Discussion on Quality Model and Evaluation Methodology for WMS

Wenli Han [1,2], Juan Ge [1,2], Libo Zhang [1,2], Jing Shen [1,2], Yang Tan [1,2]

1. National Quality Inspection and Testing Center for Surveying and Mapping Products, Beijing 100083, China
2. Technology Innovation Center for Remote Sensing Intelligent Verification，MNR，Beijing 100083, China

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Abstract

The integration of internet technologies and geographic information systems (GIS) has positioned Web Map Services(WMS) as indispensable tools for daily life, with their service quality attracting significant attention. This study proposes a quality evaluation model and method tailored for WMS, encompassing four critical dimensions: query and retrieval, map display, thematic services, and productization services. Empirical validation was conducted through functional, performance, and productization evaluations of three leading domestic platforms, utilizing technical benchmarks and user-centric metrics. Results demonstrate the model’s efficacy in quantifying service quality, aligning closely with real-world user experiences. The framework provides actionable guidelines for regulatory bodies to monitor service compliance and for providers to optimize architectural designs, thereby addressing gaps in personalization and cross-border functionalities observed in current systems. Furthermore, this work highlights the necessity of integrating emerging technologies—such as real-time traffic data and AI-driven personalization—to meet evolving demands for energy efficiency, global connectivity, and hyper-localized services. By bridging technical assessments with practical governance needs, the study offers a strategic roadmap for advancing service quality, supporting the development of China’s digital economy, and enhancing societal well-being through reliable geospatial solutions.

1. Introduction

According to the "Measures for the Administration of Surveying and Mapping Qualifications" (MNR,2021), Web Map Services(WMS) refer to software systems that provide services such as geolocation positioning, spatial search, map display, uploading and annotation, and API calls. WMS have evolved from traditional geographic information systems (GIS) to web-based geospatial service platforms (Chen,2023; Wu et al., 2022). WMS facilitate citizen’ lives, formally define these services as critical infrastructure. Nowadays, a growing number of government departments are progressively rolling out WMS, such as China's National Geospatial Public Service Platform (Tianditu) (Jiang et al.,2017； Huang et al.,2024), the U.S. Federal GeoPlatform (GeoPlatform.gov) (Liang et al., 2016; Xue et al.,2022), the UK’s data.gov.uk(Jiang et al.,2017). And large internet enterprises also provide WMS, including Baidu Maps (Baidu), Amap (Alibaba), Tencent Maps (Tencent), Google Maps (Google), Bing Maps(Microsoft), and Apple Maps, many of which offer free public access alongside premium APIs.In 2022, China's internet maps handled up to 130 billion daily average location service requests at peak, covering over 1 billion daily active users (DAU). The global Points of Interest (POI) database reached a maximum of 260 million entries, spanning more than 200 countries and regions. The global road network coverage extended beyond 70 million kilometers, enabling navigation services worldwide.These services supported over 2.3 million developers and served 600,000+ mobile applications, with map display and search functionalities available in 70+ languages (CAGIS,2022) . Gong et al.’s (2012) propose the Geospatial Service Web (GSW) to underpinthe development of a future geospatial cyberinfrastructure. The GSW excels over the traditional spatial data infrastructure by providing a highly intelligent geospatial middle ware to integrate various geospatial resources through the Internet based on interoperable Web service technologies. The development of the GSW focuses on the establishment of a platform where data, information, and knowledge can be shared and exchanged in an interoperable manner. R M Awangga(2018) proposed solution by comparing WMS and WMTS computation cost and created a product called Sampeu. Sampeu has proposed a solution by creating WMTS protocol over WMS. WMTS work on the tile-ing system where the data transform from big picture to part of the Tile is. A lot of Tile making a pyramid of cartography and serving to client one by one, so the computation cost can be decreasing.

Despite progress, WMS become more popular and important nowadays, data quality and system reliability assurance for such services is a significant challenge (Alexey Noskov & Alexander Zipf ,2018) . AP Staff (2023) reported that the family of a man who died after his car plunged off a collapsed bridge while following Google Maps directions directions , Google was notified of the bridge’s collapse but failed to update its navigation system. Cai et al.’s (2019) proposed a modified quality evaluation model of navigation digital maps suitable for internet tile map data format. Wang et al.’s (2023) discussed the detection contents and methods of Internet image map data and real scene map data. Song et al. (2012) proposed that WMS encompass geographic information data services and geographic information processing services. The quality evaluation system for WMS includes 11 quality elements, which can be represented as an 11-tuple. The primary components are: Time, Cost, Peak, Stability, Satisfaction, Reliability, Bandwidth, Server Capability, Reputation, Integrality, Accuracy. Ji et al.’s (2016) dual focus on data quality (consistency, positional accuracy) and functional performance (route planning, real-time updates). Meanwhile, for the purpose of safeguarding national sovereignty, security, and interests, as well as protecting personal privacy, Liang & Zuo (2023) summarizes the development status of problem mapcheck and analyzes the pain points of problem map intelligent check. However, these articles mostly focus on the quality issues of web map data, and do not comprehensively address the overall WMP quality, particularly the quality of the service software.

From the perspective of ordinary users, this paper proposes a model and evaluation method for the content and quality of WMS. It also conducts test validations on the service quality of three commonly used internet maps from the perspectives of function, performance, and productization of the service

Correspoding Author: Zhang Libo, Email:37856062@qq.com, tel: (+86)01063881929

software. This paper serves as an important reference for the regulation and provision of WMS quality.

2. Quality Model and Evaluation methodology

2.1 Quality Model

Based on the definition of WMS, the content of such WMS primarily includes search services, map display services, and thematic services. Therefore, the quality model of WMS is composed of the service quality of four core modules: search services, map display services, thematic services, and productized services, as shown in Figure 1.

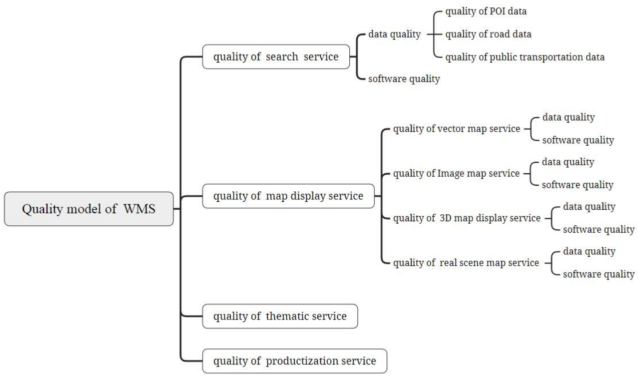


Figure 1. Quality model of WMS

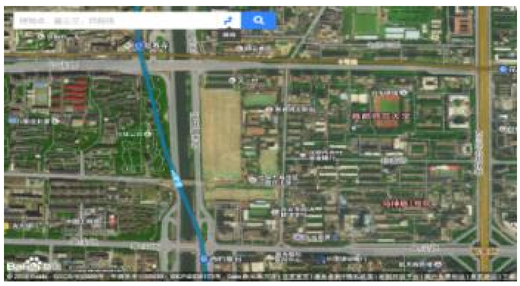
Search Services refer to the functionality enabling users to search for points of interest (POIs) such as restaurants, tourist attractions, bus stops, administrative regions, and routes via web maps. The associated data encompasses POI and geolocation datasets, road network data, and public transportation data. Core functions of these services include POI searching , route planning, and so on. Individuals can plan their travel routes based on real-time traffic conditions to avoid congestion and select the optimal transportation mode. Therefore, the quality of search services encompasses both data metrics—such as positional accuracy, completeness, and timeliness—and functional metrics, including comprehensiveness, efficiency, and usability.

Map display service involves using maps to present the features, real-world scenes, and other details of a particular location or area. At present, the primary map types displayed by WMS include vector maps, satellite imagery maps, 3D maps, and street view maps, as illustrated in Figure 2. The functionalities of map display services primarily encompass panning, zooming, and displaying information such as scale and data sources. These services enable users to view the surroundings of POIs, famous landmarks, and scenic spots from around the globe. Map display services can offer one or a combination of multiple display options. The quality of these services comprises both the quality of the map data and the quality of the display service functionalities. Data quality encompasses aspects such as positional accuracy, completeness, representational fidelity, and timeliness, while service quality encompasses the comprehensiveness, efficiency, and usability of the display functionalities.

Specialized service quality refers to the comprehensiveness and usability of various thematic functions provided by WMS for the daily production and life of the general public. Specialized service functions include positioning services, traffic condition services, map download services, map annotation services, sharing and citation services, etc. The quality of specialized services encompasses the comprehensiveness, real-time performance, and ease of use of these functions.

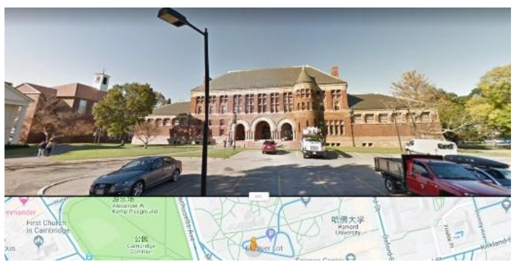
The quality of productized services refers to the degree to which WMS, as widely used products, must possess a certain level of productization. This quality encompasses aspects such as reliability, ease of use, compatibility, and customer service.

(a) Vector map



(b) Image map

(c) 3D map



(d) Real scene map

Figure 2. Map display service

This article mainly discusses the software service quality of query and retrieval services, map feature dis play services, specialized services, and productized ser vices. The functional modules that each service softwa re should include are shown in Figure 3.

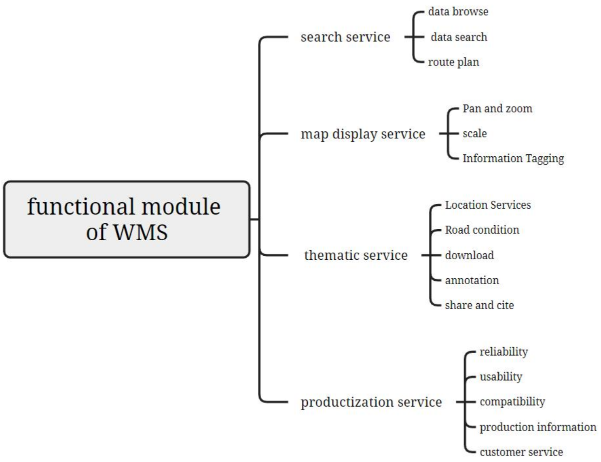


Figure 3. Functional module of WMS

2.2 Quality evaluation workflow

The quality evaluation process for WMW is as illustrated in Figure 4.

(1) Construct test sample data.

(2) Conduct testing and evaluation on the following service quality dimensions:

a. Test functional availability and result correctness using predefined test cases.

b. Evaluate the quality of each functional component (e.g., query accuracy, rendering performance).

c. Perform a comprehensive assessment of service content quality (e.g., data coverage, thematic relevance).

(3) Synthesize the evaluations from the four dimensions (Search services, map display, thematic services and productization) to derive an integrated quality evaluation of the WMS.

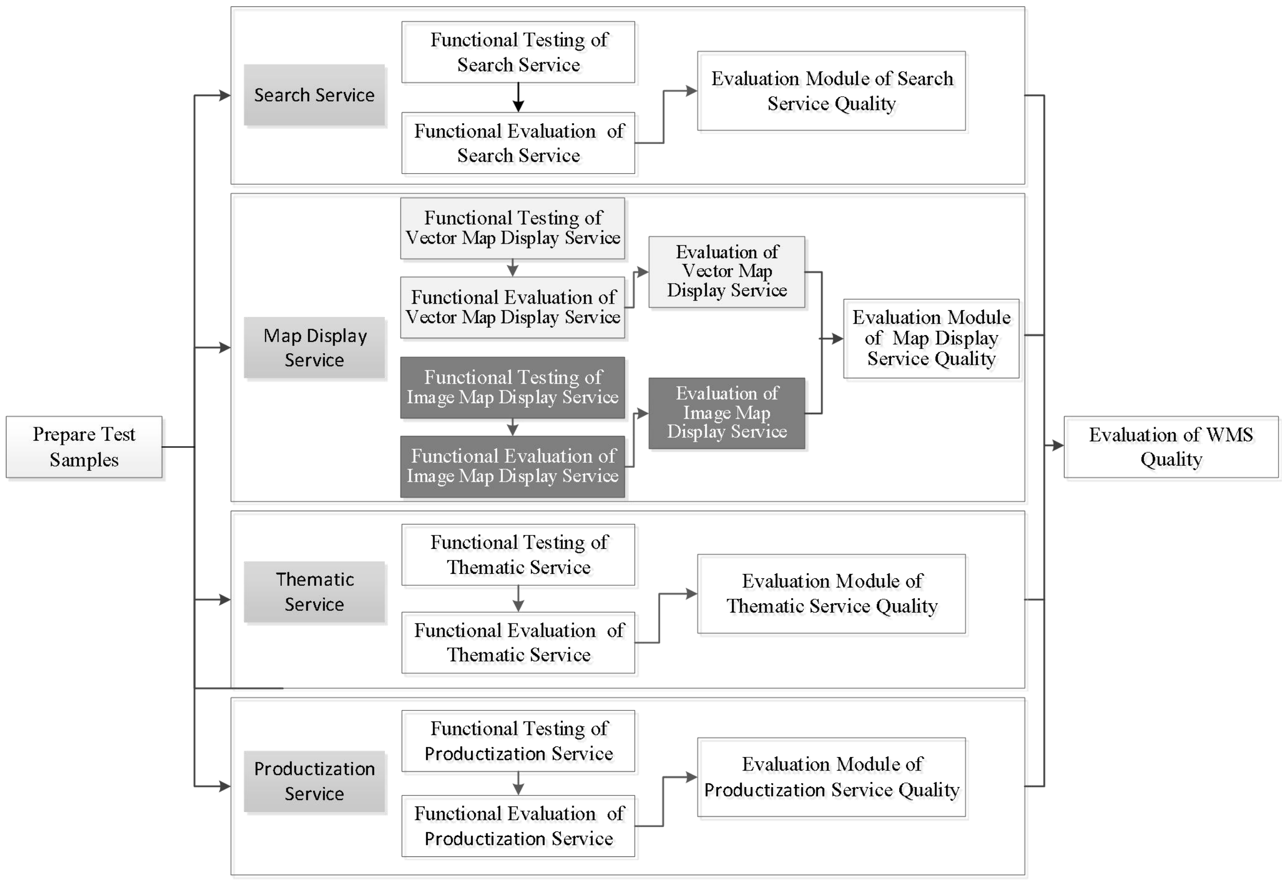


Figure 4. Quality evaluation workflow

2.3 Quality evaluation methodology

2.3.1 Service functional testing and evaluation method

Test all functional components of WMS (see Tables 2, 3, and 4). At least three test cases should be designed for each functional test, and the quality of each functional component shall be assessed based on the test results.

Score individual functionalities by aggregating results from multiple test cases. Each functionality is graded on a 100-point scale:

（1） Points are deducted proportionally if a test case fails to execute or produces errors.
（2） The minimum score for any functionality is 0 points.

2.3.2 Conformance quality level

The quality evaluation of WMS adopts the Analytic Hierarchy Process (AHP).

（1） The calculation of modules quality

For the service quality modules—search services, map display, thematic services, and productization services—calculate the quality score for each module individually. The module quality evaluation employs a weighted average method, where each functional metric is assigned a maximum score of 100 points. Weighting factors are allocated based on the relative importance of each functional metric, with the sum of weights equal to 1. The calculation follows Equation (1).

$$S_j = \sum_{i=1}^{n} p_i f_i \,(\mathrm{i}=1,2,\ldots\ldots,\mathrm{n})(\mathrm{j}=1,2,3) \,, \qquad (1)$$

Where p_i ,f_i is weight and score of the i-th function
S_1,S_2,S_3 is the service quality score of search service, thematic services and productization services .

For map display services, at least two types of map displays must be tested, with weights evenly distributed among the map display types (summing to 1). The quality score for each map display service type is calculated using Equation (1), while the quality score for map feature display services is computed with Equation (2).

$$S_4 = \frac{\sum S_{4i}}{\mathrm{n}} (i=1,\, 2,\ldots\ldots,\mathrm{n}), \qquad (2)$$

Where n is number of map display services,
S_{4i} is the service quality score of the i-th map display
S_4 is the total quality score of the map display services

(2) The calculation of WMS quality

The total score for the quality of WMS is 100 , with the weights for each service module as shown in Table 1.

Service module	weight
Search services	0.35
Map display services	0.45
thematic services	0.15
Productization services	0.05
Total	1

Table 1 Service modules and weights

The calculation of WMS quality follows Equation (3).

$$S = \sum_{j=1}^{4} P_j S_j \,(j=1,2,3,4) \,, \qquad (3)$$

P_1S_1, P_2S_2, P_3S_3 , P_4S_4 is weight and score of search service, thematic services , productization services and map display service.

3. Experiment

For this internet map service quality testing experiment, three widely used public map products in China were selected for testing, named as Product1, Product2, and Product3.

3.1 Test functions and results

For the essential functionalities of WMS, at least three test cases should be designed for each functionality. These functionalities are tested and evaluated across three products: Product 1, Product 2, and Product 3. The tested functionalities, weighting factors, and scores for their query and retrieval services, map display services, thematic services, and productization services are detailed in Table 2 , Table 3, Table 4 and Table 5.

Service Component	Tested Functionality	Tested Item	weight	Product1	Product2	Product3
Data browsing	Data Display	Graphical Rationality	0.03	3	3	3
		Relationship Coordination	0.03	3	3	3
		Map Load capacity	0.03	3	3	3
		Panning	0.03	3	3	3
		Zooming	0.03	3	3	3
		Scale Range	0.03	3	3	3
		Full-Screen Display	0.02	2	2	2
		Scale Gradation	0.01	1	1	1
		Scale Bar Display	0.01	1	1	1
		Map Approval Number and Data Source Identification	0.03	3	1.5	3
	Measurement	Distance Measurement	0.01	1	1	1
		Area Measurement	0.01	0	0	0
Searching	Input Methods	Keyboard Input	0.03	3	3	3
		Voice Input	0.015	1.5	1.5	1.5
		Handwriting Input	0.015	1.5	1.5	1.5
		Input Response Time	0.02	2	2	2
	Target Searching	Name Search	0.03	3	3	3
		Category Search	0.02	2	2	2
		Address Search	0.01	1	1	1

Service Component	Tested Functionality	Tested Item	weight	Product1	Product2	Product3
		Regional Search	0.03	0	0	0
		Nearby Search	0.02	2	2	2
		Along-Road Search	0.01	0	0	0
		Bus Stop Query	0.03	3	3	3
		Bus Route Query	0.03	3	1.5	1.5
Route planning	Planning Configuration	tart/End Point Configuration	0.03	3	3	3
	Driving Route Planning	Comprehensive Strategy	0.03	3	3	3
		Shortest Path	0.02	2	0	0
		Minimum Cost	0.02	2	2	2
		Minimum Time	0.01	0	1	1
		Replanning	0.02	2	2	2
		Route Information	0.01	1	1	1
		Via Point Configuration	0.02	2	0	0
	Public Transit Planning	Transfer Route Planning	0.02	2	2	2
		Transfer Strategy: Transfer Recommendation	0.03	3	3	3
		Transfer Strategy: Minimum Time	0.03	3	3	3
		Transfer Strategy: Fewest Transfers	0.02	2	2	2
		Transfer Strategy: Minimal Walking	0.02	2	2	2
		Transfer Strategy: Lowest Fare	0.01	0	1	1
		Transportation Mode: All Modes	0.02	2	2	2
		Transportation Mode: Rail Priority	0.01	1	1	1
		Transportation Mode: Non-Rail	0.01	1	1	1
		Route/Stop Guidance	0.02	2	2	2
		Route Travel Information	0.01	1	1	1
		Stop Vicinity Query	0.01	0	0	0
	Walking Planning	Planning and Query	0.02	2	2	0
	Cycling Planning	Planning and Query	0.02	2	2	2
	Planning Performance	Intra-City Route Efficiency	0.02	2	2	1.8
		Inter-City Route Efficiency	0.02	2	1.8	1.8
Total			1	90	84.8	84.1

Table 2.Search services tested

Map Display Type	Tested Functionality	Tested Item	weight	Product1	Product2	Product3
2D Vector Map Display	Panning and Zooming	Panning	0.20	20	20	20
		Zooming	0.20	20	20	20
	Scale	Scale Range	0.15	15	15	15
		Full-Screen Display	0.10	10	5	5
		Scale Gradation	0.10	10	10	10
		Scale Bar Display	0.05	5	5	5
	Information Identification	Map Audit Number	0.20	20	20	20
	Total		**1**	**1**	**100**	**95**
Image Map Display	Panning and Zooming	Panning	0.20	20	20	20
		Zooming	0.20	20	20	20
	Scale	Scale Range	0.15	15	15	15
		Full-Screen Display	0.10	10	5	5
		Scale Gradation	0.10	10	10	10
		Scale Bar Display	0.05	5	5	5
	Information Identification	Map Audit Number	0.20	20	20	20
	Total		**1**	**100**	**95**	**95**

Table 3. Map display services tested

Service Component	Tested Functionality	Tested Item	weight	Product 1	Product 2	Product 3

Service Component	Tested Functionality	Tested Item	weight	Product 1	Product 2	Product 3
Positioning Services	Static Positioning	Position Display	0.06	6	6	6
	Dynamic Positioning	Vehicle Positioning	0.05	5	5	5
		Pedestrian Positioning	0.05	5	5	5
Traffic Services	Real-Time Traffic	Traffic Status	0.06	6	6	6
		Traffic Restrictions	0.04	4	4	4
		Traffic Incidents	0.05	5	5	5
	Real-Time Transit	Transit Vehicle Tracking	0.04	4	4	4
		Arrival Time Prediction	0.03	3	3	3
		Transit Operational Data	0.03	3	3	3
		Transit Incident Alerts	0.03	0	0	0
Map Download	Download Services	Download by Specified Area	0.03	3	3	3
		Download by Specified Time	0.03	3	3	3
Map Annotation	Map Annotation	Location Annotation	0.04	4	4	0
		Note Annotation	0.03	3	3	0
		Route Annotation	0.03	0	0	0
		Error Correction	0.03	3	3	3
		Annotation Editing	0.03	3	3	3
		Annotation Security Review	0.06	6	6	6
		Annotation Process Guidelines	0.04	4	4	4
		Annotation Adoption Commitment	0.03	3	3	3
Sharing and Citing	Citing Configure	Point Citing and Annotation	0.04	4	4	4
		Route Citing and Annotation	0.04	4	4	4
	Map Citing	Display and Interaction	0.04	4	4	4
	Bookmarking	Bookmark	0.05	5	5	3
	Location Sharing	Location Sharing	0.04	4	4	4
Total			**1**	**94**	**94**	**85**

Table 4. Thematic services tested

Quality Element	Quality Subelement	Tested Item	Weight	Product1	Product2	Product3
Reliability	Fault Tolerance	Error Handling Capability	0.12	0.12	10	12
	Recoverability	Recovery from Environmental Exceptions	0.12	0.12	12	12
Usability	Understandability	Interface Design	0.10	0.10	10	10
		Information Prompts	0.10	0.10	10	9
	Operability	Common Functions	0.10	0.10	10	10
		Input/Output	0.10	0.10	10	10
Compatibility	Environmental Compatibility	Platform Compatibility	0.10	0.10	10	10
		Browser Compatibility	0.10	0.10	10	10
Customer Support	User Assistance	Help Documentation	0.08	0.08	8	8
		Technical Support	0.08	0.08	8	8
Total			**1**	**98**	**99**	**100**

Table 5. Productization services tested

Through testing, our three commonly used service products have performed very well. However, individual issues were also identified during the testing, as shown in Figure 5.

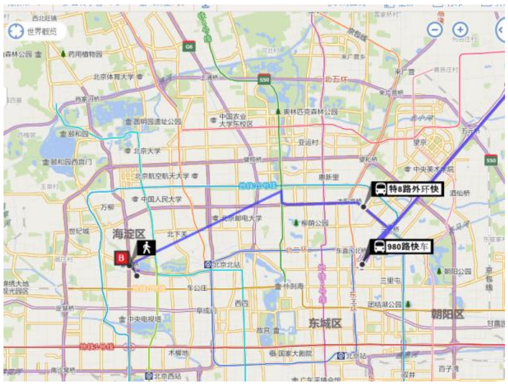
3.2 Comprehensive evaluation

Based on the test results from Tables 2 to 5, a comprehensive evaluation method was used to calculate the quality scores of the three map services. The results are shown in Table 6.

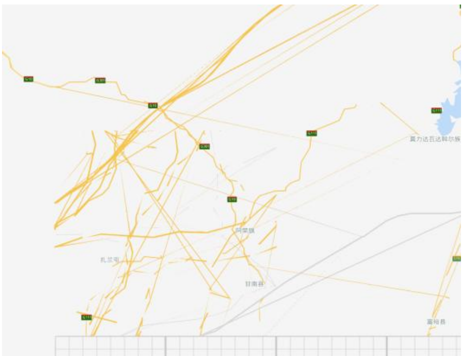
Service module	Weight	Product1	Product2	Product3
Search services	0.35	90	84.8	84.1
Map display services	0.45	100	95.0	95.0
thematic services	0.15	94.0	94.0	85.0
Productization services	0.05	98	99	100
Total	1	**95.5**	**91.5**	**89.9**

Table 6. Comprehensive evaluation of WMS

（a）Fault of location



(b) Fault of route planing



(c) Fault of vecte map display

(d) Fault of 3D map

Figure 5. Faults

4. Conclusions

Driven by technological evolution and user demand diversification, WMS have transitioned from basic spatial data provision to real-time, scenario-driven solutions. In this paper, we propose a quality model for WMS, structured around four core components: query and retrieval services, map display services, thematic services, and productization service quality. The Analytic Hierarchy Process (AHP) is introduced as the methodological framework for quality assessment. Experimental validation was conducted using three widely-used WMS products to test the proposed model and methodology.

However, this research has methodological limitations. Firstly, the evaluation scope was confined to domestically prevalent mapping platforms, excluding international counterparts such as Google Maps. Secondly, the assessment focused exclusively on domestic service provisions without examining cross-border or multinational service performance. Thirdly, the testing parameters prioritized generic functionalities rather than evaluating the sophistication and quality of personalized service offerings. Fourthly, temporal constraints precluded comprehensive comparative analyses of feature effectiveness, particularly regarding the congruence between algorithmic predictions (e.g., route planning and estimated travel times) and real-world operational data.

With the development of technologies such as the internet, big data, satellite remote sensing, and geographic information systems, WMS have seen continuous enrichment of their content. During the timeframe of this study, many WMS had not yet incorporated real-time public transportation and traffic signal data; however, most platforms have now implemented these features. To address global economic expansion, the flourishing international tourism industry, energy efficiency requirements, and the growing diversity of user demands—including personalized needs—it is imperative to persistently enhance internet mapping service capabilities. This advancement will underpin the development of a Digital China, drive the growth of the digital economy, and ultimately improve societal well-being and quality of life.

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