Approach Airspace Utilization Rate Mode of Terminal Area in Blocky Distributed Hazardous Weather

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Abstract. Hazardous weather has a great impact on the airspace operation of the terminal area, which will lead to a reduction in the utilization of the airspace of the arrival operation. Therefore, it is necessary to evaluate the airspace utilization of the terminal area in hazardous weather. This paper analyzed the impact of blocky hazardous weather area on flight path, flight distance and flight time, and established a calculation model for the terminal area arrival airspace utilization rate in the blocky hazardous weather area based on the flow volume ratio based on the time and space constraints of the terminal area airspace operation. We selected a control terminal which was affected by the blocky hazardous weather area, then used the model to calculate the approach airspace utilization rate and compared it with the approach airspace utilization rate under normal weather conditions. The results show that the evaluation results of the established model can reflect the actual operating conditions.

1. Introduction

The terminal area is the bottleneck of the air transportation network system in China. The airspace utilization rate of the terminal area is an important factor for evaluating the airspace operation efficiency of the terminal area. Therefore, the airspace utilization evaluation of the terminal area is an important reference of the airspace management and flow management. In the operation of airspace, the utilization rate of airspace changes with environmental factors, especially weather factors. When hazardous weather occurs, it is even more necessary to evaluate the airspace utilization rate under hazardous weather in order to take corresponding measures. Reasonable use of limited airspace resources to reduce flight delays and improve airspace operation efficiency.

Regarding the evaluation and application of airspace utilization, certain research results have been achieved by domestic and foreign researcher. MITRE defined the time of airspace utilization as 15 minutes, in 2000, and evaluated it from three aspects: arrival utilization rate, departure utilization rate and mixed entry and departure utilization rate [1]. In 2008, Michael used greedy heuristics and combined underutilized airspace to conserve airspace resources and use airspace effectively [2]. S. S. KAPIL and his team analyzed the utilization rate of air highways from the aspects of instantaneous occupancy and space occupancy [3]. In 2009, Xue used the "time-space graph" in road traffic theory to analyze the utilization rate of air highways [4]. In 2011, Lee shortened the flight distance by flexible airspace management and reduced the number of diversions and improved the airspace utilization rate. He used simulation to estimate the advantages and feasibility of flexible airspace reconstruction to cope with the traffic overload caused by weather deviation and the baseline situation without airspace reconstruction [5]. In 2013, Kim pointed out that flight delays will propagate along the terminal area to
the waypoints, and improved the utilization rate of the terminal area by a multi-objective optimization algorithm that assigns waypoints to approach flights [6]. Bosson used a multi-stage complex planning algorithm to construct a sequencing model of approach and departure flights, and improves the efficiency of the use of airspace in the terminal area by optimizing the order of approach and departure flights in 2014 [7]. In the same year, Zhang quantified the airspace utilization rate in terms of time, space, and capacity, and established a route airspace utilization model avoiding the influence of random factors such as bad weather [8]. Smith evaluated the function and usage of the Multi-Flight Current Route (MFCR) developed by NASA. The results show that the tool can improve the utilization of airspace under the conditions of weather constraints, sorting, and maintaining spacing [9].

In China, Shi Heping first studied the concept of airspace utilization in 2003, and proposed that the utilization rate can be expressed as the ratio of the actually used airspace in the allowable space [10]. In 2011, based on the gray correlation analysis method, Zhang established indicators from three aspects: time, space, and capacity, and calculated the medium-long-term airspace utilization [11]. In 2012, Wang used principal component analysis to calculate the airspace utilization rate based on the grey correlation [12]. In 2013, Li combined the extension analytic hierarchy process with the state classification evaluation method to judge the daily utilization level of the terminal area [13]. In 2016, Wang improved the method of gray correlation and used gray absolute correlation and principal component analysis to evaluate the annual utilization rate of the terminal area [14]. In 2017, Zhang used the method of flow-to-capacity ratio to establish short-term utilization models for intersections, cross routes, and non-cross routes, respectively, and finally weighted the short-term utilization model for the terminal area approach route [15]. Based on capacity, taking into account space and time constraints, Zhang established a route utilization model based on different altitudes [16]. In 2018, Zhang established a gray calculation model of airspace utilization in the terminal area based on the entropy method [17].

According to the analysis of the existing results, most of the research on the evaluation model of airspace utilization rate is to determine the utilization level or calculate the utilization rate from the perspective of establishing an evaluation index system, or to consider the airspace structure and the operation process of the airspace, from time-space and flow-capacity and other aspects to establish the utilization evaluation model. However, the assessment of airspace utilization under hazardous weather has not yet been seen.

Hazardous weather mainly refers to small and medium-scale weather systems such as thunderstorms, squall lines, tornadoes, and wind shear [18]. The hazardous weather area in the terminal area can be divided into three types in terms of shape and distribution characteristics: blocky hazardous weather area, scattered hazardous weather area, and belt shaped hazardous weather area. In the case of separation of departure and approach in the terminal area, this paper considers the approach airspace utilization rate in the block hazardous weather area. For the blocky hazardous weather area, according to the characteristics of it, the characteristics of the airspace operation of the terminal area under the influence of the blocky hazardous weather area are analyzed. By discussing the flight distance and time variation in the block hazardous weather area, the impact of the block hazardous weather area on the capacity is determined, and the terminal area approach airspace utilization model under the blocky distributed hazardous weather is established based on the flow-to-capacity ratio and considering the time and space constraints.

2. Operation Process of Airspace System under Hazardous Weather

2.1. Blocky Distributed Hazardous Weather

Blocky distributed hazardous weather, that is, a single hazardous weather area, the boundary is continuous, generally polygonal, within the influence of a air route segment or a waypoint, as shown in Figure 1.
The planned route

**Figure 1.** Schematic diagram of blocky distributed hazardous weather

2.2. *Operation in Blocky Distributed Hazardous Weather*

If the blocky distributed hazardous weather in the terminal area affects the planned route, the aircraft can avoid the hazardous weather area by diversion route. A single thunderstorm is a common blocky hazardous weather area in the terminal area. After the thunderstorm was found, the captain applied to the controller to fly around. After the controller agrees, the aircraft will deviate from the course at a certain change angle. The deviation direction is based on the actual situation and is generally opposite to the direction of thunderstorm movement. When it deviates from the route by a certain distance, it adjusts the course to fly on a parallel route for a period of time. After flying away from the hazardous weather area, the aircraft adjusted its course again, and flew to the next waypoint to complete the flight.

It can be seen that when the blocky distributed hazardous weather appears in the terminal area, in addition to the change in the flight time of the aircraft and the flight space of the aircraft, the capacity and flow of the terminal area also change accordingly. Therefore, when establishing the model, the changes of the above parameters should be considered, and the movement and divergence of the hazardous weather area must also be considered at the same time.

3. *Utilization Assessment Model*

3.1. *Basic Assumptions*

Basic assumptions:

1) In practice, hazardous weather will change dynamically with time, and the process is complicated. In order to describe the hazardous weather well, this article assumes that the blocky hazardous weather area moves in a certain direction at a uniform speed, and at the same time moves out at a certain speed during the movement.

2) For the perspective of operation and safety, aircraft generally fly around the hazardous weather area from the side, and do not consider avoiding up and down.

3) In view of the short time period considered, the aircraft's approach speed is set to the average approach speed.

4) The fly-around route in this article is the ideal route planned to determine the change in capacity.

5) When the approach route is not affected by hazardous weather, the static capacity of the terminal area approach is known.

3.2. *Establishment of the Approaching Airspace Utilization Model*

When the blocky hazardous weather area appears in the terminal area, the impact of the blocky hazardous weather area on the capacity is determined by the flying distance and time variation under the blocky hazardous weather area. The evaluation of airspace utilization requires comprehensive consideration of time, space and flow. However, under hazardous weather conditions, the change in airspace utilization is mainly based on the ratio of flow to capacity. Therefore, based on the flow-to-capacity ratio and taking into account the time and space constraints, the airspace utilization model of the terminal area in the block hazardous weather area is established.
3.2.1 Impact of the blocky hazardous weather area on capacity. After the appearance of the blocky hazardous weather areas, due to diversion route, the flight distance and flight time of the aircraft will change, further affecting the capacity. Therefore, we must first analyze the impact of the blocky hazardous weather area on the flight route and flight time, so as to determine the change in the capacity of the affected part according to the above parameters.

1. Variation of flight distance

In summary, in order to determine the impact of blocky hazardous weather area on the flight route and flight distance, this paper defines the concept of the change in flight distance: Due to the diversion of the aircraft, the amount of change in the flight distance of the flight route compared to the planned route. Specifically, it can be divided into two cases, that is, the blocky hazardous weather area is around the air route segment; the blocky hazardous weather area is around the waypoint or the intersection of the air route segment. Details are as follows:

1) Blocky hazardous weather area is around the air route segment

When there is a blocky hazardous weather area around the route, the flight course is shown in Figure 2.

![Figure 2. Diversion route of flight course](image)

The boundary point of the known hazardous weather is \( p_i(x_p, y_p), \ i = 1, 2, \ldots, n \). The waypoints of the route are \( A(x_A, y_A) \) and \( B(x_B, y_B) \) respectively, and the two points farthest from the route are selected from the hazardous weather boundary points on both sides of the route. Cross the two points to make straight lines \( l_1 \) and \( l_2 \) parallel to the route. Then pass \( A \) and \( B \) to make straight lines \( l_A \) and \( l_B \) perpendicular to the route, respectively, and select the two points closest to \( l_A \) and \( l_B \) from the boundary points, and then pass two points to make straight lines \( l_3 \) and \( l_4 \) perpendicular to the route. It can be seen from the above that the four straight lines \( l_1, l_2, l_3, \) and \( l_4 \) form a rectangle. Considering the safety margin, extrapolate this rectangle by the distance \( d \), and the new rectangle \( M_1M_2M_3M_4 \) is formed as a restricted flight zone formed by the hazardous weather area. The intersection of the restricted area and the route is \( M_5, M_6 \). The aircraft flies away from the hazardous weather boundary at \( g \), and the fly-around point is \( G \). The coordinates of the above points can be obtained through a geometric relationship. Now take the aircraft flying on the \( M_1 \) and \( M_2 \) sides as an example, the course direction is \( \alpha_i \), the block hazardous weather movement direction is roughly the \( M_3, M_4 \) side, the movement direction \( \beta_i \), the movement speed is \( v_n \), and the restricted zone development speed along the route is \( v_i \) (When \( t \) is greater than the development time of hazardous weather, \( v_i = 0 \)). It can be seen from the figure that when there is a blocky hazardous weather area on the route, the flight distance of the aircraft changes by:
\[ \Delta S_i = GM_1 - GM_5 + M_2B - M_6B \]  

Where: \( GM_1 = \sqrt{GM_1^2 + M_1M_5^2} \), \( M_2B = \sqrt{M_2M_5^2 + M_6B^2} \), \( GM_5 = g - d \), when \( t = 0 \), \( M_1M_5 = M_2M_5 = r_1 \), \( M_1B = f_1 \), \( M_2M_6 = f_2 \). Due to the movement and development of hazardous weather areas, \( M_6B \), \( M_1M_5 \), and \( M_2M_6 \) are constantly changing, \( M_6B = f_1 - v_n t \cos[\alpha_i - \beta_i] - v_\nu t \), \( M_1M_5 = M_2M_6 = r_1 - v_n t \sin[\alpha_i - \beta_i] + v_\nu \frac{k_1}{k_2} t \).

2) The blocky hazardous weather area is around the waypoint or the intersection of air route segments. When there is a blocky hazardous weather area around the waypoint, it can be divided into inner flight and outer flight. It is selected according to the moving direction of large hazardous weather area. The boundary point of the hazardous weather is \( p_i(x_n, y_n), \quad i = 1, 2, \ldots, n \). The waypoints are \( C(x_c, y_c), D(x_d, y_d) \) and \( E(x_e, y_e) \). The two routes are \( a_2 \) and \( a_3 \). The aircraft departs from the hazardous weather boundary at \( G \), and the detour point is \( G \).

When flying inside, use \( C \) to make a straight line \( l_c \) perpendicular to the course. We select the point closest to \( l_c \) from the boundary points, and make a line \( l_i \) parallel to \( CD \) through the point. We select the point farthest from the \( CD \) on the inside and through it make the parallel line \( l_e \) of the \( CD \). \( l_1, l_2, l_3 \) and \( DE \) form a quadrilateral. Extrapolate this quad to distance \( d \). The new quadrilateral \( K_1K_2DK_4 \) is formed as a restricted flight zone formed by a hazardous weather area, and through \( K_1 \) make a vertical line of \( DE \) and intersecting \( K_1 \).

When the blocky hazardous weather area moves to the outside of point \( D \), the moving direction is \( \beta_2 \), the moving speed is \( v_n \), and the speed of the restricted zone in the direction of route \( CD \) is \( v_\nu \). (When \( t \) is greater than the development time of hazardous weather, \( v_\nu = 0 \)). The aircraft needs to fly around on the \( K_1 \) side, as shown in Figure 3. 

![Figure 3. Inside diversion route](image)

It can be seen from the figure that when flying inside, the variation of the flying distance is:

\[ \Delta S_{zi} = GK_z + K_2E - GD - DE \]  

Where, \( G K_z = \sqrt{GK_z^2 + K_zE^2} \), \( K_2E = \sqrt{K_zK_2^2 + K_zE^2} \), \( G K_z = g - d \). When \( t = 0 \), \( K_zK_2 = k_1 \), \( K_zD = k_2 \), \( K_zK_3 = k_3 \), \( DK_3 = k_4 \), \( K_zE = k_5 \). With the change of blocky hazardous weather area, \( K_zK_2 \), \( K_zK_3 \), \( K_zE \), \( K_zD \) are also constantly changing: \( K_zK_2 = k_1 - v_n t \cdot \sin[\beta_2 - \beta_i] + v_\nu \frac{k_1}{k_2} \cdot t \), \( K_zK_3 = k_3 - v_n t \cdot \sin[\alpha_i - \beta_i] + v_\nu \frac{k_3}{k_2} t \), \( K_zE = k_5 - v_n t \cdot \cos[\alpha_i - \beta_i] - v_\nu \frac{k_5}{k_2} \cdot t \), \( K_zD = k_2 - v_n t \cdot \cos[\beta_2 - \beta_i] + v_\nu t \).
When flying outside, make straight lines $l_c$ and $l_e$ perpendicular to the course through $C$ and $E$. We select two points closest to $l_c$ and $l_e$ respectively from the boundary points, and make lines $l_5$ and $l_6$ perpendicular to $CD$ and $DE$ through two points respectively. Then we select two points farthest from the $CD$ and $DE$ respectively on the outside and through them make parallel lines $l_5$ and $l_6$ perpendicular to $CD$ and $DE$. $l_5$, $l_6$, $l_5$, and $l_6$ form a quadrilateral. Extrapolate this quad to distance $d$. The new quadrilateral $N_1N_2N_3N_4$ is formed as a restricted flight zone formed by a hazardous weather area, and intersect $N_5$ and $N_6$ with $CD$ and $DE$.

When the blocky hazardous weather area moves to the outside of point $N_1$, the moving direction is $\beta_1$, the moving speed is $v_\beta$, and the speed of the restricted zone in the direction of two routes are $v_\beta$ and $v_\beta$. (When $t$ is greater than the development time of hazardous weather, $v_\beta = 0$). The aircraft needs to fly around on the $N_1$, $N_2$ and $N_4$ side, as shown in Figure 4.

![Figure 4. Outside diversion route](image)

When flying inside, the variation of the flying distance is:

$$\Delta S_{\text{in}} = G_N + N_2N_3 + N_3N_4 + N_4E - GD - DE$$ (3)

Where, $G_N = \sqrt{G_N^2 + N_2N_3^2}$, $N_3E = \sqrt{N_3E^2 + N_4E^2}$, $GN_5 = g - d$. When $t = 0$, $N_2N_3 = r_2$, $N_3E = f_2$, $N_3D = a_1$, $DN_6 = a_2$, $N_2N_5 = r_5$, $N_3N_6 = r_5$, $N_2N_5 = a_1$, $N_3N_6 = a_2$. With the change of blocky hazardous weather area, $N_2D$, $N_2N_3$, $N_3N_6$, $N_2N_5$ are also constantly changing:

$N_3D = \alpha_1 + v_\beta t - v_\beta t \cdot \cos |\alpha_1 - \beta_1|$, $N_3N_5 = \alpha_2 + v_\beta t - v_\beta t \cdot \cos |\alpha_2 - \beta_2|$, $N_3N_6 = \alpha_3 + v_\beta t - v_\beta t \cdot \cos |\alpha_3 - \beta_3|$, $N_2N_5 = \alpha_4 + v_\beta t - v_\beta t \cdot \cos |\alpha_4 - \beta_4|$. $\frac{v_\beta}{v_\beta} = \frac{\alpha_1}{\alpha_2}$.

When there is a blocky hazardous weather area at the intersection of the route, and there are no restrictions on both sides of the route, the aircraft on the two routes will fly around from both sides and increase the interval, as shown in Figure 5.

![Figure 5. Diversion route of intersection](image)
The change in flight distance is:

$$\Delta S_s = \Delta S + \Delta D$$

(4)

Where, $\Delta S_s$ represents the average change of the distance after the flight, and the calculation as similar as the situation where there is a blocky hazardous weather area at the waypoint of the route, and the aircraft flying inside. $D$ is the increased interval.

2. Variation of flight time

In the same way, in order to determine the impact of blocky hazardous weather areas on flight time, we define the amount of flight time change: due to the flight of the aircraft, the flight time of the flight route is compared to the flight time of the planned route. The aircraft flies around the blocky hazardous weather area with an average ground speed $\tau$, and the flight distance of the flight route is $\Delta S_j$ compared to the original route, so the flight time variation of a single aircraft is $\frac{\Delta S_j}{\tau}$. So all aircraft in the period $T$, the amount of time change is:

$$\Delta T_j = \frac{\Delta S_j \cdot C_s \cdot T}{\tau}$$

(5)

Where, $C_s$ represents the static capacity of the affected part, $s$ represents the affected part.

3. Dynamic capacity of the affected part

The change in flight time means that at the same time, the number of aircraft that can be accommodated in the affected part will also change. The current time capacity can be derived from the change in flight time:

$$C_s(T) = \frac{C_s \cdot T}{\tau + \Delta T_j} = \frac{C_s \cdot T \cdot \tau}{\tau \cdot \tau \cdot \Delta T_j}$$

(6)

3.2.2 Utilization model of approaching airspace in massive hazardous weather area

1. Calculation of approach capacity change under the influence of blocky hazardous weather area

When the approach flight is affected by the blocky hazardous weather area, the difference between the static capacity $C_{\text{app}}$ of the affected part and the capacity $C_{\text{app}}(T)$ at the time $T$ of the affected part is the change in the arrival capacity at time $T$ under the influence of the blocky hazardous weather area:

$$\Delta C_a(T) = C_{\text{app}} - C_{\text{app}}(T) = C_a \cdot \rho_1 \cdot \frac{C_a \cdot \rho_1 \cdot \tau_{\text{app}} \cdot \nu_{\text{app}}}{\tau_{\text{app}} \cdot \nu_{\text{app}} + \Delta S_{\text{app}} \cdot C_a \cdot \rho_1 \cdot \tau_{\text{app}}}$$

(7)

$C_a$ is the static capacity of the terminal area; $\tau_{\text{app}}$ is the average time of arrival of the aircraft; $\nu_{\text{app}}$ is the average speed of the aircraft entering the field; $\rho_1$ is the percentage of the affected area of the block hazardous weather area as a percentage of the arrival capacity; $\Delta S_{\text{app}}$ is the amount of change in approach distance at time $T$.

Organized:

$$\Delta C_a(T) = \frac{C_a^2 \cdot \rho_1^2 \cdot \Delta S_{\text{app}} \cdot \tau_{\text{app}}}{\tau_{\text{app}} \cdot \nu_{\text{app}} + \Delta S_{\text{app}} \cdot C_a \cdot \rho_1 \cdot \tau_{\text{app}}}$$

(8)

In the same way, it can be seen that the change in the approach capacity in the period $t$ is:

$$\Delta C_a^{'} = \frac{C_a^2 \cdot \rho_1^2 \cdot \Delta S_{\text{app}}^{'} \cdot \tau_{\text{app}}}{\tau_{\text{app}} \cdot \nu_{\text{app}} + \Delta S_{\text{app}}^{'} \cdot C_a \cdot \rho_1 \cdot \tau_{\text{app}}}$$

(9)

Then in the period $t$, the average approach capacity $C_a^{'}$ under the influence of blocky hazardous
weather area is:

\[
C'_a = \frac{[C_a \cdot T_{(app)} \cdot \bar{v}_{(app)} + C'_a \cdot T'_{(app)} \cdot \Delta S'_{(app)} / \rho_j \cdot (1 - \rho_j)] \cdot t}{\bar{v}_{(app)} + C'_a \cdot T'_{(app)} \cdot \Delta S'_{(app)} / \rho_j} \tag{10}
\]

2. Calculation of the airspace utilization rate of the terminal area under the blocky hazardous weather area during the period

After the capacity is obtained, the arrival flow in the time \( t \) of the airport terminal area can be counted to obtain the arrival flow \( F'_a \) in the time \( t \). It is finally available that the utilization rate \( U'_a \) of the terminal area's approaching airspace in the blocky hazardous weather area during time \( t \) is:

\[
U'_a = \frac{F'_a / C'_a}{F'_a / C'_a} = \frac{F'_a / (T_{(app)} \cdot \bar{v}_{(app)} + C'_a \cdot T'_{(app)} \cdot \Delta S'_{(app)} / \rho_j)}{[C'_a \cdot T'_{(app)} \cdot \bar{v}_{(app)} + C'_a \cdot T'_{(app)} \cdot \Delta S'_{(app)} / \rho_j]} \cdot t \tag{11}
\]

Where, \( F'_a \) represents the arrival flow of the terminal area under the block hazardous weather area during \( t \) period; \( C'_a \) represents the average entrance capacity of the terminal area under the block hazardous weather area during time \( t \); \( \Delta S'_{(app)} \) is the block hazardous weather area during \( t \) period

The average flight distance change of next approach flight.

4. Example

A control terminal area in China is selected, and when the terminal area is affected by the blocky hazardous weather area, the airspace utilization rate of its approach is calculated. The static capacity of the approach in normal weather is 25 per hour, the average approach time is 10min.

According to the model, the airspace utilization rate of the approaching route and the crossing point are calculated separately. The type of hazardous weather is single thunderstorm. According to the regulations, when flying around a thunderstorm, it should pass 25km away from the radar echo edge according to the intensity of the thunderstorm. The cumulus and cumulonimbus phases of the single thunderstorm are about 30 minutes, so the development time of the thunderstorm is 0.5 hours [18]. Calculate the approach flow in two cases, and then determine the average flight distance change in different time periods through the block hazardous weather area and the position of the affected route. Finally, the model is used to calculate the approach airspace utilization rate in the block hazardous weather area.

4.1. The Approach Airspace Utilization Rate when the Route is Affected

When the route is affected by thunderstorm, the expansion speed along the route is known as 4 km/h. Speed is 20 km/h. The moving direction is 219°. The direction of the affected route is 189°. The average approach ground speed is 450 km/h, \( d = 25km \), \( g = 55km \). At the beginning of the study period, the following initial values of the diversion route can be obtained according to the affected route and the location of the thunderstorm: \( M_1M_2 = M_2M_3 = 32km \), \( M_1B = 40km \), \( M_3M_6 = 58km \). According to the ratio of the flow rate of each route during peak hours, the percentage of the impact of the single thunderstorm to the arrival capacity is: \( \rho_j = 0.3 \). The study period is 10:00-11:00. Taking 15min as a time slice, the average flight distance change of each time slice is \( \Delta S'_{(app)} \). We make a statistic of approach traffic flow, and calculate the approach airspace utilization rate according to formula (11), as shown in Table 1.
Table 1. Terminal area entry data and calculation results when the flight course is affected by thunderstorms

| Time slice | $F_a^r$ | $\Delta S_{(app)}^r$ | $U_a^r$ |
|------------|---------|----------------------|---------|
| 1          | 4       | 21.423               | 66.20%  |
| 2          | 4       | 23.504               | 66.38%  |
| 3          | 4       | 17.512               | 65.87%  |
| 4          | 4       | 15.447               | 65.68%  |

4.2. The Approach Airspace Utilization Rate when the Route Intersection is Affected

When the intersection of the route is affected by thunderstorms, the expansion speed along the converging route is 4km/h, the moving speed is 15km/h, the moving direction is 76°, the affected route directions are 60°, 21°, and 46°, respectively, and the average ground speed at the approach is 400km/h. The research period is from 10:00 to 11:00, and the airspace utilization rate of the approach field is calculated similarly, as shown in Table 2.

Table 2. Terminal area entry data and calculation results when the intersection is affected by thunderstorms

| Time slice | $F_a^r$ | $\Delta S_{(app)}^r$ | $U_a^r$ |
|------------|---------|----------------------|---------|
| 1          | 3       | 20.064               | 49.63%  |
| 2          | 3       | 21.746               | 49.75%  |
| 3          | 4       | 23.565               | 66.49%  |
| 4          | 4       | 25.159               | 66.62%  |

By averaging the utilization rate of each time slice, the hourly utilization rate in both cases is 66.03% and 58.12%. The statistics of the arrival traffic during peak hours under normal weather is 21, and the utilization rate of arrival airspace under normal weather is basically calculated to be about 84% by the model [13-15].

The evaluation results show that when the blocky hazardous weather area exists, it reflects that the approach airspace utilization rate will be significantly reduced. Mainly because the blocky hazardous weather area will affect the flight path of the aircraft, resulting in a reduction in flow and capacity, which is consistent with the actual situation, which shows the effectiveness of the model.

5. Conclusion

In this paper, an airspace utilization model of the terminal area under the blocky hazardous weather area is established, and the influence of the blocky hazardous weather area on the terminal area is considered. According to the operation and characteristics of the aircraft in the blocky hazardous weather area, the impact of the blocky hazardous weather area on the air route segment, the waypoint, and the intersection point is analyzed to determine the amount of flight distance change in different situations. Establish the capacity model of the affected part according to the change of flight distance. Based on the flow-to-volume ratio, taking into account the space and time constraints, respectively, the terminal airspace utilization model in the blocky hazardous weather area is established. Analysis of calculation examples shows that the evaluation calculation results of the model can truly reflect the operation of the terminal area under the influence of massive hazardous weather areas.
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