scale of the base map was 1:2000. The pilot project covered an area of 290 sq.kms, 4000 kms of water pipelines, 3000 kms of sewerage lines and 320,000 consumer connections in the BWSSB jurisdiction. It was linked to the attribute data viz. water pipeline, valve, fire hydrant, reservoir, pumping stations, BWSSB offices, storm water drain, manholes, sewer pipe, service station boundary, consumer point etc. The employees' database along with the billing system was integrated in GIS to improve the bill collection and transparency among the organisations. Data integration was achieved through data entry of alphanumerical data using Excel sheets; report of graphical data collected on

the field on reference base maps (A0 size – 1: 1200 scale); conversion of NRSA base maps into the ARCINFO /ARCFM GIS; digitization of graphical data; ARCINFO conversion after Quality Control; corrections and validation by BWSSB and final integration of data after Topology Building. 98% of attribute data was collected directly from the field.

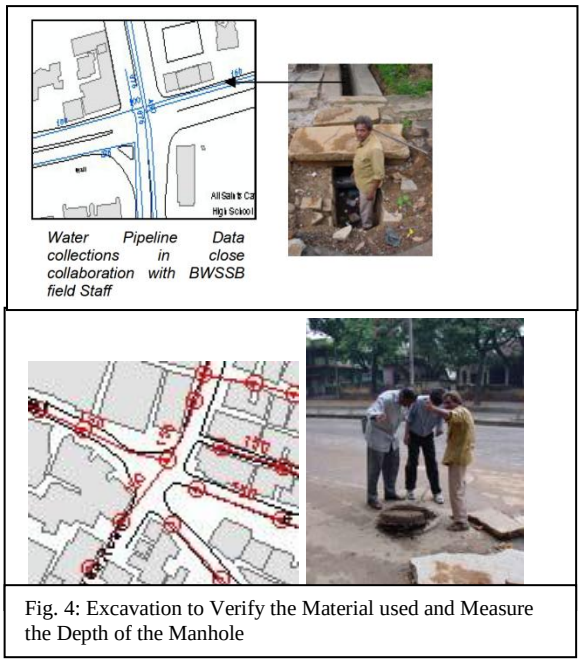

Fig. 4: Excavation to Verify the Material used and Measure the Depth of the Manhole

3.3 Bangalore Metropolitan Transport Corporation

The Bangalore Metropolitan Transport Corporation (BMTC) implemented the 'Passenger Information System (PIS)'. The PIS helps the passengers, who are travelling in BMTC buses, to get real-time information about arrival of buses at stops enroute. The corporation has introduced GPS on 1,500 buses and eventually brings all its 4,000-odd buses under GPS. The display unit, was placed at a noticeable place in the bus shelter, would digitally display arrival timing of the buses enroute. The unit was connected to the control room through GPRS. The corporation was to able provide the route map, timetable, number of buses on a particular route and other required details to the service provider.

3.4 Bangalore Metropolitan Regional Development Authority

In 2001, BMRDA established the GIS centre, which houses a spatial base map at 1:50000 including land use/land cover, drainage, water bodies, irrigation systems, contours and slopes, land geomorphology and soils, roads, rail, electricity networks and administrative boundaries. These data were essentially used for the preparation of structural and development plans. The base map of very small scale was used for urban applications.

3.5 Bangalore Development Authority

The Bangalore Development Authority (BDA) initiated Metropolitan Spatial Data Infrastructure project (MSDI) in partnership with Groupe SCE. This project was funded under an Indo-French Protocol signed between the French and the Indian Government.

The MSDI project is thus a unique "spatial data" vehicle developed for Greater Bangalore to address various issues, like the CDP revision, and to help create physical infrastructure through the deployment of a multidisciplinary approach: IT tools and GIS applications. The governing principle of the MSDI project as well as its main challenge is to build, in parallel, a Sustainable Urban Geographical Information System along with a renewed approach to city planning through the CDP revision. That is to say to provide, collect, organize and standardize all kinds of data in a mega urban database ranging from satellite images to building footprints that interest all public and private stakeholders. This database must be both spatially meaningful and usable to all kinds of experts as well as to the building of the sustainable common asset and spatial repository acting as the spatial memory of the territory. This intertwining of scales (metropolitan, city, ward, village, parcel, building), dates, issues (urban planning versus urban management) and the variety of actors make the MSDI project a showcase of GIS technology applied to a complex mega city like Bangalore.

One hundred and ten experts were mobilised comprising of town planners, architects, economists, demographers, sociologists, GIS & IT specialists, geographers, cartographers, and infrastructure and transport specialists

The main challenge and principle of the MSDI project was to build a sustainable urban geographical information system through the creation, collection, organization and standardization of huge amounts of data from over 30 public and private sources into mega urban spatial database and make use of this GIS to modify and streamline the planning process thereby making it highly efficient. This spatial repository would become a common asset to the stakeholders acting as the 'spatial memory' of the territory.

Table-1: List of Geodatabases Created for MSDI of BDA

Geo-database	Contents
Boundaries	The local administrative limits of various stakeholders
Topography	Geology, hydrography and relief information
Transportation	Network of existing railway lines, roads and proposed metro
Landmarks	Extensive list of well known landmarks
Land use	Existing land use situation as well as proposed land use for 2015
Housing_land	Buildings, development layouts, slums, urban fabrics etc
Socio_Economic	Tables containing information on demographic, health, education etc.
Environment	State forest limits, borewell distributions and depths

Utility_services	Bangalore Water and Sewerage Board network, power lines, oil pipelines
Raster_Photos	Historical maps, satellite images, DEM etc.
Cdp_support	Various supporting elements for the mapping of the Existing and proposed Land use
Technical	Support database containing grids and other templates

The database model was created keeping in mind the simplicity for use and flexibility for evolution and growth. Since the platform chosen for the GIS was ESRI's ArcGIS(R), the spatial repository was designed as multiple personal geodatabases as given in the table-1. The MSDI project was the first GIS project of this scale that the BDA was undertaking. Therefore, the choice of using simpler personal geodatabases instead of larger geodatabase along platforms like Oracle(R) was made in order to avoid complexity of managing databases for the clients.

The DUSR comprises of a digital geo-referenced large scale map (scale 1:2000) covering an area of Bangalore is 1500 km^2, 553 villages, 55,000 parcels, 6.5 lakh buildings, 15.5 km of roads, 230 km of railway, 2546 places of worship, 100691 manholes, 330,903 consumer connections, 4008 km of water pipe lines, 3245 km of sewage lines, 8115 km of drains, 450 km of HT, 90,000 parcels of existing land use, 15,000 various landmarks and 400 layouts totalling 2 GB of records in 12 geo-databases. Attribute data gathered from 1991 & 2001 Census, BWSSB, BBMP, the Slum Clearance Board and others –totally 27 stakeholders. The database model of DUSR is yet to be commissioned due to ongoing development of IT Applications.

As it is evident stakeholders such as BMRDA, BBMP, BDA, BWSSB, BMTC etc. have executed GIS projects independently without having any common spatial reference except the MSDI initiative. Also, the GIS project initiated by BMP is yet to be commissioned and may not be able to meet the present day challenges of temporal, administrative, functional, technical, jurisdictional and institutional transformations. However, some of the huge amount of field data already collected and validated can be used appropriately.

IV. NEED FOR ENTERPRISE GIS

The GIS projects were implemented by few stakeholders in Bangalore Metropolitan Area by limiting to few requirements. Even though, Bangalore Mahanagar Palike initiated the first pilot GIS project with the help of ISRO, but it was restricted to roads and properties. The second pilot project was initiated by involving KSRSAC and NRSA covering 15 features of few departments in BMP. Few of the utility and service organisations namely BWSSB, BMTC, BESCOM etc., have developed their MIS system integrating the GIS limiting to their few departmental needs. The GIS developed by BDA and BMRDA are not synchonised and oprationised. The City Government is yet form Metropolitan Planning Committee, which can act as a coordinating agency as per the 74th CAA of all the stakeholders coming within the jurisdiction of the Bangalore Metropolitan Area. The BBMP's responsibilities are also increases with the new functions that are going to be assigned to the Mahanagara Palike in the context of 74th CAA. In the absence of robust integrated GIS, the planning, co-ordinating, resource mobilization and management tasks in metropolitan area is a difficult task which are not synchronizing for meeting the demands of the citizen. It is inevitable to have a coordinated and integrated GIS System with sound technologies not only to reduce the cost but also to increase the effectiveness in service delivery and good urban governance. The experiences of other municipalities in the world have proved that Enterprise GIS would be appropriate model for Metropolitan Bangalore.

V. SWOT ANALYSIS OF GIS PROJECTS

Strengths	Weaknesses
1.Stakeholders are willing to co-ordinate the GIS in Bangalore 2.GIS projects are already operationilised in Utility and Service Departments 3.Efforts have been made to collect large scale field data in GIS projects of BMP, BMRDA and BDA	1.There is no synchronization of data of different stakeholders 2. Many of the GIS Projects of BMP and BDA are not operationsed. 3. There is no mechanism for updating both spatial and attribute data. 4.Data collection is limited to few functional aspects of metropolitan governance
Opportunities	Threats
1.E-governance initiatives under JNNURM and State Government Reforms Projects for initiating Integrated and collaborative GIS	1.Non-constitution of Metropolitan committee

VI. A CONCEPUTAL EGIS MODEL FOR BANGALORE

The methodology for developing the conceptual model of Enterprise Geographic Information (EGIS) is as follows. The methodology for implementation of EGIS in any organization involves

[1]. Developing an organization-wide GIS approach using standards and consistent methodologies that address the needs of all units of the organization
[2]. Migrating existing GIS applications and data to current GIS technology capable of supporting all potential users in a cohesive manner
[3]. Integrating GIS data and services with other information systems within the organization as part of an overall enterprise information systems solution
[4]. Adapting the GIS staffing structure to support the enterprise approach
[5]. Training the IT and GIS staff to design, develop and maintain the enterprise GIS resources
[6]. Training staff in the departments new to GIS in the effective use of GIS specific to their business needs

VII. PROPOSED EGIS CONCEPTUAL MODEL

BDA, as a planning authority has felt the need for having a common digital base map which could be used by various stakeholders for their own independent GIS implementations. The base map was prepared by digitizing over a mosaic of large scale aerial photographs (source: NRSA) being geo-referenced with Quickbird satellite images consisting of 514 layers of information. Over 300 Survey of India (SOI) ground control points were used for geo-referencing of image. Data has been collected from 27 stakeholders and is organized into 80 GIS feature classes. Ground surveys were conducted to prepare existing land-use maps, water network, urban amenities, Central Business District (CBD), land marks, road widths etc. All the data is available at the BDA central repository for internal use as well as sharing with other stakeholders.

The urban governance in a Metropolitan city like Bangalore having an administrative area of 800 sq.km, and its demands an innovative new technology for faster and timely decision making. Embracing enterprise wide GIS at the earliest is the only possible option for good urban governance. BBMP and other stakeholders have the advantage of bringing their own data into the existing common spatial database. BBMP had already initiated the GIS programs but without much success. BBMP is headed by the Commissioner and assisted by two Special-Commissioners: one for Engineering Projects and the other for Administrative functions at the central office. The administrative boundary of BBMP, after formation of Greater Bangalore has been divided into 8 zones and new 147 wards altering the boundaries of earlier 100 wards. Each zone is governed by a Joint Commissioner and is responsible for the overall functions of various departments such as Revenue, Engineering, Town Planning, Health etc.

We propose a distributed network data model as shown in figure-5. The spatial data and the available attribute data necessary for the functioning of BBMP shall be replicated in an intermediate server from the DUSR of BDA. The central server, located at the Head office will have to be replicated and synchronized database from intermediate server. The EGIS-Coordinator controls the central server and co-ordinates the zonal GIS units. He also determines data to be updated back in the DUSR repository and publishes the relevant GIS information to public who are accessing through Internet. The central data repository is replicated and synchronized to zonal servers. The replication may be in full or partial with respect to changes in the database. The administrators, at the zonal offices maintain the zonal servers and coordinate various departments for data viewing, editing and updating the central server. Each zonal server is connected to departmental servers. Each department will have an expert who will view, edit and update by synchronization with the zonal server in their respective domain through field or office staff directly. In order to reduce the load on the communication network, a separate server may be maintained by each department for viewing and editing and another replica server for updating and synchronizing with zonal server. Thus zonal offices are responsible for the maintenance of geodatabase and the central office will have the compiled and updated version of the geodatabase which may be published to Public and perform municipal functions.

CONCLUSIONS

The GIS projects were executed independently by BBMP, BDA, BWSSB, BMTC and other stakeholders without having any common spatial data reference. Also, the GIS projects, which were initiated by BMP are unable to implement effectively due to the present day administrative, functional, technical, jurisdictional and institutional challenges. BBMP has grown both population-wise and area-wise in recent time. The responsibility and quantum of services to be delivered have drastically increased due administrative, functional, institutional changes. Therefore, BBMP is compelled to adopt geospatial technology to cope up with service delivery and timely decision making. The proposed Conceptual Model of Enterprise GIS with decentralized functions at zonal level would BBMP for achieving better planning, good urban governance and management.

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BIOGRAPHIES

Raghunath M. received the Bachelors degree in Civil Engineering from the B.M.S. College of Engineering, Bangalore and Masters degree in Remote Sensing and Geographical Information Systems from the Indian Institute of Remote Sensing, Dehra Dun. He is working as Project Officer in TEQIP – World Bank funded Project at State Project Facilitation Unit (SPFU), Directorate of Technical Education, Bangalore and his research areas are Geographic Information System.

B. Shankar received the B.E. degree in Civil Engineering in 1984, M.U.R.P degree in Urban and Regional Planning in 1989 and Ph.D degree in 1997 from the University of Mysore, Mysore. He is working as Associate Professor in Urban and Regional Planning at the Institute of Development Studies, University of Mysore, Mysore. His research interests include heritage conservation, planning legislation, city planning, community participation and geographic information system.

Annexure I

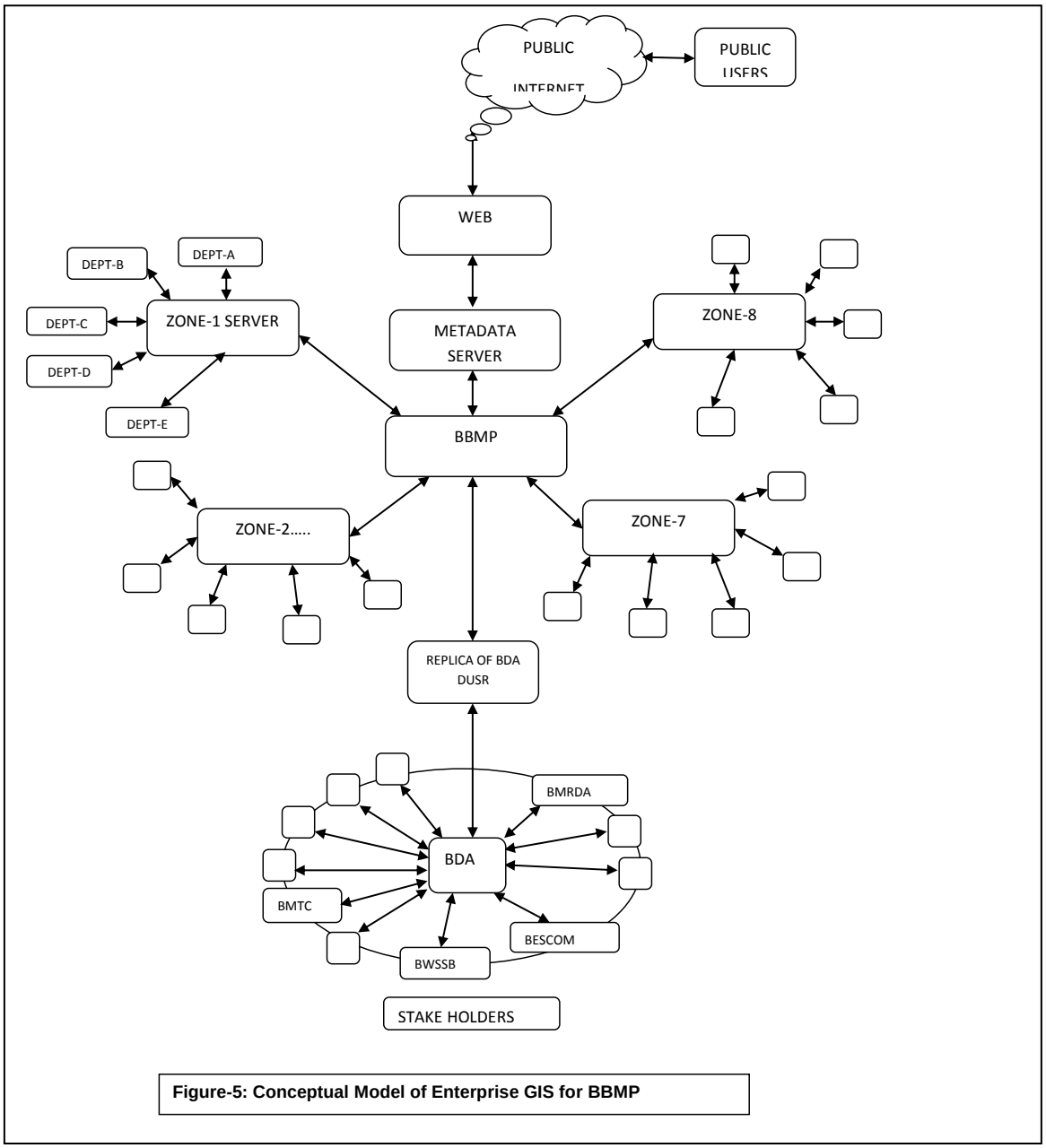

Figure-5: Conceptual Model of Enterprise GIS for BBMP