The Basic Problems and Countermeasures of Map Inspection

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ABSTRACT:

Map verification plays a crucial role in ensuring the accuracy and reliability of map data, which in turn establishes the foundation for map transparency. In China, the number of approved map inspections has been increasing annually, with a diverse range of map products being applied for inspection. Taking the example of the 'number of maps accepted for inspection' by the Ministry of Natural Resources of the People's Republic of China, there has been a consistent upward trend in the number of accepted inspections. From 2017 to 2021, the average annual growth rate of accepted inspections exceeds 18.85%. Not only are new types, uses, and formats of map products emerging, but there is also an increase in the utilization of electronic global maps. However, challenges such as the inefficient information transfer during the inspection application process and the limited automation of technical inspections persist. Furthermore, issues related to the variability of inspection results based on individual experiences need to be addressed. To tackle these problems, this paper proposes a comprehensive technical framework for map verification based on the principles of "data sharing, business collaboration, and intelligent assistance". The objective is to establish a map verification service mechanism that promotes cross-departmental coordination and intelligent cooperation. Implementing this framework will facilitate the smooth operation of national map verification services and expedite the sharing and openness of geospatial data.

1. INTRODUCTION

The openness of map data plays a vital role in providing fundamental geographic information technology services for the digital industry and facilitating the development and upgrading of the geographic information industry (Wang et al., 2022). However, it is essential to ensure the accuracy and standardization of spatial information and semantic relationships embedded in the map through map inspection. In China, according to Article 15 of the Regulation on Map Management, any map intended for public disclosure must undergo examination by the relevant surveying, mapping, and geoinformation administrative department.

The Chinese government has increasingly emphasized the importance of map inspection. The Law of the Survey and Mapping Law of the People's Republic of China has been promulgated at the national level. At the level of administrative regulations, the Regulation on Map Management has clarified the specific methods of map management. There are also a large number of industry regulatory documents. China has essentially established a legal system for map management and put forward clear requirements for the disclosure of government data. According to Article 15 of the Regulation on Map Management, "A map to be disclosed to the public shall be submitted to the Surveying, Mapping and Geoinformatics Administration Department with the examination authority for examination.". How to improve the efficiency of map inspection, how to speed up the openness of map data, and how to coordinate security and development to promote data sharing are our urgent problems to solve.

2. RELATED WORK

As a carrier of many applications, MAP not only makes life easier for the public, but also greatly promotes the progress of science. (Wang, Z.J. et al., 2023) studied the application of the map visualisation effect during the epidemic situation of COVID-19. (WANG,M.X. et al.,2022) constructed a spatial distribution model of accidents based on map visualisation of urban underground pipelines. (Lu.W.Y. et al., 2022) according to the needs of users, expand the field of map services, and study to provide new map products for the public. It is a proven fact that the sharing of maps has made an important contribution to social progress.

(WANG,X. 2022) studied the materials to be submitted before the map review and proposed solutions to related problems. (BAI,2019) analyses the design of an online examination and approval system for map inspection. (LIU et al, 2022) and (Ren J. X, et al,2021) made an in-depth study of automatic map inspection using hybrid intelligent algorithms and convolutional neural networks, respectively. However, these studies do not thoroughly address the shortcomings of the map inspection process, intelligent map inspection methods, and the complete design of the map inspection business process. Traditional map inspection faces challenges such as low efficiency, high dependence on human involvement, lack of intelligence in the inspection process, difficulty in transferring experience, and limited business synergies. As map inspection services transition from traditional windows and customization to networking and knowledge-based systems, the map inspection mechanism faces more challenges. To address these shortcomings, this paper proposes a comprehensive technical

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framework for map inspection based on "data sharing, business collaboration, and intelligent assistance." By focusing on the study of map inspection, this paper suggests a new strategy to enhance its convenience and intelligence.

3. MAP INSPECTION

Since the establishment of the Publicity Day of the Surveying and Mapping Law in China in 2018, numerous localized publicity and educational activities have been meticulously organized nationwide. These initiatives aim to enhance public awareness of national territory and foster collaboration among the entire population. Consequently, there has been a consistent increase in the number of maps submitted for review.

In China, the process of map inspection involves three stages after the applicant's initial submission: administrative acceptance, map content examination, and approval by the Ministry of Natural Resources of the People's Republic of China, as depicted in Figure 1. The administrative acceptance stage focuses on verifying the accuracy of the applicant's information. Map content examination is conducted to ensure that the displayed map content is correct. Finally, the Ministry of Natural Resources of the People's Republic of China provides official feedback regarding the compliance of the map content. Due to reasons such as incomplete information, many applicants are required to reapply for map inspection. Only applications with complete information are accepted for the map inspection process. It is important to note that there is a distinction between the 'number of applications for map inspection' and the 'number of maps accepted for inspection' in this context.

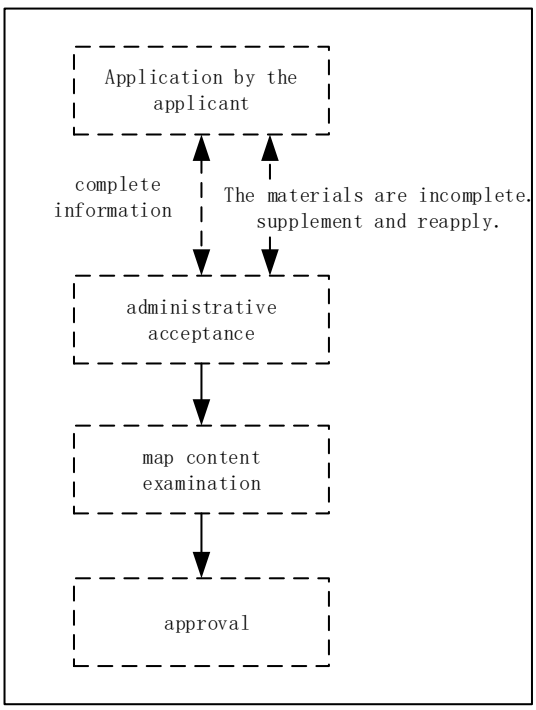

Figure 1. Schematic diagram of map inspection

3.1 The 'Number of Maps Accepted for Inspection'

With the widespread application of maps, the information conveyed through maps has become increasingly diverse. Taking the 'number of maps accepted for inspection' by the Ministry of Natural Resources of the People's Republic of China as an example, from 2017 and 2021, there is an average annual growth rate of over 18.85%. In 2021, the number reaches 15,256, as indicated in Figure 2. Despite the global economic impact of the COVID-19 pandemic in 2020, the map market was not immune to its effects. The number of acceptances also experienced a decline. However, when considering the overall development trend, the number of accepted map inspections continues to show an upward trajectory.

The growth in the map inspection business illustrates the increasingly extensive use of maps, which consequently leads to a significant increase in the workload of map inspections.

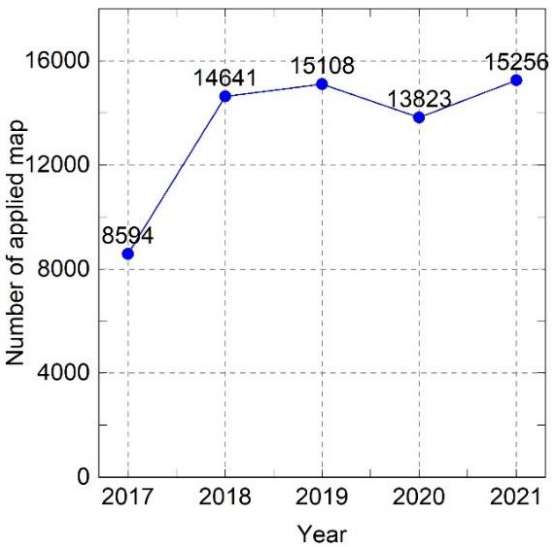

Figure 2. Number of map verification applied every year from 2017 to 2021.

3.2 Types of Application for Map Inspection

Based on the online examination and approval system of the Ministry of Natural Resources of the People's Republic of China, as well as actual usage, map products have been categorized into six functional categories. These categories include: digital maps (e.g., real scene, 3D, vector, image and Internet maps, navigation electronic maps), maps with commodity attributes (e.g., single maps, atlas), maps with educational attributes: (e.g., teaching auxiliary maps, textbook maps), globe. maps for international circulation (e.g., the printing illustrations of external processing; imported maps from abroad), maps with media attributes (e.g., public display maps, electronic maps, books, newspapers, magazines, and other products with maps).

Additionally, new types, uses, and forms of map products are constantly emerging. From traditional wall charts and illustrations to innovative products like real-world 3D maps, internet map services, and navigation electronic maps, and so on.

From 2017 to 2021, the total number of online applications for map inspection and approval was 67,422. Among these applications, maps with media attributes accounted for 47.18% of the total, maps with educational attributes accounted for 29.26%, maps for international circulation accounted for

16.62%, maps with commodity attributes accounted for 3.27%, digital maps accounted for 2.36%, and globes accounted for 1.30% (as depicted in Figure 3). During this period, the share of traditional map inspection in the overall business volume decreases from 7.33% in 2017 to 3.68% in 2021 (as shown in Figure 4).

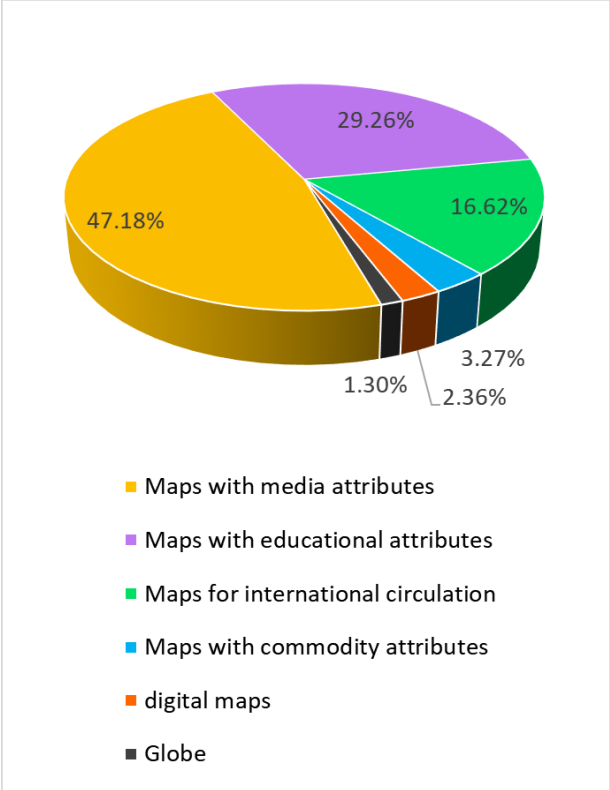

Figure 3. Proportion of various types of map verification applications from 2017 to 2021.

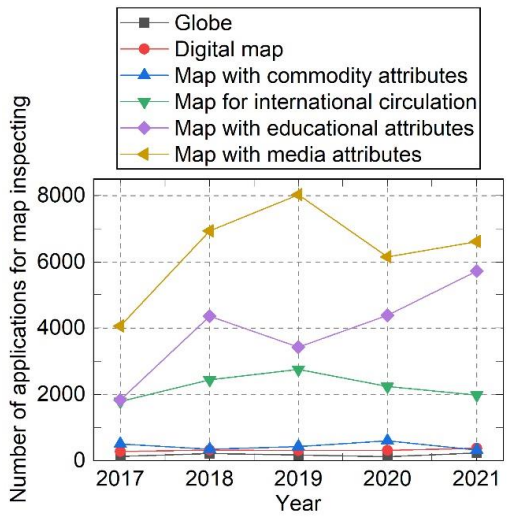

Figure 4. Number of applications for Map verification of all kinds of Public Map products from 2017 to 2021.

3.3 The Scope of Map Application Inspection

With the growing demand from map inspection applicants to expand shared map coverage, there has been an increasing number of applications for global map inspection. From 2017 to 2021, the number has witnessed a year-on-year rise, starting from 319,198 in 2017 and reaching 380,653 in 2021, reflecting a growth rate of 19.3% (as depicted in Figure 5).

Starting in 2018, applicants began applying for the inspection of electronic global maps, and the number of these applications has been steadily increasing each year. In 2021, a total of 31 batches of electronic global maps were submitted for inspection (as shown in Figure. 5).

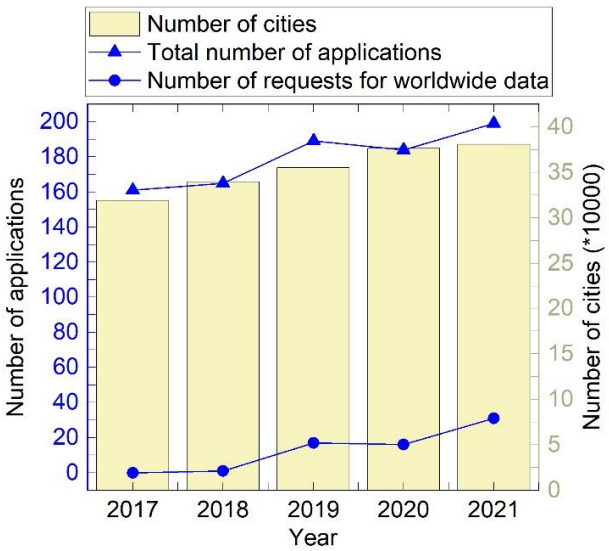

Figure 5. Total number of applications for navigation electronic maps, number of cities worldwide and global map statistics for 2017-2021

4. THE BASIC PROBLEMS AND COUNTERMEASURES OF MAP INSPECTION

4.1 The Basic Problems of Map Inspection

With the rise of digital industrialization and industrial digitalization, a wide range of map products has brought convenience to people's lives. However, there are several fundamental issues, including the low efficiency of information transfer during the map inspection application process, the limited degree of automation in the technical inspection, and the lack of an established knowledge base for expert review experiences. To address these challenges, there is an urgent need to integrate intelligent solutions and respond to the growing demand for advancements in the technical methods of map inspection, the working modes of map inspectors, and the overall working mechanism of map inspection.

4.1.1 Low Efficiency of Information Transfer in the Process of Map Inspection Application: Currently, Map Inspection has implemented online inspection and approval functionality. However, there is an information disparity between the approval department and the applicants during the map inspection application process. For instance, if the applicant's credentials have expired or if the information provided in the map inspection request is incomplete, the applicant will be notified to re-upload valid information after manual verification. This increases processing time for map inspection. To improve the efficiency of the map inspection application process and minimize delays resulting from human factors, it would be beneficial for the system to promptly detect and notify applicants of any issues encountered during application submission, as well as provide appropriate solutions. Furthermore, there is a need to enhance information sharing between the approval department and the applicants

4.1.2 The Low Degree of Automation of the Technical Examination: As the number of map inspection applications continues to rise annually, the workload of these map content inspectors is also increasing. Currently, a two-step inspection system is implemented for the technical inspection of maps. This involves a manual inspection during the initial examination and a final trial. Map content review experts identify and annotate the issues present on the sample map, providing authentication for the map content review. These annotated samples are photographed for documentation purposes. Each step in the process requires manual operation, indicating the inability to fully automate the map review process.

4.1.3 The Lack of a Knowledge Base of Expert Experience in Reviewing Drawings:
The technical review of maps necessitates expert knowledge, and the experience of each reviewer varies. Map content review experts annotate the issues present on the sample map, but the annotations are limited to the sample map itself. Although these annotated samples are photographed for documentation purposes, there is a lack of comprehensive analysis of the annotations. Consequently, the expert knowledge system remains fragmented, residing solely in the minds of experts. It is crucial to address this pressing issue in map inspection by summarizing expert experiences and converting the heuristic knowledge gained from their expertise into a real-time updated expert knowledge base on map Inspection.

4.2 Countermeasures and Suggestions

The challenges mentioned above have resulted in low work efficiency and increased work intensity in map inspection, making it more labor-intensive rather than technology-intensive.

This paper proposes a comprehensive technical framework for map verification, centered around the main themes of "data sharing, business collaboration, and intelligent assistance." This framework aims to meet the actual requirements of map inspection and leverage various fields of expert knowledge. The goal is to establish a networked, intelligent, and collaborative map verification service mechanism that enhances the efficiency and effectiveness of national map verification business. The following section outlines each procedure within this framework (as shown in Figure 6):

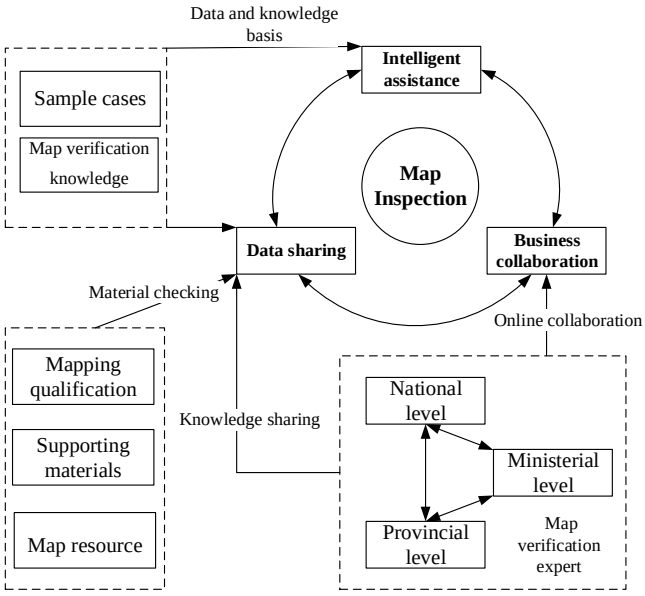

Figure 6. A comprehensive technical framework of map verification.

4.2.1 Data Sharing: Data Sharing consists of two aspects. When the material furnished is received, staffs use cross-departmental and cross-level data to real-time online examine and verify the qualification of company, the validity of material, and data resource. It not only ensures the reliability of the verification, but also reduces the time cost of it. Moreover, standard map and typical case knowledge have been publicly available. For one thing, the multi-scale, multi-type, and multi-regional standard map database provides reference for various users. For another, map verification sample database and expert knowledge database provide the data base for training intelligent models and related staffs in the manner of knowledge sharing. In particular, the map verification sample database is built by collating errors from incorrect maps and the expert knowledge database is built by summarizing the professional experience and rule knowledge of map verification experts.

4.2.2 Intelligent Assistance: Intelligent Assistance makes full use of the advancements in deep learning technology, specifically in image recognition, to enable multi-scale and object-oriented recognition of maps. In practical business scenarios, a substantial number of map inspection samples have been accumulated. By utilizing the normalized learning capability of deep learning, a machine learning model for map verification is constructed based on massive multi-scale and multi-expression map samples. Utilizing the data sharing mechanism, we have developed a comprehensive sample database by aggregating maps sourced from diverse regions, varying scales, resolutions, and different forms of expression. This database trains the machine learning model. Convolutional neural networks and hybrid intelligent algorithms are employed to analyze and learn various map features such as scale, color, and texture. As a result, intelligent discriminations of maps can be achieved. We employ convolutional neural networks and hybrid intelligent algorithms to analyze and learn various map features, such as scale, color, and texture, and achieve intelligent discrimination among maps.

4.2.3 Business Collaboration: Business Collaboration refers to three levels: man-machine collaboration, expert collaboration, and cross-departmental collaboration. In recent years, artificial intelligence has made significant breakthroughs in various fields, particularly in image recognition and expert systems, providing the technical foundation for intelligent inspection. However, the artificial intelligence technology represented by deep learning has certain limitations, such as a lack of explanation and reliability. Therefore, it is necessary to incorporate human knowledge into intelligent systems. To achieve this, we propose using computers to create a detailed map verification sample database for deep learning. Initially, the computer verifies the map, and then experts verify the preliminary examination results and update the final inspection results into the map inspection sample database. The opinions and cases reviewed by experts should be structurally stored and managed to form an expert knowledge base. It is essential to organize expert opinions in a structured manner so that the machine can understand them. For example, when inspecting an area on a map, the machine should first identify the correctness of the actual coordinate location and range are correct, the area's name aligns with national documents, the accuracy of adjacent place names, and so on. Building upon the knowledge framework of expert collaboration, networked collaborative inspections can be conducted at the departmental level. For instance, if the map includes national boundaries and coastlines, it requires across-department map inspections involving the Ministry of Foreign Affairs of Peoples's Republic of China, People's Liberation Army Navy, and other departments. We have established a review mechanism and multi-task process to collect opinions from various departments, enabling us to gather comprehensive feedback and reach an authoritative consensus. Ultimately, Networked collaboration enhances the flexibility, maneuverability, and multi-faceted coordination of map inspection

5. CONCLUSIONS

Map-related products, serving as carriers of geographic information, are widely employed and continuously updated on a global scale. These diverse map products possess value not only in the market but also across multiple sectors including scientific research, social applications, legal frameworks, cultural preservation, and military operations (WANG,J.Y., 2022). Map inspection holds great significance in China. This paper proposes a comprehensive framework to address the overall mechanism of "map inspection". The framework is based on three aspects: "data sharing, business collaboration, and intelligent assistance". Through the sharing of map inspection knowledge, interlinking departments at various levels, and the implementation of automated map inspection, we can establish a service mechanism for map inspection that facilitates cross-departmental coordination and intelligent collaboration. This framework develops the national map inspection business, ensuring the accuracy and authority of map data, providing a basis and guarantee for data openness, and promoting the diversification and globalization of map application products.

With continuous optimization of map inspection management and processes, there is still room for enhancing the proposed map inspection framework. We should selectively build various security coordination mechanisms and effectively integrate different intelligent technologies. By doing so, we can better improve the map inspection business and maximize its contribution to promoting data openness and sharing.

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