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# Construction of Airport Fuel Support Capacity Model and Numerical Simulation Verification

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***Abstract:*** *The capability of fuel support is fundamental to enhancing airport transportation capacity. This paper comprehensively evaluates various factors including the number of fuel depots situated between the airport and its surrounding supply points, the distances involved, and the transport capacities of the fuel trucks. Initially, we develop an airport fuel supply support capability model incorporating nine key variables. Subsequently, a genetic algorithm is devised to optimize the overall number of transport vehicles required. Furthermore, a computational and simulation system tailored for airport fuel support is both established and validated through rigorous calculations and simulations. The findings demonstrate that the proposed model can effectively and dynamically compute the necessary transport capacity in real-time, responsive to the prevailing fuel consumption patterns, thereby affirming the practicality and utility of paper research.*

***Keywords:*** *Fuel support capacity, Replenishment rate, Genetic algorithm, Fuel support calculation and simulation system*

## 1. Introduction

In today's globalized era, the aviation industry is witnessing unprecedented growth and development. As crucial nodes in the air transportation network, airports play a vital role in operational efficiency and support capabilities. Among these, fuel supply stands as one of the core elements ensuring the normal operation of an airport, directly impacting flight safety, punctuality, and airline operating costs. With the continuous expansion of airport sizes, the increasing number of flights, and the changing fuel demands of new aircraft models, higher demands and significant challenges are imposed on airport fuel supply capabilities. Consequently, constructing a scientific, accurate, and effective model for airport fuel supply capability and validating its performance and reliability through simulation holds great theoretical value and practical significance.

In recent years, numerous scholars and research institutions have conducted in-depth studies on airport fuel supply capabilities from various perspectives. Hu[1] discussed the necessity of rapid response support from the perspective of the primary task of aviation business needs, analyzed potential problems in the airport fuel support chain, and pointed out methods to build a stable and sound airport fuel support chain . Sun et al. [2], focusing on the overall goal of aviation fuel supply, studied an integrated management model covering fuel procurement, transportation, storage, and refueling. Zhang et al.[3] examined the number of refueling vehicles and fuel delivery positions at field conditions airfield depots, and proposed simulations and statistical analysis using GPSSW language, obtaining suitable parameters through repeated simulations and comparisons. Zhang[4], addressing the characteristics of emergency combat support such as suddenness, uncertainty, and unconventional nature, proposed the concept of using airport clusters to support emergency combat, analyzing advantages, limitations, and measures to enhance the emergency combat support capability of airport clusters. Gao[5] applied the Analytic Hierarchy Process (AHP) to determine the weights of fuel supply effectiveness evaluation indicators at LH station, used fuzzy comprehensive assessment methods to evaluate qualitative indicators, standardized model methods to assess quantitative indicators, and weighted averaging for comprehensive evaluation, establishing a scientific and feasible evaluation system. Ding[6]encapsulated the demand

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prediction optimization model based on Agent theory, fuel layout optimization model, dispatching and transportation optimization model, and strategic support fuel supply optimization model into Agents, forming a framework for a fuel supply command decision-making system. Mou[7] designed a GIS-based fuel supply system and optimized fuel distribution transportation using the Dijkstra algorithm. Huang[8] studied the design of a fuel supply information management system, employing the Particle Swarm Optimization (PSO) algorithm to optimize fuel distribution and allocation. Yang[9] designed a fuel integrated support information system based on a multi-agent system, achieving integrated fuel supply adapted to dynamic and open network environments.

The above research mainly focuses on the fuel supply system and the development of fuel supply systems, without fully considering the relationship between airports and surrounding fuel depots. This paper comprehensively takes into account all aspects and influencing factors of airport fuel supply, aiming to construct a model of airport fuel supply capability and validate and optimize it through simulation experiments.

## 2. Problem Description and Model Construction

The fuel supply support capability is a sign used to describe the relationship between the dynamic consumption and supply of fuel. The dynamic consumption of fuel is related to the number of aircraft, the average number of take - offs of aircraft, and the average fuel consumption per flight of aircraft. The supply is related to the number of fuel depots, the transportation distance between the fuel depot and the airport, the number of fuel tankers, the speed of fuel tankers, and the fuel replenishment rate, as shown in Figure 1.

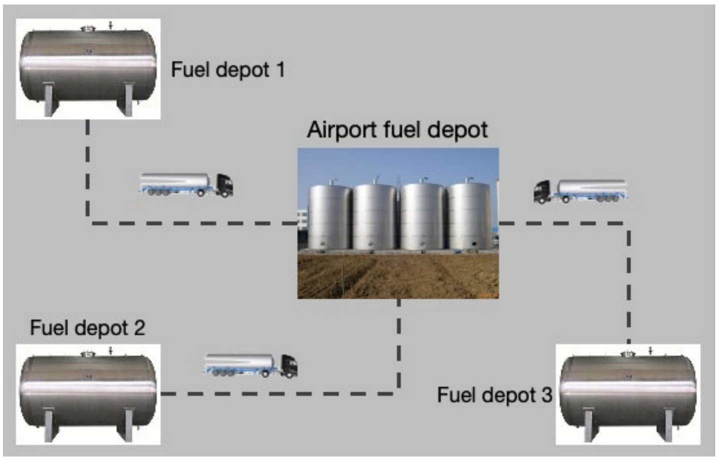


*Figure 1: Schematic diagram of fuel supply support*

The key parameter of the fuel supply support capability is the number of fuel tankers. Therefore, the following mathematical model is established:

$$\begin{cases} P_i = \dfrac{T_i \cdot C \cdot L_i}{V_i} \\ C = M \cdot T \\ Q(t) = A \cdot G(t) \cdot H \\ N_{total}(t) = \dfrac{Q(t) + S(t)}{\sum_{i=1}^{N} P_i} \\ N_i(t) = \dfrac{P_i}{\sum_{i=1}^{N} P_i} \cdot N_{total}(t) \end{cases} \tag{1}$$

Among them, $S(t)$ represents the fuel storage volume at the airport; $N$ represents the number of fuel depots; $L_i$ represents the transportation distance from the fuel depot $i$ to the airport, $i = 1,2,...,N$;

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$V_i$ represents the average speed of the fuel tanker on the transportation route from the fuel depot $i$ to the airport, $i=1,2,...,N$ ; $T_i$ represents the round - trip times of the fuel tanker on the transportation route from the fuel depot $i$ to the airport, $i=1,2,...,N$ ; $C$ represents the quantity of fuel transported by the fuel tanker; $E$ represents the replenishment efficiency of the fuel tanker; $A$ represents the number of aircraft; $G(t)$ represents the average number of take - offs of the aircraft; $H$ represents the average fuel consumption per flight of the aircraft; $P_i$ represents the effective transportation capacity of the fuel depo $i$ , $i=1,2,...,N$ ; $Q(t)$ represents the fuel consumption function; $N_{total}(t)$ represents the total number of required fuel tankers; $N_i(t)$ represents the number of required fuel tankers for the fuel depot $i$ , $i=1,2,...,N$ . $M$ represents the fuel replenishment rate of the fuel depot to the oil tanker; $T$ represents the fuel replenishment time of the fuel depot to the oil tanker.

## 3. Optimization Design of Fuel Supply Support Capability Based on Genetic Algorithm

The genetic algorithm is used to optimize the fuel supply support capability. With the fuel supply support as the goal, the fuel supply support objective function $Z(t)$ for fuel consumption, the total number of required fuel tankers, and time is constructed:

$$Z(t) = N_{total}(t) - \frac{Q(t)}{E}$$
$$s.t.$$
$$Vi \le 80km/h \tag{2}$$

Design the fitness function as $J$ :

$$J = \max Z(t) \tag{3}$$

The algorithm is designed as follows:

***Step1.*** Mutation. Use two - point reciprocal for mutation:

1) Generate two random natural numbers $x_1$ and $x_2$ ;

2) Exchange the genes at the $x_1$ and $x_2$ positions.

***Step2.*** Crossover. Use two - point crossover:

1) Randomly select two chromosomes as parents;

2) Generate two random natural numbers $x_1$ and $x_2$ ;

3) Exchange the gene segments between $x_1$ and $x_2$ to obtain two child chromosomes and perform a revision process to ensure that there is no conflict.

***Step3.*** Decoding. According to the fuel replenishment constraints and time window constraints, divide a code $S$ . The steps are as follows:

1) $i=1$ ;

2) Start the $i$ route $R_i=[0]$ , where 0 is the fuel depot;

3) Add the first point in the code $S$ to $R_i$ . If adding to $R_i$ meets the requirements, proceed to the next step. Otherwise, $i=i+1$ and go to step 2;

4) Delete the first code in $S$ . If $S$ is empty, proceed to the next step. Otherwise, go to step 3;

5) Output each sub - path.

***Step4.*** Selection. Use roulette wheel selection. The probability of an individual being selected is proportional to the value of the fitness function. As shown in Figure 2.

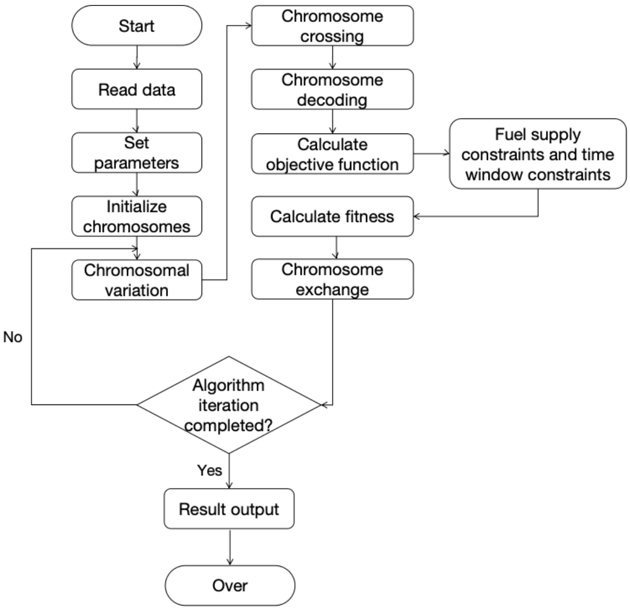


*Figure 2: Design process of genetic algorithm*

## 4. Numerical Simulation Analysis

Due to the flight requirements of aircraft, an airport fuel depot needs to replenish fuel from three surrounding fuel depots, and fuel tankers are used to transport the required fuel. The specific parameters are shown in Table 1.

*Table 1: Numerical values of simulation parameters*

<table>
<tr><th>Object</th><th>Parameter</th><th colspan="2">Value</th></tr>
<tr><td rowspan="7">Fuel depot and airport</td><td>The amount of fuel stored at the airport</td><td colspan="2">10000T</td></tr>
<tr><td>Number of fuel depots</td><td colspan="2">3</td></tr>
<tr><td>The fuel replenishment rate of the fuel depot to the oil tanker</td><td colspan="2">10T/h</td></tr>
<tr><td>The fuel replenishment time of the fuel depot to the oil tanker</td><td colspan="2">3h</td></tr>
<tr><td rowspan="3">The distance of each depot to the airport</td><td>Distance 1</td><td>35km</td></tr>
<tr><td>Distance 2</td><td>30km</td></tr>
<tr><td>Distance 3</td><td>42km</td></tr>
<tr><td rowspan="8">Fuel tanker</td><td rowspan="3">Average speed of fuel tankers on each transport route</td><td>Line 1</td><td>50km/h</td></tr>
<tr><td>Line 2</td><td>45km/h</td></tr>
<tr><td>Line 3</td><td>60km/h</td></tr>
<tr><td rowspan="3">Number of trips between fuel depots and airports per vehicle per transport route</td><td>Fuel tanker 1</td><td>2</td></tr>
<tr><td>Fuel tanker 2</td><td>2</td></tr>
<tr><td>Fuel tanker 3</td><td>1</td></tr>
<tr><td>The amount of fuel transported per vehicle</td><td colspan="2">30T</td></tr>
<tr><td>Replenishment efficiency per vehicle</td><td colspan="2">15T/h</td></tr>
<tr><td rowspan="3">Aircraft</td><td>Number of aircraft</td><td colspan="2">10</td></tr>
<tr><td>The average number of take-off sorties</td><td colspan="2">3</td></tr>
<tr><td>The average amount of fuel consumed by an aircraft in one flight</td><td colspan="2">25T</td></tr>
<tr><td rowspan="4">Algorithm</td><td>Population size</td><td colspan="2">100</td></tr>
<tr><td>Crossover probability</td><td colspan="2">0.8</td></tr>
<tr><td>Mutation probability</td><td colspan="2">0.05</td></tr>
<tr><td>Number of iterations</td><td colspan="2">50</td></tr>
</table>

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Use the airport fuel supply support calculation and simulation system independently developed by the team to conduct numerical simulation calculations for the above - mentioned cases, as shown in Figure 3.

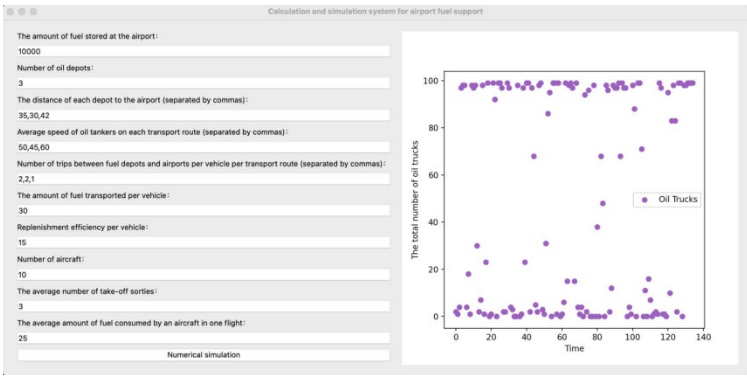


*Figure 3: Airport fuel support calculation and simulation system*

It can be seen from Figure 3 that by using the genetic algorithm to solve the fuel supply support capability optimization model, the average total number of transport vehicles required for the required fuel scale can be obtained as 19.

## 5. Conclusion

This paper addresses the requirements for airport fuel supply support and introduces a method utilizing genetic algorithm optimization for enhancing fuel supply capabilities. Initially, an airport fuel supply capability model is formulated, incorporating nine critical variables such as the number of fuel depots, the distances between these depots and the airport, the transport capacity of fuel trucks, the frequency of aircraft operations, and the fuel consumption rates of aircraft. Subsequently, a genetic algorithm with an objective function centered on optimizing fuel supply support is designed to analyze the model. Additionally, a calculation and simulation system for airport fuel supply support is developed using PyQt5, and its effectiveness is demonstrated through illustrative validation. The outcomes reveal that the proposed fuel supply capability model can dynamically compute the necessary transport capacity in real-time, responsive to actual fuel consumption scenarios. Future work will focus on expanding the dimensionality of the variables within the airport fuel supply capability model to improve its practical applicability.

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