

Developments of 3D Land administration in China – advancements and challenges

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Key words: 3D Cadastre, land register, integrated land policy, legal aspects of cadastre, China

SUMMARY

Rationale– The development of 3D information models and systems in China has progressed rapidly. Nevertheless, there is no standard 3D land administration model yet, which is applied throughout the country, and there is no legal framework supporting and advancing the developments yet. The consequence is that research and practice of 3D cadastre concepts and models remains scattered and fragmented.

Research objective– This study aims at reviewing and categorizing the developments in 3D land administration models and systems in China of the past years to analyze which developments and practices are spearheading and which possibilities exist to formulate a more general policy for 3D cadastre development.

Theoretical framework– We review the current 3D land administration conceptualizations from an international perspective and compare these to how 3D land administration is currently understood in the Chinese context of practice and academia. From this analysis we derive a set of key unknowns on 3D land administration developments in China with respect to basic understanding of the definitions, the technical aspects related to 3D models, the legal embedding of 3D land administration and the organizational requirements to make 3D land administration systems functional and operational.

Methodology – The key unknowns derived from the theoretical review are the basis for a keyword co-occurrence analysis of academic literature in Chinese and in English, and the basis for a survey design, which was distributed among a selection of key experts and practitioners in China. In addition, several expert interviews were held with prominent scientific researchers in this field to validate both the literature review and the survey results.

Results – The results from the keyword co-occurrence analysis reveal how, when and where the terms cadastre and land registration are being used and applied, and with which (other) terms 3D models are being associated. It is important to understand the Chinese connections to cadastre and hence the implications of these to the term 3D cadastre. Nowadays, the cadastre has a completely independent status. China's real estate registration is moving towards a unified rights registration of natural resources, which also has 3D implications, as many of these resources as well as rights exist in a 3D environment. Institutional integration influences what is a valid 3D land administration. The results of the survey and interviews demonstrated and confirmed that indeed the developments in both the technical and legal aspects are scattered, but that at the same time several other developments – which may not directly be associated with 3D land administration – have emerged, which influence and possibly shape the ideas of a de facto system of 3D records of properties in China. From a

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technical perspective, developments in GIS, remote sensing, BIM and digital twin technologies have generated new ideas and practices in how to shape and manage technical information. Whilst these have resulted in many types and applications of 3D models, the main purpose of these developments was not necessarily to design and innovate 3D cadastres, but to manage and support applications in for example housing, construction and environmental protection which require 3D models to generate useful outcomes. Examples include the use of key technologies for three-dimensional rights registration of natural resources, and the construction of a three-dimensional "one map" of all natural resources and unify management and application of the data of the 3D "one map" of natural resources by means of the land spatial basic information platform. These developments have generated as a side-effect the development of models which carry 3D information on legal properties, and therefore mirror the original paradigms of 3D cadastres.

Conclusions– the shape and conceptualisation of 3D land administration in China follows an emergent and operant path rather than a pre-designed policy. This process is largely driven by societal and political demands and by autonomous technological advancements in industry and in scientific research. Whilst the application of 3D models in multiple sectors has significantly increased, constructing a legal framework remains a sizable challenge. This raises the question whether such a standard framework is required in the short term, or whether the development of such a framework should no longer focus on 3D cadastres, or land administration in a narrow sense, but on an integrated approach regulating 3D-related, digital twin and AI related technologies in a broader sense. It is more about supporting a logical and responsible design public information infrastructure and its maintenance than about harmonizing heterogeneous (legal/institutional) models and systems.

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1. INTRODUCTION

Conventional land administration systems rely on two-dimensional cadastres, which implies there is no ability to administer and/or manage parcels in the vertical dimension. Traditional 2D cadastral information systems, based on 2D representation and visualisation technologies, however no longer meet the changing needs of modern (digital) societies. Still, constructing and relying on technologies and models which represent 3D spaces and legalities accurately and reliably is not a given in most countries. It is not so much a problem of technologies, but a complex problem of technological possibilities, legal reliabilities and accountabilities and process oriented data acquisition and maintenance. Part of this problem furthermore lies in standard agreements on technical definitions and legal regulations (Tang et al., 2022). For China, this problem is similar as in other countries, yet this does not mean that there hasn't been any development. Over the years of 3D cadastre research in China, there have been several changes in the form of land and house registration, yet what kind of requirements have been put forward by these changes to the cadastre? This remains unknown. At the technical level, many 3D data models and 3D spatial information models have been proposed, but since a cadastre, especially the 3D cadastre, is largely influenced by the development situation and legal system of the country or region, there is no model with high applicability or universal application. Especially for China the establishment of a three-dimensional cadastre is even more special due to the uniqueness of its land tenure system (dualistic system). Despite the rapid development of 3D information models and systems in China, there does not yet exist a standard 3D cadastral (data/information) model, which is applied throughout the country, neither is there a commonly accepted legal framework for 3D cadastres throughout the country. In fact, the research and practice of 3D cadastre concepts and models in China remains scattered and fragmented. Nevertheless, China has been conducting research on 3D cadastre for a long time. Yet, there is no precise definition of what a 3D cadastre is in China, and there are fewer studies on how to construct a 3D cadastre law. Consequently, there is no clear and complete compilation of what the most appropriate legal system for China would be, and there is a disconnect between the legal research on three-dimensional cadastres and the technical research.

The main objective of this paper is to describe and explain how, where and why 3D cadastre development occurred in China, and to explore which problems, challenges and opportunities 3D cadastre developments faces in different aspects in the context of China's unique property rights and changes in policy regimes. The paper starts by providing an introduction into the history and current status of land and property laws in China, and describing how these could impact the description and maintenance of 3D properties. The subsequent section describes some of the core definition and current insights into what constitutes 3D land administration and 3D cadastres and which technical models are currently available. and 3D cadastre from a global perspective. The next section describes the methodology of further data collection and

analysis of the developments on 3D land administration in China, followed a results section. We end the paper by deriving a set of conclusions in view of the main research question.

2. REVIEW OF LAND ADMINISTRATION IN CHINA

In 2007, the Property Law of the People's Republic of China was enacted. Article 136 states: "*The right to use land for construction may be separately established on the surface of the land, above the land or under the land. The newly established right to use land for construction shall not affect the previously established right of use*". The implementation of the Property Law secures and promotes the development of the vertical space on the land and provides a certain legal basis for a three-dimensional cadastre. How to accurately describe and express the three-dimensional characteristics of spatial and property rights of real estate and how to establish a three-dimensional cadastral information model that integrates the cadastre of real estate has become an urgent and fundamental task for the management of real estate in China (Tang et al., 2022). Although the right to develop and utilise vertical space is legally guaranteed, in practice, China's laws and regulations related to the 3D cadastre are still lacking, both at the technical level and the management level. Moving from a two-dimensional cadastre to a three-dimensional cadastre is not simply a matter of adding textual records or schematic diagrams, but it is also a fundamental transformation of the entire operational, organisational, regulatory and legal system supporting and securing the validity of the 3D cadastral information (products and services). As the latter is not yet in place, there is still a long way to go before a three-dimensional cadastre can be realised.

Article 9 of the *Land Administration Law of the People's Republic of China* (2019 Amendment) states that land in urban areas is owned by State. Land in rural areas and urban suburbs is owned by peasants' collectives, except for land that is State-owned as stipulated by law; homesteads and self-reserved land and hills are owned by peasants' collectives. Article 10 specifies that state-owned land and collective land may be legally determined for the use of units or individuals. Land in China is classified into agricultural land, built-up land, and unutilised land. According to the *Interim Regulations of the People's Republic of China Concerning the Assignment and Transfer of the Right to the Use of the State-owned Land in the Urban Areas* (2020 Amendment), Land use right concession refers to the act of the State, as the landowner, ceding the land use right to the land user for a certain number of years, and the land user pays the land use right concession premium to the State. The granting of land use rights is subject to a grant contract. The maximum number of years for land use rights concession is stipulated as follows:

- 70 years for residential land.
- 50 years for industrial land.
- 50 years for land for education, science and technology, culture, health, and sports.
- 40 years for land for commerce, tourism, and recreation.
- 50 years for integrated or other land use.

When the land use right expires, the land use right is terminated, but the land user can apply for renewal. Article 359 of the *Civil Code of the People's Republic of China* enacted in 2020 has a detailed description of the renewal of land use right, when the term of the right to use land for residential expires, it shall be automatically renewed. The renewal of the right to use

land for non-residential construction after the expiration of the term shall be handled in accordance with the provisions of law.

Land users may also acquire use rights through land use rights allocation. Article 23 of the *Urban Real Estate Administration Law of the People's Republic of China (2019 Amendment)* defines the allocation of land use right as the act of the people's government at or above the county level approving in accordance with the law to deliver the land to the land user for use after the land user pays the compensation, resettlement and other fees, or delivering the land use right to the land user for use without compensation. Land use rights acquired by way of concession can be transferred, leased and mortgaged. However, there are severe restrictions on the transfer, leasing and mortgaging of allocated land use rights.

The management of land use rights in rural areas of China under the dual urban-rural structure is different from that in urban areas. Regarding construction land, Article 62 of the *Land Administration Law of the PRC* stipulates that each rural household can have only one homestead. The right to use the homestead can only be transferred between members of the local collective economic organisation. The marketing of rural collective construction land for development purposes (transferring and leasing etc.) was completely liberalized with the implementation of the new Land Administration law in 2020.

Land registration in China is a combination of title registration and Torres registration. The development of real estate registration in China can be roughly divided into two stages. In the first stage, the land registration is separate from the building registration. The second stage is the unified registration. The *Measures for Land Registration* (Ministry of Land and Resources Decree No. 40) which were implemented in 2008 and repealed in 2017 (Ministry of Land and Resources Decree No. 78) used to be the basis for land registration in China. It stipulates the land needs to be registered on a parcel basis. A parcel is a plot or space enclosed by the boundaries of land ownership. And it indicates that land registration is conducted according to the principle of territorial registration. The *Building Registration Measures* and *Urban Real Estate Administration Law of the People's Republic of China (2019 Amendment)* regulate the building registration process in China. Building registration is the act of building registration authority in recording the rights of building and other matters that should be recorded in the building register in accordance with the law. The buildings refer to houses and other structures on the land. Building shall be registered according to the basic unit which means a building or a specific space such as blocks, floors, suites, rooms that have fixed boundaries, can be used separately, and has a clear and unique number (block number, room number, etc.). Table 1 illustrates the objects and types of building registration.

Table 1. Objects and types of registration in China

Purpose of registration	Objects of registration	Types of registration
Registration of buildings on State-owned land	Building ownership Mortgages Easements	Initial registration Transfer registration Modification registration Cancellation registration Advanced-notice registration Other types (correction, dissenting)
Registration of buildings on collective-owned land	Building ownership Easements	Initial registration Transfer registration

Purpose of registration	Objects of registration	Types of registration
(Buildings on homesteads and Buildings on other collectively owned construction land)		Modification registration Cancellation registration Advanced-notice registration Other types (correction, dissenting)

3. REVIEW OF 3D LAND ADMINISTRATION FROM LITERATURE

How a 3D land administration can contribute to solutions of local or national is strongly dependent on local situations and user needs, including the land market dynamics, existing legal frameworks and the technical capabilities of those working with the data (Van Oosterom, 2013). Paasch & Paulsson (Paasch & Paulsson, 2023) differentiate 4 components of 3D land administration and 3D cadastres: legal, technical, registration and organisation. The legal boundaries or boundary descriptions of the rights, restrictions and/or responsibilities of land and property may not necessarily align with physical ones, even though in legal terms the rights to apartments, condominiums or shared spaces are clearly defined (Paasch & Paulsson, 2021). More complicated is however recording or recognizing the de facto yet unrecorded 3D claims which exist in many developing countries, countries where registration is not complete or countries where the legal system only covers one type of legal right. One could argue in these cases that the types of rights can be extended to formal and informal (on a continuum), legal or legitimate (socially or societally), or rights which vary and/or come in bundles. Consequently, the legal framework of a continuum or set of bundles poses a great challenge for the implementation of 3D cadastre in different countries. This makes legislation, adjudication and interpretation of rights, recording and maintaining cadastral information unique in different countries, let alone their translation or expansion to 3D properties of such rights (Atazadeh et al., 2023; Ding et al., 2017; Kitsakis et al., 2019; Radulović et al., 2017; Soon et al., 2016; Zhang et al., 2023).

Despite this legal heterogeneity, there has been progress in the technical standardization. The Land Administration Domain Model (LADM) is currently commonly accepted (Paasch & Paulsson, 2021; van Oosterom & Lemmen, 2015) and adapted to local or national contexts. Researchers have adapted and modified the LADM to address the land and real estate management situation in different countries, resulting in a cadastral model that is more applicable to their country context (Ahsan et al., 2024; Felus et al., 2014; Gürsoy Sürmeneli et al., 2021; Janečka & Souček, 2017; Lee et al., 2015; Velastegui-Cáceres et al., 2020). The technical challenges often remain integration and connection with other technical systems. To overcome these integration problems, open data models have been developed for storing and exchanging three-dimensional spatial information, including IFC, CityGML IndoorGML. Adoption and adaptation of these models affect and influence the way 3D property information is de facto stored and will thus influence the way one 3D cadastres and land administration is de facto developing. Many agencies current use the combination of BIM and GIS as de facto 3D standards. BIM is an object-oriented model, it focuses on the building elements of building, while GIS can collect, store, manage, calculate, analyse, display and describe spatial information about Earth surface. In recent years, many researchers have been exploring how to convert data sources such as BIM, CityGML and IFC, to 3D cadastral

modelling (Andrianesi & Dimopoulou, 2020; Gkeli & Potsiou, 2023; Sun et al., 2023). Regarding the work flows and organisation of 3D information, it is argued that there will still be a key role for surveyors and geodetic and/or geomatic engineers. Within the respective institutional and regulatory frameworks they need to migrate their workflows to 3D submissions (Stoter et al., 2019). This implies however that cadastral and /or land administration organisations will have to be reactive which means they cannot carry out their own cadastral registration in the absence of a legal requirement to do so.

4. METHODOLOGY OF DATA COLLECTION AND ANALYSIS

The review of the status and developments relied on an extensive literature review in both English and Chinese language publications. For the literature review we used several keyword-based strategies and different scientific repositories, such as the keywords '3d cadastre', '3D spatial information', 'China', 'natural resources unified registration', and the platforms Web of Science, Google Scholar, CNKI. This resulted in 110 relevant publications. From these the analysis drew on keyword co-occurrence analysis and topic classification to interpret these documents. The keywords co-occurrence analysis is a text-mining technique that analyses the 'co-occurrence' of pairs of keywords in the review documents to visualize the relationships of keywords or topics to one another (Narong & Hallinger, 2023). The key unknowns derived from the theoretical review are the basis for a keyword co-occurrence analysis of academic literature in Chinese and in English, and the basis for a survey design, which was distributed among a selection of key experts and practitioners in China. In addition, several expert interviews were held with prominent scientific researchers in this field to validate both the literature review and the survey results.

5. RESULTS

The literature study reveals that authors in China refer to the 3D land administration or 3D cadastres in different ways. The keyword analysis generated two figures displaying clusters of keywords: Figures 1 and 2 show the high-frequency keywords that appeared alongside 3D cadastre in 3D cadastral researches in China over the past few years. The difference is that the two graphs have different data sources. The data in Figure 2 were obtained from the selected Chinese and English literature, totalling 108 articles. The data source for Figure 2 is from a total of 26 papers after a 3D cadastral related search in web of Science.

The results from the keyword co-occurrence analysis reveals how, when and where the terms cadastre and land registration are being used and applied, and with which (other) terms 3D models are being associated. It is important to understand the Chinese connections to cadastre and hence the implications of these to the term 3D cadastre. The Chinese equivalent of cadastre is *diji*, written as '地籍'. The first Chinese character '地' (di) means ground, soil and land. The second character '籍' (ji) means book and register. Literally, cadastre in China is a register of land and not necessarily a register of 3D properties. The act of surveying land and recording information in writing dates back to BCE. From its beginnings as a service for tax purposes and as an adjunct to the civil registration, the cadastre has evolved to become equal to the civil registration. Nowadays, the cadastre has a completely independent status.

Before 2018, the registration and the preliminary surveying of real estate and other natural resources are carried out by different departments, including land resources departments, agricultural departments, housing and construction departments, and surveying and mapping departments and so on. This fragmented mandate has resulted in unclear responsibilities, ineffective management and overlapping spatial planning amongst organisations and stakeholders. In order to address these issues and unify the execution of management responsibilities, the State consolidated and optimized the various departments and their respective responsibilities, and formed a unified Ministry of Natural Resources of the PRC.

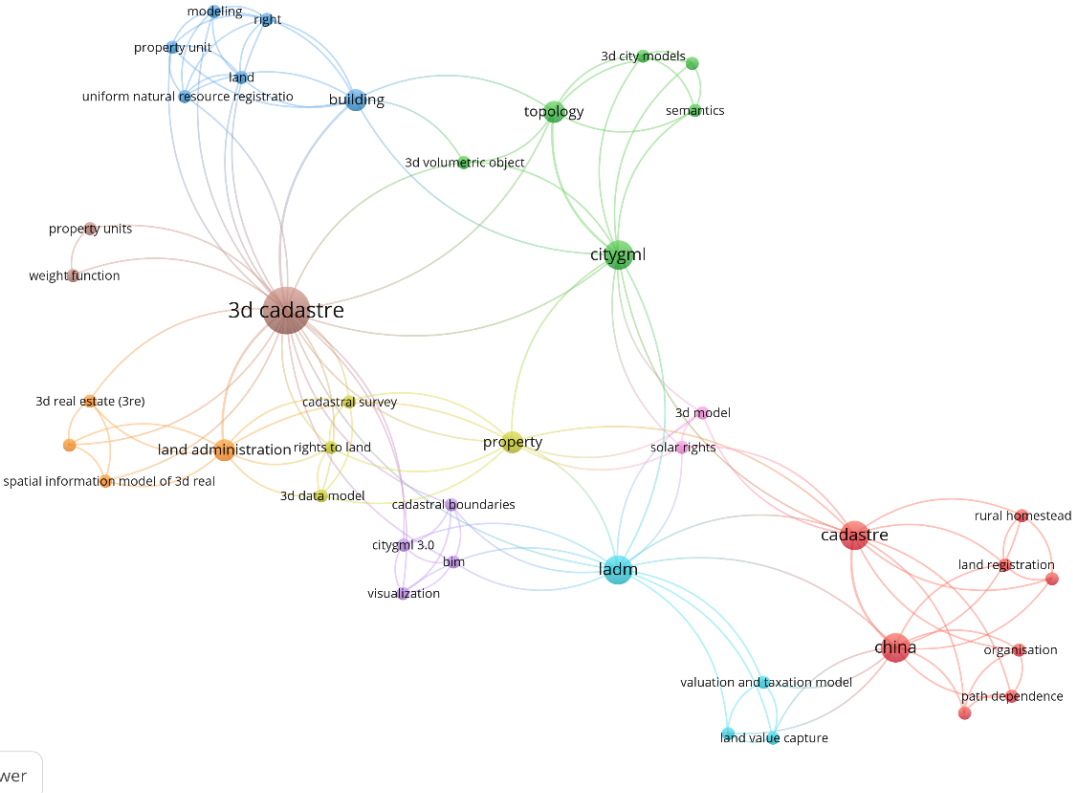


Figure 1. Keywords co-occurrence analysis

Nowadays, China’s real estate registration is moving towards a unified rights registration of natural resources, which also has 3D implications, as many of these resources as well as rights exist in a 3D environment. In 2019, the Ministry of Natural Resource together with the Ministry of Finance and ministries, triggered a circular on Interim Measures for Unified Registration of Natural Resources Rights(Ministry of Natural Resources of the PRC, 2019b). This unified registration base on the real estate registration. It needs to be noted, however, that before 2018, different natural resources were under the jurisdiction of a different sectoral institution. Institutional integration has however an effect on what is a valid 3D cadastre.

From the literature study we find that the three-dimensional cadastre emerged from describing three-dimensional use of land, which needed to be connected to both the 3D and 2D space under the policy of unification. By integrating housing and land management the basic unit of registration was extended from registering land to registering 3D property(Zhang et al., 2010). Property units are seen as part of the spatial domain (real estate property unit)

with a fixed geospatial location, shape, closed by the boundaries of ownership (surface), independent of the subject and independent of the rights. In the Representation of 3D features of urban real estate, which was implemented from 2021, 3D property unit is defined for the first time in the national standard: a three-dimensional spatial domain with fixed geospatial location and shape with fixed boundaries of tenure and independent rights, and consistent tenure, which is the basic unit of the 3D features of urban real estate (three-dimensional spatial features of real estate with three-dimensional characteristics of urban real estate), and contains three-dimensional parcels of land and structures such as houses (Ministry of Natural Resources of the PRC, 2021). Based on the urban development in China and the needs of cadastral management, Guo and Ying (Guo et al., 2013) model 3D property body into three categories: open, semi-restricted and fully restricted. All three-dimensional land use scenarios can be expressed in terms of these three categories and their combinations. Bounded three-dimensional parcels, which are three-dimensional spaces with closed boundaries, are the most typical form of 3D cadastral property rights and the key reason for the complexity of the 3D cadastre. Open parcels are the traditional 2D parcels, it is sufficient to represent them in conventional two-dimensional representation form (Ministry of Natural Resources of the PRC, 2021).

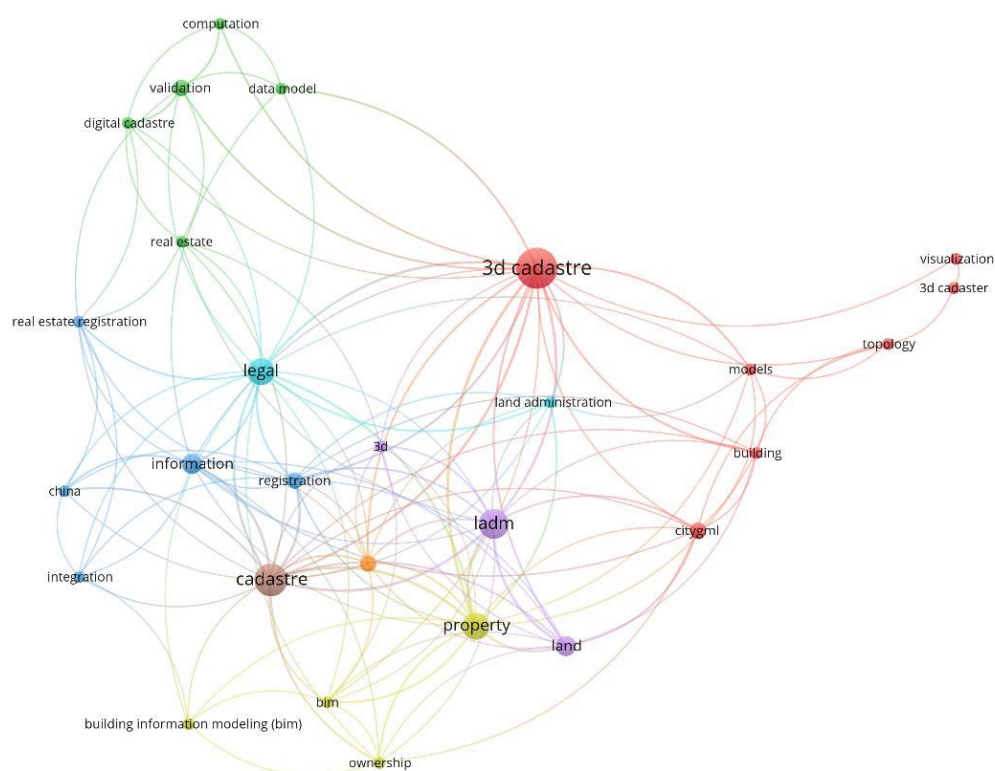


Figure 2. Keywords co-occurrence analysis based on WoS

After these initial publications which focuses primarily on how to model 3D urban features, various researchers have published about 3D models for properties and property management in China. Yu et al. (Yu et al., 2017) designed a Unified Registration Data Model for

Immovable Property; Li et al. (Li et al., 2016) create a CityGML-LADM ADE model to describe the ownership structure of condominium units; Ying et al. (Ying et al., 2018) introduce a uniform real estate registration model (Ying et al., 2018). Zhang et al. (Zhang et al., 2018) propose a 3D cadastral model in the context of actual projects; Wang et al. (Wang et al., 2014) design a hybrid 3D cadastral data model using a mixed modelling approach of B-rep and CSG(H3DCDM). Zhang (Zhang, 2016) describes a spatial data model based on geometric algebra; Zhou et al. (Zhou et al., 2021) design a 3D real estate model which integrates BIM and real estate by extending IFC model is created. This model can associate with building components and spaces in the BIM model. In addition to these examples, many other models have subsequently been proposed and validated. Nevertheless, there is not yet any consensus on a standard model or standards way to represent 3D properties. One could say that many of the models so far draw on 3D city models such as CityGML, whereas only few directly reason from LADM. Some of these include a LADM-based model for registering and managing rural homesteads was presented (Xu et al., 2022) and (Qin, 2020), who proposes a natural resource cadastre model based on LADM. Ying et al. (Ying et al., 2021) put forward a conceptual model of the full range of natural resources and a basic conceptual model for the uniform registration of full natural resources based on LADM. In 2020, *Highlights of Cyber Security and Informatisation Work of the Ministry of Natural Resources in 2020* explicitly proposed to construct a three-dimensional "one map" of natural resources, and unify management and application of the data of the 3D "one map" of natural resources by means of the land spatial basic information platform (Ministry of Natural Resources of the PRC, 2020a). The idea of constructing "one map" was detailed introduced and analysed by (Deng et al., 2022).

The results of the survey and interviews demonstrate and confirm that indeed the developments in both the technical and legal aspects are scattered, but that at the same time several other developments – which may not directly be associated with 3D cadastres – have emerged, which influence and possibly shape the ideas of a de facto system of 3D records of properties in China. From a technical perspective, developments in GIS, remote sensing, BIM and digital twin technologies have generated new ideas and practices in how to shape and manage technical information. Whilst these have resulted in many types and applications of 3D models, the main purpose of these developments was not necessarily to design and innovate 3D cadastres, but to manage and support applications in for example housing, construction and environmental protection which require 3D models to generate useful outcomes. Examples include the use of key technologies for three-dimensional rights registration of natural resources, and the construction of a three-dimensional "one map" of all natural resources, and unify management and application of the data of the 3D "one map" of natural resources by means of the land spatial basic information platform. These developments have generated as a side-effect the development of models which carry 3D information on legal properties, and therefore mirror the original paradigms of 3D cadastres.

From a legal perspective the past 10 to 15 years have seen a lot of changes in legislation to better cope with the fast-growing real estate market. This resulted not only in a revision of the systems of rights and rights registration, but also in advancements of how to manage a system securing and/or enforcing such rights. The legal embedding of 3D properties has followed a slightly different path than the technical modelling. The three-dimensional use of land were originally thought of as an exploration of three-dimensional space. The rights originally based

on the surface are extended above and below the ground, and spatial rights are therefore generated. Guaranteeing and supporting spatial rights and management is an important condition for the realisation of a three-dimensional cadastre.

Article 54 of *Some Provisions for Determining Land Ownership and Use Rights* which enacted by the Ministry of Land and Resources in 1995, stipulates that "where land is used in a three-dimensional manner (except in the case of buildings) on the ground and in the air, or on the ground and under the ground, the right to use the land is determined in favour of the user on the ground, and in the air and under the ground, the right to use the land is determined in favour of the user on the ground, and in the air and under the ground, the right to use the land may be determined as an alternative right." (National Land Administration of the PRC, 1995).

The Regulation on the Management of the Development and Utilisation of Underground Space in Cities was published in 1997, which was the first of its kind to realise the management of the utilisation of underground space (Ying et al., 2023). It was revised twice, in 2001 and 2011 (Ministry of Housing and Urban-Rural In October 2007, the *Property Law of the People's Republic of China* was implemented, of which article 136 stipulates that the right to use land for construction purposes may be established on the surface of the land, above the surface or below the surface, respectively (The National People's Congress of the PRC, 2007). The *Civil Code of the People's Republic of China*, which came into force on 1 January 2021 (The National People's Congress of the PRC, 2020), replaces the Property Law, and article 345 of the Civil Code carries over the previous provisions on the use rights of building land. This law guarantees the legality of three-dimensional use of land and related rights, and also serves as basis for the establishment of more detailed 3D cadastral laws and regulations in the future.

The *Interim Regulation on Real Estate Registration* has been in effect since March 1, 2015, and were amendment in 2019 (Ministry of Land and Resources of the PRC, 2016), thus clearly establishing the concept of three-dimensional space of land at the legal level (Ying et al., 2023). The accompanying *Implementing Rules for Interim Regulations on Real Estate Registration* (Ministry of Land and Resources Decree No. 63) also came into force in 2016 (Ministry of Land and Resources of the PRC, 2016). Article 5 of *Rules* defines the immovable property unit under article 8 of the *regulation* and specifies that the object of registration is the spatial unit. In 2019 *Guiding Opinions on Promoting the Reform of Property Right System of Natural Resources Assets as a Whole* once again emphasises the need to accelerate the establishment of separate rights to use construction land above, on and below the surface, to promote the rational development and utilisation of space, and proposes to explore the three-dimensional layering of rights to use maritime areas (General Office of the Central Peoples's Government of the PRC & General Office of the State Council of the PRC, 2019).

The *General Programme for Informatisation of the Ministry of Natural Resources* issued by the Ministry of Natural Resources proposes to "promote the construction of a three-dimensional reality database" (Ministry of Natural Resources of the PRC, In 2020, the State Council issued a notice (Letter No.96[2020] of the State Council), proposing to replicate and popularized "the three-dimensional land management model with a three-dimensional cadastre at its core" nationwide (State Council (PRC), 2020). In 2022, the General Office of the Ministry of Natural Resources issued the *Notice on Comprehensively Promoting the*

Construction of Realistic 3D China, which set new goals for the construction of 3D reality. (General Office of Ministry of Natural Resources of the PRC, 2022)

For the compilation and expression of 3D cadastral data, Shenzhen has drafted and formulated a specification document – *The Data Standard of the Three - Dimensional Property* which is also the first local standard data regulation in China (Shenzhen Digital City Engineering Research Centre et al., 2021). In 2023, Shenzhen issues a specification on 3D real scene and standardises the requirements related to 3D data at city level in Shenzhen City (Shenzhen Planning and Natural Resources Bureau, 2023)

The *Representation of 3D features of urban real estate* specifies the basic requirements for the expression of spatial and attribute information of three-dimensional spatial elements of urban real estate (Ministry of Natural Resources of the PRC, 2021). The *Technical specification for three-dimensional modelling of urban underground space* specifies the basic requirements for three-dimensional modelling of urban underground space (Ministry of Natural Resources of the PRC, 2022). In addition to these two national norms, some provinces or municipalities have drafted and issued local norms (Department of Natural Resources of Jiangsu Province, 2020; Fujian Basic Geographic Information Centre, 2015; Hubei Provincial Government, 2015; Qingdao Survey and Mapping Research Institute.

6. DISCUSSION AND CONCLUSION

The evidence demonstrates that in China neither in technology nor in legal the definitions of cadastre and 3D cadastre or 3D land administration are harmonised. The understanding of the 3D cadastre is a simple combination of the definition of 3D and the definition of cadastre. Is a 3D cadastre a collection and presentation of data? Or does it only refer to a 3D model or is it a system that combines 3D surveying, 3D modelling, 3D data visualisation and the corresponding management and legislative systems? The ambiguity of the definition of cadastre and three-dimensional cadastre may be due to the fact that cadastre is a traditional concept. As the demand for land use increases and land use becomes more complex, whether for tax or other purposes, land is surveyed and registered by the authorities. However, in the modern world, with the development of technological means, changes in management models and the establishment of legal systems, as well as the development of property rights systems and land use in a more comprehensive direction, the traditional concept of cadastre can no longer fully cover the content of the concept of "cadastre" in real life. Cadastre is no longer just a result of recording, but a system.

The possibility of a more precise definition of the three-dimensional cadastre is also influenced by the above-mentioned reasons. In addition, three-dimensional cadastre has been in the research field for many years and scientists have made many achievements. However, there has been no real promotion of 3D cadastre so far, and 3D cadastre is still in the process of practical exploration, so it is difficult to define this concept by its characteristics and attributes. The perceived consistency of concepts such as digital twins, twin cities, etc. is due to the fact that these concepts were developed later and do not require an update of the original concepts.

China's land registration has undergone two changes in the past, a unified registration of real estate and a unified registration of natural resources. As the management of various natural resources belonged to different departments before the unified registration, both changes

meant that data from different sources needed to be integrated. At the technical level, it is necessary to establish a unified global coordinate system to ensure that all types of spatial data are integrated under a unified coordinate system. Secondly, it is necessary to establish unified data standards and formats and to set up a data-sharing platform. Next is the third step, which is to collate existing data, clean redundant data and clarify the relationship between data so as to improve data quality. Data integration is a long-term process, which not only requires the collation of past data, but also puts forward new requirements for the investigation of new resource data. China's three-dimensional cadastre should have come a long way in terms of technology, and at present the technical problems of basic data collection and modelling have been solved. However, the demand in practical application is far more than that, efficient and accurate modelling and updating with the timeliness of 3D scene is the development goal. And the realisation of this goal largely depends on the efficient and high precision acquisition of 3D data. The research on technology account for a large portion in the English and Chinese literatures on 3D cadastre in China. From these studies, it is evident that Chinese researchers and scholars have overcome many difficulties in realising the technical aspects of 3D cadastre and have found methods and means suitable for China's national conditions, from data acquisition to expression to modelling to visualisation. Nowadays, the focus of the research has gradually transitioned from the development of 3D cadastre which only for land and real estate to the construction of models and data platforms for the unified registration of natural resources, including water, seas, forests, minerals, and so on. This shift implies the renewal and replacement of technologies. For example, while buildings have different shapes and underground spaces are difficult to measure, there is a need for more efficient means of obtaining three-dimensional data when dealing with more difficult to define boundaries and a wider range of objects, such as the sea, forest.

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BIOGRAPHICAL NOTES

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