Integrating Geographic Information System and Building Information Model for Real Estate Valuation

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Key words: GIS, BIM, Real estate valuation

SUMMARY

In the past decades, geographic information system (GIS) has gained much attention in the real estate valuation industry. However, the current GIS does not support modeling components inside of buildings, which is crucial for applying cost approach to appraise the property value. Thus, the aim of this paper is to introduce building information model (BIM) into real estate valuation industry with 3D GIS to improve the accuracy of valuation. In this paper, the integration of BIM and 3D GIS valuation system has been realized. A software architecture was designed to integrate data transmission between different systems. Based on which, the modified cost approach was implemented. Further, a BIM-based 3D GIS sales comparison approach was proposed. In this approach, micro-environment analyses was integrated, such as indoor daylight analysis, indoor/outdoor ventilation analysis, sunlight duration analysis, and so on. Then, based on the national standard and analysis results, the quantitative analysis was conducted and combined with other impact factors to evaluate the performance of each cases. The integration has been realized on our 3DGISSPV system with practical data of Shenzhen, China. The prototype system shows great potential to improve valuation accuracy.

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1. INTRODUCTION

Real estate valuation is the process of developing an opinion of value for real properties. The valuation results mostly depend on the accuracy of the valuation, which can lead to serious social issues. Generally, the accuracy of the valuation is influenced by the data quality of collected information, the professionality of qualified appraisers and the maturity of the technology used in determining various impact factors performance (Liu and Deng et al., 2011) . Literature shows that with the implementation of geographic information system for real estate valuation, the accuracy has been greatly enhanced.

Geographic information system (GIS) was specially designed for handling spatial data and is capable of performing manipulation, analyzing and presentation spatial relationships (Fung and Kung et al., 1995; Zeng and Zhou, 2001). By applying GIS for valuation, more data information with multi-type, multi-source and multi-scale can be managed not only from real estate industry but also from related field, such as architecture, urban planning, environmental engineering, surveying, geography, finance, economy and so on. Moreover, the experience of qualified appraisers can be managed as knowledge information in GIS with unified valuation models for professional valuation. Besides, GIS provides efficient tools for spatial related analysis. It could be easily used in determining various impact factors performance during valuation. With three-dimensional (3D) data model and visual reality technology, the real 3D environment can be built to represent the real world with not only the 3D surface but also the 3D buildings. It can also be used to simulate how views and orientation of existing properties could be affected with new developments in high density cities (Yu and Han et al., 2005).

However, the current 3D GIS does not support modeling components inside of buildings, which is crucial for precise analysis and applying cost approach to appraise the property value. Thus, building information model (BIM) is introduced to combine with GIS for real estate valuation. A building information model concludes the geometry, spatial relationships, geographic information, quantities and properties of building elements, cost estimates, material inventories and project schedule (Azhar, 2011). With proper coordinate system, BIM model can be integrated into GIS, and the rich information carriage by BIM model can be managed and used for advanced analysis in real estate valuation, such as using BIM for quantity take-off (Cheng and Chen, 2013) in cost approach, or using BIM in green building analysis (Xia and Yi, 2013) for more specific impact factor analysis.

The objective of this paper is to illustrate the combination of BIM and 3D GIS for real estate valuation to improve the accuracy of valuation. The real estate valuation system architecture was proposed with BIM interoperate in Section 2. Section 3 shows an improved modal for sales

comparison approach based on GIS and BIM. A real estate valuation system was implemented to realize the proposed methods. And this paper will be closed with some conclusions.

2. Real Estate Valuation System Based on BIM

2.1 Building information modeling

BIM (Building Information Modeling) is also known as building information model, that is an engineering data model based on the 3D digital technology and integrated of all relevant information of construction projects(Xia and Yi, 2013). It is a demonstration of the entire construction lifecycle that allows to redefine the work scope, generate high quality three dimensional design schemes, support scheduling, cost estimation, and optimize facility management and maintenance (Shou and Wang et al., 2014). The information carriage by a BIM model is not only the geometry shape information, but also non-geometry data such as the construction material, weight, price and project schedule. These data can provide more detailed information of real estate properties for more accurate valuation.

BIM model has been widely used in real estate building industry and infrastructure industry, especially for cost management. For example, Ma and Wei et al (2013) developed a BIM-based construction cost estimating application software. Cheng and Chen (2013) illustrated the usage of BIM for quantity take-off. Besides, the spatial relationships and geographic information contained by BIM make it possible to build connections between BIM and GIS.

2.2 System architecture

The proposed system integration between GIS for real estate valuation and BIM are implemented by the four layer system architecture. From bottom to top, there are data layer, engine layer, support layer and application layer.

Data layer provides the core information resources of the whole system. It includes valuation essential data, spatial data and valuation thematic data. Valuation essential data contains real estate sales records data and valuation parameters data; spatial data contains spatial related information such as land, building, road, multilevel administration zone data, remote sensing image, topographic map, land benchmark price data and point of interests; valuation thematic data refers to various types of valuation objects, including building attribute data, structures and fixtures attribute database, plants and trees data, decoration data, construction cost data as well as BIM data from professional software.

Engine layer is a part of the data storage layer, through which data released by the engine to the corresponding services. It includes ArcGIS Server (for 2D GIS application service), Terra Gate (for 3D GIS application service), Lucene (for full-text search engine services) and so on.

Supporting layer is responsible for providing the system with professional management and analysis services. This is the technical core of the whole system and it includes 3D data model, 3D visualization, valuation model and green building analysis from BIM software.

Application layer is the information technology application software implementation and presentation layer. It provides users with software interface, system management and analysis functions such as assessment, query, database management, parameter management project management, knowledge management, three dimensional analysis and green building analysis.

This architecture remains the professionality of GIS for real estate system and BIM system. In the meantime, through system data transmission for data exchange.

2.3 Data transmission

The integration with GIS for real estate system and BIM system keeps both systems physically independent but logically connected through data transmission. The data transmission mainly shows in the following three aspects: BIM model exchange, BIM related analysis request and analysis results push and extract.

2.3.1 BIM model exchange

BIM model can be exported from professional BIM software and added in GIS through public data exchange format. The exported data will also be stored and managed by GIS database for further analysis.

2.3.2 BIM related analysis request

The professional BIM software remains the functions of professional analysis such as quantity take-off, project schedule management, and sustainable building analysis and so on. Because of the sophistication of the professional analysis models, there is no need to integrate such analysis model into GIS. Thus, BIM related analysis request is used for sending a message to BIM software for further professional analysis assistant. When BIM software receives such message, the related software will be activated for specific analysis. And all the analysis process is conducted through professional BIM software.

2.3.3 Analysis results push and extract

The results generated by professional BIM software need to be pushed to GIS for valuation system. Such process can be implemented through exchange database. When the results data generated, it will be stored in the exchange database and push a message to alert GIS for valuation system to access such results. After receiving the message, GIS for valuation system can access the exact exchange database for analysis results and extract for valuation purpose.

3. Sales Comparison Approach Improvement

In 2014, the authors proposed a 3D GIS valuation model (Yu and Liu et al., 2014). On the basis of this model, BIM analysis has been applied to provide more specific analysis to enhance the valuation accuracy.

3.1 The 3D GIS valuation model

Figure 1 shows the flow chart of the 3D GIS valuation model. Improvement has been made mainly in impact factors determination, impact factors analysis and quantitative analysis. More impact factors has been taken into account for valuation; some of the impact factors analysis is using BIM related professional analysis tools; to cooperate with such analysis, the related quantitative analysis has been conducted.

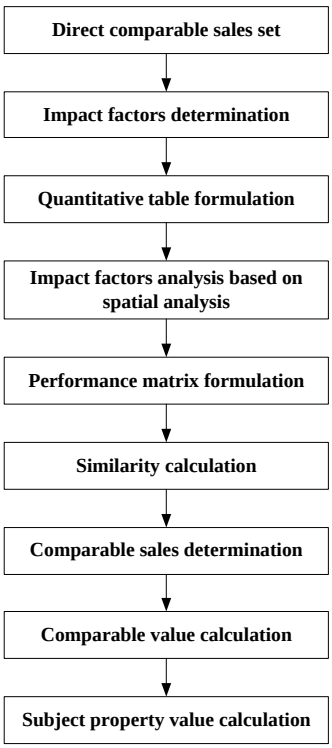

Figure 1. The flow chart of the 3D GIS valuation model

3.2 Impact factors determination

Generally, the impact factors of the real estate can be classified into two major categories regional factors and individual factors. For different type of real properties, the impact factors concerned differ. Thus, in this section, we take residential properties for example.

For residence, regional factors concern impacts from regional planning, regional prosperity, transportation convenience, landscape, environmental condition, fundamental infrastructure and public facility conditions. The specific descriptions are listed in Table 1.

Table 1. Regional impact factors table

	Impact factors	**Descriptions**	**Analysis methods**
Regional factors	Regional planning	Urban master planning and detailed planning etc.	Spatial query, spatial overlay
	Regional prosperity	Distance to multilevel business area	Spatial measurement, network analysis
	Transportation convenience	The number of public transportation facilities (such as bus stop, subway stations, etc.) and distance as well as road network service capabilities	Spatial measurement, network analysis, road network accessibility analysis, spatial statistics
	Landscape	The view of quality and distance to ocean, lake, mountain, green, forest park or golf course etc.	Visibility analysis, spatial measurement, spatial statistics
	Environmental condition	The air condition, noise, pollution, waste yard, incineration plant, power station, high-voltage power lines, etc. and the sunshine time	Spatial query, noise propagation analysis, pollutants diffusion analysis, visibility analysis, spatial statistics, BIM sunlight duration analysis, BIM community ventilation analysis, BIM noise analysis
	Fundamental infrastructure	The surrounded fundamental infrastructure, such as, water, electricity, gas, communications, cable, internet, wireless local area network, etc.	Spatial query, spatial statistics
	Public facility conditions	The distance to public facilities such as school, park, sport center, hospital, bank, ATM, supermarket, shopping mall, convenience store, theatre, etc.	Spatial query, spatial statistics

Individual factors include the plot ratio, project scale, ages, related service facilities, the rest of the land use term, decoration, and micro-environment and so on. In micro-environment, BIM indoor daylight analysis and BIM indoor ventilation analysis has been used for accurate analysis.

3.3 Quantitative table formulation based on BIM

For better understanding the performance of impact factors, quantitative standard analysis should be conducted. In our case, based on the national standard and analysis results, the quantitative analysis was conducted and combined with other impact factors to evaluate the performance of each object.

The quantitative table formulation contains the following process. First, according to the national standard or code, a quantitative classification table should be generated (as shown in Table 2). When GIS for valuation system accesses the results in the exchange database, the classification grade is firstly loaded for rapid respond in GIS. Then the grade value will be transformed to performance value as other impact factors in GIS for valuation model.

Table 2 daylight quantitative classification table

Grade	Description (average value of daylight factor c)
0	$c < 1\%$
1	$1\% \leq c < 2\%$
2	$2\% \leq c < 3\%$
3	$3\% \leq c < 4\%$
4	$c \geq 4\%$

3.4 Impact factors analysis

GIS spatial analysis models and BIM professional analysis models are used in each factor valuation. Spatial query is a special type of database query with spatial information, which support query by location and by attribute. Overlay operation is much more than a simple merging of different layers. All the attributes of the features taking part in the overlay are carried through. Spatial measurement calculates straight line distance and polygon area. Network analysis calculates the distance relied on network such as road network and river network. It further can realize accessibility analysis with the proper data support. Spatial statistics locate the analysis results by spatial information as well as mapping the results. Visibility analysis often used with DEM to calculate weather two points can see each other directly without any obstacles.

BIM sunlight duration analysis uses professional software based on BIM model to simulate the sun movement in a particular day and result in a grid with sunlight hours on the surface of buildings. BIM indoor/outdoor ventilation analysis based on CFD (Computational Fluid Dynamics) analysis model, and 3D community building models to simulate the indoor environment ventilation or surrounding environment ventilation. BIM noise propagation analysis determines the decibel value by professional analysis model. BIM indoor daylight analysis is based on the detailed 3D building model and considering the different construction materials to calculate the daylight factor under different sunlight conditions.

4. System Establishment

The proposed approach was implemented in our 3D GIS based single property valuation system (3DGISSPV). Practical data of Shenzhen, China was used in this study. Most of the spatial data are supported by relevant departments of the local government. Some of the real estate data are connected to the office systems of relevant government departments for real time data update, and some of them are supported by real estate agencies. Others are collected by manual work. The professional BIM software support is provided by TH SWARE[1]. In our study, SWARE BOQ was used for calculate bill quantity of construction works in cost approach; SWARE VENT was used for indoor/outdoor ventilation analysis; SWARE SUN was used for sunlight duration analysis; SWARE DALI was used for daylight factor analysis.

The 3DGISSPV system uses browser/server structure, which has low access burden and low process burden on the client side (user side). Users can access the system from anywhere through Internet. The 3DGISSPV system utilized visual reality combined with DEM, remote sensing images, and BIM data to establish the working environment with Skyline software for providing 3D platform, ArcGIS for spatial analysis, Oracle for database support and TH SWARE for BIM related analysis.

A BIM model data can be loaded in 3DGISSPV system. The tested BIM model data is a real case designed by TH SWARE based on AutoCAD. After loading the BIM model data, the 3DGISSPV system provides BIM building 3D visualization (Figure 2), BIM building inside navigation (Figure 3) and activating TH SWARE for detailed information (Figure 4).

In Figure 4, by clicking the "Extraction" button, the detailed bill of quantities can be calculated (Figure 5) and push back to 3DGISSPV system by clicking the "Valuation System" button. And in 3DGISSPV system such data can be loaded for the rest of cost approach valuation.

Figure 2. BIM data loaded in 3DGISSPV system

[1] www.thsware.com

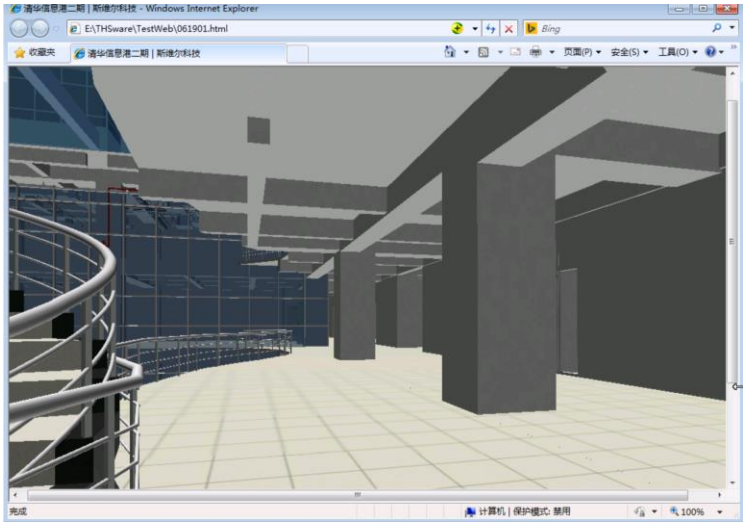

Figure 3. Inside navigation of BIM building in 3DGISSPV system

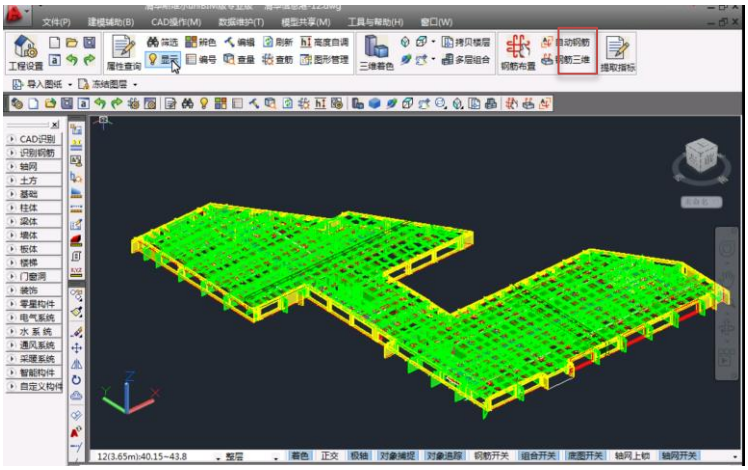

Figure 4. Detailed BIM data view in TH SWARE

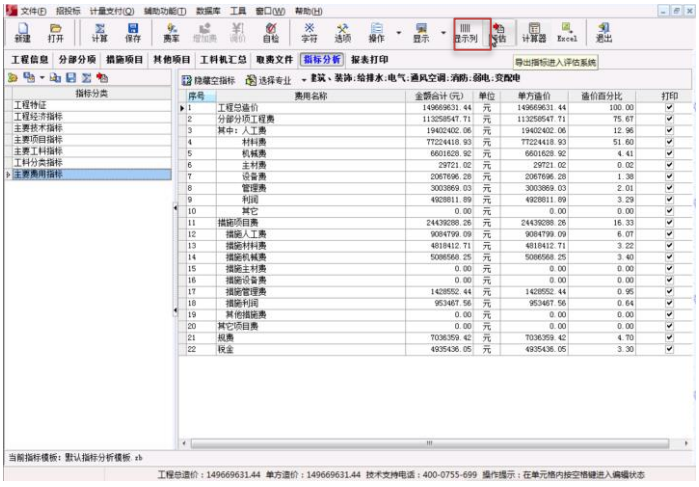

Figure 5. BOQ list

In our study, BIM based analysis was executed in professional software, such as sunlight duration analysis (Figure 6). Through data transmission method, the analysis results can be accessed in 3DGISSPV system (Figure 7).

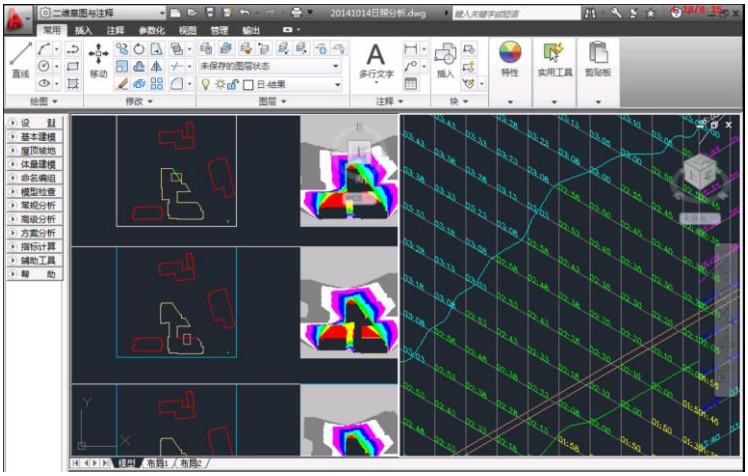

Figure 6. Sunlight duration analysis in SWARE SUM

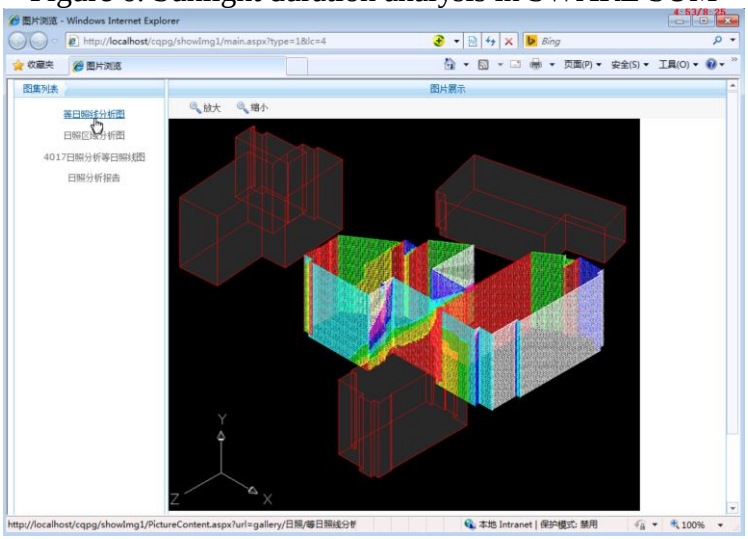

Figure 7. Sunlight duration analysis results in 3DGISSPV system

5. CONCLUSIONS

The purpose of this study is to provide a suitable way to enhance the valuation accuracy by integrating building information model and geographic information system. Building information model contains rich information such as geometry, quantities and properties of building elements, cost estimates, material inventories and project schedule and so on. These information is essential in real estate valuation especially for cost approach. Furthermore, the spatial relationships and geographic information contained by BIM data make it possible to build connections between BIM

and GIS. Thus, a system architecture was proposed with data transmission method for information exchange between different systems.

On the other hand, with BIM model data, more professional analysis can be realized. Thus, some improvement was made based on our premier 3D GIS valuation model. In this model, more impact factors were taken into account for valuation especially in environment analysis and micro-environment analysis. In the meantime, BIM related professional analysis tools were used for accurate analysis such as sunlight duration analysis, indoor/outdoor ventilation analysis, and daylight factor analysis and so on.

This study was realized in our 3DGISSPV system and practical data was used to perform the integration of BIM and GIS for accurate valuation. By using BIM technology, it can improve the accuracy of valuation and enhance the credibility of the valuation result. To sum up, the combination of BIM and 3D GIS with real estate valuation shows great benefits to promote valuation approaches, and more professional analysis should be used to assist appraisers for more reliable valuation.

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BIOGRAPHICAL NOTES

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