Towards National SDI in Pakistan: The Challenges

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Key words: LADM, CityGML, ISO-19152-2012, Spatial Data Infrastructure (SDI), Digital Cadastre, Musavi

SUMMARY

The role of geospatial technologies for sustainable e-governance at all administrative levels is certain. However, the availability of quality geospatial data is the impediment in successful application of these technologies in many developing countries around the world. Pakistan being a developing country direly needs to address the issue by developing Spatial Data Infrastructure (SDI) or Geographic Information Infrastructure (GII) at all administrative levels to serve the geospatial data needs of the country. However, the need comes with many challenges and the paper highlights some of those by giving examples from the land administration perspective.

تمام انتظامی درجوں پر پا ئیدار الیکٹرانک نظام حکومت کے لیئے جغرافیائی معلومات کا کردار یقینی ہے۔ تا ہم دنیا کے ترقی پذیر ممالک میں معیاری جغرا فیائی معلومات کا حصول اس راہ میں بڑی رکاوٹ ہے۔ دوسرے ترقی پذیر ممالک کی طرح پاکستان کو بھی اسی مسئلہ کے حل کے لئے جغرافیا ئی معلومات کا ڈھا نچہ بنانے کی شدید ضرورت ہے تا کہ ہر انتظامی سطح پر جغرافیائی معلومات کا حصول ممکن ہو سکے۔ تا ہم اس ضرورت سے منسلک کئی مشکلات بھی در پیش ہیں۔ درج ذیل مقالہ میں اس طرح کے مسائل کواجاگر کیا گیا ہے اور زمینی انتظامات سے متعلقہ مثالوں سے اس کی وضاحت کی گئی ہے۔

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1. INTRODUCTION

Geospatial technologies including Geographical Information Systems (GISs), Remote Sensing Systems (RSs) and Global Navigation Satellite Systems (GNSSs) have revolutionized our world (Agbaje, Bello, & Ojo, 2018; Kafi & Gibril, 2016; Dutta & Goel, 2017). Recent developments in geospatial software together with ubiquitous nature of location aware devices (smart wearable devices, smartphones, tablets and micro drones etc.) have empowered common masses to generate and process geospatial data for diverse application domains (Kamilaris & Ostermann, 2018). Thus Volunteered GIS (VGIS) (Goodchild, 2007) and Public Participation GIS (PPGIS) (Brown, Kelly, & Whitall, 2014; Sieber, 2006; Kingston, Carver, Evans, & Turton, 2000) have opened new vistas of opportunities and challenges at the same time (Stewart, Jacobson, & Draper, 2008).

In view of the importance of geospatial technologies, governments in both developed and developing countries have started exploiting these "enabling technologies" for ensuring good governance at almost all administrative levels (Sahroni, 2017; Shankar, Prajapati, Patel, Patel, & Kalubarme, 2017; Sharma, Joshi, & Kailash, 2015; Noor, Nor, Abdullah, & Zahari, 2014; Khan, 2013; McCall, McCall, & Dunn, 2012; Lewis & Ogra, 2010; Fisher, Myers, Sanam, & Tarus, 2009; Boondao, 2008; Caiaffa, Cardinali, Screpanti, & Valpreda, 2008) (Georgiadou, Rodriquez-Pabón, & Lance, 2006; Kemeling, Jong, Teeffelen, Berg, & Roerink, 2002). This needs government level policies and standards to streamline geospatial data generation, storage and dissemination efforts.

Spatial Data Infrastructure (SDI) or Geographic Information Infrastructure (GII) started as a formal framework in mid 1980s (Hu & Li, 2017; Coetzee, et al., 2017; Williamson I. R., 2007) that includes people, policies, standards and technologies for efficient spatial data sharing (Rajabifard & Williamson, 2001). SDIs may be generic or domain specific, may be developed for a specific sector, administrative division (sub-national SDI) or at central or federal government levels (National SDI or NSDI). SDIs thus play an important role, because geospatial data and information are important in managing everything that governments manage, from such as roads, facility networks, crime data, urban planning, land and public health.

Since early 1990s, the definition of SDI has transitioned from being a mere framework for geospatial data sharing to a new way of looking at governance and public engagement for sustainable development by facilitating the availability of and access to geospatial data (Feeney, Rajabifard, & Williamson, 2001). With the fast-paced technological advancements and ubiquitous nature of location aware devices, geospatial data is generated at higher rates than ever before. Different kinds of data are best maintained at different levels of government and NSDI is made up of many local and sub-national spatial data infrastructures. In view of this, the key questions to be addressed (by government decision makers) are;

1. What should be the national (sub-national) policies and regulatory mechanisms for geospatial data producers (regarding geospatial data generation, management and dissemination) and geospatial data consumers (regarding geospatial data exploration, access and usage?)
2. What standards are important to ensure geospatial data interoperability, reduce data redundancy and duplication of effort?

The paper explores feasibility and challenges of implementing SDI for better e-governance in Pakistan. This is demonstrated by evaluating the adaptation and application of two international standards for the land administration and 3D city modelling domain in Pakistan

2. GEOSPATIAL DATA IS AT THE CORE

SDI architectures have changed with the rapid advancement of technology and standards in recent years (Wiemann & Bernard, 2016). However, geospatial data is at the core of any SDI (as depicted in Figure 1) with the associated activities of geospatial data generation, geospatial data management or storage, and finally the geospatial data dissemination and exploration. The key question to address is how SDI standards, policies and technologies encompass these three primary activities? In the following sections we will briefly discuss each activity by raising some important questions.

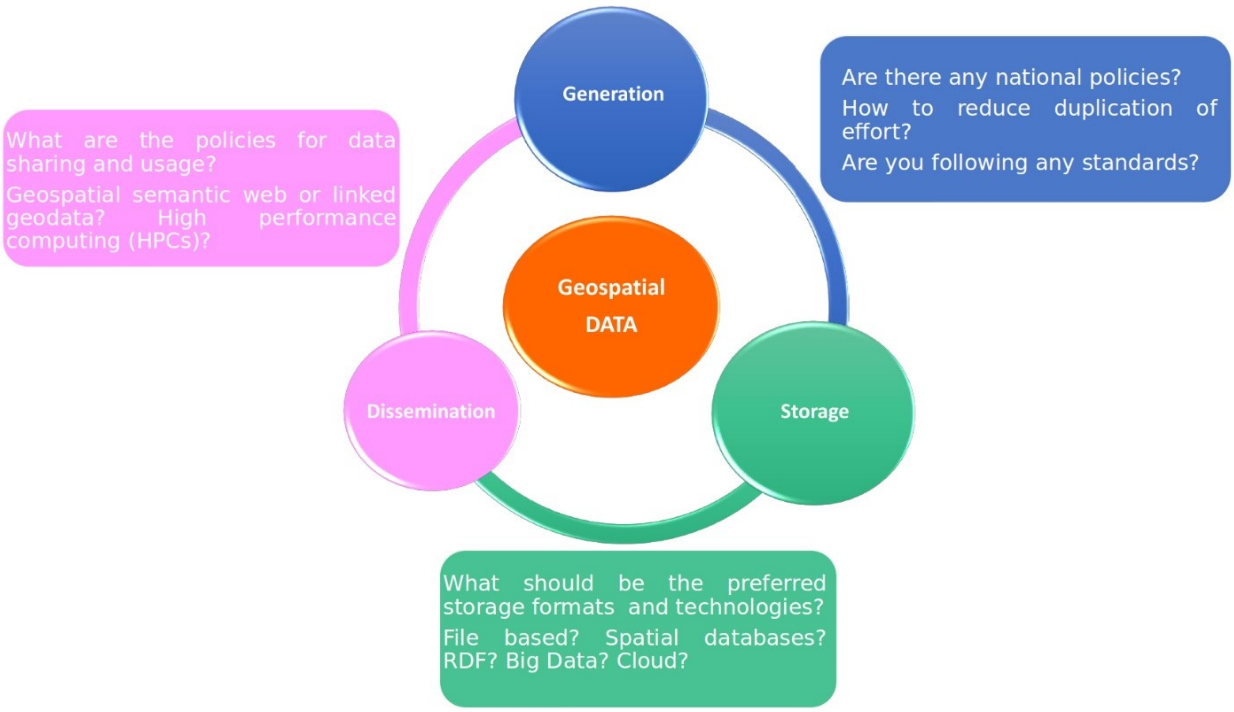

Figure 1: Data centric SDI activities and challenges

2.1 Geospatial Data Generation

Technological advancements in recent years have greatly influenced the geospatial data generation techniques. As an example, people carrying smart phones (as most have built-in

GPS, motion and other sensors) traveling in a vehicle can record road bumps (road health) on the fly and this geospatial data captured by public can be shared automatically with authorities concerned for road maintenance (Chugh, Bansal, & Sofat, 2014). The example also emphasizes the importance of PPGIS or VGI in geospatial data generation.

GIS, especially, Free And Open Source Software for Geospatial (FOSS4G) can easily be used for generating geospatial data sets by either digitizing legacy paper based maps, or generating new geospatial data sets afresh by doing surveys or capturing geospatial data using GPS enabled wireless devices (Minghini, et al., 2017)
Although there is a tremendous advancement in geospatial data capturing and generation systems, the fact brings in new challenges as well. What are the policies regarding flying a drone equipped with Light Detection and Ranging (LIDAR) for point cloud generation of an area of interest? Is there any mechanism to check whether the geospatial data sets we are interested are already in place with some individual or organization to avoid data redundancy and duplication of effort, thus saving resources?

Geospatial data either generated through conventional means or using state of the art geospatial technologies, generated by an individual or an organization must have metadata definitions that comply standards either international metadata standards or indigenously developed ones. This is necessary for ensuring geospatial data interoperability and facilitates geospatial data discovery and sharing once the SDI is in place.
Another important aspect to cover at geospatial data generation level is to ensure geospatial data quality. Geospatial data quality is important because the principle of "garbage in, garbage out (GIGO)" becomes true as we cannot be sure of the results obtained based on data whose quality is questionable. This necessitates that quality parameters and guidelines be in place to ensure quality of the geospatial data generated at all levels.

2.2 Geospatial Data Storage

Once the geospatial data is generated it needs to be stored in a digital repository or a spatial database. A Spatial Database Management System (SDBMS) facilitates the management of geospatial data for efficient storage, retrieval and processing through spatial data query support.

There are many SDBMSs both in open source (e.g. PostGIS, SQLite etc.) and proprietary (Geodatabases, Oracle Spatial etc.) domains. Recently, the NoSQL or non-relational SDBMSs (MongoDB, Couchbase, Neo4j etc) have also got much attention for geospatial data management. It has been shown that the performance of NoSQL databases is better on average than relational databases for some spatial functions (Agarwal & Rajan, 2017). The relevant questions are; which SDBMS is appropriate for storing geospatial data sets? What are the preferred data formats?

Additionally, the temporally variant geospatial data like satellite imagery gathered across many available satellite platforms will build enormous databases over time. The emerging "big data" science concepts are being applied to managing enormous amounts of geospatial data sets (Lee & Kang, 2015). The advanced cloud based storage and computing techniques are helpful to meet geospatial big data challenges (Yang, Yu, Hu, Jiang, & Li, 2016). Also, database versioning is important to keep track of changes in geospatial data sets to ensure transparency.

2.3 Geospatial Data Dissemination

One of the key objectives of SDI is to facilitate geospatial data discovery and sharing among individuals, departments, organizations or even among countries for example as in the case of European Union (Masser & Crompvoets, 2018; Vries, Crompvoets, Stoter, & VandenBerghe, 2011; Jean, 2008). Some of the relevant questions that arise are; What are the policies and protocols for geospatial data sharing? What needs to be shared? Who owns the data? What technologies will be used for efficiently and effectively disseminating geospatial data sets to end users ensuring 24/7 availability?

Geoportals in conventional SDI implementations enable the discovery and access of geospatial data and services by using keywords in metadata only. Differences in semantics used across heterogeneous data sets impede the semantic searching. However, using geospatial semantic web technologies or linked (geospatial) data technologies allow the semantic discovery and access to geospatial data (Zhang, Li, & Zhao, 2007).
Other cutting edge technologies like CyberGIS (Wang S. , 2010; Wang & Goodchild, 2018), cloud computing (Yang, Yu, Hu , Jiang , & Li, 2017; Yang, et al., 2011) and high performance computing (HPC) (Karthik, et al., 2018) provide attractive alternatives for developing effective SDIs for efficiently serving geospatial data and services.

3. LAND ADMINISTRATION CHALLENGES IN PAKISTAN

Pakistan is facing serious challenges of governance (Faisal, 2017) due to corruption, opaque legislation and poverty etc (Adnan & Fatima, 2018). The challenges are posing threats to the pace of sustainable economic development (Asghar, 2013).

The people of Pakistan are suffering the land insecurity and land dispute issues due to the entirely opaque land management system (Ali & Nasir, 2010; World-Bank, 2006). It is revealed that 40% of the court cases based on land disputes (Bardouille, Palmade, & Shah, 2005) and other worse dispute scenarios are corruption, land mafia and illegal grasping of land by feudal (Refworld, 2017; USAID, 2016; DAWN, 2010). The apex court of the country has recently given a verdict on a century old land dispute case (Tribune, 2018). The slow judicial proscess is deteriorating property market and overall economic situation in the country.

Legacy cadastral system of Pakistan was inherited from British colonial system and is based on five hundred years old methods of land record management (World-Bank, 2006). The system is complicated as it keeps land records in more than two dozen manually prepared registers and archived in poor storage environments (Ali Z. , 2013). Government of the Punjab (GoP) with the support of the World Bank invested 70 million USD and almost a decade to improve the rural land record system in the Punjab province of Pakistan, but unfortunately digitization of spatial part (parcel geometries) is not done that is of utmost importance for its later inclusion in SDI. There was a pilot study conducted under the World

Bank funded project to convert manual cadastral maps into digital form. The study failed to obtain the desired results due to complicated nature of record keeping and poor methodology (of digitizing scanned maps) (Ahsan, Hussain, & Ali, 2017).

The conventional system has number of problems as highlighted in various research papers (Ahsan, Hussain, & Ali, 2017; Ali, Zevenbergen, & Tuladhar, 2013). These problems (as summarized in Figure 2) have been categorized into two parts, causes and effects. Causes are further classified into two types institutional issues and technical issues.

The institutional set-up of the land recording system (especially in urban areas) is of opaque nature, involving many different agencies. The main ones are the provincial Board of Revenues (BoR)[1], the provincial Excise and Taxation Department (ETD)[2], and the development authorities (DAs). If the property is situated in any housing society for example (Defence Housing Authority Karachi[3] or Model Town Lahore[4]), then the land records of that property will be in the custody of that society. However, there is no single agency maintaining updated land records for all the provinces in the country, and the coordination in record keeping functions being carried out by the various agencies is limited.

On the other hand, BoR is the most important agency for land administration in case of rural areas to collect land revenue for the government and also works as the custodian of rights as well. However, BoR's land record maintenance in rural areas takes place through an intricate system that involves several levels of administration. BoR is the most important agency for land administration in case of rural areas, a body made responsible to collect land revenue for the government and custodian of rights as well. Institutional issues can only be solved through amendments in policies and legislations (Akhtar, 2017; Mirza & Adeel, 2012).

The technical issues can be resolved by adopting state-of-the-art ICT and geospatial technologies at all levels of development. In 2014, the legislative assembly of Pakistan approved a legal framework (The Gazette of Pakistan, 2014) allowing national surveying and mapping agency (Survey of Pakistan[5]) to establish National Spatial Data Infrastructure (NSDI) in Pakistan. The framework is still at infancy to practically feed the geospatial data needs of the country. Even the recent IT policies in Pakistan unfolding e-Governance initiatives. (MoIT, 2018; PITB, 2018) SDI component. India has successfully implemented NSDI (Acharya & Pandey, 2018) while our another neighboring country Iran is still struggling with SDI challenges (Kalantari, Modiri, Alesheikh,, Hosnavi, & Nekooie, 2018).

1 https://www.punjab.gov.pk/board_of_revenue, http://borsindh.gov.pk/

2 http://www.excise-punjab.gov.pk/, http://www.excise.gos.pk/

3 https://www.dhakarachi.org/

4 http://mts.com.pk/

5 http://www.surveyofpakistan.gov.pk/

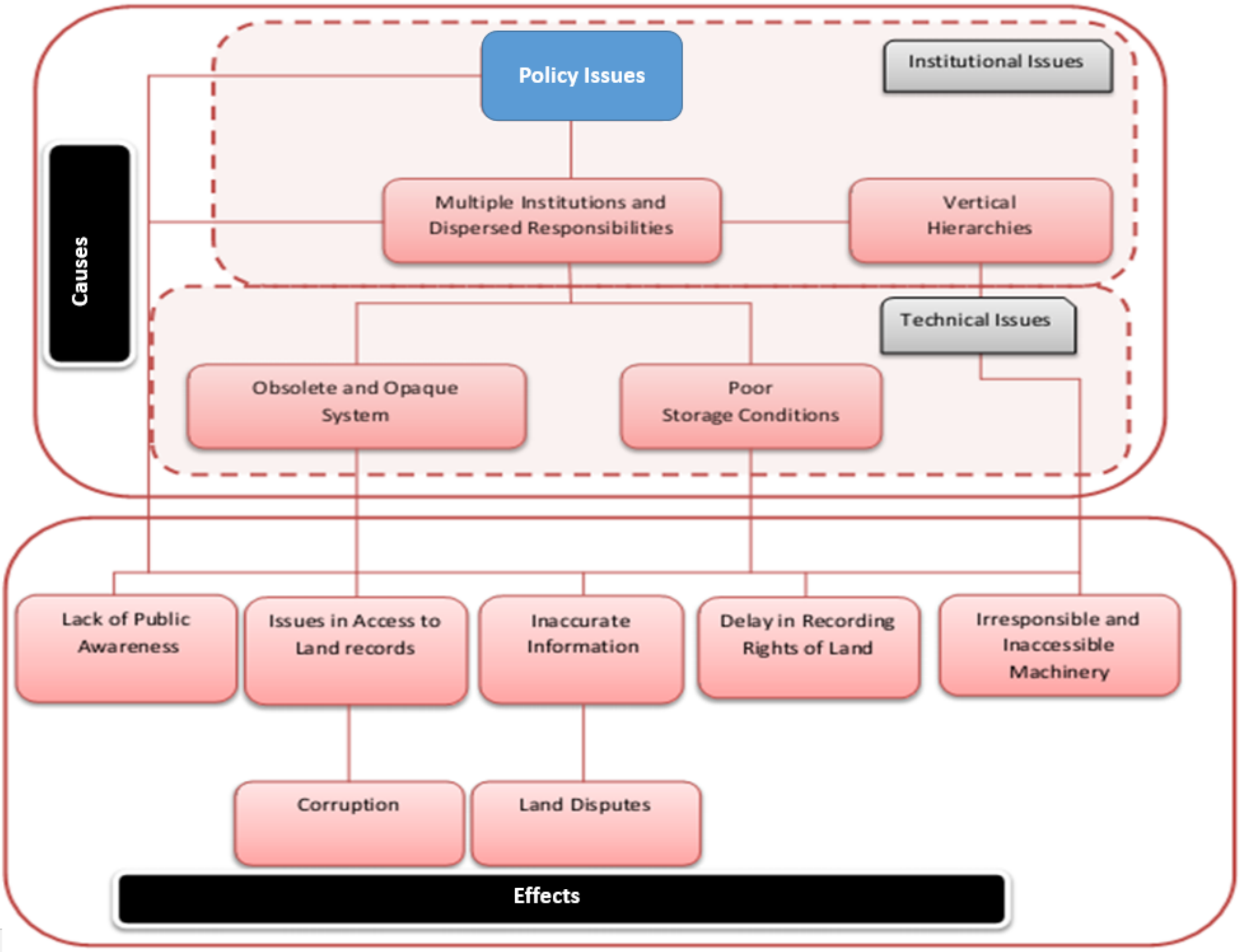

Figure 2. Issues in conventional Cadastral System of Pakistan

Most recently we have seen laudable efforts from GoP to digitize rural land records in the province (Gonzalez, 2016) while the similar practice for urban land records is still awaited (Butt, 2018). Khyber Pakhtunkwa province is also progressing towards having digital cadastre sooner or later. In the lack of national or provincial SDI, how cadastral systems are being developed and the overall process regulated? Are provinces using any international or locally developed standards?

SDI is essential for sustainable land and related resource management, administration and usage (Abdulrahman, 2014). Digital cadastre, being one of the key components of any SDI is crucial for land record management for multi domain usage (Williamson I. , 1985). FIG (International Federation of Surveyors)[6] provides complete definition of 'cadaster' as: "A parcel based, and up-to-date land information system containing a record of interests in land" (e.g. rights, restrictions and responsibilities)[7]. FIG maintains country wide digital cadastral templates[8] for digital cadaster (Steudler, Williamson, & Rajabifard, 2004). Cadastral template

6 https://www.fig.net/

7 http://www.fig.net/resources/publications/figpub/pub11/figpub11.asp

8 http://www.cadastraltemplate.org/

of Pakistan was introduced in year 2012 with later a round of update in 2017 (Akhtar, 2017; Mirza & Adeel, 2012). In the next sections, we discuss two standards from two domains to emphasize the practicality of introducing standards to turn the dream of national SDI for Pakistan into a reality.

4. LAND ADMINISTRATION DOMAIN MODEL (LADM)

LADM is generic data model for the land administration originated by International Federation of Surveyors (FIG) in 2002 which later accepted by International Standard Organization (ISO) and published as ISO 19152-2012 in 2012. LADM is not a country specific model, rather it is a conceptual schema flexible to be adopted by any country and modify according to her needs (Lemmen, Oosterom, & Bennett, 2015; Lemmen, Oosterom, & Molen, 2013; ISO/DIS-19152, 2010). There are three main packages and a sub package of LADM (Lemmen, Van Oosterom, Thompson, Hespanha, & Uitermark, 2010)

- Party (individual, company, state)
- Basic Administrative Unit (Property rights, restriction and responsibilities)
- Spatial Unit (building, parcels)
  - Survey and Spatial Representation Sub Package (survey points)

LADM package has further classes to define their role in land administration as shown in Figure 4. However, LADM is not readily usable in Pakistan's context and in order to adapt it locally we may need to add new values (attributes) to existing entities (classes) and/or even introduce additional entities (classes) to capture local phenomena. Figure 5 shows the adaptation by mapping the main packages of LADM to the newly introduced packages in the corresponding land administration structure for Pakistan called Pakistan Land Information Model (PLIS).

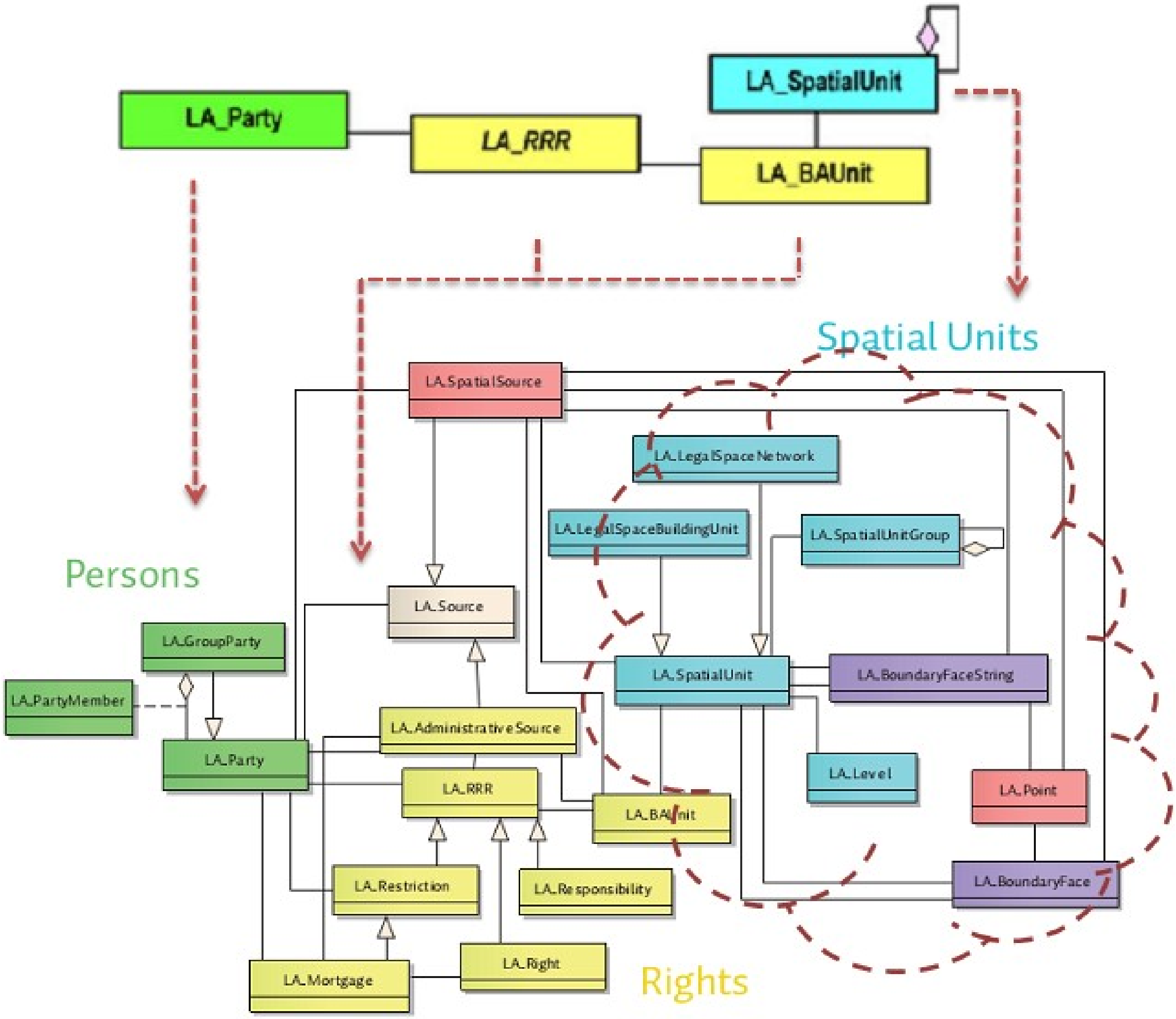

Figure 4: Land Administration Domain Model Packages and Classes

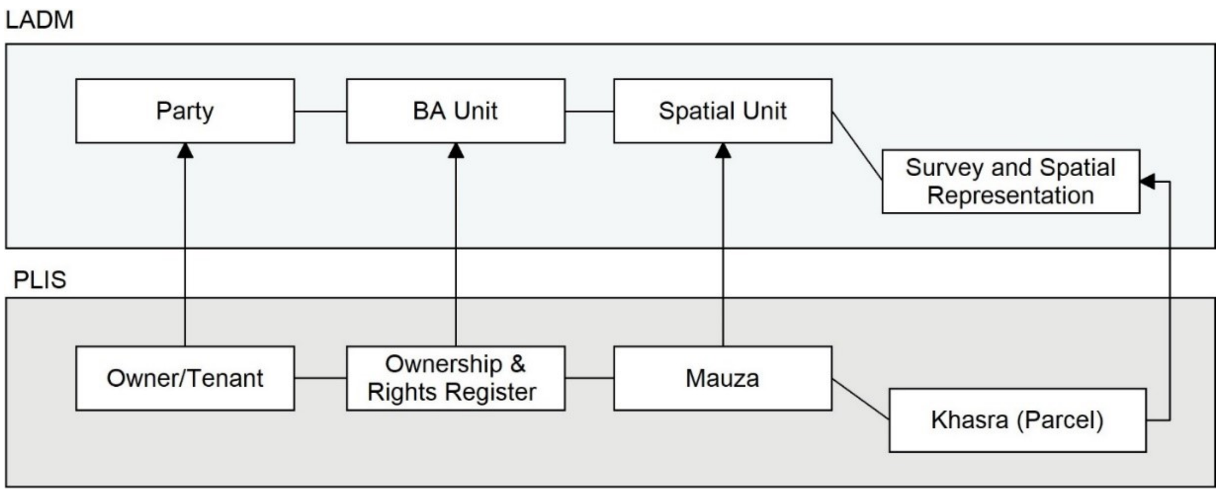

Figure 5: LADM Packages and their corresponding structure in Pakistan

Since we are focusing on investigating the spatial part of Pakistan's cadastral system and its feasibility for integration into SDI, therefore only Spatial Unit Package and Survey and Representation Sub Package of LADM is remodeled according to Pakistan's cadastral mapping needs. The mappings of spatial and sub unit classes and data relationships between LADM and PLIS are shown in Table1 and Table 2 respectively. The classes of LADM spatial unit package and, survey and spatial representation sub package each mapped with the proposed PLIS along with existing cadastral record is shown in Figure 6.

Table 1. Proposed Spatial and sub unit package classes of LADM and PLIS.

LADM Classes	**PLIS Classes**	**Existing Record**
LA_SpatialUnit	Pk_Parcels	Musavi Map
LA_SpatialUnit	Pk_Blocks	Musavi Map
LA_SpatialUnitGroup	Pk_Mauza	Musavi Map
LA_RequiredRelationship	NA	Not Exist
LA_Level	NA	Not Exist
LA_LegalSpaceUtilityNetwork	NA	Not Exist
LA_LegalSpaceBuilding	NA	Not Exist
LA_Point	Pk_Boundary_Marks	Musavi Map
LA_SpatialSource	Pk_Raster_Data	Musavi Map
LA_BoundaryFaceString	Pk_Boundary_Line	Musavi Map
LA_BoundaryFace	NA	Not Exist

Table 2. Description of PLIS data relationship.

Relationship Name	**Origin Feature**	**Destination Feature**	**Relationship type**
Parcel_Line_Polygon	PK_Parcels	PK_Parcel_Line	One-to-many
Parcel_Block	PK_Parcels	PK_Blocks	Many-to-one
Block_Mauza	PK_Blocks	PK_Mauza	Many-to-one

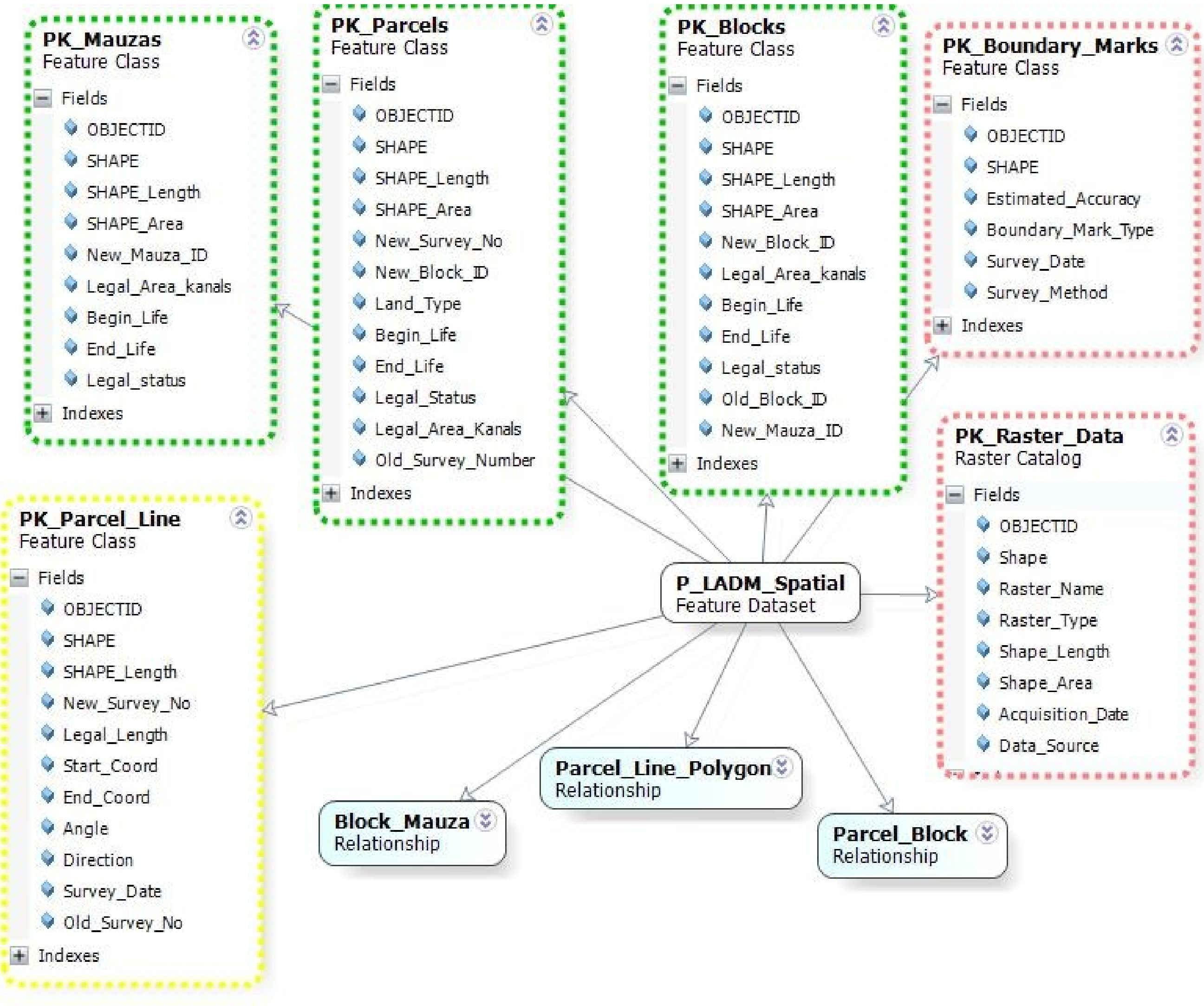

Figure 6. LDAM Spatial Unit and Survey and Spatial Representation Package for Pakistan (PLIS)

5. CITY GEOGRAPHY MARKUP LANGUAGE (CityGML)

Recent population census in the country has revealed that population density of federal capital and metropolitan city Islamabad[9] has increased from 889 to 2209 persons per square kilometer during 1998-2017. The population density of Karachi, the largest metropolis city of Pakistan, is 3066 person per square kilometer (PBS, 2018). The fact of unprecedented population growth in urban centers, especially in vertical direction, invites special attention towards the development and management of 3D cadastre.

[9] http://mci.gov.pk/

The buzzword of “smart cities” is commonplace nowadays. GIS based 3D city models provide basis for many applications ranging from sustainable urban planning and management, crises and disaster management, telecommunication, archaeology, noise and pollution modeling, telecommunication, facility management and many other domains. The questions that arise in the context of Pakistan are; do we need smart cities? Do we have 3D city models in place? How DAs in big cities and Capital Development Authority (CDA) in the capital is managing the city without having any 3D city model in place?

Buildings are one the most important components of any 3D city model (Paasch, et al., 2016). Up to the best of our knowledge CDA collects scanned CAD based 2D layout planes of homes for issuing No Objection Certificates (NOCs). Are these paper based 2D layouts are being used for any management purpose or just archived for nothing?
Architecture, Engineering and Construction (AEC) world lives with Building Information Modeling (BIM) a process that supports information management at all levels of a building’s lifecycle (Ghaffarianhoseini, et al., 2017; Gu & London, 2010). BIM manages 3D geometry using International Foundation Classes (IFC) which is an official ISO standard (ISO 16739:2013).

GIS world lives with CityGML which is the defacto Open Geospatial Consortium (OGC) standard for managing 3D city data (Gröger G. , Kolbe, Nagel, & Häfele, 2012; Gröger G. , Kolbe, Czerwinski, & Nagel, 2008). Conversion from BIM/IFC to CityGML is possible, thus opening ways for readily integrating AEC datasets into GIS for geospatial analysis (Laat & Berlo, 2011; El-Mekawy, 2010).

It is the need of the hour that CDA and other DAs require BIM compliant building models for issuing NOCs, especially for high-rise multi-storey commercial buildings. This can facilitate rapidly building and maintaining CityGML compliant 3D city models. Once 3D city models are in place, many diverse applications can be developed to manipulate these city data sets. For example, CDA can identify building law violations instantaneously sitting in room than visiting door to door thus saving many resources.

In order to support the notion of “smart cities”, SDI must support the handling of cityGML compliant 3D city models. This necessitates the careful investigation and integration of state-of-the-art 3D city modeling technologies that provide support for 3D model generation, rendering, dissemination and above all the maintenance (Navratil, Bulbul, & Frank, 2013).

6. CONCLUSION

The role of SDI is deemed crucial for sustainable e-governance at all administrative levels of a country. Pakistan, being a developing country, is still struggling with the implementation of a national SDI that may help the citizens by better geospatial data and service delivery at all levels. To achieve this much awaited goal, there are many challenges ahead. We highlighted some of the challenges that are of utmost importance.
The key challenge is the lack of government level policies and standards to streamline the geospatial data management and sharing efforts through SDI implementation at all levels. We

focused on the challenges related to standards for the implementation of national SDI in Pakistan.

This is demonstrated by showing the adaption and application of two two international standards i.e LADM and CityGML in land administration and 3D city modeling domains respectively. The land administration in Pakistan is highly disintegrated and there is disparity in urban and rural administration. Currently, the use of technology for sustainable land administration in Pakistan needs to have national and regional SDIs or GIIs as soon as possible. The standards will further pave the way for national and sub national SDI implementations. We showed that in order to apply LADM in the context of Pakistan we need to adapt the standard by introducing new values in existing classes and even introducing new classes to capture the local phenomena appropriately.

Major cities in Pakistan are growing vertically because of the rapidly growing population and urbanization thus requiring special need to manage 3D cadastre. In addition, the notion of smart cities also requires the need for having 3D city models in place, at least for major cities of Pakistan. This poses many challenges for national SDI to be able to handle 3D geospatial data sets by providing support for the management, rendering and maintenance of cityGML compliant 3D city models.

In order to turn the dream of having national SDI for Pakistan, we make some recommendations that may be helpful for the achievement of long-awaited goal;

1. Working groups should be formed at national and regional levels. The diversity of members should be ensured to cover all stakeholders.
2. Academia should take leading role and contribute in SDI design and implementation at all levels. They can also play crucial role regarding;
   - Standards: either developing new or adopting existing international standards in local context.
   - Capacity building: educating people and organizations on developing their capability and capacity to actively contribute to SDI.
3. The choice of technologies for the implementation of SDI can have profound impact on the effectiveness of the SDI. Cutting edge technologies like linked data, cyberGIS, cloud storage and computing, and HPC provide reasonable alternatives for the implementation of a sustainable SDI.

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