

Quality Inspection And Optimization Methods For Urban Territorial Space Monitoring Data Results

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Abstract

Urban territorial space monitoring is an important component of the national spatial governance system. The results of urban territorial space monitoring undertake the significant mission of providing fundamental support for territorial space planning, key technical support for urban health check and assessment, and decision-making basis for the implementation of land use control. Based on empirical data from the quality inspection of national-level urban territorial space monitoring results in 2024, this study systematically analyzes the manifestation forms of typical quality issues and conducts cause analysis from multiple perspectives. It proposes actionable strategies for quality improvement from two aspects: optimization of technical implementation processes and innovation in data quality control methods. Experimental verification shows that these strategies not only improve the efficiency of quality inspections but also enhance the quality of data results, providing strong support for the quality assurance of urban territorial space monitoring results and ensuring that the monitoring results effectively support scientific decision-making and sustainable development in territorial space governance.

1. Introduction

In 2019, The "Several Opinions on Establishing the Supervision and Implementation of the Territorial Spatial Planning System" explicitly requires the state to establish and improve an implementation and supervision mechanism for dynamic monitoring, evaluation, and early warning of territorial spatial planning. Starting from 2020, the Ministry of Natural Resources plans to organize and carry out urban territorial spatial monitoring work (Ren, et al., 2024). Taking urban territorial space monitoring as an important task. Based on the results of the previous year's change survey, urban territorial space monitoring utilizes high-resolution imagery and the latest relevant thematic data available by the end of June of the current year, combined with field surveys and other work, to refine and supplement relevant content (Zheng, et al., 2023). The goal is to grasp the total amount of urban construction, land use structure, infrastructure, and service functions, etc. (Liu, et al., 2023). The data results of urban territorial space monitoring bear the important missions of providing fundamental support for territorial space planning, offering crucial technical support for urban health assessment, and serving as a decision-making basis for the implementation of land use regulation (Luo, et al., 2023). It is of great significance for the rational planning and effective management of territorial space (Yi, et al., 2023). Therefore, the quality assurance of urban land space monitoring results is of great significance. However, the traditional data production mode and quality control methods cannot meet the current users' requirements for the quality of data results.

Based on the quality inspection results of urban territorial space monitoring in 198 county-level cities across 20 provinces in

China in 2024, this paper summarizes the typical quality issues identified, deeply analyzes their causes, and proposes targeted improvement strategies from the perspectives of production technology processes, process quality control, and quality inspection methods. The effectiveness of the proposed method is verified through experiments, providing a reference for the overall quality improvement of urban territorial space monitoring results.

2. The current situation of quality inspection of urban territorial space monitoring results

2.1 Inspection Content

Urban territorial space monitoring involves inspection and acceptance work at the county-level administrative unit. The inspection content includes basic inspection items and specialized inspection items. The basic inspection items apply to all inspection and acceptance objects, encompassing the completeness of submitted results, storage effectiveness, and the mathematical foundation of the results (Liu, et al., 2023). The objects of quality inspection include five types of results: orthophoto results, monitoring data results (change dataset (BHDataset), detailed dataset (XHDataset), supplementary dataset (BCDataset), and single layer (CQJCFWA)), production metadata, field photos, and field survey documents. Among them, monitoring data results are the main component of inspection and acceptance. From data collection, data production to quality inspection, they involve significant workload and complex techniques. The inspection content includes format consistency, dataset consistency, scope completeness, attribute structure standardization, and graphic standardization. Therefore, this paper focuses on the quality

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issues of monitoring data results and explores effective methods to improve the quality of the results. (Xi, et al.,2024,Zhao, et al.,2024).

2.2 Inspection procedures and methods

According to the implementation plan for urban territorial space monitoring technology, the monitoring scope, accuracy, and completeness of the results are verified manually using GIS-related software; the attribute content of the results is verified through data comparison; and quality control is conducted through field verification for areas with unclear indoor interpretation or inconsistencies between collected content and reference materials.

A "two-level inspection and one-level acceptance" system is implemented for the monitoring results of urban territorial space(Yao, et al., 2021). The production unit of the monitoring results is responsible for the "two-level inspection" of the quality of the results, while the provincial natural resources authority is responsible for organizing the acceptance of the monitoring results to ensure their authenticity, accuracy, completeness, and standardization. After completing the provincial acceptance, the state will carry out spot-check evaluations of the provincial-level submitted results(Yang, et al., 2023).

Based on the urban territorial space monitoring technology implementation plan, using ArcGIS software, manual verification methods are employed to check the monitoring scope, accuracy, and completeness of the results; the attribute content of the monitoring results is verified by comparing thematic data; and field verification methods are used for quality control in cases where the interpretation is unclear or there are inconsistencies between the collected content and reference materials.

2.3 Summary of Typical Quality Issues

The monitoring results of urban territorial space in 2024, after being inspected at two levels in each province and accepted at the first level, were submitted to the national level. The national authorities then organized a quality spot-check and evaluation. Based on the quality spot-check work completed for 198 county-level survey areas in 20 provinces, the following five types of common quality issues that occurred frequently were identified and analyzed.

(1)The monitoring scope of urban areas is inconsistent with national technical requirements.As shown in Figure 1.

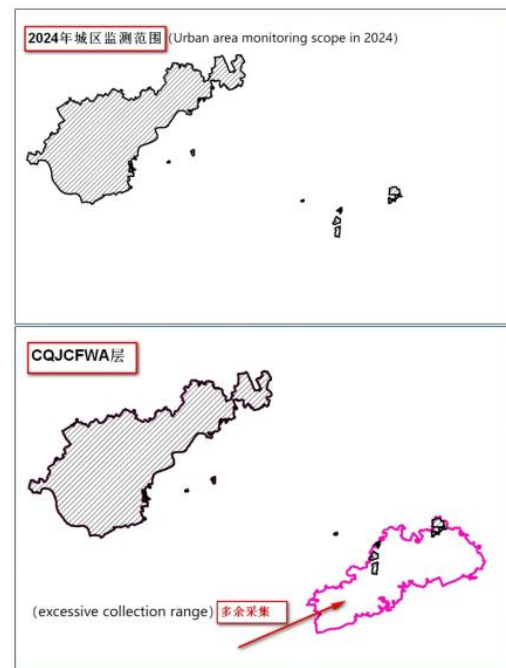


Figure 1. Scope issued by the state(above),
Excessive collection range(below)

(2)Omission or redundant collection of monitoring elements.

For Example:There are changes in the comparison between the two phases of imagery, and the changed patches that were missed should be collected into the change dataset, as shown in Figure 2 (The Children's Palace Has Been Demolished, And The Missed Disappearance Was Not Collected).



Figure 2. Omission of monitoring elements in collection

The image data has missing ground features, as shown in Figure 3, where the school's sports field was not collected.



Figure 3. Omission of collecting data on the school's sports field

(3) The logical expression of monitoring elements is inconsistent.

Some monitoring elements are expressed unreasonably, for example: area elements such as stadiums, fitness centers, and schools are incorrectly represented as point elements; "ramps" are incorrectly labeled as "connectors"; "art galleries" are incorrectly collected as area elements instead of point elements. The ownership classification of Maternal and Child Health Care Hospital does not belong to the hospital category, and it was incorrectly collected into the hospital element layer. As shown in Figure 4 and Figure 5.



Figure 4. Sports activity venue area elements are incorrectly represented as point elements

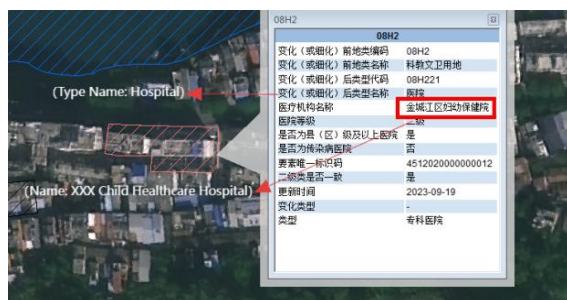


Figure 5. The Maternity and Child Health Care Hospital was incorrectly collected as a hospital element.

(4) Incorrect filling of monitoring element attributes.

Inconsistencies between attribute entries and reference materials: Attribute entries such as "Name" and "River Name" for roads do not match the reference materials; attribute values such as "Type" and "Level" for hospitals, "Name" and "Type" for schools, and "Type" for cultural activity facilities do not

align with the reference materials. As shown in Figure 6 (supplementary dataset HYDL layer, the river names do not match the reference materials).



Figure 6. The river name is inconsistent with the reference material.

(5) The scope of collection for monitoring elements is unreasonable.

The collection scope of some monitoring elements does not match the remote sensing imagery, or does not match the changed survey land-use type map spot boundary. As shown in Figure 7.



Figure 7. Inconsistency between monitoring elements and the land use category boundaries of the changed survey plot

3. Cause analysis and optimization suggestions

3.1 Cause Analysis

Based on quality issues, through communication with technical leads from multiple provinces, the following five causes of the problems have been identified:

3.1.1 Inadequate implementation of technical specifications: During the production of monitoring results, operators lack a unified understanding of attribute definitions in technical documents (such as whether "maternity and child health care hospitals are considered hospitals"), have deviations in their understanding of nationally issued technical standards, or fail to strictly follow unified rules for delineating spatial boundaries, leading to unauthorized adjustments or misjudgments of monitoring boundaries during production. The definitions of feature classification and data layer division are not clear enough, or there is a lack of deep understanding of key concepts such as "area features versus point features" and "data layer attribution," resulting in logical expression errors.

3.1.2 Inadequate multi-source data analysis and collaboration:The urban territorial space monitoring data layers have multiple attributes, and the amount of data from various departments (such as civil affairs, transportation, and education) that needs to be utilized and referenced is very large. Whether the data collection is complete and whether the analysis is reasonable and sufficient will both affect the quality of the results. Different departments adopt inconsistent standards when collecting feature data or filling in attributes. If the data analysis and utilization are unreasonable and insufficient, it will lead to confusion in the reference basis for attribute filling (such as river names, hospital levels, etc.).

3.1.3 Insufficient technical means and methods:The production and quality inspection of current urban land spatial monitoring results still rely on traditional human-computer interaction and simple comparative analysis of reference materials. In the face of the vast amount of monitoring results and reference materials, there is a lack of systematicness and scientific rigor (such as validation of element logical relationships and screening of attribute compliance). When dealing with issues such as topological tolerance and graphical standardization that cannot be discerned visually, not only is the efficiency low, but errors and omissions are also prone to occur.

3.1.4 Lack Of Field Verification:Although the resolution of remote sensing imagery has been improving annually, there are still image elements that are difficult to interpret during indoor production(such as Identification of features for demolished buildings on the site); moreover, the timing of remote sensing imagery collected from different regions (such as the east and west) is not uniform, resulting in inconsistencies between the imagery and reference materials. All of these require field verification to determine the actual content of the elements.

3.1.5 Weak Quality Control Processes:The feedback mechanism for quality issues in some operating units is inadequate, with quality problems in various stages not being promptly summarized, analyzed, and effectively fed back, but rather limited to addressing each issue as it is discovered, leading to repeated occurrences of similar problems. The handling of quality issues lacks unified standards and norms, making it impossible to provide reference for subsequent work. The scope of two-level inspections is not comprehensive, failing to effectively cover different operating units and partitions, and not conducting in-depth verification of logical consistency and attribute completeness for the full range of data.

3.2 Optimization Methods And Suggestions

3.2.1 Strengthen the technical training of production personnel:Enhance the training on interpreting technical documents, unify technical measurements and collection standards; compile high-frequency error cases as operational references for all production and quality inspection personnel to reduce misjudgments by supervisors.

3.2.2 Improve the problem feedback mechanism:Discrepancies or misunderstandings in technical solutions can lead to quality issues and even data rework. Therefore, it is essential for various production units not only to align their understanding but also to promptly report technical issues. These issues should be submitted through a unified and accessible platform, following a prescribed format, and be addressed uniformly by the provincial technical department,

thereby preventing quality problems from arising after large-scale production.

3.2.3 Conduct verification of the first data outcome:The quality verification of the "first data outcome" is of great significance for the comprehensive implementation of urban territorial space monitoring projects and serves as a crucial means of testing the rationality of the technical approach. The first item of output typically selects a county that covers diverse geographical elements as the output unit and arranges for all participating project units to produce it simultaneously. Based on the quality of the first item of output, quality issues are summarized, the feasibility of the technical approach is verified, and revisions and improvements are made to better guide the comprehensive implementation of the project.

3.2.4 Strengthen the analysis and utilization of multi-source data:In response to the characteristics of urban territorial space monitoring projects, which involve a wide range and large volume of reference sources, each province can establish a data analysis team to conduct timeliness and reliability analyses on reference materials from different sources. Priority should be given to selecting authoritative data that is complete, timely, and of high quality. Data cleaning should be carried out to eliminate redundancy and ensure that the mathematical foundation and format of the data remain consistent. The data should be uniformly distributed for use, improving efficiency and accuracy in its application.

3.2.5 Strengthen resource investment and technological innovation:The collection of monitoring elements is based on the principle of "what you see is what you get". Data production units can use high-resolution remote sensing images to reduce deviations in collection scope and minimize erroneous collections due to image resolution. The monitoring elements comprise 36 data layers across 3 datasets, with each layer containing several attribute items and including three data types: point, line, and area. Manual verification not only involves a significant workload but also risks errors and omissions. The quality inspection system (shown in Figure 8, Figure 9), developed based on the inspection content of urban territorial space monitoring results, can effectively reduce human errors in aspects such as format consistency, dataset consistency, and attribute standardization, thereby improving the efficiency and accuracy of production and quality inspection.



Figure 8. Quality inspection assistance system

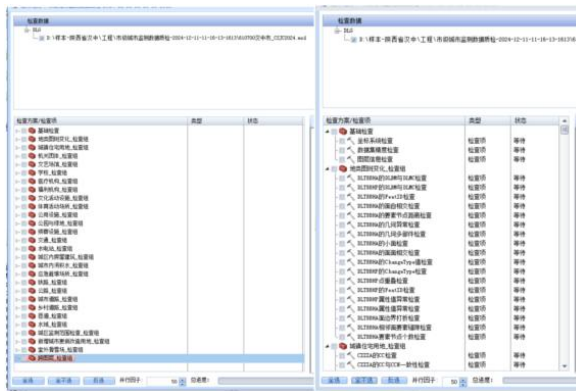


Figure 9. Inspection items for different elements(left), Specific inspection content for different elements(right)

3.2.6 Optimize the quality control process:Develop a detailed quality inspection plan, clarify inspection key points, strengthen quality inspections of intermediate results, promptly identify and resolve issues, and eliminate potential quality hazards.

4. Verification results and conclusions

4.1 Experimental Result

In conjunction with the nationwide quality inspection conducted in 2024,In order to ensure the generality of the experimental results,This study considers three aspects: comprehensive monitoring result elements, widespread and diverse quality issues, and exceeding the error rate limit.Select a representative county-level monitoring result for experimental verification (this county failed the first round of inspection with an error rate of 3.59% ($P \leq 2\%$)). Data production was completed using the method proposed in this paper. This production unit comprised 17,633 elements (points, lines, and polygons). Quality checks were conducted using a quality inspection system for urban land space monitoring achievements developed through secondary development based on ArcGIS (shown in Figure 10). The inspection was carried out by one quality inspector. The quality inspection system automated 10 out of 14 inspection sub-items and semi-automated the remaining 4. The system inspection took only 2 hours, while manual verification took 24 hours. Not only were the inspection results (error rate) significantly improved compared to the first round of checks, but the efficiency and accuracy of the quality inspection were also greatly enhanced. (shown in Table 1)

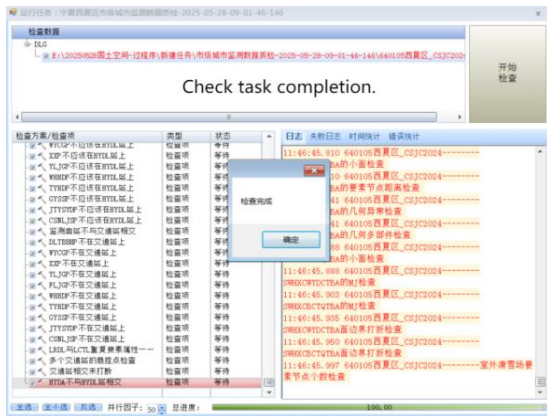


Figure 10. System check completed

Inspection method	Traditional manual inspection	Quality inspection system assistance
Automation rate (%)	0	71
Quality Inspector	2	1
Time spent on quality inspection (h)	60+	26
Improved efficiency (%)	-	57
Error rate ($P \leq 2\%$)	3.59	1.2

Table 1. Comparing the quality inspection efficiency of monitoring results with traditional methods

4.2 Conclusion

The urban territorial space monitoring project is an important practice in the field of natural resource management, aiming to comprehensively grasp the current status and trends of territorial space development and utilization through dynamic monitoring, data analysis, and scientific evaluation. This project is of great significance for promoting sustainable urban development, optimizing the territorial space layout, and enhancing governance capabilities. The quality of its outcomes is directly related to the scientificity and rationality of national strategic decisions.In our work, we proposed methods to optimize data production and improve the efficiency of quality inspection. Through experimental verification, we effectively improved the accuracy of data production and the efficiency of quality control, providing a scientific and feasible reference for the reliability of urban land space monitoring results.

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