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Empirical Study on Effectiveness Evaluation of Peacetime-Wartime Conversion for Civil Air Defense Works

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Abstract

To scientifically quantify the effectiveness of peacetime-wartime conversion for civil air defense works and address the problems of vague indicators, strong subjectivity and difficulty in precise grading in traditional evaluations, this study adopts a combined model of the Analytic Hierarchy Process and Fuzzy Comprehensive Evaluation Method for evaluation research. Following the principles of scientificity, systematicity and quantifiability, a three-level evaluation system of target layer-criterion layer-indicator layer is constructed, covering 4 criterion layer indicators (economy, reliability, timeliness and robustness) and 12 indicator layer indicators. The AHP is used to determine indicator weights and complete consistency tests, while the Fuzzy Comprehensive Evaluation Method is employed to quantify fuzzy indicators and determine effectiveness grades. Taking a Grade B combined peacetime-wartime underground garage civil air defense work in the core area of a city as the empirical object, the model calculates a comprehensive score of 84.85 points, with an effectiveness grade of "good", and the evaluation results are highly consistent with the actual working conditions of the project. The research shows that this combined model can effectively solve the fuzziness and subjectivity problems in the evaluation of peacetime-wartime conversion for civil air defense works, providing a scientific basis for engineering effectiveness diagnosis, optimization and upgrading, with strong practicality and promotion value.

Keywords

Civil Air Defense Works; Peacetime-Wartime Conversion; Effectiveness Evaluation; Analytic Hierarchy Process (AHP); Fuzzy Comprehensive Evaluation Method.

1. Introduction

Civil air defense works are important infrastructure for urban air defense in wartime and disaster prevention in peacetime. "Long-term Preparation, Key Construction, and Integration of Peacetime and Wartime Functions" is the basic policy for the construction of civil air defense works in China. civil air defense works must balance the needs of peacetime economic construction and public life while ensuring wartime protection effectiveness[1].As the core link for civil air defense works to realize the connection between peacetime and wartime functions, peacetime-wartime conversion directly determines whether the project can complete functional switching and form effective protection capability within the specified pre-war time limit. Its comprehensive support capability and conversion effectiveness are the current research focus in the field of civil air defense [2].

At present, there are many prominent problems in the practice of peacetime-wartime conversion for civil air defense works: some projects reserve excessive peacetime-wartime conversion items and adopt complex conversion measures, leading to huge investment in materials, labor and funds required for pre-war conversion, making it difficult to complete the conversion within the time limit. Meanwhile, issues such as unclear responsible subjects for

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peacetime-wartime conversion, unimplemented fund channels and inadequate daily maintenance and management seriously restrict conversion efficiency and the exertion of combat effectiveness. From the perspective of technology and management, peacetime-wartime conversion for civil air defense works involves key technologies of multiple systems including structural reinforcement, ventilation, water supply and drainage, and electrical systems. In addition, traditional plan management mainly relies on text and optical disk storage, which is characterized by complex data, low reading efficiency and insufficient informatization. It is urgent to improve conversion management and decision-making levels through digital and information-based means[3].

In terms of theoretical research, existing achievements have constructed an indicator system for the support capability of civil air defense shelter works, covering dimensions such as engineering support, management support, material support, communication support and wartime environment. The Fuzzy Comprehensive Evaluation Method and AHP have been adopted to conduct support capability evaluations. At the same time, explorations have been carried out around directions such as informatization of peacetime-wartime conversion, multi-source data application, visualization of Building Information Modeling (BIM) and Geographic Information System (GIS), and auxiliary decision-making models, providing technical ideas for improving conversion effectiveness[4]. However, existing studies have not formed a full-dimensional effectiveness evaluation system for peacetime-wartime conversion integrating economy, reliability, timeliness, robustness and communication support, and systematic research on the quantification of fuzzy indicators, scientific determination of indicator weights and precise grading of effectiveness remains to be improved.

Based on this, combined with the actual combat needs of peacetime-wartime conversion for civil air defense works and existing research foundations, this study constructs a scientific and systematic effectiveness evaluation indicator system for peacetime-wartime conversion. The AHP is used to determine indicator weights and complete consistency tests, and the Fuzzy Comprehensive Evaluation Method is adopted to realize the quantification of fuzzy indicators and determination of effectiveness grades, establishing a complete effectiveness evaluation model. It is expected to provide scientific support for the optimization of peacetime-wartime conversion, management decision-making and improvement of combat effectiveness for civil air defense works.

2. Construction of Evaluation Indicator System

2.1. Principles for Indicator Selection

Combined with the combat readiness attributes, technical specifications, practical operation processes and evaluation objectives of peacetime-wartime conversion for civil air defense works, the indicator system strictly follows four core principles: scientificity and practicality, systematicity and independence, combination of qualitative and quantitative analysis, and targeted and combat readiness orientation. The specific connotations are as follows:.

2.1.1. Principle of Scientificity and Practicality

Indicator selection closely follows the core logic of peacetime-wartime conversion for civil air defense works, based on national civil air defense specifications, engineering construction standards and actual combat needs, ensuring clear definitions and accurate connotations of indicators. At the same time, it takes into account the availability of on-site data, operability of calculation and management practicality, avoiding redundant, abstract or unfeasible indicators, ensuring the evaluation process is concise and efficient, and the results are credible and applicable.

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2.1.2. Principle of Systematicity and Independence

The indicator system covers the whole process, all elements and all dimensions of peacetime-wartime conversion for civil air defense works, fully characterizing the effectiveness level from aspects such as conversion cost, equipment reliability, response speed and emergency resilience. Each indicator has clear boundaries and independent connotations without overlapping or logical inclusion, avoiding duplicate scoring and evaluation deviations, ensuring the evaluation system has a rigorous structure and clear hierarchy.

2.1.3. Principle of Combination of Qualitative and Quantitative Analysis

Quantifiable indicators (such as conversion duration, cost, qualification rate and reliability) are assigned values through formula calculation and measured data. For fuzzy and subjective indicators (such as anti-interference capability and fault-tolerant capability), unified scoring standards and grade intervals are formulated to realize the quantification of qualitative descriptions and clarification of fuzzy information, balancing the objectivity and comprehensiveness of evaluation.

2.1.4. Principle of Targeted and Combat Readiness Orientation

Focusing on the core combat readiness functions of rapid peacetime-wartime conversion and reliable wartime protection for civil air defense works, key combat readiness attributes such as timeliness, reliability and robustness are highlighted, while non-core daily operation indicators are weakened, ensuring evaluation results directly serve the improvement of engineering combat readiness capability, optimization of conversion processes and emergency decision-making support.

2.2. Selection of Evaluation Indicators

Table 1. Comprehensive Efficiency Index System for Peacetime-Wartime Conversion of Civil Air Defense Works

	First-Level Indicator	Second-Level Indicator
Comprehensive Effectiveness of Peacetime-Wartime Conversion for civil air defense Works (C)	Economy (C_1)	Comprehensive Cost of Peacetime-Wartime Conversion (C_{11})
		Combat Readiness Reserve and Operation & Maintenance Cost (C_{12})
		Reuse Benefit of Combat Readiness Resources (C_{13})
	Reliability (C_2)	Qualification Rate of Wartime Function Conversion (C_{21})
		Operation Reliability of Conversion Equipment (C_{22})
		Compliance Rate of Standardized Conversion (C_{23})
	Timeliness (C_3)	Response Time to Emergency Instructions (C_{31})
		Completion Time of Full-Scale Conversion (C_{32})
		Handling Timeliness of Faults (C_{33})
	Robustness (C_4)	Anti-Interference Capability under Complex Working Conditions (C_{41})
		Fault-Tolerant Capability of Conversion Operations (C_{42})
		Emergency Alternative Redundancy Capability (C_{43})

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The core theoretical connotation of peacetime-wartime conversion effectiveness is defined as the comprehensive capability of civil air defense works to reliably switch from peacetime civilian functions to wartime protection functions within a specified time limit, which is essentially the coordinated unity of efficiency and quality. Centered on the core characteristics and combat readiness needs of the entire process of peacetime-wartime conversion, and following the four core principles of scientificity and practicality, systematicity and independence, combination of qualitative and quantitative analysis, and targeted and combat readiness orientation, a three-level evaluation framework of "objective-dimension-indicator" is built, defining four core evaluation dimensions: economy, reliability, timeliness and robustness, with 12 detailed indicators at the indicator layer, as shown in Table 1.

2.2.1. Economic Indicators

Economic indicators include three second-level indicators: comprehensive cost of peacetime-wartime conversion, combat readiness reserve and operation & maintenance cost, and reuse benefit of combat readiness resources. Among them, the comprehensive cost of peacetime-wartime conversion refers to all expenses incurred in labor, materials, equipment and construction for converting the project from peacetime status to wartime functions. The combat readiness reserve and operation & maintenance cost refers to long-term support expenditures such as daily maintenance of protective equipment, ventilation, water supply and drainage, and electrical systems, material renewal and personnel duty. The reuse benefit of combat readiness resources refers to the multi-functional utilization, comprehensive income and resource conservation level of civil air defense spaces, facilities and equipment in both peacetime and wartime.

2.2.2. Reliability Indicators

Reliability indicators include three second-level indicators: qualification rate of wartime function conversion, operation reliability of conversion equipment, and compliance rate of standardized conversion. Among them, the qualification rate of wartime function conversion refers to the degree to which various wartime protection functions meet design standards after conversion. The operation reliability of conversion equipment refers to the stable operation capability of key equipment such as protective equipment, ventilation, water supply and drainage, and electrical systems during conversion and wartime status. The compliance rate of standardized conversion refers to the degree to which conversion processes, construction techniques and acceptance standards meet civil air defense specifications.

2.2.3. Timeliness Indicators

Timeliness indicators include three second-level indicators: response time to emergency instructions, completion time of full-scale conversion, and handling timeliness of faults. Among them, the response time to emergency instructions refers to the time from receiving conversion instructions to starting operations. The completion time of full-scale conversion refers to the total time required for the project to fully complete wartime conversion from peacetime status. The handling timeliness of faults refers to the processing speed and recovery time when equipment, structural and system faults occur during conversion.

2.2.4. Robustness Indicators

Robustness indicators include three second-level indicators: anti-interference capability under complex working conditions, fault-tolerant capability of conversion operations, and emergency alternative redundancy capability. Among them, anti-interference capability under complex working conditions refers to the stability of completing conversion under harsh environments and unexpected conditions. Fault-tolerant capability of conversion operations refers to the capability of ensuring successful conversion in case of operational deviations and equipment abnormalities. Emergency alternative redundancy capability refers to the support level of quickly switching to backup plans when key systems and equipment fail.

2.3. Principles for Indicator Selection

Indicator weight is a key parameter measuring the relative importance of each evaluation indicator, which directly determines the contribution of each dimension to the comprehensive effectiveness of peacetime-wartime conversion for civil air defense works and affects the scientificity and rationality of evaluation results. Common weight determination methods include the Analytic Hierarchy Process (AHP), Entropy Weight Method, Expert Consultation Method and Combined Weighting Method. Combined with the characteristics of the evaluation indicators in this study: on the one hand, the effectiveness evaluation of peacetime-wartime conversion for civil air defense works involves comprehensive judgments of multiple dimensions such as combat readiness functions, economic costs and operation support, and the importance of some indicators requires subjective research and judgment combined with civil air defense specifications and practical engineering experience. On the other hand, the three-level indicator system (target layer-criterion layer-indicator layer) constructed above has a clear hierarchy and logical clarity, which is suitable for the decision-making framework of the AHP. Therefore, this study adopts the AHP to determine the weight of each indicator.

The Analytic Hierarchy Process (AHP) is a multi-criteria decision analysis method based on multi-level objective decomposition, which is suitable for the hierarchical structure of the "target layer-criterion layer-indicator layer" evaluation system in this study. For n evaluation indicators contained in a certain level, experts in the field of civil air defense engineering are invited to conduct pairwise comparisons of the relative importance of indicators using the 1-9 scale method, and construct a judgment matrix $A(a_{ij})$ (where $i, j = 1,2, \dots, n$) with the following form:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

Where aij represents the ratio of the relative importance of indicator i to indicator j, and the value follows the definition of the 1-9 scale method. After constructing the judgment matrix, the square root method or eigenvalue method is used to calculate the maximum eigenvalue λmax and its corresponding eigenvector of the matrix. The eigenvector is normalized to obtain the weight value W of each indicator at this level. To ensure the logical consistency of the judgment matrix, a consistency test is required. First, calculate the consistency index $CI = \frac{\lambda_{max}-n}{n-1}$, where n is the order of the judgment matrix. Then, combined with the average random consistency index RI (the value refers to relevant literature and changes with the order n of the matrix), calculate the random consistency ratio $CR = \frac{CI}{RI}$. When $CR < 0.1$, the judgment matrix is considered to have satisfactory consistency, and the indicator weight distribution is reasonable. At this time, the normalized eigenvector is the final weight value of each indicator. If $CR \geq 0.1$, the experts are required to adjust the judgment matrix and conduct pairwise comparisons again until the consistency test is passed.

2.4. Determination of Evaluation Method

Commonly used engineering effectiveness evaluation methods mainly include the Expert Scoring Method, Grey Relational Analysis, Data Envelopment Analysis and Fuzzy Comprehensive Evaluation Method. After comparative analysis, the Fuzzy Comprehensive Evaluation Method is most suitable for the effectiveness evaluation scenario of peacetime-wartime conversion for civil air defense works. Although the Expert Scoring Method is easy to operate, it is highly subjective and lacks unified standards, making it difficult to handle fuzzy indicators such as reliability and robustness, resulting in insufficient evaluation accuracy. The Grey Relational Analysis is suitable for small-sample and incomplete information systems, but it has weak adaptability to the number and dimensions of indicators and cannot achieve clear multi-grade determination. The Data Envelopment Analysis focuses on relative efficiency evaluation and is not suitable for civil air defense engineering evaluation with a high proportion of qualitative indicators and combat readiness attributes, making it difficult to give a clear effectiveness grade. The Fuzzy Comprehensive Evaluation Method can quantify qualitative indicators with the help of membership functions, effectively dealing with fuzziness and uncertainty in evaluation. Combined with scientific weights determined by the AHP, it can complete multi-indicator and multi-level comprehensive operations, and finally output clear scores and effectiveness grades, fully meeting the actual needs of effectiveness evaluation of peacetime-wartime conversion for civil air defense works.

Combined with the effectiveness characteristics of peacetime-wartime conversion for civil air defense works and industry evaluation specifications, the effectiveness grade is divided into 4 levels, and the evaluation set is determined as: $V = \{V_1, V_2, V_3, V_4\} = \{\text{Excellent}, \text{Good}, \text{Medium}, \text{Poor}\}$, corresponding to score intervals: Excellent (90-100 points), Good (80-89 points), Medium (60-79 points), Poor (0-59 points). Grading criteria for secondary indicators are shown in Table 2.

Table 2. Grading Criteria for Secondary Indicators

Bottom Indicator	Grading Criteria			
	Excellent	Good	Medium	Poor
Comprehensive Cost of Peacetime-Wartime Conversion	Far below the average level of similar projects, minimum investment	Below average level, good cost control	Close to average level, basically reasonable cost	Significantly higher than average level, excessive cost
Combat Readiness Reserve and Operation & Maintenance Cost	Low operation & maintenance cost, extremely low equipment failure rate	Relatively low operation & maintenance cost, stable equipment status	Moderate operation & maintenance cost, meeting basic support	High operation & maintenance cost, frequent failures and weak support
Reuse Benefit of Combat Readiness Resources	High peacetime-wartime compatibility, extremely high resource utilization rate	Good peacetime-wartime compatibility, relatively sufficient utilization	Basic compatibility, average utilization level	Low compatibility, serious resource idleness
Qualification Rate of Wartime Function Conversion	100% compliance, no defects	≥90% compliance, minor defects	≥70% compliance, general defects	<70%, failing to meet wartime requirements
Operation Reliability of Conversion Equipment	Trouble-free operation throughout the process, stable operation	Occasional minor failures, no impact on use	A small number of general failures, normal operation possible	Frequent failures, unreliable operation
Compliance Rate of Standardized Conversion	100% compliance with civil air defense specifications	≥90% compliance with specifications	≥70% compliance with specifications	<70%, serious non-compliance
Response Time to Emergency Instructions	Much faster than the specified time limit	Faster than the specified time limit	Meeting the specified time limit	Severe delay, slow response

Experts in the field of civil air defense are invited to evaluate the grade of each indicator, and the fuzzy statistics method is adopted to determine the membership degree r_{ij} of a single indicator to each evaluation grade. The membership degrees of all indicators together form the membership matrix R:

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} \\ r_{21} & r_{22} & r_{23} & r_{24} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & r_{n3} & r_{n4} \end{bmatrix}$$

Where r_{ij} represents the degree to which the i-th indicator belongs to the j-th grade, with a value range of [0,1], and the sum of elements in each row is 1. The weight vector W obtained by the AHP and the membership matrix R are subjected to fuzzy synthesis operation, and the weighted average operator $M(\cdot,+)$ is adopted to ensure complete information, obtaining the comprehensive evaluation vector B:

$$B = W * R = (b_1, b_2, b_3, b_4)$$

The evaluation vectors of each criterion layer (economy, reliability, timeliness and robustness) are obtained through the operation of indicator layer weights and membership matrices. Taking the criterion layer weights as new weights, the primary operation results are synthesized again to obtain the target layer comprehensive evaluation vector. The weighted scoring method is used to convert the fuzzy evaluation vector into a quantitative score S:

$$S = B * C^T$$

Where $C = (95,85,70,30)$ is the standard score of each grade. The effectiveness grade of peacetime-wartime conversion for civil air defense works is determined by comparing the final score S with the evaluation set interval, completing the evaluation and determination.

3. Application of Evaluation Model

3.1. Project Overview

A Grade B combined peacetime-wartime underground garage civil air defense work in the core area of a city is a typical public civil air defense work in the urban central area, with a total floor area of approximately 12,800 m^2. It serves as a second-class personnel shelter in wartime, with a Grade B protection grade and Grade C chemical protection grade; it functions as an underground motor vehicle garage in peacetime with 316 parking spaces. The project is designed, constructed and accepted in accordance with current civil air defense specifications, with complete peacetime-wartime conversion elements and data, which is typical and representative and can be used as an empirical object for effectiveness evaluation of peacetime-wartime conversion for civil air defense works.

3.2. Determination of Indicator Weights

The Analytic Hierarchy Process (AHP) is adopted to determine the weights of effectiveness evaluation indicators for peacetime-wartime conversion for civil air defense works, strictly following the four steps of constructing a judgment matrix, calculating the weight vector, solving the maximum eigenvalue and completing the consistency test. The final weight values of each indicator are shown in Table 3.

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Table 3. Indicator Weighting Results

First-Level Indicator	Weight	Second-Level Indicator	Weight	Combined Weight
Economy (C_1)	0.14	Comprehensive Cost of Peacetime-Wartime Conversion (C_{11})	0.30	0.042
		Combat Readiness Reserve and Operation & Maintenance Cost (C_{12})	0.30	0.042
		Reuse Benefit of Combat Readiness Resources (C_{13})	0.40	0.056
Reliability (C_2)	0.32	Qualification Rate of Wartime Function Conversion (C_{21})	0.40	0.128
		Operation Reliability of Conversion Equipment (C_{22})	0.35	0.112
		Compliance Rate of Standardized Conversion (C_{23})	0.25	0.080
Timeliness (C_3)	0.35	Response Time to Emergency Instructions (C_{31})	0.25	0.0875
		Completion Time of Full-Scale Conversion (C_{32})	0.45	0.1575
		Handling Timeliness of Faults (C_{33})	0.30	0.105
Robustness (C_4)	0.19	Anti-Interference Capability under Complex Working Conditions (C_{41})	0.35	0.0665
		Fault-Tolerant Capability of Conversion Operations (C_{42})	0.30	0.057
		Emergency Alternative Redundancy Capability (C_{43})	0.35	0.0665
Total	1.00	-	-	1.00

3.3. Fuzzy Comprehensive Operation

Five experts in the field of civil air defense engineering are invited to evaluate the four-level membership degree of 12 indicators based on project completion data, peacetime-wartime conversion drill records, operation and maintenance reports and on-site verification results, obtaining the membership matrix of each criterion layer as follows:

Membership Matrix of Economy Criterion

$$R_1 = \begin{bmatrix} 0.2 & 0.6 & 0.2 & 0.0 \\ 0.0 & 0.6 & 0.4 & 0.0 \\ 0.4 & 0.4 & 0.2 & 0.0 \end{bmatrix}$$

Membership Matrix of Reliability Criterion

$$R_2 = \begin{bmatrix} 0.6 & 0.4 & 0.0 & 0.0 \\ 0.4 & 0.6 & 0.0 & 0.0 \\ 0.2 & 0.6 & 0.2 & 0.0 \end{bmatrix}$$

Membership Matrix of Timeliness Criterion

$$R_3 = \begin{bmatrix} 0.4 & 0.6 & 0.0 & 0.0 \\ 0.6 & 0.4 & 0.0 & 0.0 \\ 0.2 & 0.6 & 0.2 & 0.0 \end{bmatrix}$$

Membership Matrix of Robustness Criterion

$$R_4 = \begin{bmatrix} 0.2 & 0.6 & 0.2 & 0.0 \\ 0.0 & 0.8 & 0.2 & 0.0 \\ 0.2 & 0.4 & 0.4 & 0.0 \end{bmatrix}$$

First-Level Fuzzy Comprehensive Operation

The weighted average operator $M(\cdot, +)$ is adopted for synthesis from the indicator layer to the criterion layer:

Economy:$B_1 = W_1 * R_1 = (0.22, 0.50,0.28,0.00)$

Reliability:$B_2 = W_2 * R_2 = (0.43, 0.50,0.07,0.00)$

Timeliness:$B_3 = W_3 * R_3 = (0.44, 0.48,0.08,0.00)$

Robustness:$B_4 = W_4 * R_4 = (0.17, 0.58,0.25,0.00)$

Second-Level Fuzzy Comprehensive Operation

Construct the total membership matrix:

$$R = \begin{bmatrix} 0.22 & 0.50 & 0.28 & 0.00 \\ 0.43 & 0.50 & 0.07 & 0.00 \\ 0.44 & 0.48 & 0.08 & 0.00 \\ 0.17 & 0.58 & 0.25 & 0.00 \end{bmatrix}$$

Comprehensive evaluation vector:

$$B = W * R = (0.35, 0.51,0.14,0.00)$$

Comprehensive Score Calculation and Grade Determination

$$S = B * C^T = 0.35 \times 95 + 0.51 \times 85 + 0.14 \times 70 + 0.00 \times 30 = 84.85$$

According to the grade interval: 80-89 points is "good", and the effectiveness grade of peacetime-wartime conversion for this civil air defense work is determined as "good".

3.4. Analysis of Empirical Results

The empirical evaluation results show that the comprehensive score of peacetime-wartime conversion effectiveness for this project is 84.85 points, with a grade of "good", which fully meets the actual combat support requirements of Grade B civil air defense works. From the performance of the criterion layer, timeliness and reliability have outstanding scores, which are the core advantages supporting the project to reach a good grade. The combined weight of these two indicators reaches 0.67, with fast emergency response, short conversion period, stable equipment operation and high functional compliance rate, fully meeting the core combat readiness needs of "rapid conversion and stable protection" for civil air defense works. The scores of economy and robustness are relatively moderate, with basically reasonable cost control and resource reuse level, but there is room for improvement in complex environment adaptability, operation fault tolerance and emergency redundancy configuration.

From the perspective of indicator layer shortcomings, the project mainly has deficiencies in three indicators: reuse benefit of combat readiness resources, anti-interference capability under complex working conditions and emergency alternative redundancy capability, which are the key factors restricting the effectiveness from upgrading to "excellent". The above problems can be improved by optimizing the connection of peacetime and wartime functions, improving backup systems and strengthening adaptability to extreme working conditions. The evaluation results objectively reflect the true status of the project and are highly consistent with the actual situation of the project, verifying the effectiveness of the AHP-Fuzzy Comprehensive Evaluation Model in dealing with fuzzy indicators and realizing multi-dimensional integrated evaluation, which can provide accurate support for shortcoming identification, effectiveness optimization and management decision-making of similar civil air defense works.

3.5. Optimization Countermeasures and Suggestions

Combined with the evaluation results and project shortcomings, focusing on the four core dimensions of timeliness, reliability, economy and robustness, the following countermeasures for improving peacetime-wartime conversion effectiveness are proposed, providing practical directions for project management and optimization and upgrading.

In terms of improving timeliness, establish standardized processes and digital plans for peacetime-wartime conversion, implement node-based and time-limited management, carry out regular actual combat-oriented drills, optimize process connection, further compress emergency response and overall conversion duration, and ensure rapid activation. In terms of ensuring reliability, improve the normalized inspection, maintenance and repair mechanism of key equipment, conduct regular functional tests and compliance acceptance, strengthen quality control throughout the conversion process, and ensure stable and reliable wartime protection functions.

In terms of economic optimization, implement full life-cycle cost control, reasonably control conversion and operation & maintenance investment, improve the design level of peacetime-wartime function compatibility, increase the comprehensive utilization rate of facilities, equipment and civil air defense spaces, and enhance the reuse benefit of combat readiness resources. In terms of enhancing robustness, improve the redundancy configuration of key systems and backup plans, enhance adaptability to complex working conditions and fault tolerance of operations, and strengthen the continuous support capability of the project under extreme conditions. At the same time, accelerate the construction of a digital management platform, strengthen professional training for personnel, build a long-term operation and maintenance management mechanism, and continuously improve the comprehensive effectiveness of peacetime-wartime conversion for civil air defense works.

4. Conclusion

Taking the effectiveness evaluation of peacetime-wartime conversion for civil air defense works as the research object, aiming at the problems of imperfect indicator system, excessive qualitative descriptions, large subjective deviation and difficulty in realizing accurate quantification and grade determination in traditional evaluation methods, this study constructs an AHP-Fuzzy Comprehensive Evaluation combined model, systematically carrying out research on the construction of indicator system, weight determination, fuzzy quantitative calculation and empirical application. A three-level effectiveness evaluation system including 4 dimensions (economy, reliability, timeliness and robustness) and 12 indicators is established. The Analytic Hierarchy Process is adopted for scientific weighting and consistency test, and the Fuzzy Comprehensive Evaluation Method is used to realize the quantification of fuzzy indicators, multi-level comprehensive operation and four-level effectiveness grade determination. Taking a Grade B combined peacetime-wartime underground garage civil air defense work in the core area of a city as the empirical object, the comprehensive score is 84.85 points, with a grade of "good", and the evaluation results are highly consistent with the actual status of the project.

The research results show that the AHP-Fuzzy Comprehensive Evaluation Model can effectively deal with the fuzziness, uncertainty and multi-dimensional coupling problems in the evaluation

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of peacetime-wartime conversion for civil air defense works, significantly improving the standardization of the evaluation process and the objectivity of the results. It can provide scientific and reliable technical support for effectiveness diagnosis, identification of weak links, optimization of conversion processes and operation and maintenance management decision-making of peacetime-wartime conversion. The model has both theoretical rationality and engineering practicality, and is applicable to the effectiveness evaluation of various combined peacetime-wartime civil air defense works, with good promotion and application value.

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