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Article

Research on Dynamic Monitoring of Real Estate Market Health Based on Multi-Source Data—Taking Liaocheng City as an Example

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Abstract: To improve the accuracy of real estate market monitoring, this paper addresses the significant regional differentiation and outdated traditional monitoring methods in the Liaocheng real estate market. Based on the digital twin theoretical framework, it integrates multi-source data such as online sales contracts for commercial housing, land auctions, and water and electricity consumption to construct a dynamic monitoring model for the health of the real estate market. The study establishes a three-dimensional evaluation index system of supply and demand balance, price fluctuations, and market vitality, uses the entropy weight method to determine objective weights, and achieves regional health classification through K-means clustering. Empirical results show that the Liaocheng real estate market exhibits a significant spatial differentiation pattern of "healthy and active core areas and pressured peripheral counties and cities". Dongchangfu District and Linqing City are considered healthy areas, Yanggu County and Gaotang County are considered relatively cold areas, while Shen County, Dong'e County, Chiping District, and Guan County are considered excessively cold areas. Cross-validation using online sales contracts and water and electricity data reveals a phenomenon of "high online sales contracts and low electricity consumption" in peripheral counties and cities, indicating a high vacancy rate risk. The study proposes a zoned and classified control strategy and constructs an integrated governance system of "monitoring-early warning-control", providing methodological support for the refined management of the city and county-level real estate markets.

Keywords: real estate health; multi-source data fusion; dynamic monitoring

1. Introduction

1.1. Research Background and Significance

Effectively monitoring the regional real estate market is crucial for implementing the national "city-specific policies" approach and preventing and mitigating real estate risks. Traditional monitoring models relying on statistical reports and sampling surveys suffer from bottlenecks such as data lag, narrow coverage, and difficulty in cross-verification, making it challenging to accurately grasp the complex and ever-changing market situation [1,2]. Liaocheng City serves as a typical case, exhibiting a significant differentiation in its real estate market—"active in the core area and under pressure in peripheral counties"—posing a severe challenge to traditional monitoring methods. With the development of information technology, multi-source data such as

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online contract signings, land auctions, and water and electricity consumption offer new opportunities to address the shortcomings of traditional monitoring. This data can reflect market operations in real time from multiple perspectives, including transactions, supply, and actual usage, offering advantages such as broad coverage, high timeliness, and verifiability [2, 3]. Digital twin theory provides methodological support for integrating multi-source data and constructing dynamic monitoring models that map virtual and real data [4].

1.2. Current Research Status and Innovative Ideas

Current research in the field of real estate market monitoring has developed various methods, including constructing comprehensive evaluation systems based on dimensions such as supply and demand and prices; introducing big data such as search engine indices to assist in trend judgment [1,5]; and applying econometric models and machine learning algorithms for prediction and early warning. However, existing research still has significant shortcomings in the systematic integration and analysis of high-value data such as online contract signing, land, and water and electricity data; the refined assessment of regional differentiation within prefecture-level cities; and the implementation of the digital twin concept into a closed-loop management scheme [2,6]. To fill these research gaps, this paper, based on the digital twin framework, innovatively integrates multi-source data to construct a dynamic monitoring model for the health of the real estate market applicable to the city and county levels. It focuses on solving key issues such as the construction of a multi-source data evaluation index system, objective weighting and clustering evaluation methods, internal differentiation characteristics and risk identification, and the formulation of differentiated control strategies, in order to improve the precise governance capabilities of the real estate market at the district and county levels.

2. Construction of a Theoretical Framework for Real Estate Monitoring Based on Multi-Source Data Fusion

2.1. Theoretical Framework of Digital Twin and Multi-Source Information Fusion Mechanism

This paper uses digital twin theory as its core guiding framework to construct a “digital mirror” that can dynamically reflect the actual operation of the real estate market. Drawing on the classic JDL model in the field of multi-source information fusion [6], a three-layer data processing workflow is designed: At the data layer, online contract signing data, land data, and water and electricity data are collected, cleaned, standardized, and spatially matched to form a consistent dataset. Online contract signing data, as a direct record of market transactions, constitutes the “fundamentals” of market operation; land auction data reflects future expectations and market confidence on the supply side, serving as a “leading indicator” of market development; and water and electricity consumption data reveals the actual usage and occupancy rate of properties, acting as a “verifier” of real market demand. At the feature layer, key features in three dimensions—supply and demand balance, price fluctuations, and market vitality—are extracted from the fused data. Supply and demand balance is the foundation of a healthy market; price fluctuations are an important signal of market activity; and market vitality comprehensively reflects the level of transaction activity and participant confidence. At the decision-making level, the entropy weight method combined with linear weighting is used to obtain a comprehensive health score. K-means clustering is applied to group regions, identify different types of market patterns, and realize the sublimation from data to decision, completing the “perception-analysis-decision” closed loop of the digital twin.

2.2. Data Indicator Evaluation, Early Warning and Linkage Analysis Framework

A four-step analytical framework of “data-indicators-assessment-early warning” is constructed: the system collects and processes multi-source data to form a standardized dataset; a health evaluation index system is established from three dimensions; the entropy weight method is used to determine the index weights and calculate the comprehensive score, and K-means clustering is used to classify the health levels; the causes of risks are identified through cross-validation of multi-source data, and tiered early warning and differentiated control strategies are proposed. This framework transforms the concept of digital twins into an operational solution, providing support for the refined management of the real estate market.

3. Establishment of a Health Evaluation Model for the Real Estate Market

3.1. Study Area and Data Sources

This study selects Liaocheng City, Shandong Province, as the analysis object. The eight districts and counties under its jurisdiction exhibit gradient differences in their real estate market development stages, demonstrating good regional representativeness. The research period spans from 2020 to 2024, covering the complete market cycle. Data sources include: online sales data for commercial housing (Municipal Housing and Construction Bureau), land auction data (Municipal Natural Resources and Planning Bureau), and water and electricity consumption data (electricity and water departments). All data underwent rigorous preprocessing, including missing value imputation, outlier correction, price deflation, and indicator standardization.

3.2. Construction of Health Evaluation Index System

Based on the core logic of market operation, a health evaluation index system with three dimensions is constructed (see Table 1): Supply and Demand Balance Index: This index measures the short-term supply and demand relationship in the market by using the ratio of "month-end available sales area to the average sales area over the past six months", and is a negative indicator. Price Volatility Index: This index is calculated using January 2020 as the base period. It separates cyclical fluctuation components using CPI deflator; smaller fluctuations indicate a healthier price system. Market Vitality Index: This is a composite index comprising three sub-indicators: transaction activity (growth rate of residential property transaction area), developer expectations (change rate of land transaction floor price), and actual demand intensity (growth rate of water and electricity consumption).

Table 1. Evaluation Index System for the Health of Liaocheng Real Estate Market.

Evaluation Dimensions	Key Indicators	Indicator Properties	Data Source	Calculation Methods and Explanations	Health Direction
1. Supply and demand balance dimension (reflecting market fundamentals)	Supply and demand balance index	negative indicators	Municipal Housing and Construction Bureau (Online Transaction System for Commercial Housing)	Month-end saleable area/ Average sales area over the past 6 months Note: This ratio represents the inventory clearance cycle (in months). The higher the value, the more severe the oversupply and the greater the pressure to clear inventory.	The lower the value, the healthier.
2. Price fluctuation dimension (reflecting market stability)	Price volatility index	negative indicators	Municipal Housing and Construction Bureau (average price on record), Municipal Statistics Bureau (CPI)	1. Using January 2020 prices as the base period (100), calculate the fixed-base price index for each period. 2. Use CPI to perform deflating to obtain the real price index. 3. Apply methods such as the HP filter to separate the cyclical fluctuation component of prices and calculate its fluctuation amplitude. Note: The smaller the absolute value of the fluctuation amplitude, the more stable the price.	Smaller fluctuations indicate better health
3. Market vitality dimension (reflecting market activity and real demand)	Market Vitality Index (Composite Indicator)	Positive indicators	Multi-source data fusion	It is synthesized by standardizing the following three sub-indicators:	The higher the value, the healthier.

Table 1. Cont.

Evaluation Dimensions	Key Indicators	Indicator Properties	Data Source	Calculation Methods and Explanations	Health Direction
	Trading activity (sub-indicator 1)	Positive indicators	Municipal Housing and Construction Bureau (online contract signing data)	Year-on-year (or month-on-month) growth rate of commercial residential property transaction area Note: Directly reflects the level of market activity.	
	Developer expectations (Sub-indicator 2)	Positive indicators	Municipal Bureau of Natural Resources and Planning (Land Auction Data)	The change rate of the floor area price of residential land transactions or the land premium rate Explanation: Reflects the confidence and expectations of real estate development enterprises in the future market.	
	Real Demand Intensity (Sub-indicator 3)	Positive indicators	State Grid Liaocheng Power Supply Company and Liaocheng Water Group (data from sampled residential communities)	The water and electricity consumption composite index represents the growth rate of average water and electricity consumption per household in representative sample communities. Note: Used to verify the genuine residential demand behind online transaction registrations and identify investment-driven and speculative vacancy.	
	Synthesis method	-	-	The data of the above three sub-indicators are standardized and the dimensions are eliminated. Then, an equal-weighted average or a weighted average based on the weights determined by expert consultation is used to finally synthesize the market vitality index.	

3.3. Entropy Weight Method and Cluster Analysis

The entropy weight method was used to objectively determine the weights of each indicator. The calculation steps are as follows: data standardization; calculation of feature weights; calculation of entropy values and difference coefficients; and final determination of weights. After calculating the comprehensive score based on the weights, the K-means clustering algorithm was used to automatically classify the samples, avoiding bias caused by subjectively set thresholds. The weight calculation results show that the market vitality index has the highest weight (0.5706), followed by the supply and demand balance index (0.3250), and the price volatility index is 0.1044. This indicates that market vitality, which integrates multi-dimensional information, has become the most core indicator for measuring market health.

3.4. Model Validation and Robustness Testing

The reliability of the conclusions was ensured through cross-validation of multi-source data and model robustness testing. The “evidence triangle” method was used to cross-verify the data from multiple sources. Calculation of the “online contract signing-occupancy deviation rate” revealed that the deviation rate in a healthy market was below 10%, while the deviation rate in a risky market exceeded 30%, indicating a risk of speculative vacancy. Model validity testing showed that internal consistency tests demonstrated a reasonable model structure; external validity tests proved

that the predicted results were highly consistent with reality; and the advantages of the research methodology ensured that the results were naturally generated based on the data structure.

4. Empirical Evaluation Results and Analysis

4.1. Overall Health Assessment Results

Based on data from 2020 to 2024, the results of the health assessment of the real estate market in the eight districts and counties of Liaocheng City are as follows (see Table 2).

Table 2. Assessment Results of the Health of the Real Estate Market in Various Districts and Counties of Liaocheng City (Average from 2020 to 2024).

Districts and Counties	Overall Health Score	Health Level	Supply and Demand Balance Index	Price Volatility Index (%)	Market Vitality Index	Key Features Overview
Dongchangfu District	0.8608	healthy	0.92	4.2	0.8788	Supply and demand are basically in balance, prices are stable or rising moderately, and the market is active and driven mainly by real demand.
Linqing City	0.8851	healthy	0.85	7.8	0.9826	Supply and demand are basically in balance, prices are stable or rising moderately, and the market is active and driven mainly by real demand.
Yanggu County	0.6847	cool	1.05	3.5	0.5549	Supply and demand are slightly loose, prices are under pressure, market activity is insufficient, and the destocking cycle is prolonged.
Gaotang County	0.6528	cool	1.12	2.9	0.5344	Supply and demand are slightly loose, prices are under pressure, market activity is insufficient, and the destocking cycle is prolonged.
Shen County	0.3507	too cold	1.68	−2.1	0.2137	The supply and demand are severely imbalanced, inventory is high, prices have fallen significantly, market confidence is low, vacancy rates are high, and risks are prominent.
Dong’e County	0.3585	too cold	1.52	−1.8	0.2162	The supply and demand are severely imbalanced, inventory is high, prices have fallen significantly, market confidence is low, vacancy rates are high, and risks are prominent.
Chiping District	0.1225	too cold	2.15	−5.3	0.0767	The supply and demand are severely imbalanced, inventory is high, prices have fallen significantly, market confidence is low, vacancy rates are high, and risks are prominent.
Guan County	0.1044	too cold	2.40	−6.7	0.0000	The supply and demand are severely imbalanced, inventory is high, prices have fallen significantly, market confidence is low, vacancy rates are high, and risks are prominent.

Note: The overall health score of this market only reflects the relative health level, not an absolute evaluation; the health evaluation takes into account long-term trends and multiple indicators, and short-term fluctuations in trading volume do not affect the overall health level.

4.2. Spatial Differentiation Characteristics Analysis

The assessment results show that the Liaocheng real estate market exhibits a significant “core-periphery” differentiation pattern. Healthy areas possess a solid demand base due to the agglomeration effect of population, industry, and public resources. Dongchangfu District, as the city center, shows a balanced market performance

across the board; Linqing City scored the highest but harbors hidden risks, requiring vigilance against a housing price bubble. Less desirable areas lack the "siphoning effect" of the core urban area, resulting in weak market demand growth and a high risk of sliding into the "overly cold" range during an overall market downturn. Overly cold areas are fraught with risks; all four counties/districts (including Shen County) scored below 0.36, with Guan County and Chiping District scoring below 0.13. These areas face multiple risks, including severe supply-demand imbalance, continuous price declines, and market depletion. High vacancy rates in some areas warrant close attention.

4.3. Discovery from Cross-Validation of Multi-Source Data

Cross-validation of online contract signing data and electricity consumption data reveals that the online contract signing rate and actual occupancy rate are highly correlated in core areas (e.g., 91.7% in Dongchangfu District), indicating that housing transactions are primarily driven by genuine residential demand. However, peripheral counties and cities exhibit a phenomenon of "high online contract signing, low electricity consumption", with some developments showing online contract signing rates exceeding 80% but actual vacancy rates exceeding 40%, suggesting a high proportion of vacant properties purchased for investment or the existence of abnormal transaction practices. The fundamental reason for this regional differentiation lies in uneven development. Core urban areas create a "siphoning effect", while peripheral counties and cities face challenges such as weak population growth and insufficient industrial support, resulting in limited effective demand and a negative cycle of "insufficient demand—falling prices—weakening expectations."

4.4. Key Risk Warning Signals

Three types of early warning signals were identified: risk of localized overheating (price increase of 7.8% in Linqing City); risk of regional overcooling (health score of less than 0.15 in Chiping District and Guan County); and risk of market authenticity (significant discrepancy between online contract signing and electricity consumption). These signals provide clear targets for precise regulation.

5. Construction of a Differentiated Regulatory Policy System

5.1. Precise Regulation Strategy Based on Zoning and Classification

Healthy areas: The policy focus is on "stabilizing expectations and preventing risks." Maintaining policy continuity, optimizing the supply structure, implementing a "dual-limit, dual-competition" mechanism, limiting the annual increase in new home prices to no more than 5%, and improving purchase restriction policies. Risky areas: The policy focus is on "reducing inventory, promoting consumption, and preventing risks." On the land supply side, the supply of land for commercial residential use will be suspended or reduced; on the demand side, down payment ratios will be lowered, and housing subsidies will be provided; regarding inventory reduction, the government will acquire some existing housing stock and convert it into affordable housing.

5.2. Construction of Dynamic Monitoring and Early Warning Platform

Build a multi-source data sharing platform to integrate departmental data and achieve information sharing and routine integration. Strengthen data cross-validation and establish a "transaction-occupancy" deviation early warning model. Establish a regular reporting and emergency response system, generate quarterly health monitoring reports, and clarify the corresponding handling procedures for early warning levels.

5.3. Supporting Safeguards and Long-Term Mechanisms

Strengthen training for grassroots staff in big data analytics to enhance their ability to use new technologies for market monitoring. Improve expectation management and information disclosure to guide market participants towards stable expectations. Refine risk management plans and establish a sound early warning and handling mechanism for financial risks in the real estate market.

6. Conclusions and Outlook

This paper constructs a dynamic monitoring model for the health of the real estate market, which effectively enhances the breadth and depth of monitoring through multi-source data fusion. Empirical analysis shows that the Liaocheng real estate market exhibits significant internal spatial differentiation, displaying a dual structure characterized by a "healthy and active core and a cold and pressured periphery." This differentiation is the result of the combined effects of multiple factors, including the economy, population, and industry, confirming the necessity and feasibility of differentiated regulation. The proposed regional and categorized regulation strategy and the integrated governance system of "monitoring-early warning-regulation" provide a practical path to overcome the limitations of "one-size-fits-all" regulatory policies. Future research will focus on expanding data dimensions, introducing machine learning algorithms to optimize the model's predictive capabilities, strengthening policy simulation and early warning functions, promoting the model's practical application in more cities, and continuously improving its refinement and practicality. With the continuous development of data and technology, a dynamic and intelligent monitoring and early warning system will be continuously improved, contributing greater value to promoting the stable and healthy development of the real estate market.

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Conflicts of Interest

The author declares no conflict of interest.

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