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Developing a 3D cadastre for the administration of urban land use: A case study of Shenzhen, China

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ABSTRACT

Fast economic growth and rapid urbanization present a challenge to the limited urban land resources of China. Specifically, they encourage a shift in the concentration on the surface of land parcels to the space above and below them. Recent development in land utilization in developed cities has broken the traditional frame of the parcel-based or 2D cadastre. The three-dimensional (3D) cadastre is now accepted by researchers as an effective technical means to support the administration of space. Taking Shenzhen, a quite developed city in China as a case study, this paper presents an ad hoc paradigm to develop a 3D cadastral system for the management of land space use in it. The demand for a 3D cadastre is shown through two actual instances of land space exploitation. Relying on current legislation, administration, and 3D technology, we design a full 3D cadastral system and embed it in the current cadastral system so that the administration of land space can be realized without an alteration in the frame of cadastral data or in current administrative procedures. Presenting an application example, we demonstrate the easy implementation and practicability of our 3D cadastral system. We find, however, that current institutions require some but not excessive modification when fully implementing it for land administration.

1. Introduction

The management of rapid urbanization, one of the signs and motors of China's economic development, has been and is a fundamental issue. As a developing country with a very large population, China's swift economic development has certainly reduced poverty, even though about 90 million of its people still fall under the poverty line, earning less than US$ 234 a year (Lu, 2011). However, a conflict between urban growth and limited land resources has increasingly emerged; in effect, current urban development, which takes the form of urban sprawls, is not sustainably affordable. Therefore, further urban expansion requires a change in land use patterns, since the latter are considered critical for promoting sustainable progress in developing countries (Foley et al., 2005; Tilman et al., 2001; Turner, Lambin & Reenberg, 2007).

To meet this challenge, well-developed cities such as Shanghai, Guangzhou, and Shenzhen turned several years ago to the vertical use of land space, that is, the space above and below surface land parcels. However, traditional two-dimensional cadastral technology has proven to be deficient in the management of these newly conceived urban spaces; thus, the 3D cadastre is emerging as an effective means to support the administration of space in three dimensions (Agdas & Stubkjær, 2011; Benhamu & Doytsher, 2003; Chong, 2006; Choon, Hussin, & Oon, 2010; Doner et al., 2010; Hassan, Ahmad-Nasruddin, Yaakop & Abdul-Rahman, 2008; Stoter, Ploeger, Louwman, Oosterom, & Wünsch, 2004).

Shenzhen, our case-study city, is located in the southeastern coastal region of China, adjacent to Hong Kong, and is one of the most economically advanced cities of the country; it has experienced rapid and steady economic growth and urbanization. According to the *Shenzhen Statistic Yearbook of 2010*, its total population is about 8.9 million and its land area about 1,991 square kilometers, covering 6 (restructured into 8) districts. The GDP of Shenzhen has increased 3.75 times since 2000, reaching about US$ 1,281 billion in 2009. The proportion of primary industry, which was 37% of the GDP in 1979 and 0.7% in 2000, has decreased to less than 0.1% today. The per capita GDP is about US$ 14,495, the highest of all Chinese cities, and 4.3 times the national average. With such accelerated growth, the urban area (construction acreage) has sprawled enormously. The construction acreage of the core, four district (Futian, Luohu, Nanshan, and Yantian) urban area of the Shenzhen Special Economic Zone increased by 64% from 1990 to 2000 but by only about 8% from 2000 to 2010. The city's outskirts, covered by two districts (Bao-an and Longgang [now Bao-an, Guangming, Longgang and Pingshan]) became the major construction area contributor in this last decade. Fig. 1 shows the pattern in the change of construction areas from 1990 to 2010,

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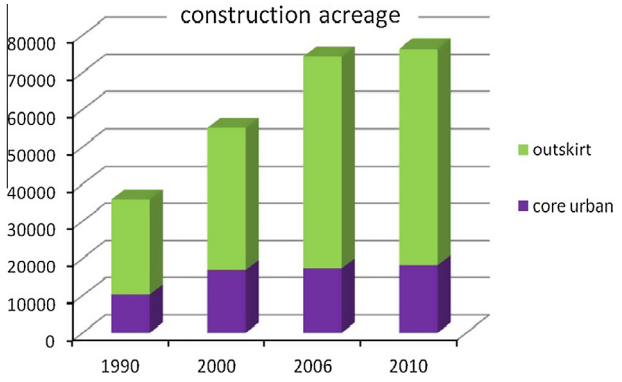

Fig. 1. Construction acreage during 1990–2010.

and Fig. 2, which indicates land use in 2010, reveals that the core urban area has very limited surface available for further construction.

However, the core urban area is the economic and social nerve center of the city, and land (space) is always in demand to support its increasing activities. The use of space under or above its surface is a rational alternative. Such space must be effectively and consistently managed to prevent legal conflict with the existing cadastre. To meet this objective, it is best to administer tri-dimensional urban space with a 3D cadastral system than with the current 2D cadastral system.

Much research (Agdas & Stubkjær, 2011; Benhamu & Doytsher, 2003; Chong, 2006; Choon et al., 2010; Doner et al., 2010; Hassan et al., 2008; Paulsson & Paasch, 2011; Sorensen, 2011; Stoter, 2004; Stoter & Oosterom, 2005; Stoter, Ploeger, Louwman, Oosterom, & Wünsch, 2011) has discussed the management of 3D property in cadastral systems and acknowledged that a full 3D cadastre is the best solution. However, most practical 3D cadastral systems are configured either with multi-layer parcels, such as those in Israel (Benhamu & Doytsher, 2003), or with 3D property objects registered on 2D cadastres, such as those in Australia, Norway (Stoter & Oosterom, 2005), Malaysia (Hassan & Rahman, 2011), and the Netherlands (Stoter et al., 2011). A full 3D cadastral system has been rarely reported in the literature, and the lack of appropriate 3D toolkits or software systems for implementing the functionality of 3D in a cadastre is one of the main reasons for its essential absence. Some 3D tools may be good at 3D modeling but not good at visualization; some may provide precise visualization but fail to manage effectively 3D geometrical objects; some packages may provide effective geometrical computations but still lack modules to maintain 3D topologies.

This paper provides an ad hoc 3D cadastre solution for the management of urban land space in Shenzhen city. Its main contribution lies in the proposal of overall technical settings for a full 3D cadastral system that is restricted by (1) existing data and available techniques and (2) the current legal and administrative context. The remainder of this paper is structured as follows. Its next section presents two examples to illustrate that Shenzhen is now in an administrative transition from surface to land space use; it is followed by an outline of the context for the development of a 3D cadastre for this administration. Section 4 presents the main technical issues for the achievement of a 3D cadastral system in Shenzhen city. These include the primary geometrical hypotheses for the use of space and the 3D data model and its implementation. In Section 5, a simple application is presented. Finally, conclusions are drawn, on the basis of the previous sections and some issues for future study.

2. From the surface to the spatial use of land

The clarification of ownership and property rights are the keys to land administration. When the ownership of a piece of land is defined as all things within a spatial "cone" formed geometrically from the earth's center to the sky, ownership can be well specified by 2-dimensional geometry. A parcel-based cadastral system can unambiguously handle spatial relationships among various property owners and the transitions among themselves and with other parties. The rights to land within the "cone" are homogeneous and can be projected onto the unique map layer of the 2D cadastre without any confusion. With the evolution of society and economy, land becomes precious, and rights to it must be refined to suit different purposes; thus, the nature of space below or above ground is

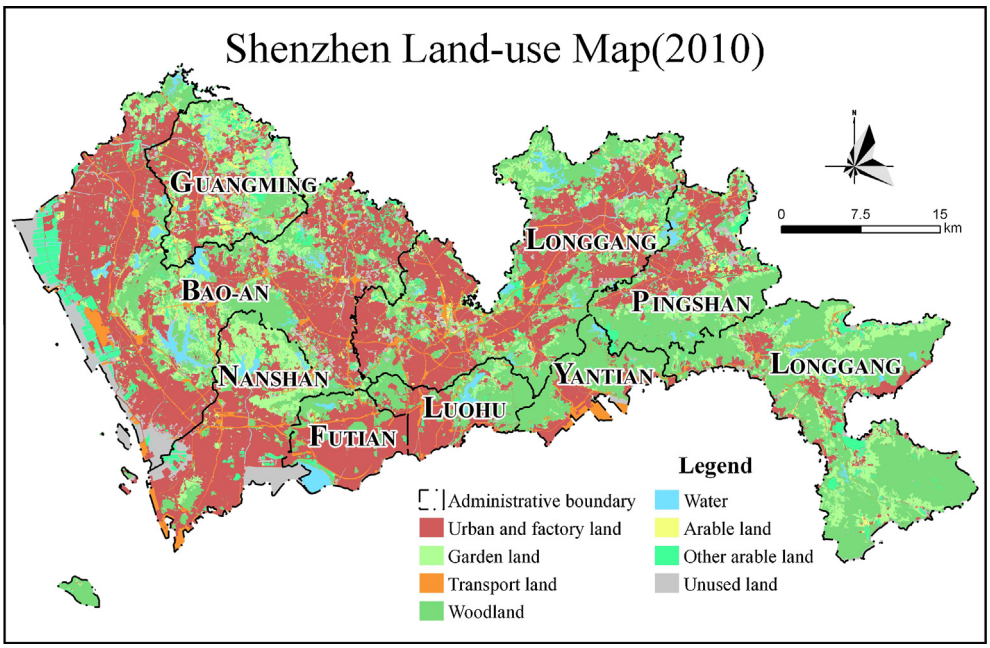

Fig. 2. The land use of Shenzhen city in 2010.