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Arc GIS and 3D Visualization of Land Records: A Case Study of Urban Areas in Punjab

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Abstract Real estate objects are three dimensional, however they are usually dealt in one or two dimensions. In modern construction industry, the land ownership is counted above as well as beneath the earth surface which requires the measurement, ownership documentation and the rights as volume (3D). Major socioeconomic issues of Pakistan are high population growth rate, high rate of urbanization, industrialization and alarming rate of conversion of agricultural land in to non-agricultural uses. During the past few decades, the trend of urbanization resulted in huge horizontal expansion of the cities which raised many problems, e.g., traffic conjunction, security and slums. To address these problems, vertical growth of cities was emphasized and all the major cities of Pakistan were populated with skyscrapers but its legal, technical and the institutional perspectives were not planned which led to the insecure land tenure and failure to control the horizontal expansion of cities. This paper analyzes the current land record system in urban areas of Punjab and identifies its limitations. We explore the need of volume parcel registration through a case study and demonstrates a 3D land registration solution by using Arc GIS Parcel Fabric and Arc Scene data models.

Keywords Spatial data · Tenure · Cadaster · Land registration

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1 Introduction

Land registration system is the process of determining and recording land boundaries, land title and land rights. The current land registration system in Pakistan lacks a major component: the spatial component; as no spatial information about the land boundaries is maintained by the land registration institutions. There are a number of acts in public law related to land registration and a number of organizations are involved in this registration process. Land record management system of Pakistan is based upon a top-down approach. Physical land records are not maintained at Federal level however, all the laws related to land are approved at the federal level. The land record system physically operates at the provincial level. Town Municipal Authority [3] is the main custodian of land records in urban areas of Punjab, where the records are maintained at district and tehsil levels. However, for small urban settlements only Tehsil Municipal Administration is responsible for land record management.

Due to various social, economic, health and safety reasons, the percentage of urban population in almost all major cities of Pakistan, in particular in Punjab, has significantly increased in the past few decades. Tab. 1 reports the trend of urbanization since 1951 at country level, in Punjab Province and in Lahore. The statistics presented in the table show a consistent increase in the percentage of urban population. Due to poor planning in cities and failing to provide the basic facilities in rural areas, this huge rate of urbanization gave birth to many problems. Poor and outdated land management system is an important problem amongst many others, like pollution, insecurity, inflation, lack of health, education and other facilities. To manage the urban problems of the mega cities, the direst need is the security of land tenure which is only possible by developing a secure land registration system. Vertical expansion demands an updating of land registration system for provision of spatial and non-spatial

Table 1 Population growth and percentage of Urban Population in Pakistan, Punjab and Lahore. Popul. shows the total population of Lahore in Millions and Density is in Person per Square Kilometer in Lahore.*[Source: Pakistan Bureau of Statistics]*

Year	% of Urban Population			Lahore	
	Pakistan	Punjab	Lahore	Popul.	Density
1951	17.74	17.37	75.90	1.13	640
1961	22.52	21.50	80.73	1,63	917
1972	25.41	24.42	84.62	2,59	1,460
1981	28.21	27.60	84.30	3,54	2,000
1998	32.52	31.27	82.44	6,32	3,565

information of land parcels and land rights. Existing deed based registration system practiced in urban areas lacks spatial component for 2D as well as 3D parcels. Moreover, a huge diversity of institutions and actors is being observed regarding land records management. Inconsistency in land records is found amongst various actors and there are no standard protocols for data exchange. All the private housing schemes and high rise building plans are approved duly by the City District Government [2].

Several countries struggle with 3D cadastral issues where the introduced solutions partly solves the problems of 3D cadastral registration and no country so far has fully incorporated 3D properties into 3D cadastral base maps. However, few countries e.g., Sweden, Norway, Australia, have applied the approach of visualizing the footprints of 3D property units [19,17]. The extensive research on the current situation of 3D cadastral registration for these countries concludes that none of the existing solutions is complete. A major limitation identified in these solutions is their inability to address the technical issues such as storage, query and visualization of property units in 3D. In some cases, e.g., in Israel [19,21], the 3D information is only available through titles, survey plans or deeds. The consequence is that it is not possible to view 3D parcels interactively with 2D parcels.

Over the years, in addition to many other applications, Geographical Information System (GIS) has proved to be a useful tool for managing and analyzing 2D cadastral information [8,6,15,14]. For a long time, the GIS community assumed that everyone understands the 2D display of geographic information although the world around us is three-dimensional [16]. The use of 3D in GIS started not more than a decade ago; and still it has not received much acceptance by a large GIS community. To illustrate the current practices of registration authorities, a case of an apartment building, Fazal Apartments, in Lahore is evaluated. Land records development of three major actors: Lahore Development Authority (LDA), Board of Revenue (BOR) and Excise and taxation department are examined to emphasize the need of 3D cadaster solutions. Fazal Apartments is a multistory building with mix land use and complex geometries. All the apartments and shops are given a unique identifier (ID) which also indicates its location in terms of strata, e.g., apartments at ground floor are given ID number starting with letter G, at first floor with letter F, second floor with letter S, and so on. Fard (a legal document of ownership) is on the name of original owner of Fazal Apartments, who has sold all the shops and apartments and now retains the rights of basement and roof only. Basement parking and community hall is on rent. In multistory developments, parcel identifier is owner's choice; and even different buildings under revenue department and other institutions have different formats.

In the Board of Revenue, *Fard* is a legal document that establishes the land ownership in a parcel. In case of vertical developments, multiple owners and uses in a building, only one Fard is available with a sole owner. It means that a building with multiple apartments, various owners and diverse land uses is given only one property number in land register with a single owner. The individuals owning a shop or an apartment do not get any Fard as proof of ownership and they only have a sale deed duly registered in the concerned Town Municipal Authority (TMA) registrar office and signed by an assistant registrar. Information in a sale deed is mainly in textual format consisting of multiple pages. Its major components are parcel address, value, information about the buyer and the seller, information about the previous transactions of property, details of property taxes, and the land rights. Excise and taxation department is another institution that maintains land record information in two forms, PT1 and PT10. It maintains a property number along with its owner, uses and dimensions information of the property. The property number given to a parcel is different in each land record organization so if in sale deed PT1 number is given then it can be related to revenue office records and again its not a custom in all sale deeds. Moreover, the PT1 number changes as the owner of the property changes. In order to enhance tenure security, the Punjab Government has recently started *Land Record Management and Information System* (LRMIS) project [1] to computerize the land records and to improve the land record services by using geospatial techniques.

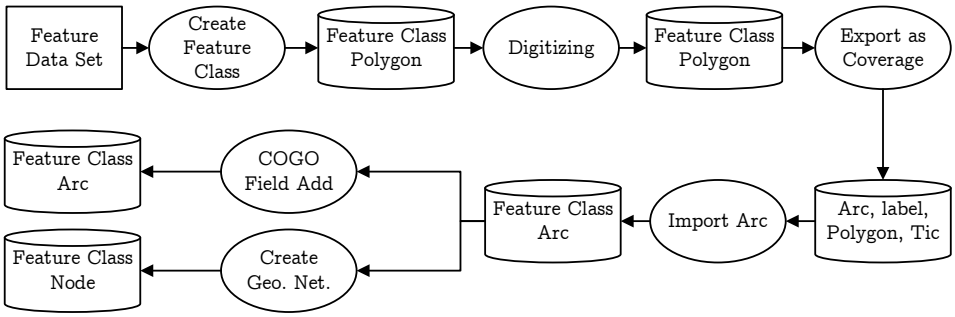


Fig. 1 Feature dataset development methodology.

2 Materials and Methods

The registration objects in 2D cadaster are traditional planar parcels whereas in 3D cadaster the registration objects are 3D property objects [12]. The 3D geographic space of a property object is defined accurately in 3D cadaster [7]. At present, the following nomenclature is used to represent the 3D legal spatial objects [11]:

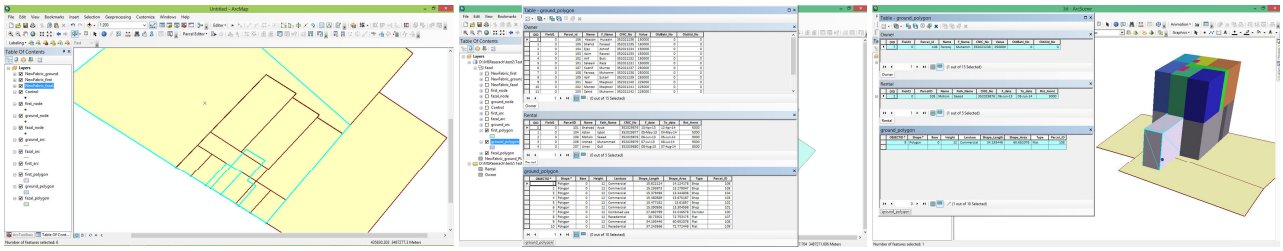
1. Full 3D cadaster registration: representation of entire parcels/space in 3D.
2. Hybrid approach: representation of entire parcels/ space in 2D and for volume parcels maintain a legal and spatial relationship with 2D parcel.
3. 3D tagging: maintaining the entire parcels/space in 2D and volume parcel references are maintained in non-spatial data.

In the Punjab Government Land Record Management and Information System (LRMIS) project, 3D tagging approach is being used to maintain information for 3D volume parcels. This paper adopts the hybrid approach for volume parcels. Geometries and spatial relationships of volume parcels are developed as 2D objects in different layers and for analysis of complex problems, a 2D parcel is displayed in a 3D space. Hence, the traditional legal requirements for 3D cadaster can be maintained by a common coordinate system and topological rules. The parcel fabric data model introduced by ESRI (Environmental Systems Research Institute) in 2010 is crafted to realize the FIG (Fédération Internationale des Géométres) future vision of cadaster. It incorporates parcels in geospatial data as points and lines rather than shape files [4]. The cadastral fabric is a continuous model of land objects (parcels) that provides an electronic representation of legal cadaster [13]. The geo-database is the main storage component of the system and it can hold the complete cadastral fabric database ranging from a small project to a state or federal government database. The cadastral fabric model implements topology as a flexible set of integrity rules that defines the behavior of spatially related geographic features and feature classes. User can model spatial relationships such as adjacency and can manage the integrity of coincident geometry between the feature classes, such as coincident parcel boundaries and subdivision boundaries [10].

In order to realize a 3D cadastral model, building footprint plans were scanned and georeferenced by coordinates acquired through GPS survey. The plans were scanned by using Vidar large-format scanner on a resolution of 300 dpi. The scanned images were georeferenced with the coordinates acquired through field survey. By using GPS instrument Garmin Oregon 550, the coordinates of all turning points of entire plot were acquired and then georeferencing was processed in Arc Map. Spatial reference system was specified as UTM Zone 43, WGS 84 and Transverse Mercators projection. By using the scanned building plans, 2D parcel fabric was created with attributes of absolute location, topology, coordinate geometry attributes, COGO components, and relationship between the land and property [9]. Fig. 1 shows the detail design and methodology of the proposed spatial data development model.

By adopting the above described methodology, a feature dataset was created using the entire plot, ground floor parcels and first floor parcels. For each object, the feature classes of arc, nodes, control points and polygons were produced. COGO fields of Arc feature class were also developed which make it possible to calculate the arc length and bearing as editing of parcel boundaries overtime is only possible if there is topological relationship based upon geometric network is available [18, 20]. An important ability of parcel fabric is the association with other features classes which are cadastral dependent on parcel boundaries. To develop a relationship between a parcel and a building (land and property) Fazal plot parcel fabric was kept as a base parcel while ground floor and first floor were joined with base parcel to visualize the relationships of infrastructures at different floors. Parcel on any floor of this building maintains its spatial relationship with the original parcel as demonstrated in Fig. 2a.

The final step in our physical model is to demonstrate all the geometries and non-spatial relationships in 3D data. To this purpose, when feature dataset was created for each floor, two attributes were introduced in attribute data, namely base and height (both in feet). For ground floor base was 0 and



(a) (b) (c)

Fig. 2 Land property relationship: (a) Topological relationships between base parcel and joined parcels, (b) Attribute relationships between base parcel and joined parcels, (c) Querying land tenure of volume parcels

height was 12 feet and for first floor, the base was 12 feet and height was 24 feet. Data set in Arc Scene[1] was extruded according to these two columns which enabled the visualization of apartments and their corresponding right holders. The major goal of any parcel registration system is to demonstrate land tenure. The 3D physical model developed here fully satisfies this requirement; land tenure in all 3 dimensions can be queried in developed dataset as shown in Fig. 2b.

3D volume parcels can be scaled, shifted and rotated according to user interaction and attributes of requested geometries can also be displayed. The proposed model enables visualization of 2D parcel, volume parcels and tenure data in the same interface. In addition to visual representation of the volume parcels with land tenure, the parcel fabric in 3D (as shown in Fig. 2c) can be used for tax assessment, zoning and planning purposes. Moreover, it is flexible enough to change in the predefined elements of the database and to associate with a number of new elements as needed for new activities. Furthermore, the parcel fabric can manage from a small group of parcels to hundreds of thousands of parcels and is capable to process from a few COGO values to thousands of values [5] which shows that the model is capable to handle huge and complex data.

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