ABSTRACT
Our living environment is under real threat of various global issues like global warming, rising sea-level, changing weather patterns, floods and hurricanes etc as well as local issues like housing affordability, traffic congestion, pollution, health and environmental degradation etc. All these issues are inter-related and cities are the major contributor. These issues can’t be addressed in isolation and require an integrated approach for problem solution. Spatial Information is critical for better response to these problems. But absence of required information is affecting such efforts. Recent advancement in Information & Communication Technologies (ICT) has enabled development of spatial data platforms like Spatial Data Infrastructures (SDI) for affective and efficient data integration, information sharing and its application for informed decision making. Better urban planning and management at local level can overcame many of the problems faced and this paper explores how SDI based on Service Oriented Approach can facilitate this process using Unified Modeling Language (UML) technique.

INTRODUCTION
Effects of human induced actions in the form of climate changes, global warming, and environment pollution etc are seriously affecting our planet. For example, in ten year period from 1993 – 2003, the average rise in sea-level is about 3.1 mm per year and is increasing rapidly (Alley et al., 2007). Studies have demonstrated that 1 meter rise in sea-level due to global warming can affect more than 50 million people in developing countries with many areas completely disappearing (Dasgupta et al., 2007). Similarly global warming can result to droughts in some areas while more floods in other parts of world (Roach, 2008). USA experienced one of its worst hurricanes, Katrina, in 2005 whereas in Europe, almost 35,000 people died due to heat weave of 2003 (Morley, 2007). Excessive burning of fossil fuel in cities and change in land use are the two major factors for increased concentration of CO2 in atmosphere causing global warming (Alley et al., 2007). Reasons of this excessive fossil fuel burning and change in land use especially in urban areas are highlighted in next section.
World population is increasing rapidly in last one century as a result of improved health facilities. However, this increase is more dominant in urban areas as cities provide better living and economic opportunities. According to the recent reports by UN (2006),
urban proportion of world total population has quadrupled in last one century. Accommodation of this urban population requires more area for housing, recreation, transportation, business, infrastructure and utility services. As most of the urban areas are surrounded by agriculture land, forest and natural streams, therefore, an increase in urban areas involve destruction of these prime green areas by disturbing natural equilibrium. Additional economic activities in the form of industrial development cause more carbon emission. More dependence on transportation and its increased usage due to large distance by horizontal expansion of cities generate more carbon emissions. Transport sector is a major source of carbon emission with urban transport generating more than half of it (Lidskog et al., 2003). Air pollution is a major cause of morbidity and mortality in developing countries along with diseases like asthma, chronic obstructive pulmonary disease and lead poisoning etc (Moore et al., 2003). In many cases, solid waste is disposed off as landfill contaminating underground water making is unsafe for drinking (Unnisa and Srivani, 2008). These few examples highlight the contribution of urban areas to global warming and other environment problems which are real threat to our survival. As urban areas are the major source of these local and global environment problems, therefore, a comprehensive strategy for urban planning and management is indispensable (Hunt et al., 2007).

**URBAN PLANNING**

Complexity of urban problems creates the demand for a coordinated effort. Urban problems like housing affordability, slums, traffic congestion, pollution, poverty, crime and infectious diseases etc can not be solved in isolation without evaluating their relationship with other problems and any isolated effort creates other problems. For example in 1960, big and tall buildings were erected to solve the housing problem in France, but after some time, new problems of delinquency and violence emerged in these buildings due to overcrowding (Laurini, 2001). Interdependence between various urban elements like housing, transportation, and job places etc demands for planning. At the same time, role of private market is increasing in physical development and different services and facilities are provided by different authorities at different times, therefore, a working environment can not be achieved without coordinated efforts in the light of a guided plan (Neutze, 1986)

**Modern Concepts**

Traditional system of urban planning is unable to provide a sustainable living environment for all sectors of society and therefore, efforts are underway to change the nature and practice of urban planning. New principles of sustainability, integration, transparency, market responsiveness, inclusiveness and accessibility to land have been proposed for modern planning (Hague, 2008). For this, planners needs to design new techniques and tools for service delivery. For example, information about current planning policies, proposals should be readily available to general public for more public participation. Presentation of this information in four dimensions will help people better understand what these proposal mean, how their environment will look like and what will be their impact (Howard and Gaborit, 2007). Efforts like urbansim for modelling urban land-use, transportation and environmental impacts are underway (Borning et al., 2008). Concepts of e-planning system enabling information sharing to public for more awareness, participation & transparency with creation of alternative
scenario for impacts analysis before implementation can be a reality in future (Chen et al., 2007). Application of modern Information & Communication Technologies (ICT) is not limited to e-planning only but extends to virtual environment. One such concept is virtual Australia, which extend beyond digital earth and is defined as a virtual model containing and representing everything from sky to the bedrock (Thompson et al., 2008). Availability of spatial and non-spatial information in appropriate format and development of such models useful for generating alternative scenarios based on varying policy and situations can help planners and decision makers for informed decision making.

**Problems and Issues**

Planners started to model relationship between different elements of urban environment from 1960s onward. Various models for forecasting and analysing relationship between land-use and transportation were developed. These models required a lot of information and its processing. But due to non-availability of required information and limited computer processing power, these models failed to achieve desired results (Lee, 1973). Later on, advancement in computing technology was instrumental in developing various general purpose information systems and more specially Geographic Information Systems (GIS). Successful launch of remote sensing satellites resulted in collection of large amount of spatial data in the form of satellite images. But most of these efforts related to GIS development were fragmented without any coordination causing duplication and wastage of resources. Similarly more stress was on collection of satellite images rather than its sharing and application as described by vice president of America Gore,A (1998) referring to Landsat satellite imageries “*In spite of the great need for the information, the vast majority of those images have never fired a single neuron in a single human brain. Instead, they are stored in electronic silos of data.*” Such isolated practices where data collection is more focused than its sharing and application are unable to get full benefits from current technology and resources. Many large cities lack comprehensive knowledge infrastructure for informed decision making as individual departments are working on ad-hoc-ism regarding data collection (Carrera and Hoyt, 2006).

In contrast to current practices, new proposed planning models are information hungry and depend heavily on static as well as dynamic information about environment. Even these models can not be properly designed, tested and validated without required information. This situation can really hamper our efforts of analysing complex relationship between various urban environment elements and evaluation of alternative development proposals through modelling. Therefore, current practices of information sharing and application are analysed in next section to better understand the actual situation.

**Current practice of information sharing**

Urban planning being a multi-disciplinary approach relies heavily on information about urban environment from different organisations and departments. As urban planning is perceived and practices differently throughout the world, therefore, it is difficult to precisely define their requirements. However, some of the common information requirements are highlighted in figure 1 (Kaiser et al., 1995, Edralin, 1986, Williams, 1968)
One of the most critical information is about cadastral which forms the basis of many planning functions. Up to date cadastral information is pre-requisite for planning & development of land as well as for provision of infrastructure and services. It is required not only by planners but also by many other professionals involved in planning and management of resources at local level. People are also interested in it for tenure security. However in many developing countries, local authorities are unable to cope with higher demand of land registration process. This lack of good cadastral information is a serious constraint on the efficient city growth (Dowall and Clark, 1996). Planning for the provision of housing and other services is based on the projection of population information already collected by censes organisation from time to time.

Fig. 1: Information requirement of planners & decision makers at local level.

Value of information depends on how effectively and efficiently, it is used. Most of the departments have double role as information user and well as information provider / generator as result of their day to day activities. For example, census department requires good quality base maps and land use maps prepared by planning and mapping departments, but at the same time census data is required by various other departments like planning, utilities, economic / tax, emergency and utility services providers. In the same way planning information in the form of various development plans, policies, land use maps and city growth patterns is valuable to many local departments and in result planning department needs information about cadastral, population, economy, transport, environment and utilities etc available in different departments. However, practically very little sharing in appropriate mechanism is exercised between different departments especially at local levels due to different social, cultural, administrative and technical reasons (Arbeit, 1993, Carrera and Hoyt, 2006). This isolated and uncoordinated complexity is highlighted in figure 2.

As a result of this uncoordinated style, sometimes departments are unaware of information availability within other departments and this ignorance leads to the duplication of data collection and management efforts. In certain situation, even if departments are aware of information availability, issues like aggregation of the available information, varying contents, standards, currency and absence of metadata reduces the utility of available information (Hovy, 2008).

Above discussion show the diverse requirements of planners regarding secondary information and their current status of sharing. Similar uncoordinated situation can be expected in other fields as well which is not a very good prospect for implementing the concepts like e-planning and virtual Australia for informed decision making and
improved public participation at policy level. There is an urgent need to coordinate efforts of various stakeholders for better information sharing and its application.

![Diagram showing un-coordinated information sharing between different departments]

**Fig. 2: Un-coordinated information sharing between different departments**

**SDI DESIGN TO FACILITATE URBAN PLANNING**

Information must be regarded as infrastructure and as local authorities can not afford to develop other type of infrastructure like water supply, sewerage, utilities services and roads etc, again and again than why it happens with information infrastructure? This wastage of resources can be avoided by using a coordinated approach as presented in figure 3.

Many actors are involved in information industry. However, to make it simple, two broader categories of Government and private sector are used. These departments collect either primary information through surveys, discussions or secondary information from other departments. For example, health department may collect basic information about population from census department, but may conduct surveys to better analyse different health / disease patterns. Simultaneously information about health facilities like number of doctors, beds etc is generated for their own activities. This information about health facilities is very important for emergency services / disaster management departments and decision makers. This dual role of information collector as well as information generator is common in other departments and organisation as well.

In certain situation, different departments need similar situation with some varying contents. Proper coordination of data collection efforts through a single survey incorporating the needs of all stakeholders can save precious time and resources.
Standardisation of information is critical for sharing and integration. Various social, cultural and administrative issues need to be resolved as well. Availability and sharing of required information can be used for creation of different services in compliance with the needs of experts through integration. Visual representation of our environment in three & four dimension will facilitate public in better understanding planning proposal and their long-term impacts. Similarly various simulations can be designed on the basis of these services to visualise the impacts in different scenarios. For example, estimate of deforestation or increase in pollution as a result of city expansion with varying population growth rates. This system will facilitates more public participation, transparency and informed decision making fundamental for sustainable and liveable urban environments. Spatial Data Infrastructure is such an enabling platform which can facilitate much desired information sharing, integration and services delivery from global to national level and from national to local level.

**Fig. 3:** Coordinated efforts for better information sharing, application & service delivery

**Spatial Data Infrastructure (SDI)**

SDI as its name suggests is system of communication dealing with spatial data & information. Its main objective is better sharing and application of spatial information. Rajabifard (2002) describes SDI as an enabling platform based on dynamic, hierarchic concept with the aim of facilitating and coordinating the exchange and sharing of spatial information between different stakeholders and include data, people, standards, policy and access network represented in figure 4. It enables users to save resources, time and efforts by avoiding duplication of efforts related with information collection, maintenance and integration (Chan et al., 2001).
SDI being an evolving concept is perceived and practiced differently throughout the world (Rajabifard et al., 2006). Initially the concept of information linking was promoted with concept of product based model. These SDIs were also referred as first generation of SDI. From 2000 onward, focus shifted to second generation SDI with process based model and their objective was to provide improved communication system enabling the community for sharing and using the information (Rajabifard et al., 2002).

As information is collected and managed at different level. Therefore, a hierarchy of SDI is proposed by different researchers as represented in figure 5 (Rajabifard et al., 2000). These SDI at different levels are interrelated and are based on each other. At regional level in Europe, INSPIRE (Infrastructure for Spatial Information in Europe) is one such initiate since 2001. Main emphasis of INSPIRE is on sharing and application of available data relating to environment for better environment planning & management (Masser, 2007). At national level, different countries are in process of developing NSDI and initial focus of effort was mainly on this level. But later on, it was realised that it is the local level SDI with large scale, people relevant datasets that is most important and form the basis for other levels.

Urban planners at city level are more interested in local level SDI but so far most of the work relating to local SDI is conceptual and limited practical work is done on technical design and development of SDI. Professionals in local authorities with limited expertise find it difficult to take full benefit in the absence of any standard model. In the next section, some aspects of local SDI design are presented and explained how different services and models can be developed for effective planning and management to eliminate environment problems.

**Local SDI design**

SDI needs to incorporate the needs of all stakeholders making the design of SDI a multidimensional and complex job. Therefore, Commission on Spatial Data Standards of the International Cartographic Association (ICA) presented a general SDI design. As the information is collected, managed by different department at different places, therefore various recent model in the filed of distributing computing were analysed and
finally Reference Model of Open Distributing Computing (RM-ODP) was selected (Cooper et al., 2005). This model has the flexibility of emphasizing different aspects of design in different viewpoints. A viewpoint is a subdivision of the specification of a complete system with some particular area of concern. RM-ODP is explained into five different viewpoint listed below (Farooqui et al., 1995).

- Enterprise viewpoint
- Information viewpoint
- Computation viewpoint
- Engineering viewpoint
- Technology viewpoint

These separate viewpoints are not completely independent of each other; rather some key items are related with each other. Each viewpoint has its own importance, but as the objective of SDI is improved sharing and application of information, therefore information viewpoint attains more importance. Author’s Professional background of urban planning helpful in better understanding of information/services requirements of planners is very useful in the design of information viewpoint explored in next section. With the development of 2nd generation of SDI, emphasis is shifting form simple sharing of data towards more advanced level of provision of services. Therefore Service Oriented Architecture (SOA) approach will be applied for the design of SDI following four general principals of modelling (Klosterman, 2008).

1. All models are wrong- some models are useful
2. Prediction is hard, especially about the future
3. Keep it simple, stupid (KISS)
4. Use it because it is BAD (Best Available Data)

**SDI information viewpoint**

This viewpoint is based on the information requirement identified in the earlier section of this paper and presented in figure 1. It starts from the bottom with basic dataset available in different departments and ends at the top with advanced levels of services generated through geo-processing of information. ICA Commission on Spatial Data Standards has divided available data into four main categories of vector, raster, alphanumeric and multimedia (Cooper et al., 2005). But to make it simple and easy to understand, we have focused only on first three categories of data.

Data can be available in printed or digital format. In case of Alphanumeric, it can be converted into digital format using simple database software with attributes defined in viewpoint. Whereas maps can be digitized manually or through automatic procedure using same geodetic reference system and incorporating required attributes. Satellite images or other interpolated data in raster format are expected to be in digital format. Integration of information for services development is explored in next part.

Cadastral data comprise maps and registers. Maps describe the relative geometry and location whereas register include ownership, use and other valuable information. To integrate both datasets, a standard reference ID will be included in map as well as in register. This reference ID can be based on some serial number or coordinates of central point of cadastre. As different departments may be responsible for information about land use and value, therefore for that case, separate register for land-use and value can exist. All these register will include standard reference ID and address beside other useful information. Address will be used to locate land parcel on ground as it may not be feasible to identify parcel using standard Reference ID. However, at time, address
may be refined by different authorities and it may be difficult to integrate information, therefore, standard reference ID will form the basis of integration of cadastre. After incorporating register and vector maps, standard cadastral information can be generated by geo-processing. A standard geo-coded address file can be generated for geo-coding other alphanumeric information from different departments on address basis.

Fig.5: Information Viewpoint of SDI from urban planning perspective

Data about population and housing, community facilities, economy etc can be geo-processed for overlay on other maps for better understanding and analysis. Only education and health sectors are highlighted under community facilities but these will include all other community facilities like post offices, libraries, police station etc. Information about utilities infrastructure is critical to evaluate capacity analysis for new development. Normally this information is hard to obtain using traditional system. But geo-coding monthly usage of each utility service at parcel level and then geo-processing it with available network can assist us to find current status of their usage and future requirements. Data about weather like rainfall, temperature, wind and pollution is monitored at certain location and than interpolated for analysis. Standard geo-processing based on a uniform reference system and interpolation technique makes it really valuable. Otherwise different reference system and varying interpolation techniques means different users will be using different information. Standard image processing techniques can be used to explore land covers information from satellite images.

Once required information is available, next step will be the development of services facilitating planners and decision makers for informed decision making. Some of the
most common services or analyses are land suitability analysis, capacity analysis, environment impact analysis and hazard analysis. Land suitability analysis will be performed by evaluating feasibility of land for development by analysis topography, soils and geology information along with availability of infrastructure, related services and nature of land cover. Map showing different ranges of land from most-suitable to less-suitable for development can be generated and displayed in three dimensional to better communicate this information to decision makers and public enabling them informed decision making. Similarly hazard analysis can be performed by geo-processing information about land, environment, transportation, flood plains with population and housing. Local authorities can better identify critical areas vulnerable to disaster and necessary measures can be taken to reduce the impact of disasters. Even in worst case scenario, authorities can better identify affected areas, estimate the damage and devise improved strategy for recovery.

Capacity analysis is another very useful service for evaluating the capacity of natural resources like pollution absorbing capacity of environment, availability of drinking water as well as that of man made resources like transportation, utility services network. This information can be used for framing future growth strategies at city level. At neighbourhood level, planners can estimate the demand of new development against system capacity and in certain cases, efforts for capacity increase can be made in advance for important locations. These are only few examples of different services, which are outcome of local SDI. Many more services can be developed as up-to-date information continues to rise.

Other important components like metadata and services for discovery and retrieval in the form of geo-portal are part of the whole system. This viewpoint highlight the effectiveness of SDI in better information sharing and its application for the development of many critical services required by planners and decision makers for informed decision making.

CONCLUSION AND RECOMMENDATIONS

Urban areas are the major source of our local/gLOBAL problems and therefore, urban planners need to act more effectively and efficiently for informed decision making with public participation at policy level. Efforts for modelling the complex relationship between various urban elements are hindered due to the limited availability of information. Spatial Data Infrastructures (SDI) is one such platform for improved information integration, sharing and services delivery. Some of the most common services required by planners and decision makers at local level are explained in this paper as information viewpoint of local SDI. These services can be utilized by professionals in other fields as well without any need of data collection and integration efforts. Coordinated efforts between stakeholders will ensure development of comprehensive SDI satisfying requirement of each partner. Availability of information in appropriate format like three and four dimensions will not only increase public participation and transparency, but will also increase business opportunities. It will save precious time and resources of planners and facilitate them in better planning and management.

Presently no detailed model of local SDI is available. But with the coordination of stakeholders, international organization working on technical and other issues, researcher etc this can be a reality. Limited work on the design of local SDI as one
viewpoint is presented and other viewpoints are being developed paving a path for successful implementation of model. Once such platform starts functions, planners can device better policies and informed decision making and play an effective role in achieving sustainable cities as information availability, integration, service delivery and public participation is improved.

REFERENCES


**BRIEF BIOGRAPHY OF PRESENTER**

Mr. Faisal Masood Qureshi is doing PhD in Centre for Spatial Data Infrastructures & Land Administration, Department of Geomatics, University of Melbourne-Australia. His research area involves integrated urban planning system using Spatial Data Infrastructure. Mr. Faisal has his professional master in City and Regional Planning. During practical experience of serving as town planner at local level, accessibility of latest spatial information was one of the main problems faced by him and other professional colleagues. With the professional background of urban planning and practical experience of planning and GIS, he is exploring the role of Spatial Data Infrastructure to facilitate the accessibility of spatial information at local level particularly for urban planners in developing countries.