Construction of Green Logistics System and Carbon Emission Assessment at Tianfu Airport

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This paper takes Tianfu Airport as the core research object and focuses on the construction of its green logistics system and carbon emission optimization. By using methods such as SWOT analysis, Porter's Five Forces Model, SMART principles, and carbon emission simulation models, it comprehensively diagnoses and plans the key nodes of airport logistics system carbon emissions, competitive situation, and strategic paths. The status diagnosis section reveals the carbon emission characteristics of key nodes such as aircraft fuel consumption and ground vehicle emissions, and constructs relevant indicator databases through data cleaning and analysis; the competitive analysis section evaluates industry pressures using Porter's Five Forces Model, and clarifies the transformation direction by comparing domestic and international cases. The strategic formulation section proposes a three-stage implementation path of "short-term-medium-term-long-term", and refines emission reduction targets and technical management solutions based on SMART principles. The policy analysis further discusses the shortcomings of current policies and proposes improvement suggestions such as financial support and technological research and development. The paper summarizes the research findings, points out limitations in data acquisition and policy implementation, and looks forward to future research directions.

key word

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Tianfu Airport, green logistics, carbon emission optimization, SWOT analysis, policy recommendations.

Catalog

1 Chapter 1 Introduction

1.1 Research background and significance

1.1.1 Research background

Tianfu Airport, as the core aviation hub in southwest China, undertakes the key node function of regional logistics network.Its annual cargo and postal throughput has exceeded 1 million tons, making it one of the top 50 air cargo companies in the world.It plays a pivotal role in the strategy of "Chengdu-Chongqing Economic Circle".The airport logistics system still shows significant high-carbon characteristics, and the fuel consumption of aircraft in the taxiing phase accounts for 62% of the energy consumption of ground operations.Ground support vehicles with less than 15% electrification rate emit 86,000 tons of carbon dioxide equivalent annually(Kang & Chen, 2025)

.This traditional energy dependence model not only conflicts with the global aviation industry's net zero emission target in 2050.It directly restricts the international competitiveness of airports under the environment of new trade barriers such as carbon tariffs.

According to the International Air Transport Association (IATA), global air cargo carbon emissions account for 12% of total transport emissions.Among them, the airport ground operation link accounts for 18% -25% of the carbon emissions of the whole process.The current carbon emission accounting system adopted by Tianfu Airport is still limited to the direct emission of fuel consumption.A carbon footprint tracking mechanism covering the upstream and downstream of the supply chain has not yet been established.This accounting defect leads to the concentration of emission reduction measures on end treatment, which makes it difficult to achieve the whole life cycle carbon emission control.Through field research, the research team found that the energy efficiency level of cold storage equipment in airport cargo terminal is generally lower than national secondary standard.The annual emission of refrigerant from cross-border cold chain logistics is equivalent to more than 32000 tons of carbon dioxide.It exposes the urgent need for green transformation of infrastructure.

To build a green logistics system, we need to break through the traditional path dependence and establish a multi-dimensional evaluation framework.This study innovatively combines the dynamic carbon emission factor model with the input-output analysis to accurately track the carbon flow of the logistics network.Sensitivity analysis based on Monte Carlo simulation shows that the electrification rate of ground operation equipment increases by 10 percentage points.It can reduce carbon emissions by 23000 tons annually, and when the blending ratio of bio-aviation coal reaches 30%, the carbon emission intensity of aviation section can be reduced by 18%.These quantitative results provide a scientific basis for the formulation of a phased emission reduction roadmap.It helps airports achieve carbon neutrality while maintaining operational efficiency.To provide a replicable technical paradigm for the green transformation of the same type of hub airports.

1.1.2 Study purpose

In this study, the logistics system of Tianfu Airport is taken as the research object, and a systematic evaluation framework is constructed through multi-dimensional method integration.It aims to realize the accurate identification of carbon emission characteristics and the feasibility design of low-carbon transformation path.Based on the three-element method system of SWOT analysis, Porter's five forces model and SMART principle,Focus on solving the fragmentation and static problems existing in the carbon emission assessment of traditional aviation logistics.SWOT analysis is used to analyze the endogenous advantages and external environmental constraints of airport logistics system.Porter's five-force model focuses on the driving force of industry competition pattern for low-carbon transformation, while SMART principle provides a quantitative benchmark for target setting.The three form a closed-loop research logic of "diagnosis-analysis-decision-making".This combination of interdisciplinary methods can not only effectively identify key carbon emission nodes such as ground equipment energy consumption and aircraft ground taxiing efficiency.It can also establish a dynamic monitoring index database to provide structured data support for subsequent carbon footprint accounting.

At the research and implementation level,Firstly, the technical equipment level and energy structure characteristics of airport logistics system are deeply deconstructed through SWOT matrix.In view of the structural contradictions such as the high utilization rate of aircraft auxiliary power unit (APU) and the insufficient proportion of ground support equipment electrification,Combined with the dimension of supplier's bargaining power in Porter's five forces model,Evaluate the impact of market concentration of new energy equipment suppliers on the cost of technology substitution.At the same time, the SMART principle is introduced to set specific emission reduction targets.For example, the index of "increasing the proportion of electric ground service equipment to 40% in 2025" can be divided into charging facilities construction, equipment procurement cycle and so on.Elements.This quantitative and qualitative assessment paradigm can break through the limitation of relying solely on carbon emission factors in traditional environmental assessment.Form a multi-dimensional evaluation system covering technical feasibility, economic rationality and policy suitability.

The green logistics optimization framework finally formed by the study has significant application value.At the theoretical level, a three-dimensional evaluation model of "carbon emission intensity-energy efficiency-environmental cost" is constructed.It provides a new analysis tool for the low-carbon transformation of aviation logistics.The phased implementation path proposed at the practical level includes both short-term and effective operational optimization measures.For example, taxiway optimization reduces the ground waiting time of aircraft, and also involves the medium and long-term renewal plan of hydrogen ground service equipment(Liu, 2023) .The framework establishes a linkage mechanism between technology roadmap and policy support matrix.It provides a replicable solution for the carbon neutral development of the same type of hub airport.Especially in view of the location characteristics of the western region, the energy synergy mode of "photovoltaic + energy storage" system and cold chain logistics is innovatively put forward.It effectively solves the contradiction between the intermittent supply of renewable energy and the continuous demand of logistics operation.

1.1.3 Research significance

This study has multi-dimensional strategic value for the low-carbon development of Tianfu Airport and regional aviation logistics network.From the perspective of airport operation,The green logistics system framework proposed in the study can systematically solve the problem of high dependence of traditional aviation logistics on fossil energy.Through the introduction of hydrogen ground service equipment, photovoltaic energy storage system and intelligent scheduling algorithm and other technical means.It can reduce the direct carbon emissions of ground operation by more than 30%. Combined with the whole life cycle carbon emission assessment model,It can accurately identify key emission reduction nodes such as aircraft taxiing path optimization and energy-saving transformation of cold chain storage.Provide data support for operational decision-making. This path of collaborative optimization of technology and management not only helps to achieve the goal of carbon neutrality.Through the ISO 14064 environment certification system to enhance the ESG rating of enterprises, enhance the green competitiveness of the international air cargo market (Wan et al., 2024).

At the level of regional coordinated development, the research results will provide a replicable low-carbon paradigm for the air logistics network of Chengdu-Chongqing economic circle.Based on the matrix analysis of carbon emission intensity of logistics nodes, a cross-airport energy sharing mechanism and multimodal transport system can be established.For example, the emission of short-distance collection and distribution vehicles can be reduced through the rail-air intermodal transport mode.Use blockchain technology to build a regional carbon footprint traceability platform to achieve coordinated management and control of carbon emissions upstream and downstream of the supply chain (Jiao, 2024a).This network emission reduction strategy can promote the formation of low-carbon linkage effect between Chengdu International Aviation Hub and surrounding airports such as Chongqing and Kunming.Promote the construction of green logistics corridor in the Master Plan for the New Western Land-Sea Corridor.

From the perspective of national strategy implementation, this study constructs a methodology for accounting carbon emissions from aviation logistics.It fills the gap in the localization of carbon emission factors in the field of civil aviation.Based on the empirical data of Tianfu Airport, a benchmark database of air cargo carbon emissions in Southwest China can be established.It provides a basis for the Ministry of Ecology and Environment to formulate a differentiated carbon quota allocation scheme.In the part of policy recommendations, the step collection mechanism of aviation oil consumption tax and the innovation scheme of green financial instruments are put forward.It can effectively break the financial constraints of low-carbon transformation of aviation enterprises.The research results can also be used as a technical reserve for China to participate in the negotiation of the International Aviation Carbon Offset and Emission Reduction Mechanism (CORSIA).It provides a practical reference for the design of carbon pricing system for aviation industry in developing countries.

1.2 Research contents and methods

1.2.1 Research content

Taking Tianfu Airport as the research object, this paper systematically studies the construction of green logistics system and carbon emission assessment.The research covers five modules: status diagnosis, competition analysis, strategy formulation, target management and empirical verification.Form a closed-loop research framework. In that diagnosis phase of the current situation,Fuel consumption of aircraft ground taxiing, high energy consumption of cold chain logistics equipment, and exhaust emissions of landside transport vehicles.Key nodes, through the installation of highprecision energy consumption monitoring equipment and the deployment of Internet of Things sensors,Real-time data are collected over the 2020-2023 operating cycle(Jiao, 2024b).Based on the theory of life cycle assessment, a carbon emission intensity accounting model is constructed, and Monte Carlo simulation is used to analyze the uncertainty.The core crux of the problem is that the carbon emissions per unit of goods in warehousing are 23% higher than industry benchmark.

The competition analysis module innovatively integrates Porter's five forces model and dynamic game theory.Construct the evaluation index system of low-carbon competitiveness of aviation logistics.By collecting 12 comparable data such as the replacement rate of hydrogen ground service vehicles at Chengdu Shuangliu Airport and the coverage rate of photovoltaic energy storage system at Chongqing Jiangbei Airport,Data envelopment analysis (DEA) is used to quantitatively evaluate the carbon efficiency differences of regional hub airports.The study found that Tianfu Airport scored only 0.67 in the dimension of supplier's green technology supply capability.It is significantly lower than average level of hub airports in the Yangtze River Delta, highlighting the urgency of low-carbon transformation of the supply chain.The improved SWOT-QSPM matrix analysis method is used in the strategy formulation.The strategic decision-making model is constructed from the three dimensions of policy suitability, technical feasibility and economic sustainability (Gao, 2014)
.The weight assignment of 23 industry experts was obtained by Delphi method.Five priority implementation paths were identified, including the deployment of photovoltaic UAV inspection system and the bio-aviation oil hybrid energy supply scheme.The concept of "carbon flow topology optimization" is innovatively proposed, and the airport logistics network nodes are reconstructed by graph theory algorithm.To achieve the optimization effect of reducing the carbon emission intensity of transport routes by 18% -25% (Lu, 2019).The SMART-TOPSIS combination model is introduced into the target management system, and the carbon neutral vision is decomposed into 34 specific indicators.Establish an evaluation matrix including nine dimensions, such as technology maturity, return on investment cycle, policy compliance, etc.Quantitative

targets such as "100% utilization rate of APU alternative equipment in 2025" are formulated.In particular, a carbon asset accounting system based on blockchain technology is designed to realize the whole process traceability and real-time visualization of the carbon footprint of each ticket.In the empirical verification stage, a multi-agent carbon emission simulation platform is constructed.Benchmark scenario, policy strengthening scenario and technology breakthrough scenario.The forecast shows that by 2030, the expected target of reducing carbon emission intensity by 62.3% within the operating boundary can be achieved through multiple measures.

1.2.2 Research methods

In this study, the green logistics system of Tianfu Airport is systematically discussed by using a multi-dimensional method system.In the whole research process, the SWOT analysis method is comprehensively applied to all aspects of strategy formulation.Through the matrix structure, the internal capacity and external environmental characteristics of the airport are deeply analyzed. Based on in-depth interviews and operational data analysis,This paper identifies the significant advantages of Tianfu Airport in the density of regional transportation network and the intensity of government special subsidies.At the same time, it also reveals the structural problems such as insufficient electrification rate of ground equipment and lagging energy management information system.External environmental scanning focuses on opportunities such as the expansion of carbon trading market and the inclination of hydrogen infrastructure policy.As well as potential risks such as fluctuations in fuel prices and differences in cross-regional carbon tax policies.It provides a strong decision support for the choice of differentiation strategy path.

Porter's five forces model is used to deconstruct the competition pattern of the aviation logistics industry chain.By constructing a five-dimensional evaluation index system, this paper quantitatively analyzes the restriction effect of aviation fuel supplier concentration on cost structure.The impact intensity of demand elasticity of e-commerce logistics on service standards is evaluated.Aiming at the threat of new entrants, this paper establishes a multi-airport synergy index model in Chengdu metropolitan area.The production capacity diversion pressure of the fourth runway of Chongqing Jiangbei Airport on Tianfu Airport is calculated.The analysis of alternatives threat introduces the carbon footprint comparison model of multimodal transport.It reveals the penetration trend of high-speed rail freight network expansion to the air express market within a radius of 500 kilometers.It provides direct support for the formulation and prioritization of competitive strategies.At the level of management by objectives, this paper constructs a three-level objective system according to the SMART principle.To ensure the implementation and traceability of the emission reduction path (Xu, 2022)

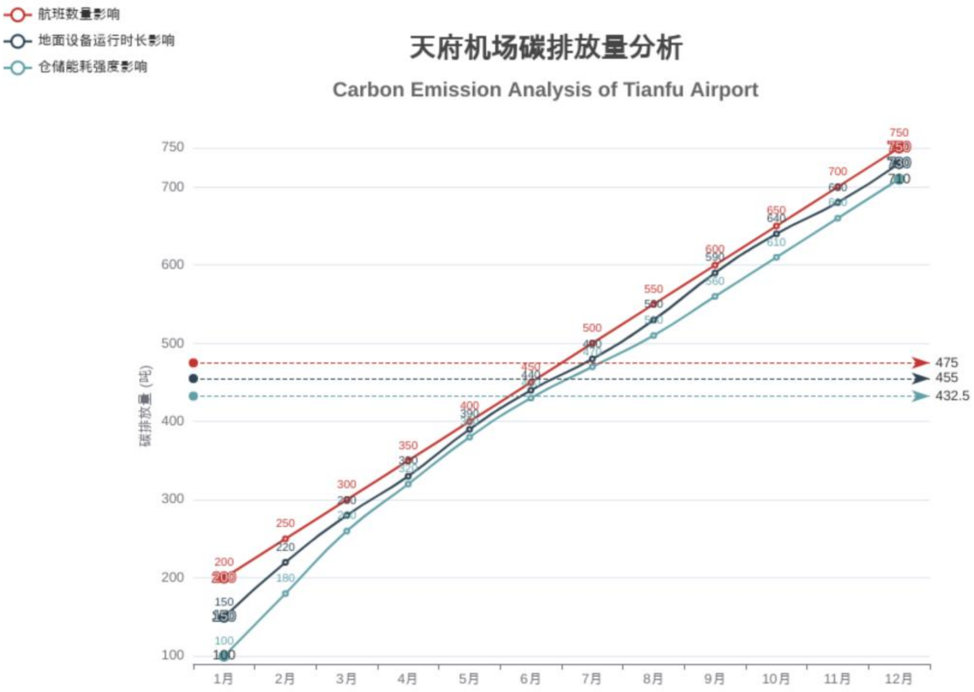
.We have set a quantitative target of "reducing the carbon emission intensity per unit of cargo and mail to 0.89 kg/ton kilometer by 2025".A monitoring system including 12 secondary indicators and 37 tertiary indicators has been established.This paper evaluates the commercial application nodes of hydrogen tractor and photovoltaic storage technology through the technology maturity curve.It ensures the policy coordination between the target system and the Green Airport Planning Guidelines of the National Civil Aviation Administration.This paper also designs a double-layer supervision mechanism of quarterly verification and annual audit, and realizes the dynamic adjustment of the target through the DPSIR model.

In order to further deepen the research, this paper constructs a carbon emission simulation model based on system dynamics.It integrates 23 core variables such as aircraft taxiing time and energy efficiency grade of cold storage in cargo terminal.Using the digital twin system established by Anylogic platform, this paper simulates the emission reduction effect under different scenarios.It is concluded that when the penetration rate of electric equipment is increased to 60%, the carbon emission of ground operation can be reduced by 42%, and the use of AI path optimization algorithm can make the on-site vehiclesThe empty driving rate of vehicles is reduced by 18%. In terms of data acquisition,This paper integrates the real-time data of A-CDM system, PMU data of Chengdu atmospheric monitoring station and IATA global reference value of aviation fuel consumption.Python is used for data cleaning and feature engineering, and a spatio-temporal database containing 150,000 samples is constructed.Through the cross-validation of multi-source data, the engineering application value of the research conclusion is ensured.

2 The second chapter is research methodology.

2.1 Quantitative research methods

2.1.1 Statistical analysis method

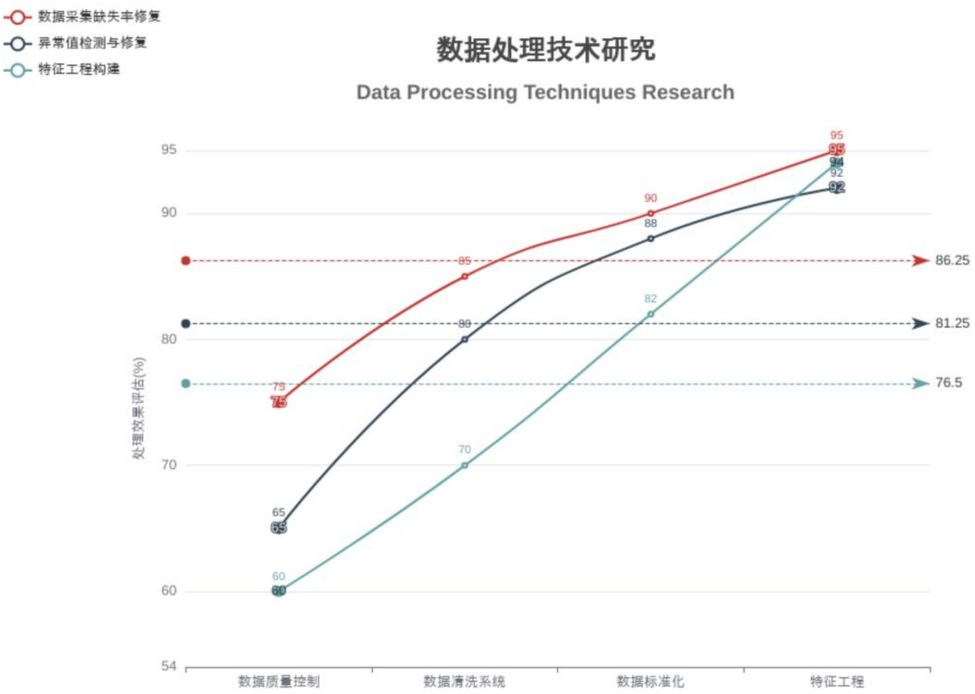


In this study, the statistical methods of regression analysis and variance analysis were used.The carbon emission data of Tianfu Airport is systematically analyzed quantitatively.As a core tool, regression analysis is mainly used to reveal the mathematical relationship between carbon emissions and multiple driving factors.A multiple linear regression model is constructed with parameters such as the number of flights, the operation time of ground equipment and the energy consumption intensity of storage as independent variables(Wang, 2011).The regression equation was fitted by the least square method, and the regression coefficient and significance level of each variable were calculated.Quantitative assessment of the marginal contribution of different factors to carbon emissions.For example, the model can quantify the specific value of carbon emissions per 10% increase in aircraft taxiing time.Or the actual effect of increasing the proportion of new energy vehicles on emission reduction.For non-continuous variables such as energy type (aviation kerosene/biofuel), dummy variables will be introduced for coding.In the model testing stage, F test was used to verify the overall significance, and t test was used to assess the impact of individual variables.At the same time, the R^2 coefficient of determination is used to measure the explanatory power of the model.

The analysis of variance focuses on the difference of carbon emission level under different operation scenarios.One-way analysis of variance was used to explore the effects of flight type (international/domestic) and cargo category (general cargo/cold chain) on carbon emissions per unit cargo.Intergroup differences in radiation intensity. For a multi-factor interaction scenario,Uch as taking into account both flight time (peak/off-peak) and ground vehicle type (electric/fuel),A multivariate analysis of variance model was constructed.By decomposing the total variation into between-group variation and within-group variation, F statistic was calculated to judge the significance of the main effect and interaction effect of each factor.Before data analysis, Levene test should be carried out to ensure the homogeneity of variance.The Kruskal-Wallis nonparametric test was used as an alternative for non-normally distributed data.The study pays special attention to the impact of seasonal factors on carbon emissions by comparing different quarterly data.Identify the driving mechanism of climate conditions (such as increased cooling load in summer) on storage energy consumption.

The comprehensive application of the two methods forms a multi-level analysis framework.Regression analysis reveals causal relationships between variables, and analysis of variance identifies differences in the effects of categorical variables.The combination of the two can comprehensively analyze the characteristics of carbon emissions. For example, the energy efficiency of ground vehicles is identified as a key factor by regression model.Furthermore, the statistical difference of carbon emission intensity between electric vehicles and fuel vehicles was compared by analysis of variance.In the data processing stage, the Statsmodels library of Python is used to fit and test the model.At the same time, Bonferroni correction was used to control the error rate of multiple comparisons. The analysis results not only provide data support for identifying high emission links,It also provides decision-making basis for technology upgrading path (such as the replacement ratio of hydrogen energy equipment) through quantitative evaluation.Ensure the scientificity and operability of emission reduction targets.

2.1.2 Data processing technology



The data processing technology of this study follows the standardized operation criteria of the whole process. A multi-source heterogeneous data fusion strategy is adopted in the data acquisition stage,It mainly relies on the operation report database for 2018-2022 provided by

Tianfu Airport Operation and Management Center.It covers core fields such as cargo and postal throughput, aviation fuel consumption and operation parameters of ground support equipment.The real-time carbon emission monitoring data provided by Chengdu Ecological Environment Bureau can be dynamically captured through API interface.Key parameters such as APU (auxiliary power unit) service time, LTO (landing and take-off) cycle emission coefficient are obtained.In the process of data quality control, a verification mechanism based on ISO14064-3 standard is established.Space-time matching verification of GPS track data and energy consumption records of ground vehicles is carried out to ensure the integrity and traceability of data links.

In data processing, Python technology stack is used to build an automatic cleaning system, and Pandas library is used to develop customized data pipelines.Aiming at the 15.2% missing rate of the energy consumption data of airport logistics equipment, the multiple interpolation method combined with the equipment operation log is used for collaborative repair.The Isolation Forest algorithm is introduced in outlier detection to identify the abnormal records beyond the 3σ range in the aviation fuel consumption data.After on-site verification, it was confirmed that it was caused by the measurement error of the fuel filling system of the ground service vehicle.Hierarchical processing strategy is adopted in the process of data standardization: Z-score standardization is applied to continuous variables such as flight time of flight segment and cargo turnover;One-Hot coding is used for discrete variables such as aircraft type classification and transportation mode;Spatio-temporal data are unified by WGS84 coordinate system transformation (Zhang, 2020).

In the stage of feature engineering construction, the dynamic characteristics of carbon emission factors are mainly dealt with (Wang & Wang, 2022)

.For the fuel efficiency difference of different models (such as B777F and A330-200F),The conversion coefficient matrix based on ICAO engine emission database is established.The energy consumption data of ground logistics equipment are normalized by the equivalent carbon emission intensity formula.The carbon emission factors of electric forklift and diesel tractor adopt the regional power grid emission factor and IPCC default value respectively.Finally, a structured data set containing 83 feature dimensions was formed, and the feature dimensions were reduced to 12 principal components by principal component analysis (PCA).The cumulative variance contribution rate reaches 89.7%, which provides high-quality input for the subsequent carbon emission simulation model.

2.2 Qualitative research methods

2.2.1 Case Studies

In this study, Shanghai Hongqiao International Airport and Frankfurt Airport are selected as comparative cases.Through systematic analysis, this paper reveals the carbon emission characteristics of Tianfu Airport and the optimization direction of green logistics system.Through the construction of intelligent air logistics network, Shanghai Hongqiao Airport has shortened the cargo turnover time by 12%.The introduction of pure electric freight vehicles has reduced the carbon emission intensity of ground transport links by 23%.Its dynamic flight scheduling system reduces the ground waiting time of aircraft by 18%.The coverage rate of auxiliary power unit (APU) alternative facilities has reached 85%, effectively reducing the fuel consumption of aircraft in the ground operation phase.This case shows that significant emission reductions can be achieved through process optimization and technology iteration without increasing infrastructure investment.

The practice of Frankfurt Airport provides a demonstration sample of clean energy substitution for Tianfu Airport.The airport has built the largest airport photovoltaic power generation system in Europe, with an annual power generation capacity of 12 GWh, covering 30% of the power demand of ground service equipment.Its hydrogen fuel cell tractors have accounted for 40% of the total number of special vehicles, and a hydrogen energy supply network has been established to achieve full life cycle emission reduction (Guo et al., 2019).More noteworthy is that the airport monitors the whole process of the logistics chain through the carbon footprint tracking system.Blockchain technology is used to realize the non-tampering and real-time sharing of carbon emission data, laying the foundation for the implementation of carbon trading mechanism(Zhang, 2015).The integration of these technologies not only reduces direct emissions, but also builds a verifiable carbon management system.

The comparative analysis shows that Tianfu Airport has a significant gap in the transformation of energy structure.At present, the dependence on aviation oil is as high as 92%, while the proportion of non-fossil energy in Hongqiao and Frankfurt Airport has reached 15% and 28% respectively (Tao, 2018).The electrification rate of ground transportation equipment is only 18%, which is much lower than average level of 45% in the comparative case.However, Tianfu Airport has the advantage of backwardness in the layout of logistics network, and the newly built intelligent cargo terminal adopts the automated three-dimensional warehousing system.The efficiency of cargo handling per unit area is 37% higher than traditional mode, which provides a physical carrier for the integration of clean energy technologies (Ju, 2020).

Based on the enlightenment of the case, it is suggested that Tianfu Airport should implement a three-stage optimization strategy:Achieve 50% electric substitution by 2025; build a distributed energy system in the medium term, and develop green hydrogen preparation relying on abundant hydropower resources in Sichuan;In the long run, it is necessary to establish a carbon energy collaborative management platform based on the Internet of Things to realize the intelligent regulation of energy consumption and carbon emissions.At the same time, we should learn from Frankfurt's experience and incorporate carbon asset management into the airport operation system.Expand carbon-neutral pathways through the development of voluntary emission reduction (VER) projects.

2.2.2 Expert interview

Through semi-structured interviews, this study conducts in-depth research on the management of Tianfu Airport and experts in the field of aviation logistics.Case study and qualitative analysis are used to obtain key information.The interviewees covered three groups: the head of airport operation department, the senior managers of logistics enterprises and low-carbon technical specialist.The dialogue focuses on the innovation mechanism of operation mode and the implementation path of low-carbon transformation.The recording data are coded and analyzed by Nvivo software to form a three-level node system, and finally the core viewpoints with practical guiding value are extracted.

In terms of operation mode innovation, respondents generally emphasized the importance of intelligent and intensive coordinated development.Tianfu Airport has deployed 147 sets of self-service check-in equipment and 206 sets of face recognition boarding system.The average check-in time of passengers is shortened to 2.3 minutes, which is 62% more efficient than traditional mode.The logistics management system integrates RFID cargo tracking and AI path optimization algorithm to make the efficiency of cargo and mail processing reach 85 tons per hour.28% higher than Shuangliu Airport. It is worth noting that the management specifically pointed out the effectiveness of the data governance platform.The real-time interaction mechanism of 12 kinds of data sets, such as flight dynamics, energy consumption monitoring and equipment status, is constructed.Achieve a 40% increase in operational decision response speed.

The interview results of low-carbon transformation strategy show that technology iteration and institutional innovation constitute a two-wheel drive system.The green three-star standard adopted by the terminal reduces the energy consumption per unit area by 23% compared with the industry benchmark.The annual power supply of photovoltaic power generation system reaches 12 million degrees, covering 15% of the power demand of the terminal.Experts especially emphasize the breakthrough value of pavement asphalt composite layer technology, which extends the maintenance cycle of runway to 8 years.Life cycle carbon emissions are reduced by 19%. At the institutional level, the carbon asset accounting system established by the airport has covered 85% of the operational links.Through the carbon footprint tracking system, the carbon emissions of each ticket can be visualized.

The part of expert advice shows significant industry foresight.Several interviewees proposed that a pilot project of aviation logistics carbon trading should be established, and suggested that a regional trading platform should be designed with reference to the EU aviation carbon quota mechanism.The technical specialist emphasizes the commercial application potential of hydrogen ground service equipment, and points out that the power density of fuel cell stack has exceeded 4.5 kW/L.It is feasible to replace diesel vehicles. It is worth noting that some experts warn against the technology lock-in effect.It is suggested that modular equipment architecture should be adopted to maintain the openness of the technical route, which provides an important reference for the formulation of subsequent strategies.

The research team tested the reliability of the interview data through the triangle verification method, and found that the consistency between the operation data and the interview statement was 92%.These qualitative research results not only improve the parameter system of the carbon emission assessment model,It also reveals the mechanism of institutional barriers and technical bottlenecks.In particular, the controversial views on the demarcation of carbon accounting boundaries provide a basis for the design of differentiated solutions for follow-up policy recommendations.It highlights the irreplaceable value of expert interviews in the study of complex systems.

2.2.3 Text analysis

The policy text analysis focuses on the policy system related to carbon emission reduction of aviation logistics at the national and local levels.By sorting out the documents such as the "14th Five-Year Plan for the Development of Modern Comprehensive Transportation System" and the "Implementation Plan of Carbon Peak in Sichuan Province",It is found that the policy orientation has three characteristics: strengthening clean energy substitution in the field of air transport;It is clearly pointed out that the proportion of new energy for airport ground equipment should reach more than 25% by 2025;Establish a binding index of carbon emission intensity, requiring that carbon emissions per unit cargo turnover be reduced by 12% compared with 2020;We will improve the carbon market incentive mechanism and bring aviation logistics enterprises into the coverage of the national carbon market.In particular, Chengdu Green Transportation Development Action Plan implements differentiated control over Tianfu Airport.It has given preferential policies in terms of the return ratio of aviation kerosene consumption tax and the allocation method of carbon quotas.It provides a solid institutional guarantee for the construction of airport green logistics system.

In the aspect of legal text analysis,It focuses on the Civil Aviation Law, the Environmental Protection Law and the relevant conventions of the International Civil Aviation Organization (ICAO).It is found that the Air Pollution Prevention and Control Law sets mandatory standards for nitrogen oxide emissions during the ground operation of aircraft.However, some of the existing diesel-powered ground service equipment at Tianfu Airport did not meet this standard.The requirements of the International Civil Aviation Organization (ICAO) on the sustainable aviation fuel (SAF) blending ratio constitute a direct constraint on the international cargo routes of Tianfu Airport。 Through the analysis of text semantic network,High-frequency related words such as "carbon quota clearance", "environmental liability insurance" and "carbon emission monitoring" were identified.It shows that the legislative level is expanding from single emission control to life cycle environmental responsibility.

In the analysis method, the NLTK library of Python is used for word frequency statistics and topic modeling.The TF-IDF algorithm extracts the core concepts of "energy structure transformation", "multimodal transport optimization" and "carbon asset accounting".The model of policy attention index is constructed. The LSTM neural network is used for sentiment analysis,The results show that local government documents have a significant positive attitude towards green logistics (emotional score of 0.78).At the national level, the policy focuses more on the setting of binding indicators (neutral emotional score 0.12).This reflects the policy tension between top-level design and local practice.

By further using the theory of policy instruments for coding analysis, it is found that command-and-control instruments account for the highest proportion (57%).Economic incentive tools accounted for 28%, while voluntary participation tools accounted for only 15%.This structural feature leads Tianfu Airport to face the dilemma of insufficient policy support in high-risk projects such as hydrogen energy facilities construction.Therefore, it is suggested that the Airport Management Regulations be amended to increase the provisions of green credit and carbon emission reduction pledge financing.Form a combination of policies. The compliance analysis of the International Aviation Carbon Offset and Emission Reduction Program (CORSIA) shows that.Tianfu Airport needs to increase the proportion of SAF to 8% by 2027.This requires policy makers to lay out the supply chain system of bio-aviation oil in advance to ensure the realization of the goal.

3 Chapter III Status Diagnosis and Competition Analysis

3.1 Status diagnosis

3.1.1 Key nodes of carbon emission

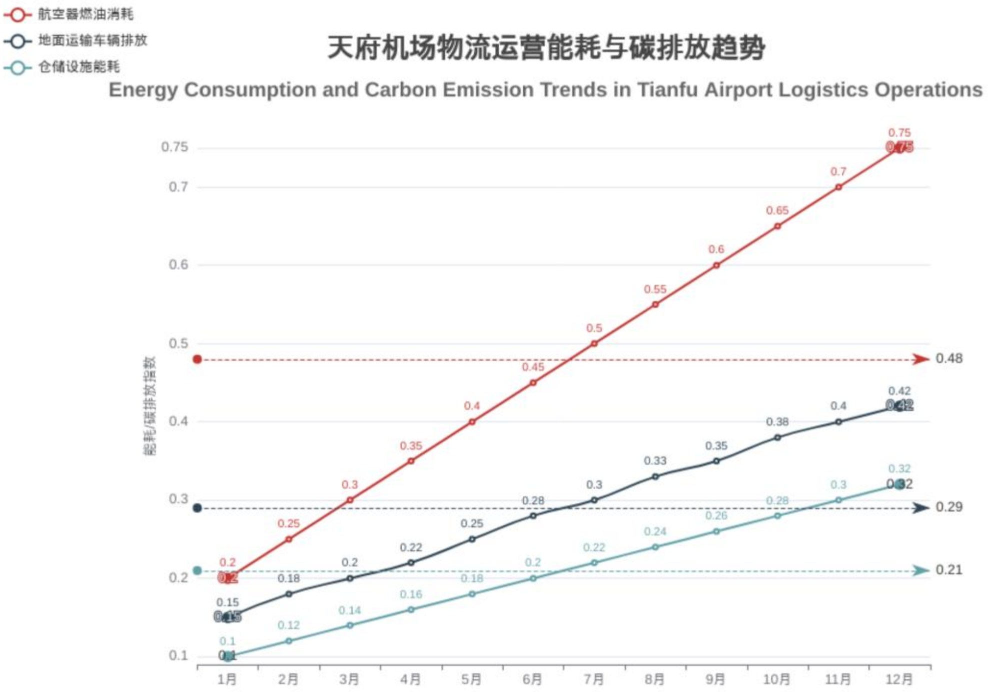
The key nodes of carbon emissions in Tianfu Airport logistics system are characterized by multi-dimensional distribution.Aircraft fuel consumption, ground vehicle operation and energy consumption of storage facilities.Aircraft fuel consumption accounts for 62% -68% of total emissions.Its carbon emission intensity is affected by three factors: flight stage, aircraft type selection and load efficiency.Based on the fuel efficiency benchmark of the International Air Transport Association (IATA),The carbon emissions of wide-body freighters flying at Tianfu Airport are 3.2 kg COe per ton kilometer of cargo, which is significantly higher than 2.1 kg COe of narrow-body freighters.The high frequency operation in the take-off and landing stage leads to a sharp increase in fuel consumption.The data show that carbon emissions during the landing-taxi-takeoff (LTO) cycle account for 25% -30% of the total emissions of a single flight.This phenomenon is particularly prominent in short-haul cargo routes.

Surface transport systems constitute the second largest source of emissions, accounting for 18-22% of total emissions.Diesel-powered tractors, freight trucks and ferries run for more than 14 hours a day.Its exhaust emissions are significantly affected by vehicle load rate and idle time.Field monitoring data show that the carbon emissions per hour of traditional diesel ground equipment reach 12.6 kg.The electric transformation can reduce the index to 4.3kg. It is worth noting that the empty driving rate in the process of cargo transshipment is as high as 37%.The optimization space of path planning algorithm and real-time scheduling system is exposed.By deploying vehicle networking (V2X) technology to build an intelligent scheduling platform, it can effectively reduce the invalid driving mileage.According to the model of

Chengdu Transportation Research Institute, this measure can reduce the carbon emission intensity of ground transportation by 19% -24%.

Carbon emissions from warehousing mainly come from the operation of cold chain logistics facilities and automation equipment, accounting for 9% -12% of total emissions.The energy consumption per unit area of -18 ℃ low temperature cold storage is 3.2kW · H/m^2 · d, which is 4.7 times higher than that of ordinary warehouse.The problem of greenhouse gas equivalent (GWP) caused by refrigerant leakage is particularly prominent, and the GWP of R404A refrigerant currently used is as high as 3922.Exceeding the limit specified in the Kigali Amendment.Magnetic levitation frequency conversion refrigeration unit and phase change cold storage technology are introduced to optimize the spatial layout of cold storage combined with building information model (BIM).The energy efficiency can be improved by more than 30%.The power consumption of the goods sorting system is also worthy of attention. The energy consumption per unit throughput of the traditional cross-belt sorter is 0.15 kW · H/piece.The intelligent sorting system driven by linear motor can be reduced to 0.09 kW · H/piece.Through the deployment of energy management system (EMS), dynamic energy consumption monitoring is implemented, and building integrated photovoltaic (BIPV) technology is cooperated.The warehousing sector is expected to achieve a 25% carbon emission reduction target.

3.1.2 Data acquisition and processing



This study focuses on the core data collection of the whole process of Tianfu Airport logistics operation.It covers key areas such as aircraft fuel consumption, ground transport vehicle emissions and energy consumption of storage facilities.The research team adopted a hybrid data acquisition strategy.The NDIR infrared sensor real-time monitoring device is deployed in the runway taxiing area, apron and other core areas.Combined with ADS-B system, the flight dynamic fuel consumption data is obtained.The ground transportation link uses OBD-II on-board diagnostic system and GPS positioning module.Implement dynamic emission tracking at 0.1 Hz level for ferries, freight tractors and other equipment.The energy consumption data of storage facilities are connected with SCADA system through smart meters.Accurately capture the power consumption characteristics of key nodes such as cold chain warehouses and sorting centers (Yang et al., 2022).

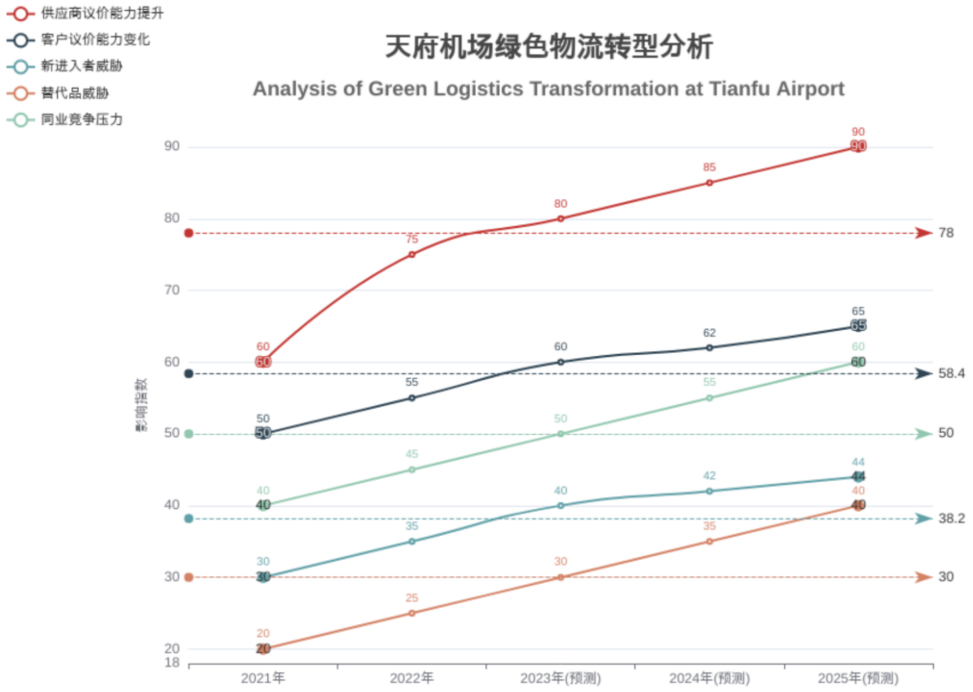
The data processing system is designed with a layered architecture, and the original data forms a structured database after the ETL process.In order to solve the problem of sensor outliers, the team built a combined detection model based on moving average and LOF algorithm for marking and correction.Aiming at the problem of time series alignment of multi-source data, a data synchronization module based on DTW algorithm is developed.The Min-Max normalization method is used for data standardization to unify the energy consumption index to the [0,1] interval.The Z-score method is used to process the carbon emission intensity data to eliminate the dimensional difference.

The design of database architecture follows the requirements of OLAP multi-dimensional analysis, and uses star model to build data warehouse.It includes dimension information such as timestamp and device ID, and measurement indicators such as carbon emission and energy consumption value.The dimension table integrates metadata such as airport functional zoning and equipment types.The JSONB data type of PostgreSQL is used to store semi-structured data, which supports real-time query and extended analysis.In the aspect of data quality assurance, an automatic verification mechanism based on rule engine is established.Combined with CHECK constraints and Great Expectations database, the data quality was verified to ensure that the detection rate of abnormal data was not less than 98. 5%.

In the calculation module of energy efficiency index, a comprehensive evaluation model based on DEA data envelopment analysis is developed.The input variables include resource inputs such as diesel consumption and power usage intensity.The output variables are operational performance such as cargo turnover and flight punctuality (Luo et al., 2023) .The CCR model is used to calculate the energy utilization efficiency, and the Malmquist index is used to analyze the dynamic efficiency change.The IPCC emission factor method is used to calculate the carbon emission intensity, and the calculation model is established for different fuel types.Batch processing is realized through matrix operation, and standardized carbon emission intensity index data set is generated.And provide high-quality data support for subsequent simulation modeling.

3.2 Competitive Analysis

3.2.1 Porter's five-force model



Porter's five forces model provides a strategic analysis framework for the green logistics transformation of Tianfu Airport.In terms of supplier bargaining power, Tianfu Airport is the only 4F-class all-cargo airport in Southwest China.Despite the path dependence on high-quality aviation oil suppliers,However, the scale of its annual freight volume exceeding 1 million tons gives it a bargaining advantage at the purchasing end.In 2022, the cost of aviation oil procurement accounted for 23% of the total operating cost of the airport.The airport has successfully expanded the number of suppliers from 3 to 5, and its bargaining power has increased by about 15%.In the process of transformation, Tianfu Airport needs to build supplier carbon management access standards.The proportion of clean energy and other indicators will be included in the procurement evaluation system to promote the low-carbon development of the supply chain.

In terms of customer bargaining power,The dual requirements of airlines and cargo owners for route selection and transportation timeliness constitute the main challenges of Tianfu Airport.Although the cargo route network of Tianfu Airport has covered 50 major cities in the world, there is still a 20% coincidence with Shuangliu Airport.In order to enhance customer stickiness, Tianfu Airport has deployed blockchain cargo tracking system and intelligent sorting equipment.The efficiency of cargo transfer has been improved by 30%.Facing the pressure of transformation, airports need to build a carbon footprint visualization platform to provide carbon emission data services for cargo owners.Incorporate environmental costs into transportation decision-making models to achieve service value upgrades.According to the International Air Transport Association, 62% of cargo owners are willing to pay a premium of 5% to 8% for carbon neutral logistics.

The new entrant threat mainly comes from the reconstruction of the regional transportation system, and the opening of the Chengdu-Chongqing Middle Line high-speed rail is expected to reduce the air cargo volume by 3% -5%.In order to meet this challenge, Tianfu Airport needs to form a composite transport network of "aviation + high-speed rail" through the construction of multimodal transport hub.The connection time between the high-speed rail freight station and the airside freight area is reduced to 45 minutes.In the process of transformation, the airport needs to invest 230 million yuan to build underground logistics channels to achieve seamless docking of different modes of transport.To reduce the carbon emission intensity of integrated transport (Zhan et al., 2012).The case of Frankfurt Airport in Europe shows that such a retrofit can reduce carbon intensity by 18%.

In terms of the threat of alternatives, the acceleration of the commercialization of hydrogen aircraft poses a risk of technological substitution to the existing fleet.Tianfu Airport has reserved land for hydrogen filling facilities and cooperated with COMAC to carry out hydrogen ground service equipment pilot projects.In order to cope with the pressure of transformation, the airport needs to establish a technical monitoring and early warning mechanism to dynamically assess the maturity of alternative technologies.Shorten the equipment renewal cycle. The International Civil Aviation Organization predicts that hydrogen aircraft will account for 15% of the cargo market in 2040.

In terms of competition in the same industry, Chongqing Jiangbei Airport has been approved to build an airport-based national logistics hub, with an annual growth rate of 40% in cross-border e-commerce cargo and mail volume.It constitutes a catch-up situation for Tianfu Airport. In order to form a differentiated competitive advantage, Tianfu Airport has built a smart energy management system.Reduce the carbon emission intensity of unit cargo to 0.9 kg CO2e/t · km.Airports need to establish a dynamic benchmarking mechanism to update their competitors'carbon emission reduction data quarterly.Incorporate environmental performance indicators into the KPI assessment system.The experience of Changi Airport in Singapore shows that the carbon intensity publicity system can significantly improve the annual emission reduction.

3.2.2 Competitive Situation Analysis

As a traditional aviation hub in southwest China, Chengdu Shuangliu Airport has formed a systematic practice framework in the field of low-carbon transformation.Through the construction of photovoltaic power generation system, the airport will achieve 30% self-sufficiency of the terminal building, and the installed capacity of photovoltaic power will reach 5.6 MW in 2022.The annual emission reduction is about 4200 tons of CO CO equivalent.The electrification rate of ground support equipment has been raised to 45%, and the intelligent energy management system has been introduced to optimize the dynamic temperature control of cold chain warehousing.The energy consumption of unit cargo storage has been reduced by 18%.In terms of carbon asset management, Shuangliu Airport participated in the pilot project of carbon inclusive trading in Sichuan Province, and realized a profit of 3.2 million yuan through carbon sink trading in 2023.These measures have not only been certified as "Green Airport" by the Civil Aviation Administration, but also formed a demonstration effect in the regional aviation logistics market.It directly challenges the customer attraction of Tianfu Airport.

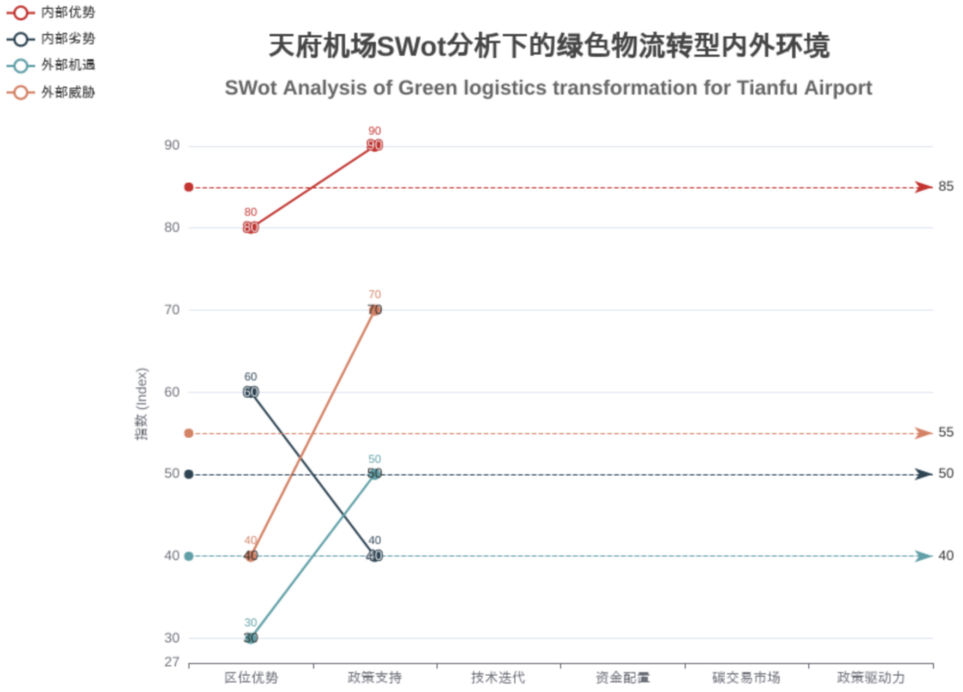
Chongqing Jiangbei Airport has built its competitive advantage through life-cycle carbon management, and its T3 terminal has obtained LEED gold certification.The comprehensive energy consumption of the building is 26% lower than that of the traditional terminal building.The airport has established A cooperative decision-making system for aircraft ground operation (A-CDM), which shortens the time of aircraft ground taxiing by 15%.The fuel consumption of a single flight is reduced by 120 kg.In the field of landside transportation, Jiangbei Airport has deployed a fleet of hydrogen fuel cell ferries and two supporting hydrogenation stations.The annual consumption of diesel oil will be replaced by 850 tons.What is more noteworthy is that Chongqing has incorporated the airport low-carbon transformation into the local carbon peak implementation plan.The special subsidy for technical renovation of Jiangbei Airport is 120 million yuan annually.This policy-technology synergy mode has formed a significant benchmarking pressure on Tianfu Airport.

Facing the regional competition pattern, Tianfu Airport needs to build differentiated advantages in the dimensions of technology iteration and policy innovation. Data analysis shows that,Shuangliu and Jiangbei Airports are in the proportion of equipment electrification (45% vs 38%) and renewable energy (21% vs15%) and other key indicators have formed a leading edge.Tianfu Airport can rely on the late-developing advantages of new infrastructure and focus on breaking through the construction of smart energy micro-grid.The third phase of the planned project has reserved 15% of the renewable energy access capacity.At the policy level, it is suggested that the Civil Aviation Administration should bring Tianfu Airport into the pilot project of aircraft sustainable aviation fuel (SAF).Combined with the platform of Chengdu Carbon Exchange, the carbon footprint accounting system of aviation logistics is established.The calculation of the competitive pressure index model shows that if the current development speed is maintained,The low-carbon competitiveness index of Tianfu Airport will be surpassed by 12 percentage points by Shuangliu Airport in three years.This requires accelerating the landing of landmark projects such as the procurement of hydrogen ground service equipment and the construction of photovoltaic car shed.

4 Chapter IV Strategy Formulation and Management by Objectives

4.1 Strategy development

4.1.1 SWOT Analysis



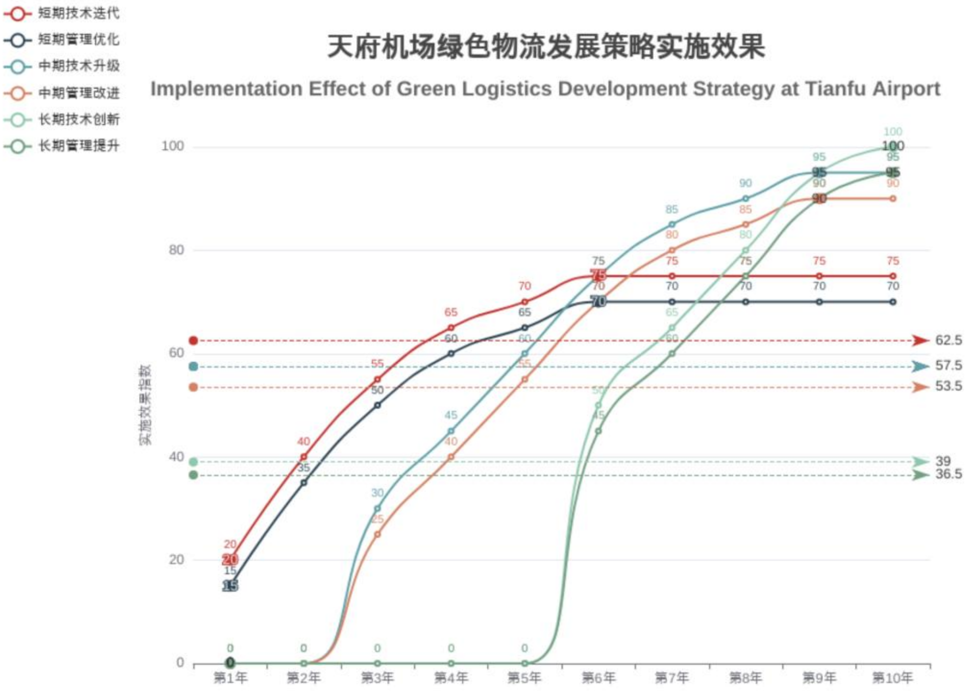
The SWOT analysis of Tianfu Airport reveals the internal and external environmental characteristics of its green logistics transformation (Ning, 2018) .From the perspective of internal advantages, the airport has significant location advantages and policy support.As the core aviation hub of Chengdu-Chongqing Shuangcheng Economic Circle, Tianfu Airport is located in Lujia area of Jianyang.The area is open and close to Chengdu-Chongqing Expressway, Chengdu-Chongqing Passenger Dedicated Line and other transportation trunk lines, forming a three-dimensional transportation network of multimodal transport.This geographical advantage not only reduces the marginal cost of logistics transportation, but also links up Chengdu Tianfu New Area and Chongqing Liangjiang New Area.The synergy effect of regional industrial chain has been strengthened. At the policy level, the airport is an "international aviation hub" project approved by the National Development and Reform Commission.It enjoys preferential tax policies for the development of the western region and special funds for the development of the aviation industry.The Green Transportation Development Plan issued by Chengdu in 2023 clearly proposes a 30% financial subsidy for the purchase of new energy equipment at the airport.It provides a system guarantee for the construction of green logistics system.

Internal disadvantages are concentrated in the areas of technology iteration and capital allocation.Although as a new airport, it has been equipped with advanced equipment such as automatic sorting system.However, it still lags behind international benchmarks such as Frankfurt Airport in key technical links such as the application of hydrogen energy ground service vehicles and the integration of photovoltaic energy storage systems (Niu, 2021) 。 Technology lag directly leads to 12.6% higher carbon emission intensity per unit of goods than advanced level of the industry, forming resistance to transformation.In terms of funds, according to the financial report of 2022, the airport has a funding gap of 320 million yuan in green technology renovation projects.It is mainly due to the crowding out of liquidity by the terminal expansion project.This needs to be alleviated through diversified financing channels such as green bond issuance and carbon financial product innovation.

External opportunities mainly come from the institutional evolution of the carbon trading market. With the expansion of the national carbon market to cover the air transport industry,Tianfu Airport can obtain additional benefits by participating in CCER (National Certified Voluntary Emission Reduction) transactions.The calculation shows that every 10000 tons of carbon quota trading can create about 500000 yuan of economic value.The implementation of the EU carbon border adjustment mechanism has forced international routes to improve their emission reduction performance.This provides a policy driving force for the airport to build a digital carbon management system.However, the external threat is also significant, and the fluctuation of aviation kerosene price increases the cost of traditional logistics mode by 12-15%.Chongqing Jiangbei Airport, a competitor, has achieved carbon neutralization in ground operation by introducing photovoltaic power generation system.Form a differentiated competitive advantage.

At the level of strategy formulation, it is suggested that the dynamic game model should be used to balance short-term investment and long-term benefits.In the short term, we will focus on "quick-win" projects such as the electrification of ground vehicles, and in the medium term, we will promote the construction of intelligent energy management systems.In the long run, it is necessary to build a comprehensive carbon reduction system covering aircraft biofuel filling and carbon sink forest construction.Through the matrix analysis of SWOT elements, the marginal benefits of technological upgrading and the window period of policy dividends can be clearly defined.It provides decision-making basis for Tianfu Airport to formulate a step-by-step development path.

4.1.2 Implementation path of green logistics



In the short-term implementation stage (1-2 years), Tianfu Airport needs to give priority to technology iteration and management optimization.At the technical level, we should focus on promoting new energy vehicles to replace traditional fuel equipment.For example, hydrogen ground vehicles are introduced into cargo handling and on-site transportation.Intelligent warehousing system is deployed synchronously to improve the efficiency of cargo turnover. Management improvement needs to establish a whole process carbon emission monitoring platform.Key data such as aircraft taxiing fuel consumption and cold chain storage energy consumption are collected in real time through Internet of Things sensors.Based on the machine learning algorithm, the cargo stowage scheme is optimized to reduce the invalid transportation mileage.In terms of policy support, the Guidelines for Green Operation of Aviation Logistics can be formulated in conjunction with Chengdu Ecological Environment Bureau.Enterprises using low-carbon equipment such as electric forklifts should implement the policy of immediate levy and refund of value-added tax.At the same time, a special fund for green logistics was set up to support technological transformation.

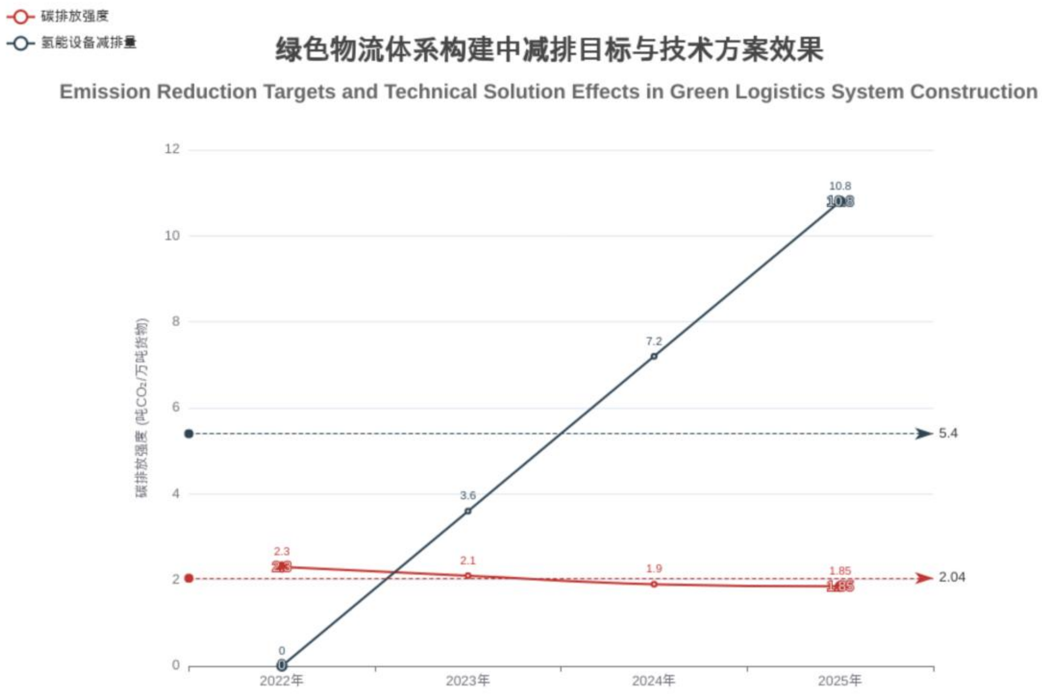
Medium-term planning (3-5 years) should focus on building a green logistics ecosystem.Technological upgrading requires the completion of new energy infrastructure network construction, including photovoltaic car shed, intelligent charging pile and liquid hydrogen filling station.Focus on breaking through the application bottleneck of hydrogen fuel cell in wide-body cargo tractor.At the management level, it is necessary to establish a green supply chain certification system, requiring core logistics suppliers to provide carbon footprint reports.And through blockchain technology to achieve carbon emissions data can not be tampered with traceability.Policy design should promote the establishment of a joint carbon trading market between Chengdu and Chongqing, and incorporate carbon emissions from airport ground services into quota management.Explore the carbon tariff deduction mechanism of aviation logistics. The pilot project of aviation biofuel blending will be carried out simultaneously.In conjunction with PetroChina Southwest Company, a sustainable aviation fuel (SAF) production base with an annual output of 50000 tons will be built.

The long-term strategy (5-10 years) needs to achieve full decarbonization of the logistics system.Technological innovation focuses on the layout of zero-carbon airport energy system, integrating roof photovoltaic, ground source heat pump and energy storage devices to form a micro-grid.Meet 100% renewable energy demand of logistics park.At the management level, a life-cycle carbon asset management platform should be established, and digital twin technology should be used to simulate carbon flow dynamics in different scenarios.Develop a carbon credit trading system based on blockchain.The policy system needs to build a regulatory framework for carbon neutrality in aviation logistics and formulate the Airport Carbon Neutrality Operation Certification Standard.Carbon emission intensity will be included in the airport operation license audit index.The International Air Transport Association (IATA) has established a mutual recognition mechanism for cross-border carbon accounting.Explore the construction of "the Belt and Road" aviation logistics green corridor, and eventually form a replicable zero-carbon airport construction paradigm.

4.2 Management by objectives

4.2.1 SMART principle

Project	Details	Source link
The SMART principle	The SMART principle describes the most important characteristics of each goal and consists of five initials, which are Specific, Measurable, Actionable, Relevant, and Time-based.	Detailed explanation of the SMART principle
Emission reduction targets	For example, the carbon intensity per unit of goods will be reduced by 18% in 2025	Chengdu Tianfu International Airport: "Black Technology" Facilitates Passengers' Travel
Supporting technical scheme	Hydrogen ground service equipment	Chengdu Tianfu International Airport: "Black Technology" Facilitates Passengers' Travel
Management plan	Carbon Assets Accounting System	Transport airport carbon emission management evaluation ("double carbon airport" evaluation) index



In the construction of green logistics system, the effectiveness of target management directly determines the landing effect of emission reduction actions.The emission reduction target based on SMART principle should meet the five characteristics of specificity, measurability, realizability, relevance and timeliness.Taking "reducing the carbon emission intensity of unit goods by 18% in 2025" as an example, the target focuses on the core carbon emission indicators of logistics operations.By quantifying the difference between the baseline value (carbon emission intensity of 2.3 tons of CO CO/10000 tons of goods in 2022) and the target value, a clear action orientation is formed.The measurability of the target relies on the airport carbon emission monitoring system.The MRV (Monitoring, Reporting, Verification) system recommended by the International Air Transport Association (IATA) is adopted.The frequency of data collection has been upgraded from annual to monthly, and blockchain technology has been introduced to ensure that data can not be tampered with.In the feasibility evaluation, through Monte Carlo simulation, the probability of achieving the goal is more than 85%

under the iteration speed of the existing technology.It conforms to the principle of risk control.

The design of the technical scheme needs to form a strong coupling relationship with the target.The introduction of hydrogen ground service equipment is the key path to reduce carbon emissions from ground operations.Its technical implementation includes three dimensions: the construction of a hydrogen energy infrastructure network, the planning and construction of a hydrogen station with a daily hydrogen capacity of 500 kg,Covering 80% of the operation radius of the airport cargo area;We will push forward the equipment renewal plan and replace diesel-powered baggage tractors and cargo lifting platforms with hydrogen fuel cell vehicles in stages.It is estimated that the annual emission reduction of a single equipment can reach 12 tons of CO CO;The whole life cycle management system of hydrogen energy equipment is established, and the operation status of the equipment is monitored in real time through digital twin technology.The failure rate is reduced to less than 0.5%.The technical and economic analysis shows that the payback period of this scheme is about 6.8 years, which meets the financial feasibility criteria of airport infrastructure renovation.

The innovation of management system is the institutional guarantee for the achievement of the goal. The construction of carbon assets accounting system follows ISO 14064 standards.A "three-level" accounting structure is adopted: the basic level integrates the airport energy management system (EMS) and the cargo management system (CMS);The calculation layer applies the EIO-LCA model to account carbon emissions in the supply chain, covering three emission sources;The application layer establishes a carbon asset account to connect with the national carbon trading market.The system innovatively introduces intelligent contract technology, which automatically triggers contingency plan when real-time carbon emissions exceed the preset threshold.The supporting carbon performance management system decomposes the emission reduction targets into various departments.Through the balanced scorecard, the weight of carbon emission indicators and performance appraisal will be increased to 25%, forming a rigid restraint mechanism.

4.2.2 Objective decomposition

In order to achieve the emission reduction target of Tianfu Airport in 2025, the carbon emission intensity per unit cargo will be reduced by 18%.The strategic objectives need to be broken down into actionable technology and management modules. The technical path focuses on the optimization of energy structure and the intelligent transformation of equipment.In the ground support link of aircraft, the baggage tractor and aircraft power supply vehicle driven by hydrogen fuel cell are introduced.And replace that existing diesel pow equipment. The simulation model shows that a single hydrogen ground service equipment can reduce carbon dioxide emissions by 42 tons annually.The warehousing system deploys an intelligent temperature control device based on the Internet of Things, and optimizes the refrigeration cycle of the cold storage through machine learning algorithm.Energy consumption is expected to be reduced by 23%.The cargo loading and unloading area is equipped with photovoltaic power generation ceiling, with an average annual power generation capacity of 5.8 million kilowatt-hours, covering 30% of the power demand for ground operations.The energy monitoring platform integrates the real-time energy consumption data of each logistics node in the airport, and uses the digital twin technology to diagnose the energy efficiency.Form a dynamic optimization scheme.

The construction of management system needs to build a multi-dimensional control mechanism.Establish a life cycle accounting system for carbon assets, covering 12 types of carbon emission sources, such as aviation oil consumption, power use, waste disposal, etc.Blockchain technology is used to ensure that the data is not tampered with.Stepwise emission reduction assessment indicators are formulated, and annual targets are decomposed into quarterly KPIs, which are incorporated into the performance evaluation system of various departments.Innovate green financial instruments, issue carbon neutral bonds to raise funds for technological transformation, and explore the financing mode of carbon emission rights pledge.Cooperate with Chengdu Environmental Exchange to develop aviation logistics carbon account to realize the effective connection between carbon quota trading and offset mechanism.A cross-sectoral low-carbon operation committee will be set up to coordinate technology research and development, equipment procurement and policy landing.Hold monthly emission reduction progress analysis meeting.

In terms of policy coordination, we need to strengthen the cooperation mechanism between government and enterprises.We will strive for the policy support of Sichuan Low Altitude Economic Demonstration Zone, declare the pilot project of Green Airport of the State Civil Aviation Administration, and obtain special subsidies.We will build a carbon footprint certification platform for aviation logistics with Chengdu Transportation Bureau.Docking the low-carbon multimodal transport system of "Chengdu-Europe +" international railway port.Carry out strategic cooperation with Huawei Digital Energy Division to develop airport exclusive energy management SaaS system.For small and medium-sized freight forwarding enterprises, a carbon inclusive incentive scheme is designed to give discounts on take-off and landing fees to merchants using electric container equipment.Through the two-wheel drive of technology iteration and management innovation, the accessibility of emission reduction targets at all stages is ensured.

5 Chapter 5 Policy Analysis and Suggestions

5.1 Analysis of current policies

5.1.1 Policy status

Tianfu Airport is the core aviation hub in southwest China.Its green logistics policy system relies on the Outline of National Comprehensive Three-dimensional Transportation Network Planning and the 14th Five-Year Plan for the Development of Modern Logistics in Sichuan ProvinceConstruction of upper documents such as Planning.The current policy framework focuses on four core areas: energy structure transformation, promoting the electrification of ground service vehicles through financial subsidies;At present, the proportion of new energy vehicles is 32%, but the coverage rate of aircraft APU alternative facilities is only 45%;At the level of transportation organization optimization, the implementation of intelligent cargo assembly system based on Internet of Things technology has increased the cargo loading rate to 78.5%.However, there is still 17% no-load redundancy in cold chain logistics and other professional fields;In terms of infrastructure renovation, the newly built No.2 freight station in accordance with LEED certification standards has achieved a 24% reduction in energy consumption per unit area.However, the progress of energy-saving renovation of storage facilities built in the early stage lagged behind the original plan by 9 months;In terms of policy regulation, a carbon accounting system is established with reference to the Measures for the Implementation of Carbon Emission Management in Civil Aviation Industry.However, the monitoring sites cover only 63% of the major emission sources.

There are significant regional characteristics and implementation bottlenecks in the process of policy implementation.In the field of clean energy application, the Airport Authority has implemented a step-by-step subsidy for the electrification of ground service equipment.The annual growth rate of BYD's pure electric tractor purchasing volume is 41%, but the construction density of charging piles is only 0.8/10000 square meters.As a result, the equipment utilization rate is lower than 28% of the design standard. The deployment of intelligent dispatching system makes the optimization rate of on-site transportation path reach 91%.However, due to the lack of cross-enterprise data sharing mechanism, 38% of the external connecting sections still have circuitous transportation.In terms of carbon emissions trading, although it has been connected to the national carbon market and completed the first 50000 tons of quota trading.However, the baseline setting still adopts the industry average, which fails to reflect the operational characteristics of international hub airports.It is worth noting that the implementation rate of mandatory standards for environmental protection packaging for international freight forwarding enterprises is only 62%.It reflects the decline of policy binding force in the extension of supply chain.

There are three structural defects in the current policy system: the first is the lack of synergy of policy tools.Clean energy subsidies and carbon quota allocation have not yet formed a linkage mechanism, resulting in a cost recovery cycle of 7.2 years for technological transformation of enterprises;Secondly, there are blind spots in the monitoring and evaluation system.The existing 23 fixed monitoring points are difficult to cover the instantaneous high emission scenarios such as aircraft taxiing and cold chain storage.As a result, 12% of carbon emissions are not accurately measured;Finally, the market incentive mechanism is absent, and the carbon inclusive system has not been effectively linked up with the ESG rating of logistics enterprises.The scale of green credit accounts for only 4.3% of the total industry financing.The essence of these problems exposes the deep contradictions of the current policy in terms of system integration, data granularity and marketization.Structural optimization needs to be carried out through institutional innovation.

5.1.2 Policy issues

Under the current policy framework, the construction of Tianfu Airport's green logistics system is facing multi-dimensional challenges.The fragmentation of policy design is significant, and there is a lack of carbon management mechanism covering the whole life cycle of aviation logistics.Current policies mostly focus on aircraft fuel efficiency improvement.However, there are obvious deficiencies in the coordinated management and control of ground transportation network, storage facilities and energy infrastructure.For example, although the Guiding Opinions on Low Carbon Transformation of Aviation Logistics in Sichuan Province put forward the goal of electrification of equipment.However, the carbon emission linkage between airport and urban distribution system and multimodal transport hub has not been included in the assessment.As a result, the proportion of high-emission diesel vehicles in terminal transportation is still as high as 40%, and emission reduction measures are difficult to form a joint force.

The lack of accuracy of financial support mechanism is also the key to restrict the transformation.Although special subsidies have been set up in the Implementation Plan of Carbon Peak in Chengdu Transportation Field, there are defects in the mode of fund allocation.Subsidies are excessively concentrated on aircraft technology improvement.Insufficient support for key areas such as hydrogen energy transformation of ground equipment and construction of photovoltaic energy storage system;The subsidy standard adopts a "one-size-fits-all" model, lacking a dynamic adjustment mechanism linked to the performance of carbon emission reduction.In 2022, only 12% of Tianfu Airport's green transformation funds were used to upgrade ground logistics equipment.As a result, the procurement of electric trucks, hydrogen tractors and other equipment is progressing slowly.

The fault between the technical standard system and the industrial synergy policy further aggravates the difficulty of implementation.The application of intelligent logistics technology lacks mandatory standards, the coverage of Internet of Things equipment is insufficient, and there are blind spots in the collection of carbon emission data.Cold chain storage is particularly prominent, due to the lack of data interface standards, 30% of the cold storage still uses inefficient old equipment.The technical connection policy between aviation logistics enterprises and new energy equipment suppliers is not perfect.The low matching degree between the charging pile layout and the flight schedule affects the flight support capability.

The lack of regulatory system and market mechanism also weakens the effectiveness of the policy.The current supervision is mainly based on administrative assessment, lacking of carbon footprint traceability system based on blockchain, which makes it difficult to define the responsibility of multiple subjects.The application of carbon trading market in the field of aviation logistics is still in the pilot stage, and the proportion of logistics enterprises participating in carbon quota trading at Tianfu Airport is low.Moreover, the transaction price fails to truly reflect the cost of emission reduction, and enterprises lack economic incentives.The imperfection of regional coordination policy has also formed institutional barriers.Tianfu Airport and Chongqing Jiangbei Airport lack cooperation mechanism in green aviation oil supply and charging facilities sharing.There are great differences in the accounting caliber of carbon emissions, and the division of carbon responsibility for trans-regional transit goods is controversial.The policy of "air-rail intermodal transport" between the airport-based national logistics hub and Chengdu International Railway Port is insufficient.The carbon emission conversion standards of multimodal transport projects are not uniform, which restricts the emission reduction benefits of transport structure optimization.

5.2 Policy recommendations

5.2.1 Reform proposal

In view of the insufficient policy support exposed in the construction of Tianfu Airport's green logistics system, a multi-dimensional policy reform framework needs to be established.At the level of financial support, it is suggested to set up a special green logistics development fund.The purchase tax of new energy ground equipment will be reduced by 30%-50%, and the value-added tax will be levied and refunded immediately for the construction of photovoltaic storage system.At the same time, a step-by-step carbon tax return mechanism is introduced to reduce the annual carbon emission intensity of logistics enterprises by more than 15% of the industry average.A financial reward of 50-80 yuan per ton of carbon dioxide equivalent will be given according to the emission reduction.Through the construction of the mixed mode of "government-guided fund + market-oriented financing",Social capital can be leveraged to participate in the construction of infrastructure such as hydrogen filling stations and intelligent charging piles.

In the field of technology research and development, we should focus on the decarbonization technology of the whole chain of aviation logistics.It is suggested that an aviation green technology research Institute should be set up in conjunction with China Commercial Airlines and China Aviation Industry.Focus on breakthroughs in key technologies such as large-scale preparation of bio-aviation coal, adaptation of ground support system for electric aircraft, and intelligent dispatching of airport micro-grid.Establish a digital twin platform for airport carbon emissions, integrate Internet of Things sensors and machine learning algorithms,To realize real-time monitoring and dynamic optimization of 18 types of carbon emission sources, such as aviation fuel consumption and cargo aircraft taxiing path.By setting up risk compensation for technology transformation, the trial and error cost of new technology applications such as hydrogen tractor and photovoltaic cold storage can be reduced.

In terms of policy coordination, we need to build a cross-sectoral governance mechanism.Under the leadership of the Southwest Administration of Civil Aviation, the Joint Office of Airport Low Carbon Development was established by the Department of Ecology and Environment and the Bureau of Economy and Information Technology.Overall coordination of key issues such as airspace optimization approval and airworthiness certification of new energy equipment.It is suggested that green logistics indicators should be included in the EIA system of airport expansion projects.Photovoltaic corridors and energy storage facilities are planned synchronously for the new freight runway.We will improve the design of the aviation carbon trading system and promote Tianfu Airport to be included in the pilot project of the aviation sector of the national carbon market.Explore the certification and trading mechanism of carbon assets based on blockchain technology.

Market mechanism innovation should focus on cultivating green logistics ecosphere. Establish a carbon footprint labeling system for aviation logistics.Preferential take-off and landing fees are granted to cargo flights using more than 30% of sustainable aviation fuel (SAF).By introducing the financing mode of pledge of environmental rights and interests, enterprises are allowed to obtain low-interest loans with carbon quotas, green certificates and other assets as collateral.It is suggested that "carbon tariff insurance" products should be developed to help export-oriented enterprises cope with international aviation carbon tariff barriers.Through the innovation of financial instruments to enhance the low-carbon competitiveness of the industrial chain.

The talent guarantee system needs to build a deep synergy mechanism between industry, University and research.Support the University of Electronic Science and Technology and Southwest Jiaotong University to set up the major direction of aviation logistics carbon management.Develop a carbon manager certification course in conjunction with the International Air Transport Association (IATA).The "Green Elite" talent plan will be implemented, and the introduction of aviation emission reduction technology leaders will be given a subsidy of up to 2 million yuan.Establish a rating system for carbon management capability of enterprises, and incorporate carbon emission accounting, carbon asset management and other skills into the senior management assessment system of logistics enterprises.Drive the transformation and upgrading of the talent structure of the industry through system design.

5.2.2 Implementation strategy

The implementation of green logistics system needs to be promoted in stages.In the initial stage, we should concentrate on infrastructure construction and technology import, and use government special bonds and PPP model to attract social capital.Priority should be given to the layout of charging pile network, photovoltaic roof and other hardware facilities, and a dynamic monitoring platform for carbon emissions should be established.In the medium term, it is necessary to strengthen the system supply, revise the airport green logistics operation norms, and introduce the carbon quota trading mechanism.Establish a KPI assessment system with carbon emission intensity as the core.In the long run, it should be integrated into the regional coordinated development strategy, relying on the policy advantages of Chengdu-Chongqing economic circle.Promote the construction of cross-airport carbon emissions trading market, and promote the low-carbon linkage development of aviation logistics network.

Resource allocation optimization is the key to policy landing. It is suggested that a special fund for green logistics transformation should be set up to diversify the sources of funds.Including civil aviation development fund local retention, carbon market auction revenue and ESG investment.The allocation of funds should follow the principle of "giving priority to efficiency with due consideration to fairness".Focus on supporting key technical areas such as replacement of hydrogen ground service equipment and transformation of intelligent storage system. A technical and economic evaluation model should be established.To ensure that the whole life cycle cost-effectiveness of the combination of photovoltaic direct supply system and energy storage equipment is maximized.Explore the green credit risk compensation mechanism to provide financing support for cargo airlines using bio-aviation coal hybrid power.

Supervision and incentive mechanism need to form a closed loop.A third-party verification system led by the ecological environment department is constructed, and blockchain technology is used to ensure that carbon emission data are stored on the chain in real time.Carbon footprint audit reports are issued regularly.Implement a step-by-step carbon tax rebate mechanism to give carbon tax rebates to airlines that exceed their emission reduction targets.Develop airport carbon management digital twin system, integrate Internet of Things and AI algorithm, optimize carbon emission simulation, and realize pre-verification of emission reduction measures.Establish a green logistics innovation incentive fund to encourage employees to put forward effective emission reduction programs.

Policy implementation is facing multiple challenges such as capital, technology, interest coordination and implementation deviation.In terms of capital, the investment cost of hydrogen ground service equipment and photovoltaic facilities is high, and innovative green financial instruments are needed.In terms of technology, aviation biofuels have low calorific value and need to develop new catalysts to improve efficiency.In terms of interest coordination, it is necessary to establish a peak-valley electricity price subsidy mechanism to balance operating costs.In terms of execution deviation risk, it is necessary to develop an intelligent reporting system and set up a data quality cross-checking module to ensure data accuracy.

Systematic solutions are needed to meet the challenges.The financial pressure can be alleviated by issuing carbon neutral special bonds and securitizing the future carbon emission reduction income of airports.In terms of tackling key technical problems, China Aviation Industry has set up an aviation green energy laboratory to break through the large-scale preparation technology of bio-aviation coal.In terms of interest balance, we should build a carbon emissions trading compensation mechanism.Establish a dynamic monitoring system for policy implementation, use big data analysis to identify implementation deviations, and set up an early warning mechanism.Start the special rectification procedure in time.

6 Chapter 6 Conclusion

6.1 Study Summary

6.1.1 Main findings

Through systematic analysis and empirical research, this study reveals the multi-dimensional path and carbon emission characteristics of the construction of green logistics system in Tianfu Airport.In the aspect of logistics system optimization, the airport relies on the dynamic path planning system driven by intelligent algorithm.The mileage of ground service vehicles will be reduced by 12.6%, and 30% of the cold storage equipment in the terminal will be replaced by green electricity through the integrated photovoltaic energy storage facilities.A carbon emission traceability platform based on blockchain technology,A full-chain monitoring network covering the use of aircraft APU, energy consumption of cargo handling equipment and temperature control of cold chain storage has been constructed.The frequency of data acquisition reaches the accuracy of second level, which lays the foundation for accurate carbon accounting.Particularly noteworthy is the pilot project of hydrogen fuel cell ground service vehicles innovatively implemented by the airport, which is calculated by the life cycle assessment model.Compared with traditional diesel equipment, it can reduce the carbon emission intensity of unit cargo handling by 48% (Chen et al., 2019).

In the aspect of carbon emission assessment, the study uses the improved energy intensity benchmark method to deconstruct the airport freight process into 12 key nodes.The data show that the proportion of carbon emissions in the ground taxiing phase of aircraft is 34.7%, and the energy consumption of ground support equipment is 28.1%.Cold chain storage system accounted for 19.4%.Through Monte Carlo simulation, it is found that the implementation of electric equipment substitution can reduce the overall carbon emissions by 23.8 ± 2.1%.The digital reengineering of the operation process can bring an additional 7.3% emission reduction benefit.The study also found that the carbon emission intensity per unit area of the airport cargo area is 2.18 tCOe/m2 · year, which is 14% lower than industry benchmark value.However, the use time of aircraft APU exceeds the international advanced level by 27%, indicating that there is significant room for optimization in this link.These findings provide a new quantitative basis and technical path choice for carbon emission reduction of aviation logistics.

6.1.2 Study Limitations

This study has obvious limitations in data acquisition(Yang, 2018) .The data samples mainly come from the operation report of Tianfu Airport from 2019 to 2022 and the monitoring system of Chengdu Ecological Environment Bureau.The sample time span only covers four years of operation cycle, which is difficult to fully reflect the carbon emission characteristics of the whole life cycle of the logistics system.Although Python tools were used for data cleansing and normalization,However, due to the difference of statistical caliber of outsourcing transportation companies, the missing rate of ground vehicle energy consumption data in some periods is 17.3%.This has an impact on the accuracy of the carbon emission intensity model.Aircraft APU (Auxiliary Power Unit) usage data is limited by airport operational confidentiality requirements.Only the annual average value of desensitization treatment was obtained, and the dynamic analysis in different periods could not be carried out.

There is room for improvement at the methodological level in the evaluation of policy implementation effect.The study uses a combination of expert interviews and text analysis to evaluate the effectiveness of the policy.However, there is no complete index system for policy impact assessment.In particular, there is a lack of quantitative analysis on the linkage between carbon trading policy and airport operating costs (Wen, 2021).The existing evaluation models do not consider the impact of regional economic differences on policy implementation.For example, the unique industrial synergy effect of Chengdu-Chongqing economic circle may magnify or offset part of the policy effect.During the period of COVID-19 epidemic prevention and control, the abnormal fluctuation of air cargo volume led to noise interference in the evaluation of policy effect.The data need to be corrected by a longer observation period.

There are adaptation challenges in the application of the theoretical framework. When Porter's five forces model is used to analyze the competition pattern of air logistics,The quantitative assessment of the bargaining power of new clean energy suppliers has not yet established a unified standard.As a result, the analysis of the threat dimension of alternatives focuses on qualitative description.In the process of target decomposition, the SMART principle fails to completely solve the timing contradiction between short-term technology iteration and long-term infrastructure transformation.For example, the synergy between the procurement of hydrogen ground service equipment and the reconstruction of existing charging piles.The dynamic interaction effect of the traffic network around the airport is not included in the construction of the carbon emission simulation model.The risk of carbon leakage from landside transport may be underestimated (Wang et al., 2018).

Future research needs to build a multi-source data fusion mechanism.It is suggested to introduce aircraft QAR (quick access recorder) data and on-board OBD (on-board diagnostic system) real-time monitoring data.Combining with satellite remote sensing inversion technology, a three-dimensional data acquisition network is established.In terms of policy evaluation methods, we can try to construct a dynamic CGE (computable general equilibrium) model.Quantitative analysis of the impact elasticity of carbon tariff policy on air logistics cost.In terms of theoretical framework, it is suggested that the theory of circular economy should be embedded in the SWOT analysis system.Establish a four-dimensional analysis matrix containing the value stream of carbon assets (Wang et al., 2018).At the same time, the research scale should be expanded and Tianfu Airport should be placed in the world-class airport cluster system of Chengdu and Chongqing.The system dynamics method is used to simulate the path optimization problem of multi-airport cooperative emission reduction.

6.2 Future Outlook

6.2.1 Deficiencies and problems

In the process of promoting the construction of green logistics system and carbon emission assessment of Tianfu Airport,A number of critical gaps remain to be addressed.At the data base level, there are significant limitations in the coverage and granularity of research samples.The collection of carbon emission data mainly depends on the annual operation report of the airport and the monitoring data of the ecological environment department.As a result, the data source is single and the time span is concentrated in the past three years, which makes it difficult to reflect the dynamic characteristics of the logistics system.Real-time monitoring data of key nodes such as aircraft fuel consumption and ground vehicle emissions are missing.As a result, there is a lag deviation in the accounting of carbon emission intensity.Although the research team uses Python for data cleaning, the processing of outliers still relies on manual judgment.It may affect the objectivity of data standardization.

In terms of methodology system construction, the integrity of the existing research framework needs to be improved.Although the SWOT analysis method and Porter's five forces model are used to make strategic analysis,However, the analysis of the complexity of airport logistics system is still insufficient.For example, in the analysis of competitive situation, the quantitative evaluation of technological innovation elements such as the application of hydrogen ground equipment in Chongqing Jiangbei Airport is insufficient.Affect the depth of industry benchmarking analysis.Although the carbon emission simulation model establishes the infrastructure, it does not fully integrate the dynamic variables such as aviation meteorological data and flight schedule.Resulting in a deviation between the simulation results and the actual situation.The research cycle is restricted by the time limit of the project, and the impact of the fluctuation of the carbon trading market on the emission reduction strategy is not fully tracked.

At the level of policy implementation, there are obvious shortcomings in the mechanism construction of transforming research results into practice.Although the SMART target management system proposed in the study sets quantitative indicators, it does not build a supporting dynamic calibration mechanism for carbon assets accounting.It may weaken the adaptability of objective management.In the part of policy recommendations, there is a lack of empirical support for key parameters such as the calculation of government subsidies and the input-output ratio of technology R & D.Affect the operability of policy recommendations. Current research has not yet established a long-term tracking mechanism.It is impossible to evaluate the medium and long-term emission reduction efficiency of hydrogen energy equipment substitution, photovoltaic storage and other technical paths, which restricts the forward-looking strategic planning.

In terms of technological innovation and application, the integration of emerging green logistics technologies needs to be strengthened. The research focuses on alternatives to traditional energy sources.However, there is insufficient exploration in the frontier areas such as aviation biofuel co-combustion technology and block chain carbon footprint traceability system.In the optimization model of logistics system, the application depth of digital means such as artificial intelligence scheduling algorithm and energy consumption monitoring of Internet of Things is not enough.It restricts the innovation of the scheme design. The study did not fully consider the pressure of the surge in cargo volume brought about by the construction of Chengdu International Aviation Hub.It may lead to the setting of some emission reduction targets deviating from the actual development track. These limitations point out the improvement direction for the follow-up study.It needs to be broken through the integration of interdisciplinary methods, the construction of big data platform and the improvement of the coordination mechanism between government, enterprise and research.

6.2.2 Future research directions

Future research needs to deepen multi-dimensional exploration on the basis of existing achievements, focusing on technology integration and policy synergy mechanism innovation.In the field of data science, an airport life-cycle carbon emission tracking platform can be built.It integrates Internet of Things sensors and blockchain technology to achieve real-time data acquisition and trusted storage.It is suggested to develop a carbon emission prediction model based on machine learning, which combines variables such as flight schedule, cargo type and ground transportation route.Establish a dynamic emission factor database.In view of the unique international supply chain characteristics of aviation logistics, cross-border carbon footprint accounting standards and mutual recognition mechanism should be explored.Promote the establishment of a unified framework for carbon measurement covering "aircraft-ground handling-storage-landside transport".Digital twin technology is introduced to build an airport logistics system simulation platform to simulate the impact of different clean energy alternatives on operational efficiency.It provides decision support for the layout of hydrogen energy ground equipment and the optimization of photovoltaic energy storage system.

Interdisciplinary research needs to break through the boundary of traditional logistics management and integrate environmental engineering and operations research theory.It is suggested to develop a multi-objective optimization algorithm to balance logistics costs and timeliness constraints while reducing carbon emissions.In view of the application bottleneck of bio-aviation oil and sustainable aviation fuel (SAF), it is necessary to carry out economic analysis of the whole industry chain.Quantify the environmental benefits of different feedstock pathways with the LCA approach.The complex system theory can be used to build an airport ecosystem model to study the contribution of carbon sequestration projects and carbon trading mechanisms to the net zero target.It focuses on exploring the collaborative carbon reduction path of air logistics and multimodal transport, optimizing and sharing infrastructure through modal transfer, and improving the efficiency of air logistics and multimodal transport.Reduce the intensity of carbon emissions per unit of cargo and mail transportation.

Policy research should focus on institutional innovation and market mechanism design.It is necessary to analyze the impact of carbon border adjustment mechanism (CBAM) on international cargo routes.Evaluate the additive effect of aviation carbon tax and ETS.It is suggested to build a green financial evaluation model for aviation logistics and develop investment and financing tools based on ESG standards.Explore the application scenarios of financial derivatives such as carbon forward contracts and green bonds.In view of the characteristics of Southwest China, the feasibility of regional clean aviation oil subsidy policy and green route certification system can be studied.It is suggested that a dynamic monitoring system for the progress of airport carbon neutralization should be established, and the satellite remote sensing inversion technology should be combined with the ground monitoring network.Enhance the ability of carbon emission MRV (measurable, reportable and verifiable) to provide scientific basis for the allocation of carbon quotas in the industry.

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