

System Effectiveness Evaluation of China's Aviation Emergency Communication System

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Abstract

To address the challenges posed by heterogeneous equipment, geographically dispersed deployment, and complex operational patterns in China's aviation emergency communication missions, this paper proposes a system-oriented effectiveness evaluation method for aviation emergency communication systems. Two operational modes, namely immediate-response coverage and cross-regional redeployment coverage, are considered, and a multidimensional evaluation framework is developed, incorporating spatial coverage, population coverage, response timeliness, redundancy support, and node connectivity. Population density, spatial distribution, and disaster risk levels are integrated as demand-oriented weighting factors, while a nonlinear redundancy model is introduced to capture diminishing marginal returns. Based on the actual deployment of China's aviation emergency communication platforms, together with nationwide airport network and population distribution data, simulation experiments are conducted to evaluate system effectiveness. The results indicate that the current system has established a preliminary nationwide cross-regional support capability, with redeployment coverage reaching 92.23%. However, limitations remain in immediate-response coverage, response timeliness, and redundancy support during the initial phase of disaster relief operations, revealing a structural characteristic of broad regional accessibility but insufficient local support. The proposed method provides a quantitative basis for aviation emergency communication system planning, deployment optimization, and future capability development.

Keywords: aviation emergency communication; aviation equipment; system effectiveness evaluation; system-of-systems

1. General Introduction

With the increasing frequency of extreme climate events and the rising risk of major natural disasters, emergency communication capability has become a critical component of modern national emergency management systems. Following disasters such as earthquakes, floods, typhoons, and wildfires, terrestrial communication infrastructures are highly vulnerable to power outages, base station failures, and transmission link disruptions, often resulting in large-scale communication blackouts that severely hinder situational awareness, command and control, and rescue coordination. Compared with conventional ground-based communication systems, aviation emergency communication platforms offer significant advantages, including rapid deployment, wide-area mobility, minimal terrain constraints, and the capability to rapidly establish integrated air–space–ground communication links. Consequently, they have become an indispensable component of modern emergency communication architectures. In recent years, the rapid development of advanced aviation communication platforms, such as large fixed-wing unmanned aerial vehicles (UAVs), unmanned helicopters, and high-altitude long-endurance platforms, has promoted the evolution of aviation emergency communication from single-platform support toward multi-platform coordination, cross-regional deployment, and system-level operations.

Existing studies on aviation emergency communication and UAV-enabled wireless networks have mainly focused on communication link analysis, UAV coverage modeling, temporary network deployment in disaster scenarios, and flight path optimization. [1] established air-to-ground

communication coverage models based on UAV flight altitude and communication radius, providing an important foundation for airborne communication capability analysis. [2] systematically summarized the applications and challenges of UAV-assisted wireless communications and discussed the potential of aerial platforms for emergency networking. [3] conducted a comprehensive review of UAV cellular communications and highlighted their advantages in coverage enhancement, emergency communication, and network recovery, while pointing out that most existing studies remain limited to localized scenario modeling. [4] further investigated airborne communication node coordination and dynamic networking mechanisms from the perspective of UAV network architectures, emphasizing the importance of multi-node collaboration in complex disaster environments. [5] presented a comprehensive survey of Flying Ad-Hoc Networks (FANETs), focusing on distributed airborne networking and cooperative communication mechanisms, while [6] analyzed the communication, coordination, and sensing capabilities of drone networks for multi-UAV collaborative operations. [7] explored the integration of wireless sensor networks and multiple UAVs for natural disaster management, demonstrating the advantages of coordinated aerial systems in emergency response. In the field of public safety communications, [8] proposed UAV-assisted heterogeneous network architectures for rapid communication recovery after disasters, and [9] reviewed legacy and emerging technologies for public safety communication systems. [10] further developed a unified framework for UAV-assisted emergency networks, jointly considering communication recovery, resource scheduling, and disaster response operations. In addition, [11] investigated the reliability and robustness of emergency communication networks from the perspective of network topology and redundancy, while [12] analyzed the topological characteristics of UAV-assisted post-disaster communication networks.

These studies have provided valuable insights into communication mechanisms, deployment optimization, network resilience, and collaborative networking. Despite these advances, several limitations remain in current research. First, most studies focus on individual platform performance or localized mission scenarios, lacking a comprehensive system-level evaluation framework for national aviation emergency communication systems. As a result, the operational characteristics of heterogeneous platform collaboration cannot be fully represented. Second, existing studies mainly emphasize communication coverage and network connectivity while insufficiently considering population distribution, disaster risk levels, and priority protection requirements, making it difficult to achieve demand-oriented capability assessment. Third, current approaches rarely distinguish between different operational modes, such as rapid direct-response deployment during the initial disaster phase and sustained cross-regional ferry support during later stages, limiting their ability to characterize system effectiveness under diverse mission conditions. In addition, redundancy capability is commonly modeled using linear weighting methods, which may overestimate the contribution of redundant coverage and fail to reflect the diminishing marginal effects observed in practical operations. Recent survey studies have also pointed out that existing UAV emergency communication research lacks unified effectiveness evaluation frameworks and practical large-scale validation methods [13].

To address these limitations, this paper proposes a system-architecture-oriented effectiveness evaluation method for aviation emergency communication systems. From a holistic system perspective, the proposed method distinguishes between direct coverage and ferry coverage operational modes and establishes a multidimensional evaluation framework incorporating spatial coverage, population coverage, rapid response capability, redundancy capability, and node connectivity. Population density, spatial distribution, and provincial disaster risk indices are incorporated as demand-oriented weighting factors. In addition, a nonlinear function is introduced to capture the diminishing marginal effects of redundancy enhancement, improving the consistency between the evaluation model and practical operational characteristics. Based on actual deployment data of China's aviation emergency communication platforms, nationwide airport network information, and population distribution data, a nationwide simulation assessment is conducted to evaluate the strengths and deficiencies of the current system in terms of coverage capability, rapid response capability, and redundancy support capability.

Compared with existing studies, the main contributions of this work are fourfold. First, a comprehensive effectiveness evaluation framework is established from a system-of-systems perspective rather than a single-platform perspective. Second, direct coverage and ferry coverage are incorporated into a unified analytical framework to better represent real aviation emergency communication operations. Third, population and disaster-risk weighting factors are introduced to transform conventional area-oriented assessment into a demand-oriented evaluation methodology.

Finally, a nonlinear modeling approach is adopted to characterize the marginal effects of redundancy capability, thereby improving the rationality and engineering credibility of system effectiveness evaluation. The results of this study can provide theoretical support and quantitative guidance for aviation emergency communication system planning, deployment optimization, and capability development.

2. Technical Foundation

For the aviation communication command equipment system, system effectiveness evaluation is conducted from two primary dimensions: direct coverage capability and ferry coverage capability. Direct coverage capability mainly assesses the ability of the existing equipment system, based on the current deployment locations and available assets, to satisfy potential aviation emergency communication command mission requirements across China. Ferry coverage capability evaluates the ability of the system—particularly medium- and large-sized fixed-wing UAV platforms capable of redeployment and emergency response operations—to support potential aviation emergency communication command missions through cross-regional ferry flights.

(i) Direct Coverage Capability

- **Spatial Coverage Ratio:** The proportion of the geographical area that can be simultaneously covered by all operational units of the aviation emergency communication system, relative to the total area requiring potential emergency communication coverage nationwide.

$$A_{ave} = \frac{\sum_{i=1}^{n} A_i}{A_{nation}} \tag{1}$$

where A_i is the effective coverage area of the *i*-th system unit, and A_{nation} is the total area requiring coverage.

- **Population Coverage Ratio:** The ratio between the total population within the reachable areas of all operational units and the total population requiring protection nationwide. This indicator reflects the system's response coverage capability for high-risk population areas, emphasizing "who can be covered" rather than "where can be covered."

$$P_{ave} = \frac{\sum_{j=1}^{m} P_j}{P_{nation}} \tag{2}$$

where P_i is the population effectively covered by the *i*-th system unit, and P_{nation} is the total population requiring coverage.

- **Redundancy Coverage Capability:** The degree to which any given point within the coverage area is overlapped by multiple operational units. This indicator evaluates the system's redundancy support and resilience when facing concurrent missions, resource conflicts, or high-intensity demand.

$$C_{ave} = \frac{1}{N} \sum_{i=1}^{N} \omega_i \cdot n_i \tag{3}$$

where N is the total number of sampling points within the national coverage area, n_i is the number of units covering the *i*-th sampling point, and ω_i is a weighting factor determined by population density.

- **Rapid Coverage Capability:** The average flight time (excluding preparation time) required for the nearest responsive unit to reach each effective sampling point within the coverage area, measured in hours (*h*). This indicator represents the spatial response efficiency of the system and serves as a core metric of system timeliness.

$$T_{ave} = \frac{1}{N} \sum_{i=1}^{N} t_i \tag{4}$$

where t_i is the response time from the nearest unit to the *i*-th sampling point.

(ii) Ferry Coverage Capability

- **Node Connectivity:** The ability of fixed-wing platforms to effectively connect available airport nodes nationwide. This indicator reflects the connectivity of fixed-wing platforms within the national emergency rescue network. Node connectivity is calculated based on the national airport network, flight speed, and allowable flight time.

$$C_{ave}=\frac{\sum_{i=1}^{n} C_i}{N_{total}} \tag{5}$$

where C_i is the number of airports reachable by the *i*-th fixed-wing aircraft, and N_{total} is the total number of airports nationwide.

- **Spatial Coverage Ratio:** Refers to the percentage of the total geographical area that can be simultaneously covered by all transit-accessible operational units within the current aviation emergency communication system, in proportion to the total area of potential national aviation communication, command and rescue demand zones.

$$A_{ave}=\frac{\sum_{i=1}^{n} A_i}{A_{nation}} \tag{6}$$

Where A_i denotes the effective coverage area of the *i*-th system unit, and A_{nation} represents the total spatial area requiring coverage.

- **Population Coverage Ratio:** Refers to the percentage of the total population residing within the accessible regions of all transit-reachable operational units in the current system, relative to the total population in need of support nationwide. This indicator reflects the response and coverage capacity of the aviation emergency communication system for high-risk population zones, emphasizing “who can be covered” rather than “where can be covered”.

$$P_{ave}=\frac{\sum_{j=1}^{m} P_j}{P_{nation}} \tag{7}$$

Where P_j denotes the effective covered population of the *i*-th system unit, and P_{nation} represents the total population requiring coverage.

A SD model for comprehensive urban disaster risk level combination evaluation was constructed in [14]. It integrates similarity and difference to calculate the risk values for all 31 provinces across China. According to the Risk Emergency Rescue Department, the comprehensive risk levels are divided into four grades: high, medium-high, medium, and low, the risk values and levels for 31 provinces. Then the risk values and levels for 31 provinces across China are shown in the Table 1.

Table 1 –The risk values and levels for 31 provinces across China

Province	Risk Value	Risk Level
Beijing	4.613	High
Tianjin	3.708	Medium-high
Hebei	3.000	Medium-high
Shanxi	2.87	Medium
Inner Mongolia	2.251	Medium
Liaoning	2.749	Medium
Jilin	1.569	Low
Heilongjiang	2.121	Low
Shanghai	4.483	High
Jiangsu	3.071	Medium-high
Zhejiang	3.000	Medium-high
Anhui	2.257	Medium
Fujian	4.121	High
Jiangxi	1.895	Low
Shandong	2.897	Medium
Henan	2.318	Medium
Hubei	2.619	Medium
Hunan	2.870	Medium
Guangdong	4.052	High
Guangxi	3.121	Medium-high
Hainan	3.483	Medium-high
Chongqing	3.251	Medium-high
Sichuan	3.734	Medium-high
Guizhou	3.180	Medium-high
Yunnan	3.552	Medium-high
Tibet	2.985	Medium
Shaanxi	3.613	Medium-high
Gansu	3.226	Medium-high
Qinghai	2.000	Low
Ningxia	2.251	Medium
Xinjiang	2.251	Medium

By comprehensively calculating regional risk levels, regional risk values, population density, and population spatial distribution, the aviation emergency communication demand index for China can be obtained as illustrated by the demand heat map in Figure 2. When evaluating the effectiveness of the aviation emergency system, it is necessary to comprehensively consider various factors such as comprehensive risk weight, population density, and population spatial distribution. Therefore, the demand index can be used as a weighted parameter to calculate the system coverage for evaluating the system effectiveness.

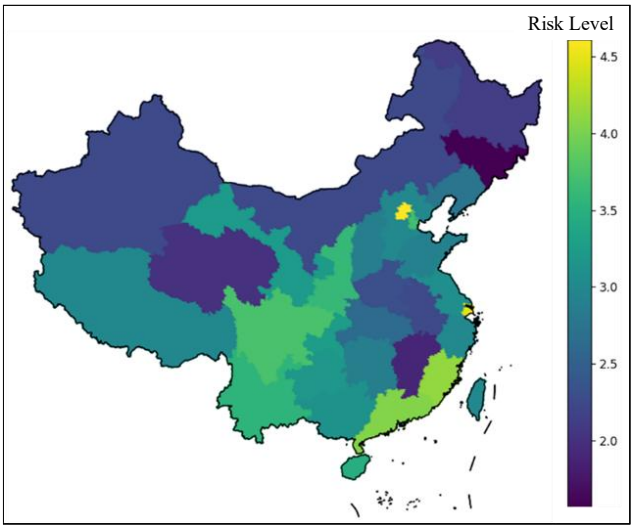


Figure 1 – The regional risk level of 31 provinces across China

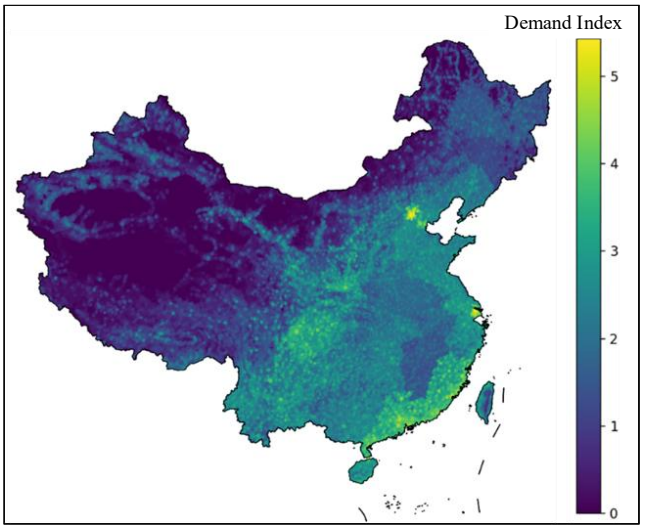


Figure 2 – Comprehensive aviation emergency communication demand for China

Using exponential aggregation, system effectiveness is divided into three components: comprehensive coverage, rapid coverage capability, and redundancy coverage capability. The redundancy coverage multiplier in form of the Sigmoid function is introduced to model marginal effects in redundancy enhancement. Then the system effectiveness is calculated as follows:

$$E=\frac{100\cdot P_c}{T_{ave}}\cdot Sigmoid(C_{ave})=\frac{100\cdot P_c}{T_{ave}}\cdot\frac{1}{1+e^{-2\cdot(C_{ave}-1)}} \tag{8}$$

The overall system effectiveness is obtained by using the Euclidean distance method to aggregate the effectiveness scores of the direct coverage effectiveness E_{direct} and the ferry coverage effectiveness E_{ferry}:

$$E_{overall}=\sqrt{(E_{direct}^2+E_{ferry}^2)/2} \tag{9}$$

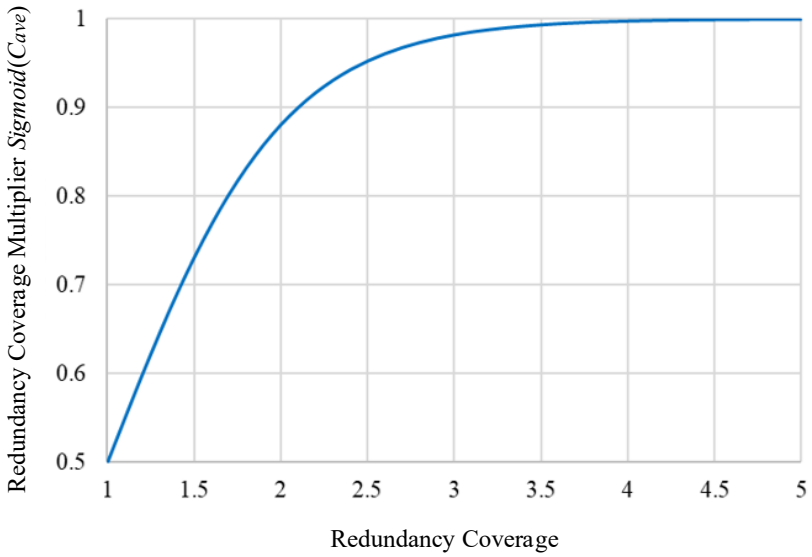


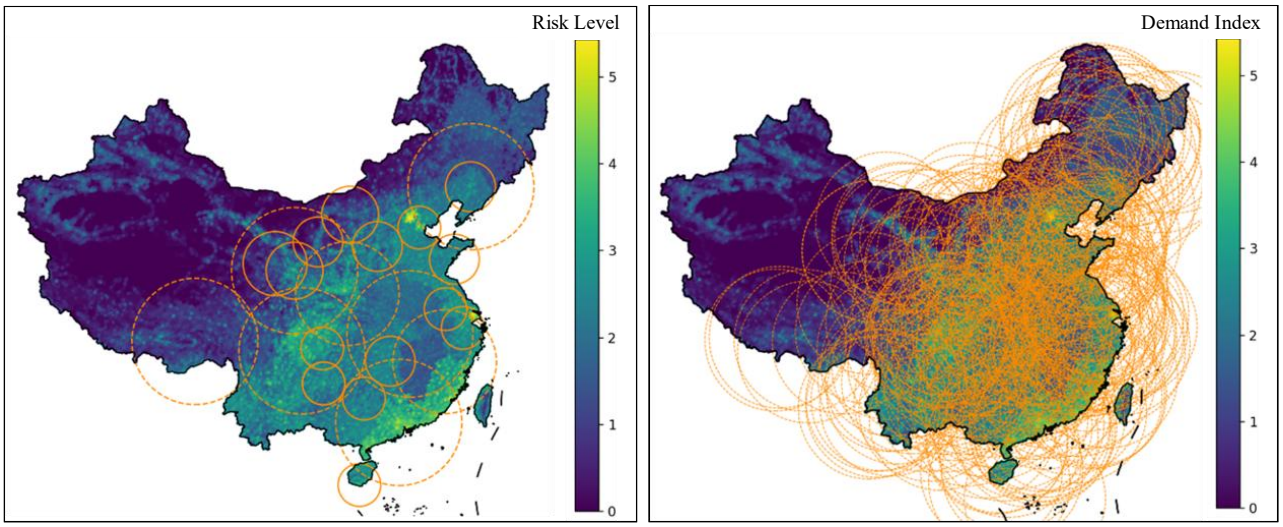
Figure 3 –Curve of Redundancy Coverage versus Redundancy Coverage Multiplier

3. 2025 Layout of China's Aviation emergency communication system

A comprehensive system effectiveness evaluation of the aviation communication system is conducted. In the evaluation process, according to the relevant plans of provinces, main cities, and autonomous regions across China, China establishes an aviation emergency communication system comprising 8 large long-endurance fixed-wing UAVs and 16 large unmanned helicopters. The locations of existing general aviation airports and commercial airports capable of supporting takeoff and landing operations are used as the airport infrastructure dataset. The population density distribution of China is used as the population distribution data map and the quantified risk levels of 31 provinces are used as sampling calculation weights to evaluate effectiveness of the aviation emergency communication system in 2025. The results of the system effectiveness evaluation are presented in Table 2 and coverage heat map of China's aviation communication system in 2025 is illustrated in Figure 4.

Table 2 – Effectiveness Evaluation Results of China's Aviation Communication System in 2025

System Capabilities under Direct Coverage Mode		System Capabilities under Ferry Coverage Mode	
Area Coverage Rate	70.13%	Node Connectivity Rate	80.40%
Comprehensive Weighted Coverage Rate	54.12%	Area Coverage Rate	92.23%
Redundancy Coverage	1.583	Population Coverage Rate	82.31%
Redundancy Coverage Multiplier	0.762		
Average Flight Time/h	1.2		
Effectiveness under Direct Coverage Mode	0.3319	Effectiveness under Ferry Coverage Mode	0.8231
Overall Effectiveness	**0.6276**		



(1) Direct Coverage Capability (2) Ferry Coverage Capability

Figure 4 – Coverage Heat Map of China's Aviation Communication System in 2025

The evaluation results demonstrate that China's aviation emergency communication system has initially achieved nationwide deployment capability and cross-regional response mechanisms. Large fixed-wing aircraft under ferry-based deployment exhibit significant national coverage potential (ferry coverage rate: 92.23%; node connectivity rate: 80.40%), with robust cross-regional communication access and mobile support capabilities. However, the system's direct coverage rate is merely 70.13% (54.12% after weighting), indicating inadequate responsiveness in time-critical missions—particularly during the initial disaster phase and emergency "golden time"—which constrains the practical effectiveness of command communication support.

(i) The current system exhibits a structural characteristic of "broad regional accessibility but insufficient localized support capability." Despite the theoretical feasibility of nationwide aviation communication support via ferry-based deployment, its average response time of approximately 1.2 hours cannot satisfy the requirement for immediate coverage and rapid link establishment in sudden disaster scenarios, especially in remote areas. Sole reliance on this mode in high-risk regions, densely populated areas, and geographically complex zones poses practical challenges, including deployment delays and unstable communication links.

(ii) With a redundancy coverage degree of 1.583, the system is far from forming a multi-point overlapping support structure. It is therefore imperative to enhance deployment density and optimize node configuration to improve the system's resilience and adaptability to concurrent missions and

complex operational scenarios.

(iii) The overall system effectiveness score (0.6276) indicates that while a foundational nationwide mobile support capability has been established, deficiencies persist in rapid response, redundancy, and fine-grained coverage in high-risk areas. It is recommended to strengthen local deployment in eastern coastal regions and central-western high-risk areas, increase the proportion of direct coverage, and alleviate response lags associated with ferry deployment through measures such as hotspot node pre-positioning and downward deployment of rapid-response equipment.

4. 2035 Layout of China's Aviation emergency communication system

Considering China's natural disaster risk distribution, population density, and regional development levels, it is anticipated that by 2035, a multi-echelon aviation emergency communication system with tiered response capabilities—ranging from long-range to short-range—will be established. The system comprises three levels:

(i) **National-level long-range strategic support force:** based on large, long-endurance fixed-wing communication platforms, designed to achieve wide-area communication support with a "6-hour arrival" target (3 hours preparation + 3 hours flight). This force primarily addresses major earthquakes, catastrophic disasters, large-scale emergencies, and cross-regional support missions.

(ii) **Provincial-level medium-range support units**: based on large unmanned helicopters, intended to realize regional emergency response with a "4-hour on-site arrival" target (1 hour preparation + 3 hours flight). These units serve as a key collaborative supplement to fixed-wing platforms, balancing communication stability and deployment flexibility, and are suitable for inter-provincial disaster support and medium-intensity missions.

(iii) **Short-range tactical support forces**: based on medium-sized compound-wing UAVs, designed to primarily serve near-field disaster sites, achieving rapid response within 2 hours (1 hour preparation + 1 hour flight), thereby fulfilling the first-response communication access requirements for local emergencies.

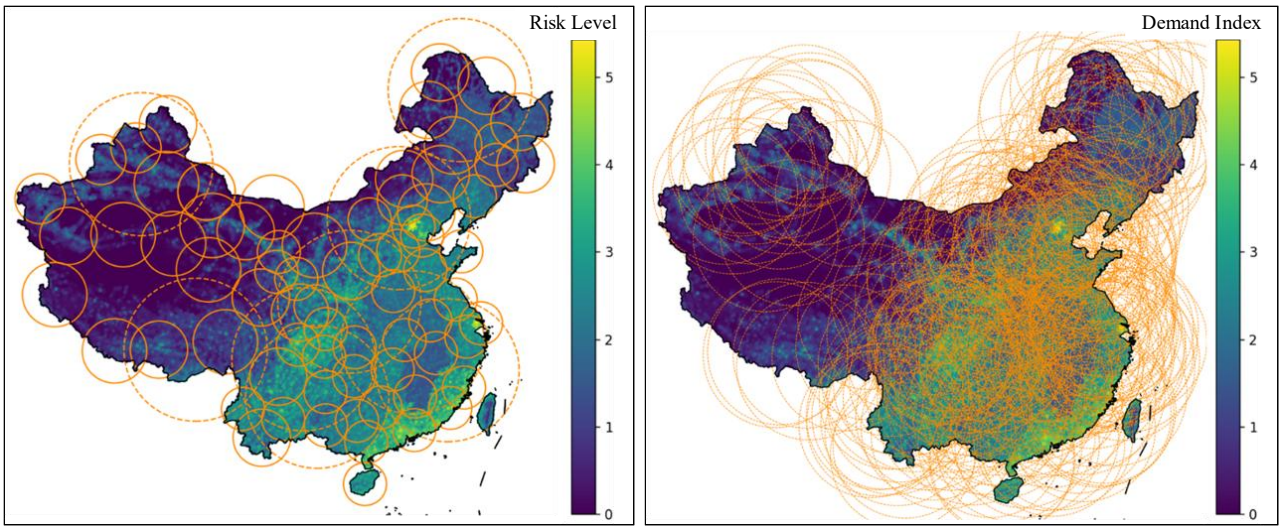
Based on these requirements, two system layout schemes are proposed and analyzed in this paper.

4.1 System Layout Scheme A

System Layout Scheme A: By 2035, China's aviation emergency communication system will comprise 82 aircraft, including 9 large fixed-wing UAVs and 73 small to medium-sized unmanned helicopters. Based on the system effectiveness model proposed in this paper, the effectiveness evaluation results for Scheme A are presented in Table 3 and the coverage heat map of Scheme A is illustrated in Figure 5.

Table 3 – Effectiveness Evaluation Results of System Layout Scheme A

System Capabilities under Direct Coverage Mode		**System Capabilities under Ferry Coverage Mode**	
Area Coverage Rate	95.69%	Node Connectivity Rate	88.07%
Comprehensive Weighted Coverage Rate	91.05%	Area Coverage Rate	98.44%
Redundancy Coverage Degree	2.32	Population Coverage Rate	94.81%
Redundancy Coverage Multiplier	0.934		
Average Flight Time/h	1.06		
Effectiveness under Direct Coverage Mode	0.8024	Effectiveness under Ferry Coverage Mode	0.9481
Overall Effectiveness	0.8783		
Average annual cost / Total cost	CNY 0.159 billion/CNY 1.905 billion		
Cost-effectiveness Ratio	5.524		
Input-output Ratio	14.88		



(1) Direct Coverage Capability (2) Ferry Coverage Capability

Figure 5 – Coverage Heat Map of System Layout Scheme A

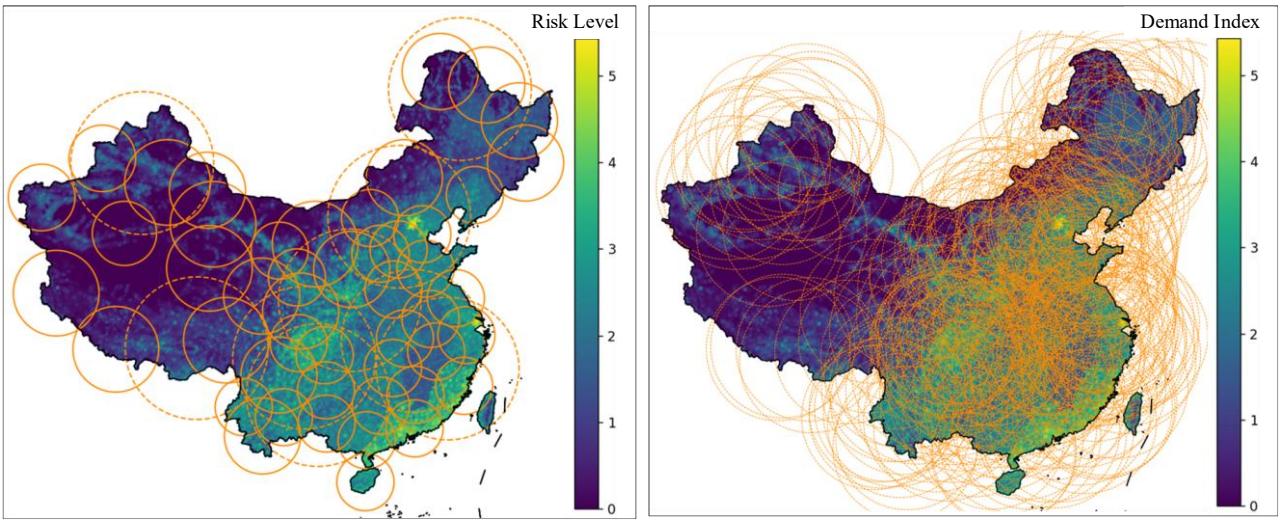
Scheme A adopts a layered architecture consisting of 9 large fixed-wing UAVs and 73 small to medium-sized unmanned helicopters, effectively addressing the original system's limitations of "insufficient direct coverage and significant ferry time delays." The direct area coverage rate increases from 70.13% to 95.69%, and the weighted coverage rate rises from 54.12% to 91.05%. The ferry area coverage ratio reaches 98.44%, with a node connectivity of 88.07%. The system's redundancy coverage degree increases from 1.583 to 2.32, and the redundancy coverage multiplier rises from 0.762 to 0.934. Average flight time decreases from 1.2 hours to 1.06 hours. Overall effectiveness jumps from 0.6276 to 0.8783, representing a 39.9% improvement, with the direct coverage mode effectiveness increasing by 141.7%. This system achieves a transition from "regional support" to "comprehensive domain integration," providing aviation communication command and support capabilities capable of responding to complex disaster scenarios and concurrent multi-point missions.

4.2 System Layout Scheme B

System Layout Scheme B: By 2035, China's aviation emergency communication system will comprise a total of 57 aircraft, including 9 large fixed-wing UAVs and 48 small to medium-sized unmanned helicopters. Based on the system effectiveness model proposed in this paper, the effectiveness evaluation results for scheme B are presented in Table 4 and the heat map of coverage capability of scheme A is illustrated in Figure 6.

Table 4 – Effectiveness Evaluation Results of System Layout Scheme B

System Capabilities under Direct Coverage Mode		System Capabilities under Ferry Coverage Mode	
Area Coverage Rate	95.56%	Node Connectivity Rate	88.07%
Comprehensive Weighted Coverage Rate	90.04%	Area Coverage Rate	98.44%
Redundancy Coverage	2.51	Population Coverage Rate	94.81%
Redundancy Coverage Multiplier	0.954		
Average Flight Time/h	1.23		
Effectiveness under Direct Coverage Mode	0.7001	Effectiveness under Ferry Coverage Mode	0.9481
Overall Effectiveness	0.8334		
Average annual cost / Total cost	CNY 0.131 billion/CNY 1.572 billion		
Cost-effectiveness Ratio	6.362		
Input-output Ratio	12.81		



(1) Direct Coverage Capability (2) Ferry Coverage Capability

Figure 6 – Heat Map of Coverage Capability of System Layout Scheme B

Scheme B adopts a resource consolidation strategy, reducing the total number of platforms from 82 to 57. By expanding the coverage radius of individual platforms and optimizing their placement, it achieves a direct area coverage rate of 95.56% and a comprehensive weighted coverage rate of 90.04%, representing increases of 25.4% and 66%, respectively, compared to the 2025 baseline. The ferry area coverage rate (98.44%) and node connectivity (88.07%) are comparable to those of scheme A. The effectiveness under the direct coverage mode is 0.7001 (lower than scheme A's 0.8024), and the average response time is 1.23 hours (longer than scheme A's 1.06 hours), indicating relatively limited capability for time-sensitive missions. However, Scheme B achieves a redundancy coverage degree of 2.51 and a redundancy multiplier of 0.954 offering enhanced fault tolerance and concurrent mission support. The overall effectiveness is 0.8334, representing a 32.7% improvement over the 2025 baseline. Scheme B is suitable for wide-area deployment under resource constraints or as a supplement to a layered architecture featuring "high-density response zones combined with high-redundancy support zones."

5. Summary of System Evaluation and Optimization

Based on modeling, simulation, and evaluation of the two system layout schemes for the 2035 aviation emergency communication system, the following key conclusions are drawn to provide quantitative support for strategic selection and resource allocation in future system development.

(1) Significant differences in system scale are accompanied by marginal gains in effectiveness, exhibiting a characteristic of "structural optimization compensating for resource expansion." Scheme A deploys 82 aerial platforms (9 large fixed-wing UAVs and 73 small/medium unmanned helicopters), forming a high-density node system. Scheme B reduces the count to 57 platforms (still 9 fixed-wing UAVs, with helicopters reduced to 48), resulting in a more compact structure. Despite an approximate 30% reduction in total amount of aircraft, the overall effectiveness of Scheme B reaches 0.8334, only about 5.1% lower than Scheme A's 0.8783. This indicates that under optimized site selection and coverage radius, the relationship between resource intensity and system capability is non-linear; reasonable structural optimization can partially compensate for a reduction in platform numbers.

(2) Direct coverage capability is the key differentiating variable between the two system layout schemes and a dominant factor affecting response efficiency and emergency quality. Under direct coverage mode, Scheme A achieves an effectiveness of 0.8024, significantly higher than Scheme B's 0.7001 – an improvement of approximately 14.6%. Correspondingly, the average flight response time is reduced from 1.23 hours to 1.06 hours. This implies that Scheme A is better suited for sudden disaster scenarios requiring high frequency and rapid response, possessing stronger in-situ link establishment and quick-reaction capabilities. Scheme B, in contrast, relies more on extended coverage radius and ferry coordination, trading some response timeliness for higher deployment efficiency and redundancy performance.

(3) Ferry support capabilities are comparable, serving as an important scheduling mechanism to compensate for insufficient direct reach. Both schemes are equipped with nine fixed-wing platforms,

achieving a ferry coverage area rate of 98.44%, a node connectivity degree of 88.07%, and a ferry-mode effectiveness of 0.9481. This indicates that the fixed-wing platforms form an efficient, region-wide backbone support system in both structures, capable of rapid deployment to remote blind areas and cross-regional assembly. For resource-constrained scenarios, the retention of ferry capability provides fundamental support for flexible deployment.

(4) System redundancy coverage reaches high levels in both layouts, but through different means: Scheme A relies on node density, while Scheme B relies on coverage expansion. Scheme A has a redundancy coverage degree of 2.32 and a multiplier of 0.934. Scheme B achieves 2.51 and 0.954, respectively, performing better – indicating that with fewer nodes, the latter achieves higher concurrency support capability. This advantage stems from an increased platform coverage radius and better site selection, making Scheme B suitable for strategic emergency scenarios requiring high redundancy but low dispatch density. Scheme A is more applicable to mission-dense areas or high-density target zones, using platform density to support mission throughput and resource scheduling flexibility.

(5) In terms of comprehensive cost-effectiveness evaluation, the two system layout schemes exhibit distinct emphases in system effectiveness and resource allocation strategy. Scheme A achieves an overall effectiveness of 0.8783, an input-output ratio of 14.88, a total investment of CNY 1.905 billion (annual average CNY 0.159 billion), and a cost-effectiveness ratio of 5.524, demonstrating strong suitability for major mission scenarios under high-redundancy configuration. Scheme B realizes an overall effectiveness of 0.8334 with a lower total investment of CNY 1.572 billion yuan (annual average CNY 0.131 billion), a higher cost-effectiveness ratio of 6.362, and an input-output ratio of 12.81, exhibiting superior economic performance. In summary, if the primary orientation is mission coverage integrity and high-reliability response, Scheme B offers greater mission-carrying capacity; if the goal is controllable construction cost and optimal cost-effectiveness, Scheme B demonstrates superior resource allocation efficiency. The two system layout schemes are respectively suited for high-safety-redundancy scenarios and high-frequency routine operation scenarios, both possessing practical feasibility from the perspectives of policy-driven or market-expansion contexts.

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