Spatiotemporal Variations in High-Quality Urban Construction Levels in the Lanzhou-Xining Urban Agglomeration and Their Influencing Factors: A Postprint

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Abstract

Quality urban construction constitutes an important component in response to the strategies of ecological civilization, high-quality development, and new-type urbanization. Taking 30 cities (counties) in the Lanzhou-Xining urban agglomeration as the research object and urban built-up areas as the basic spatial units, this study evaluates the quality urban construction level of the Lanzhou-Xining urban agglomeration across eight dimensions: land use, economy, society, ecology, environmental protection, transportation, municipal infrastructure, and image quality. The results indicate: (1) In terms of temporal variation, the comprehensive quality of all cities shows a continuous overall improvement, yet the quality construction remains at a relatively medium-low level; the dimensional quality changes of individual cities are complex, exhibiting multiple patterns including stable type, improvement type, decline-then-rise type, rise-then-decline type, and mixed type. (2) Spatially, the comprehensive quality of cities demonstrates a transformation from a "dual-core" to a "multi-core coexistence" pattern; significant disparities exist in dimensional quality with an unbalanced distribution. (3) The contributions of dimensional quality vary significantly across cities, with characteristic quality cities gradually emerging, basically forming three types: single-dominant, dual-dominant, and multi-dominant dimensional types. (4) Quality urban construction is influenced by numerous factors, with their impact following the order: built-up area scale > population scale > per capita GDP > urbanization rate > external transportation > topographic relief; urban scale represents the primary influencing factor for quality urban construction in the Lanzhou-Xining urban agglomeration, urbanization rate and per capita GDP serve as secondary factors, while natural factors have the weakest influence but play a fundamental role.

Full Text

Preamble

Spatiotemporal Variation of Quality City Construction Level and Its Influencing Factors in the Lanzhou-Xining Urban Agglomeration

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Abstract: Quality city construction constitutes a critical response to national strategies of ecological civilization, high-quality development, and new urbanization. This study evaluates the quality city construction level within the Lanzhou-Xining urban agglomeration in northwestern China, using 30 cities (counties) as research objects and urban built-up areas as the basic spatial units. The evaluation framework encompasses eight dimensions: land use, economic, social, ecological, environmental protection, transportation, municipal administration, and image quality. Results reveal: (1) Temporally, the comprehensive quality of all cities shows sustained improvement, yet remains at a relatively low-to-medium level. Changes in sub-dimensional quality are complex, exhibiting multiple patterns including stable, progressive, decline-then-rise, rise-then-decline, and mixed types. (2) Spatially, the comprehensive quality pattern transforms from a "dual-core" to a "multi-core coexistence" structure, with significant inter-dimensional disparities and unbalanced distribution. (3) Contributions of sub-dimensions vary markedly among cities, with distinctive quality cities gradually emerging, classified into single-dimension, dual-dimension, and multi-dimension dominant types. (4) Multiple factors influence quality city development, with influence strength ranking as: built-up area size > population size > per capita GDP > urbanization rate > external transportation > topographic relief. City scale represents the primary influencing factor, urbanization rate and per capita GDP are secondary factors, while natural factors exert the weakest but foundational influence.

Keywords: Lanzhou-Xining urban agglomeration; quality city; spatiotemporal variation; influencing factors

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Introduction

The 19th National Congress of the Communist Party of China declared that China's socio-economic development has shifted from high-speed growth to high-quality development, imposing new requirements and directions for quality city construction in the new era. Urban quality will become the core capability to resist development risks and enhance sustainability, as well as crucial capital for improving urban competitiveness and attracting high-end talent. The Central

Economic Work Conference emphasized that China's economic spatial structure is undergoing profound changes, with central cities and urban agglomerations becoming the primary spatial forms for carrying development elements and the main platforms for implementing quality city construction.

The Lanzhou-Xining urban agglomeration, as an important cross-provincial urban agglomeration in northwest China, plays a pivotal role in achieving national territorial and ecological security and maintaining prosperity and stability in the northwest region. However, constrained by its natural geographic location, it exhibits significant development gaps compared with eastern urban agglomerations, greatly restricting the pace of quality city construction. Therefore, scientifically understanding the quality city construction level of the Lanzhou-Xining urban agglomeration and identifying weaknesses in different cities' quality construction is crucial for promoting high-quality development and enhancing the competitiveness of this urban agglomeration.

International research on urban quality originated from studies on quality of life. American economist John Kenneth Galbraith proposed the concept of quality of life to reveal the contradiction between high living standards and relatively backward social-spiritual needs among American residents. Subsequent research integrated environmental factors into the quality of life concept to reveal differences in urban economic development and welfare levels across countries and periods. Later studies combined quality of life with urban livability and sustainable development, considering that development levels in architecture, urban transportation, green infrastructure, water management, economic development, ecosystem health, intelligence, environmental factors, and tourism constitute important components of urban quality.

Domestic research began later, with different emphases in different periods. The 1990s focused on soft quality construction such as urban culture, image, and design. Since the 21st century, research has gradually shifted from single to comprehensive elements, with socio-economics, public services, road traffic, ecological environment, and human settlements becoming important content of urban quality construction. Under new era requirements such as new urbanization, high-quality development, and urban renewal, China issued the *New Urbanization—Quality City Evaluation Index System* (GB/T 39497-2020) in 2020, providing a development guide for orderly quality city construction.

Quality city construction represents the quality improvement process of urban systems and their elements, as well as a coordinated process to solve human-land relationship contradictions in urban systems. It exhibits typical characteristics of complexity, comprehensiveness, regionality, and timeliness. Facing China's high-quality socio-economic development, urban quality research should be forward-looking, guiding, and dynamic. However, current research has several deficiencies: (1) In system composition, studies should not only highlight traditional economic development, social culture, ecological environment, and public services, but also emphasize the human-land coordination 思想 in the new territorial space era, strengthening respect and protection for the "land" that carries cities. This requires enhancing land intensive use quality, ecological security quality, and landscape image quality. (2) In research scope, traditional studies often use municipal or county areas to represent cities, mixing urban and rural qualities and failing to accurately grasp quality construction issues of regional growth poles. Urban built-up areas should be used as spatial representation. (3) In research content, most studies focus on static evaluation of single cities, lacking spatiotemporal dynamic research and mechanism analysis of various cities within urban agglomerations, making it difficult to effectively understand common problems and development paths.

Therefore, this paper selects 2010, 2015, and 2018 as research time points, uses the built-up areas of 30 cities (counties) within the Lanzhou-Xining urban agglomeration as basic research units, establishes a comprehensive quality city evaluation index system, and quantitatively analyzes the spatiotemporal variation characteristics and influencing factors of quality city construction in the Lanzhou-Xining urban agglomeration to scientifically understand its problems and mechanisms.

1.1 Study Area

The Lanzhou-Xining urban agglomeration is a cross-provincial urban agglomeration in western China centered on Lanzhou (Gansu Province capital) and Xining (Qinghai Province capital). This study uses the Lanzhou-Xining urban agglomeration scope defined in the *Lanzhou-Xining Urban Agglomeration Development Plan* as the study area, located between 34°51 -37°38 N and 99°01 -105°38 E, covering 30 cities and counties in Gansu and Qinghai provinces with a total area of 9.75×10^{4} km^2. As the agglomeration lies at the junction of the Tibetan Plateau and Loess Plateau with complex landforms and the Yellow River running through it, it has formed various distinctive cities.

In 2018, the Lanzhou-Xining urban agglomeration achieved a GDP of 4880.64×10^{8} yuan with a permanent population of 1238.86×10^{4} people. This study uses the built-up areas of 30 cities (counties) within the agglomeration as the research units for quality city evaluation.

[Figure 1: see original paper]

1.2.1 Comprehensive Evaluation Index System

Based on the "Five-in-One" overall layout and coordinated human-land development theory, oriented toward high-quality development, harmonious human settlements, and sustainable development, and combining previous research with the *New Urbanization—Quality City Evaluation Index System*, this study establishes a quality city comprehensive evaluation index system following systematic and scientific principles. The system comprises 8 primary indicators: land use quality, economic quality, social quality, ecological quality, environmental protection quality, transportation quality, municipal quality, and image quality.

Based on data availability, reliability, and representation, 28 secondary indicators are determined (Table 1).

1.2.3 Evaluation Index Standardization

Based on the characteristics of secondary indicators, different standardization methods are applied for positive, negative, and interval contribution indicators.

For positive indicators:

$$Z_i = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}}$$

For negative indicators:

$$Z_i = \frac{X_{\max} - X_i}{X_{\max} - X_{\min}}$$

For interval contribution indicators:

$$Z_i = \begin{cases} \frac{X_i - X_{\min}}{X_{\min}^{-} - X_{\min}} & \text{if } X_i < X_{\min}^{-} \\ 1 & \text{if } X_{\min}^{-} \leq X_i \leq X_{\max}^{-} \\ \frac{X_{\max} - X_i}{X_{\max} - X_{\max}^{-}} & \text{if } X_i > X_{\max}^{-} \end{cases}$$

where X_i is the actual value of indicator i; $X_{\min}$ and $X_{\max}$ are the minimum and maximum values; $X_{\min}^{-}$ and $X_{\max}^{-}$ are the lower and upper threshold values.

For positive and negative indicators, standardized values range in [0,1]. For land use rationality indicators, the 达标率 (compliance rate) compares the proportion of five major land use categories with the average value P from *Standard for Classification and Planning of Urban Land Use* (GB50137-2011). Values closer to 1 indicate more reasonable proportions and are treated as negative indicators.

1.2.4 Weight Determination

The entropy method can reflect indicator information value while overcoming information overlap and is widely applied in socioeconomic research. This study uses the entropy method to calculate indicator weight coefficients (W_j).

1.2.5 Dimension and Comprehensive Quality Index Calculation

Following the United Nations Human Development Index (HDI) evaluation method, dimension quality indices and comprehensive quality indices are calculated by summing standardized data multiplied by corresponding weights.

Dimension quality index:

$$I_i = \sum_{j=1}^{n} Z_{ij} W_{ij}$$

where I_i is the quality index of primary indicator i; n is the number of secondary indicators; Z_{ij} is the standardized value; W_{ij} is the weight.

Comprehensive quality index:

$$I = \sum_{i=1}^{m} I_{iW} i$$

where I is the comprehensive quality index; m is the number of primary indicators (8 in this study); W_i is the weight of primary indicator i.

1.2.6 Classification

Based on literature and expert recommendations, quality city levels are divided into five grades: high quality (0.8-1.0], relatively high quality (0.6-0.8], medium quality (0.4-0.6], relatively low quality (0.2-0.4], and low quality (0.0-0.2] (Table 2).

1.2.7 Location Quotient

The location quotient reflects the specialization degree of a certain dimension quality and its contribution to comprehensive quality. A larger location quotient indicates higher dimension quality and greater contribution to comprehensive quality.

2 Results and Analysis

Using the quality city evaluation index system and comprehensive assessment method, this study evaluates and visualizes the quality city construction level of 30 cities (counties) in the Lanzhou-Xining urban agglomeration from 2010 to 2018 using ArcGIS 10.2.

2.1.1 Overall Continuous Improvement with Relatively Low-to-Medium Level

From 2010 to 2018, the comprehensive quality index of the Lanzhou-Xining urban agglomeration shows a yearly upward trend, increasing from 0.32 to 0.43, indicating continuous quality improvement. Most cities experienced significant quality improvement in 2015. However, the overall construction level remains at a relatively low-to-medium stage, with large gaps between highest and lowest values (0.29 in 2010, 0.28 in 2015, and 0.27 in 2018), showing persistent polarization and significant inter-city differences. As a major cross-provincial urban agglomeration in western China, strengthening cooperation and achieving integrated regional development remains challenging.

2.1.2 Complex and Diverse Sub-Dimensional Quality Changes

Sub-dimensional quality changes in the Lanzhou-Xining urban agglomeration are complex and diverse, exhibiting stable, progressive, decline-then-rise, rise-then-decline, and mixed patterns (Figures 2 and 3).

[Figure 2: see original paper]
[Figure 3: see original paper]

Stable type is dominated by municipal quality, remaining stable around 0.4 throughout 2010–2018, with gentle curves. Only Dongxiang County, Haidong City, and Huangyuan County showed noticeable growth.

Progressive type is dominated by ecological quality. From 2010 to 2018, ecological quality of 30 cities (counties) improved steadily, with quality indices rising from 0.37 to 0.51. Only Hualong County, Haiyan County, Jianzha County, Guinan County, and Yongdeng County showed decline.

Rise-then-decline type is dominated by economic and social quality. Economic and social qualities showed significant improvement from 2010 to 2015, but many cities declined after 2015. Image quality also exhibited this pattern, with many cities declining after 2015. Land use quality in Dingxi City, Xining City, Jingyuan County, and Hualong County was higher in 2010 than in 2018.

Decline-then-rise type is dominated by environmental protection quality, which decreased to varying degrees (about 0.05) in 2015 but increased in many cities (about 0.07) in 2018.

Mixed type is dominated by land use and transportation quality. Land use quality in Yongdeng County and Jingtai County showed continuous rise, while Jianzha County, Guinan County, Lanzhou City, Yongjing County, Huangzhong County, and Huangyuan County showed continuous decline. Transportation quality showed complex patterns with different trajectories across cities.

These variations reflect that during 2010–2018, the Lanzhou-Xining urban agglomeration was in key periods of the 11th, 12th, and 13th Five-Year Plans. Different construction foundations, problems, and policy priorities directly affected dimensional quality construction differences.

2.1.3 Significant Contribution Differences and Emerging Characteristic Quality Cities

Location quotient analysis reveals significant differences in sub-dimensional contributions to comprehensive quality (Figure 4). Cities with location quotient >1.2 can be classified into single-dimension, dual-dimension, and multi-dimension dominant types (Table 3).

[Figure 4: see original paper]

Single-dimension dominant cities are most numerous, increasing from 6 in 2010 to 13 in 2018, dominated by environmental protection quality (Weiyuan, Lintao, Linxia), ecological quality (Huangzhong, Huangyuan, Xunhua, Gonghe, Guide), and land use quality (Yongdeng, Gaolan, Jingtai, Longxi, Minhe, Haiyan). Dual-dimension dominant cities include Yongjing and Datong (ecological-environmental), and Huangzhong, Xunhua, and Guide (ecological-land use). Only Tongren County is multi-dimension dominant. This indicates that characteristic quality cities are gradually forming, with land use, environmental protection, and ecological quality dominance being most prominent by 2018.

2.2.1 Spatial Transformation from "Dual-Core" to "Multi-Core Co-existence"

Spatially, comprehensive quality shows a transformation from "dual-core" to "multi-core" pattern. From 2010 to 2018, Lanzhou and Xining, as provincial capitals, had significantly higher quality levels than other cities, forming a "dual-core" regional growth pole (Figure 5). By 2018, multiple high-quality cities emerged, with "central collapse" and "core-periphery" phenomena at provincial borders. The "dual-core"structure persisted, but with the construction of "China's Potato Capital," "China's Medicine Capital," and "Lanzhou Yuzhong Ecological Innovation City," as well as the Qinghai-Gansu tourism loop, cities like Dingxi, Baiyin, Haidong, Guide, Longxi, Yuzhong, Yongdeng, Yongjing, Gonghe, and Weiyuan showed noticeable quality improvement, forming multiple coexisting cores with more uniform distribution.

[Figure 5: see original paper]

Comprehensive quality also shows prominent distribution along transportation corridors. High-quality cities are mainly distributed along east-west transportation corridors, showing a "branch-like" distribution pattern, indicating that transportation accessibility is an important factor promoting quality city construction.

Sub-dimensional quality shows large spatial disparities and unbalanced distribution (Figure 6). Land use quality was relatively balanced by 2018, reaching relatively high levels across all cities. Ecological and environmental protection qualities improved from relatively medium to relatively high levels. However, other dimensions remain unevenly distributed.

[Figure 6: see original paper]

2.3.1 Influencing Factors

Quality city development involves multiple aspects affected by various factors. Drawing from limited literature, this study considers factors from urban internal and natural environmental perspectives, including socio-economic factors such as development stage, economic level, city scale, and transportation construction.

Selected factors include: urbanization rate (X_1) for development stage, per capita GDP (X_2) for economic level, population size (X_3) and built-up area size (X_4) for city scale, external transportation (X_5), and topographic relief (X_6) as natural factor. Using Geodetector' s factor and interaction detection with dimension indices and comprehensive quality index as dependent variables (Y), results show q values representing explanation degrees.

[Figure 7: see original paper]

Factor detection results show: (1) Influencing factors vary across development stages. Except topographic relief, all factors show decreasing influence over time. In 2010, built-up area size (X_4) had the strongest influence ($q = 0.503$), followed by urbanization rate (X_1, $q = 0.282$), per capita GDP (X_2, $q = 0.516$), external transportation (X_5, $q = 0.282$), and population size (X_3, $q = 0.282$). By 2018, built-up area size remained dominant ($q = 0.826$), followed by population size ($q = 0.767$), urbanization rate ($q = 0.374$), external transportation ($q = 0.374$), and per capita GDP ($q = 0.374$). This reflects that city scale is the primary factor, with land use scale as the carrier and population agglomeration driving quality demands. The declining influence of other factors indicates quality improvement has become a spontaneous urban development goal.

(2) **Interaction effects** exceed single-factor effects (Table 4). Interaction detection reveals mostly non-linear and bi-linear enhancement relationships, with interaction effects significantly stronger than single factors. In 2010, the interaction between external transportation and per capita GDP was strongest ($q = 0.934$). In 2018, the interaction between built-up area size and population size was strongest ($q = 0.934$). Interaction effects show stage-specific characteristics: during 2010–2015 (rapid urbanization), cities with higher urbanization rates emphasized quality construction; after 2015, urbanization rate' s influence weakened while city scale became the main factor.

(3) **Main influencing factors vary significantly across dimensions**. Urban infrastructure forms the foundation for quality city construction. During 2010–2015, urbanization rate was the main factor for transportation, image, environmental protection, and municipal qualities, but its influence weakened annually. Due to natural environmental constraints on urban development space, population size significantly affects land use, image, environmental protection, and economic qualities, showing increasing influence on land use quality. Per capita GDP is the main factor for social quality, as public service facilities depend on national income. Land use scale is the main factor for economic and ecological qualities, as economic development requires space for industries, while intensive land use under natural constraints improves construction efficiency and ecological quality.

Overall, city scale is the key factor causing quality city construction differences among cities. The Lanzhou-Xining urban agglomeration should leverage orderly urban expansion to promote quality construction while avoiding negative impacts of excessive scale.

3 Discussion

Urban quality represents the organic unity of urban spiritual taste and development quality, integrating multi-dimensional, multi-level, and multi-domain urban quality. Its core is creating and developing cities from a human perspective. The spatiotemporal variation of comprehensive quality in the Lanzhou-Xining urban agglomeration reflects the "people-centered" quality city construction 理念. Since the 18th Party Congress incorporated ecological civilization into the overall layout and the 19th Party Congress identified the principal contradiction as unbalanced and inadequate development versus people' s growing needs for a better life, quality city construction has accelerated through initiatives like "Civilized City," "Sponge City," "Garbage-Free Zones," and "Toilet Revolution." By 2018, characteristic quality cities dominated by land use, ecological, and environmental protection qualities have emerged. However, given the relatively singular types, cities must identify weaknesses to achieve balanced development across all dimensions.

The overall improvement from 2010–2018 aligns with reality, while the low-to-medium level is consistent with the agglomeration' s development status among China' s urban agglomerations. As the only cross-provincial urban agglomeration in western China, it faces constraints including high proportions of traditional industries, small economic aggregate, low per capita levels, and weak natural environmental carrying capacity. Located in the Yellow River basin' s ecologically fragile zone, its development requires both key development for sustained socio-economic progress and restricted development for ecological protection. Future quality construction should turn disadvantages into advantages by strengthening ecological quality while enhancing other dimensions to achieve leapfrog development.

Influencing factors show the pattern: built-up area size > population size > per capita GDP > urbanization rate > external transportation > topographic relief. This reflects that in the new territorial space era, human-land coordination is crucial, with intensive land use, economic efficiency, and urbanization stage being core factors, while natural factors are not decisive but foundational. This aligns with the "people-oriented" service concept, where quality improvement has become a spontaneous urban development goal.

The Lanzhou-Xining urban agglomeration, in its cultivation and development stage, faces fundamental and regional constraints including conflicts between functional upgrading and environmental carrying capacity, development gaps caused by differential conditions, insufficient development due to natural constraints, and resource loss risks from competition with other agglomerations. As socio-economic development accelerates, urban demand hierarchies will change. Future research should explore transformation mechanisms and pathways from low-quality, unbalanced, and uncoordinated development to high-quality, balanced, and coordinated development.

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Note: Figure translations are in progress. See original paper for figures.