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Research Article

Constructing Scenarios' Network-of-Flight Conflict in Approach of Intersecting Runway

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For studying the mechanism of flight conflict in approach of the intersecting runway, this paper applies the case study, scenario construction, and complex network, analyzes the operational risks of the intersecting runway, and researches the general rule of flight conflict. We constructed a network model of scenario evolution of flight conflict with selecting Beijing Daxing International Airport as the research object, which included 169 nodes and 263 edges. It proposed path evolution and verified the effectiveness of this network. We analyzed the degree centrality, median centrality, and closeness centrality of the network, and the results showed that the comprehensive value of 5 nodes is high, including go-around (V2), conflict resolution (C22), the warning light of aft cargo dJor was extinguished (F12), suspend subsequent take-off operations (F5), and keeping visual flying (C26). The results show that this method provides a new research way for the control strategy of chain breakage and the mechanism of scenario evolution of flight conflict.

1. Introduction

In recent years, in order to cope with the shortage of airport runway capacity in the development of civil aviation industry of China, airports are being rebuilt and expanded all over the country, which is a project with huge demands on land resources and environment. The airport with the intersecting runway has many advantages. On the one hand, it can adapt to the change of wind direction, realize omnidirectional take-off and landing, improve the efficiency and safety of the runway operation, and increase the flow. On the other hand, land resources can be greatly saved. The airports using the intersecting runway is becoming a superlarge and large airports, for example, Beijing Daxing International Airport [1], which operated in 2019.

There has been rich experience in the operation of the parallel runway in China. In 2005, Beijing Capital International Airport was the first airport in China to implement the independent operation of two runways. At the same time, the Civil Aviation Administration of China has continuously released the operation rules for multiple runways, such as CCAR-98TM [2] and CCAR93TM—R2 [3]. However, serious flight conflicts still occur in the operation of parallel runways in China. For example, the "10.11" flight conflict (serious accident) sign occurred in Shanghai Hongqiao Airport in 2016 [4].

2. Research Actuality

Because flight conflict is the direct cause of the plane crash [5], the research on the intersecting runway is relatively early abroad; most of the work progress to the prediction and prevention of the conflict stage, whose content involves the ground early warning system, the pilot alarm information, intersecting runway take-off location identification system, take-off and landing aircraft separation operation [6–8], etc.

However, due to the fact that the intersecting runway operation mode has not been officially used in China, current studies still focus on the wake interval, runway capacity, flight data analysis [9–11], and other related issues. The research in this area is relatively rare. In the relevant research on flight conflict, domestic scholars mostly take parallel runway as the basis and focus on conflict hotspot identification and the establishment and solution of the relief model [12–14].

Complex network has been applied to the risk scenarios' evolution process of the deep-water drilling platform [15] and amphibious seaplanes [16] and achieved remarkable results. At the same time, many hot problems in the field of civil aviation also applied to the single-layer and multi-layer complex network, such as the route network [17], the flight delays [18], traffic distribution strategy [19], and security vulnerability analysis [20], based on the performance of navigation (PBN) [21].

The research actuality at home and abroad is supplemented and modified as follows: at present, many research studies on the prediction and prevention of aviation safety incidents rely on aviation safety incident reports, but most of the reports have problems such as large content and non-standard language and writing style [22]. Therefore, it is vital to accurately identify why these incidents occurred in the aviation safety incident report [23]. Xu et al. studied Natural Language Process (NLP), text mining techniques, machine learning, and other aspects, which effectively improved the accuracy of information processing [24, 25].

At present, there are relatively few studies on the combination of the operation mode of the intersecting runway and the scenarios' evolution of flight conflict. In view of the actual operational requirements and potential safety problems of airports with superlarge intersecting runway in China, this paper adopts complex network theory and scenario analysis method to conduct scenario evolution and risk analysis of flight conflict of the intersecting runway, in order to explore a new way of describing and analyzing flight conflict risk.

3. Construction of Method and Model

3.1. Theoretical Method

3.1.1. Construction of Scenario Theory. A scenario is a collection of a large number of similar events and various risks that may occur in the future [26, 27]. Scenario elements are usually analyzed from three dimensions of disaster body, disaster-resistant body, and disaster body [28]. Situational elements are the key factors of situational construction, which can reflect the development state and trend of events.

3.1.2. Complex Network Theory. Qian Xuesen defined that the complex network is the network with a part or all of the properties of self-organization, self-similarity, attractor, small world, and scale-free [29]. Based on system theory, graph theory, and statistical theory, the complex network can represent intuitively connectivity between system structures by establishing accident scenarios [30]. The complex network is described by a weighted directed acyclic connected graph $G = (V, L, W)$ of the sparse matrix, which is suitable for the study of accidents with complex accident mechanism, numerous risk factors, and risk factors with complex relationships and complex accident models' components.

(1) The node degrees

Node degree is the set of the input degree and exit degree of the node and the number of edges connected by nodes. The degree of node t is denoted as

$$k_t = \sum_s a_{ts}. \tag{1}$$

In the type, k_t is the degree of the node and a_{ts} is the number of edges connected between nodes v_t and v_s. Node degrees can reflect the importance of nodes. The greater the degree of the node is, the more important the nodes in the network are.

(2) The degree centrality

The degree centrality of nodes is to measure how closely a node in the network is connected with all other nodes. The degree centrality of nodes is denoted as

$$C_D(v_t) = \frac{\sum_{t=1}^{s} a_{ts}}{s-1}. \tag{2}$$

In the type, $C_D(v_t)$ is the degree centrality of nodes and a_{ts} is the number of edges connected between nodes v_t and v_s (excluding self-ring). The degree centrality of a node reflects the degree of association between a node and other nodes in the network. The greater the degree centrality of a node, the closer the connection between the node and other nodes.

(3) Median centrality

Median centrality of a node is the ratio of the number of shortest paths a node has passed to all shortest paths in the network. The median centrality of a node is noted as

$$C_B(v_t) = \sum_{s \neq v \neq t \epsilon V} \frac{\sigma_{st}(v)}{\sigma_{st}}. \tag{3}$$

In the type, $C_B(v_t)$ is the median centrality of nodes and $\sigma_{st}(v)$ is the number of shortest paths through nodes v. Median centrality of nodes is another index that reflects the importance of nodes in the network. The greater the median centrality of nodes, the higher the position of nodes in the network.

(4) Closeness centrality

The closeness centrality of a node is the ratio of the number of all nodes related to a node in the network to the number of all shortest paths passing through this node:

$$C(v_s) = \frac{1}{\sum_{v_s} d(v_s, v_t)}. \tag{4}$$

In the type, $C(v_s)$ is the closeness centrality of nodes and $d(v_s, v_t)$ is the distance between nodes v_s and v_t. Closeness centrality of nodes is a parameter that measures the importance of nodes by the average length of shortest paths between nodes. The greater the proximity centrality of nodes is, the more important the nodes in the network are.

3.2. Analysis of Risk Characteristics of Intersecting Runway Operation. The flight conflicts of the intersecting runway have varied causes and complex evolvement process, which is suitable for using the complex network to study. The complex network is between the regular grid and random network. The nodes are connected into edges in a self-organizing way, and the initial event evolves into the final event through different paths. The evolution of the intersecting runway flight conflict scenario has the following characteristics.

3.2.1. Complexity. The risks of flying at low and medium altitudes, especially in tower control areas, eventually emerge in the operation. In the process of flight, facing the influence of turbulence, thunderstorm, wind shear, ice accumulation, and other bad weather, restrictions on airspace imposed by military aviation activities have randomness and variability, and aircraft and air traffic control equipment are prone to failure. These risk factors interact with each other in a complex way, projecting them into the network as nodes.

3.2.2. Small-World Character. The small world of the evolution of the risk of intersecting runway flight conflict is reflected in that, although there are many risk factors affecting flight conflict events, it can occur in a few short nodes between the initial event and the resulting event.

3.2.3. Scale-Free Features. The scale-free property of the complex network mainly describes the problem of the node degree. A few nodes in the network have a lot of connections, while most do not. In the evolution process of flight conflict scenarios for the intersecting runway, most risk factors revolve around the results of flight conflict and several major risk factors leading to flight conflict, such as aborted approach, go-around, re-approach, and so on, which reflect the scale-free characteristics in the evolution process.

3.2.4. Community Structure Characteristics. Intersecting runway flight conflict situation evolution concerns the four types of risk factors of Human, Machine, Ring, and Tube. The complex network provides a model that can show the interrelationships between each type of the risk factor and the interaggregation of related risk factors. Categorizing these risk factors, we can identify the commonalities of these risk factors and the relationships between each type of factor.

3.3. Construction of Scenarios' Evolutionary Network Model of Flight Conflict in Approach Stage

3.3.1. Identification of Operational Risk Factors for Airport with Intersecting Runway Configuration. This study was based on the real layout of the intersecting runway of Daxing Airport. Major operational risks in the approach phase are shown in Table 1.

3.3.2. Network Model Construction Procedures. The process of constructing the evolution network model of flight conflict scenarios in the approach stage of Daxing Airport's cross-runway is as follows:

(1) *Data Processing.* Collected and sorted out laws and regulations related to intersecting runway operation of civil aviation as well as relevant data of Daxing Airport's operating and natural environment; a total of 906 flight conflict incidents were collected and summarized from 2010 to 2019. The cases were divided into 6 categories, including aborted approach, rejected take-off, runway unusable, ground activities, unmanned aerial vehicles, and certain consequences.

(2) *Case Study.* We defined relevant risk factors that could lead to flight conflict as a keyword library, applied the Chinese Word Segmentation technology of Python ieba function library to extract the keywords in the event, and counted the frequency of statistical keyword, logical relationship, and other parameters, and the keyword library is modified by the results of the Chinese Word Segmentation technology to make it closer to the case contents.

(3) *Construction of Scenario Group.* Constructed the logical link between the keywords in taking a single case as a unit, extracted the safety risk factors, scenario description, scenarios' elements and nodes of flight conflict occurring during aircraft approach in the terminal area of the airport with the intersecting runway, and constructed the scenario group and evolution network

(4) *The Construction of Complex Network.* Sorted out the public node of different scenarios and plotted complex network diagrams for flight conflict scenarios in the intersecting runway terminal area of Daxing Airport.

(5) *Analysis of Experimental Results.* Calculated network parameters including node, edge, and weight and analyzed their influence on flight safety.

4. The Empirical Analysis

4.1. The Experimental Background. This paper is based on the actual layout of the intersecting runway of Daxing Airport and assumes that the flight conflict would occur after the 11L/29R runway was put into operation: the landing would be made on the 29R runway, the approaching aircraft would stop the approach and go-around, and its track would cross with the aircraft taking off and landing on other runways, resulting in flight conflict.

4.2. Complex Network Construction. The risk factors of the abort approach event case set, namely, nodes of the complex network, were extracted, including 37 nodes. The risk factors (nodes) of the abort approach scenario are shown in Table 2.

By sorting and screening invalid edges in the network (go-around⟶abort approach), the obtained directed network graph contains 78 edges, as shown in Figure 1.

By the same token, the nodes of the other 5 cases were extracted and constructed to network. Because of the limit of

Table 1: Operational risk.

Risk category	Risk name	Risk description
Flight risk	TCAS warning	Daxing Airport consists of four runways. The 11L/29R runway is an intersecting runway located in the East. Due to different operation modes, it is easy to cause TCAS warning
	Flight conflict	There will be a potential flight conflict with the operation of landing on 29R runway: the plane go-around track on 29R runway will cross with the tracks of the operating plane on the others runways
	Under the minimum interval	When multiple runways approach and take off at the same time, it is easy to trigger alarm, and there have been incidents that the approaching aircraft of adjacent runways under the minimum interval
	Wrong runway	There is an air force airport runway on the west side, which is not used for civil aviation, but it was easy to landed on the wrong runway and generate TCAS alarm
Environmental risk	Tailwind	When the aircraft runs northward, it is easy to run tailwind in spring and summer, which reduces the take-off and go-around performance of the aircraft
	Unstable approach	In the southward operation, due to the influence of terrain, it is easy to face turbulence, which has great interference on the approach stability and flight parameters
Operation limit	Forbidden zone	There are a lot of forbidden zones around Beijing
	Secondary radar fault	Taking off and landing aircraft without secondary radar transponders is prohibited in the airport; when secondary radar transponders fail on the ground or in the air, restrictions are formed

Table 2: Risk factors of the aborted approach scenario (nodes).

Numbers	Risk factors
A1	Abort approach
A2	Wind shear
A3	Turbulent flow
A4	Go-around
A5	Thunderstorm
A6	Rainfall
A7	Unable to see the runway
A8	Excessive tailwind
A9	Turbulence
A10	Excessive gust
A11	The control orders plane to slow down
A12	Causes of runway configuration
A13	Failed to get off the runway in time
A14	Reapproach
A15	Flap fault
A16	Unable to see the front plane
A17	Still has catch-up trend
A18	Under the wake interval
A19	Overweight
A20	Continue to catch up with the front plane
A21	Catch up with the front plane
A22	Dissatisfaction landing interval
A23	Bird strike
A24	There is a trend of catching up
A25	Unstable approach
A26	Runway suspended
A27	Bias navigation
A28	Avoid
A29	Ground proximity warning
A30	Crossing the runway waiting line
A31	Conflict
A32	Crosswind
A33	TCAS warning
A34	Conflict warning
A35	PTCAS
A36	Blind approach
A37	Frost fog
—	—

the space, it is not here. Sorted public nodes and used uniform labels to realize the connectivity of each network and get directed network diagram flight of conflict of Daxing Airport intersecting runway, which had a total of 169 nodes' risk factors (such as Table 3) and 263 sides (as shown in Figure 2).

According to Table 3 and Figure 2, the nodes V1–V30 are common nodes of all kinds of events, nodes A1–A21 represent the abort approach events, nodes B1–B16 represent runway unavailable events, nodes C1–C34 represent cause events that may cause certain consequence, nodes D1–D12 represent UAV events, nodes E1–E20 represent ground activity events, nodes F1–F36 represent rejected take-off type events. The nodes of all kinds of events are connected with each other through V1–V30 nodes, which constitute the flight conflict scenario evolution network model of Daxing Airport's intersecting runway.

4.3. Network Parameters. Table 4 shows model parameters of the flight conflict scenario evolution network model of Daxing Airport's intersecting runway.

Table 4 shows that the network density of the network is 0.009, and the network density is low, indicating that the model network is relatively loose, the evolution of the risk event is less, and the relevance is general; the network is 1.556, indicating that each node of the network is connected to 2 other nodes, which conforms to the small-world characteristics of the complex network. In the mean calculation method, the weight of each side will be defaulted to 1. If the weight is considered while calculating the node degree, it can be obtained that the average weight of the network is 20.337, indicating that the degree of discrete of side weight distribution in the network is large [31].

The weights of some edges are large, some are small. Few nodes have a large number of connections, and most nodes are rare, reflecting the no-scale characteristics of the complex network. The average path length of the network is

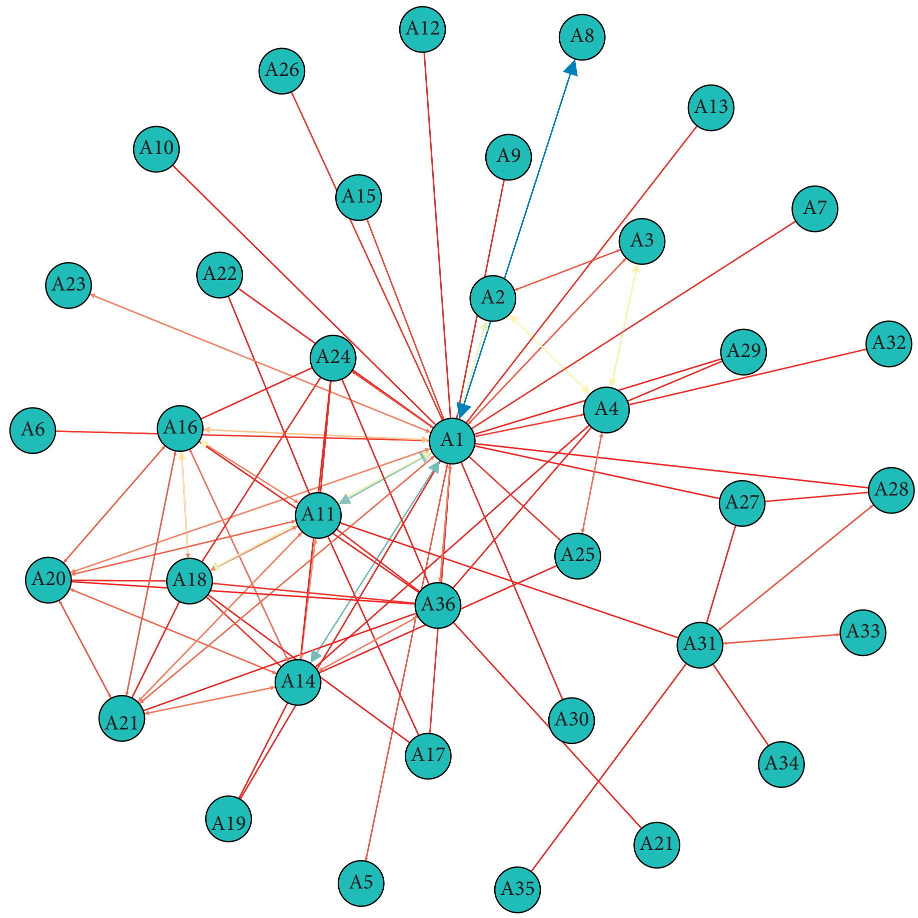

Figure 1: Directed network graph of the aborted approach cases.

3.143, indicating that each node can affect other nodes only through the average of 3.143 units. The network diameter of the network is 9, indicating that any of the nodes in the network may cause flight conflicts up to 9 steps. The average cluster coefficient is 0.097, which reflects that the interaction between nodes is low.

5. Experimental Results' Discussion

5.1. Node Degree and Degree Distribution. Table 5 shows that, in the flight conflict scenario evolution network model of Daxing Airport's intersecting runway, for the degree, the degrees and in-degree of the node (V1) are max. The degrees (degree value 38) are max, indicating that it is the most important node in the network, and the in-degrees (degree value 32) are max, indicating that the risk factors leading to the suspension of approach are the most, and it is difficult to control. V1 is a key risk factor and one of the necessary conditions leading to flight conflict. The result is completely consistent with the actual situation.

In terms of out-degree, the controller makes notification (V18), blind approach (V16), and check (V19), which are the three nodes with the largest out-degree. V18 is a process event and not a risk factor, so it can be ignored here. V16 is a node describing the approach state, which is a risk factor, and its large degree indicates that it is more likely to cause subsequent risk events in the process of blind approach.

Nodes with higher degrees should be paid attention during the evolution of flight conflict scenarios at the Daxing Airport crossing runway.

5.2. Betweenness Centrality of Nodes. Table 6 shows that the betweenness centrality values of V19 and V1 are the largest, which indicates that the shortest paths V19 and V1 pass are the most, and V19 and V1 play the most important role in the risk transmission process of the whole network.

The analysis of the actual case shows that the factors causing V1 include the abnormal state of runway and all kinds of approach equipment. In this case, the controller will inform the relevant ground personnel to check and clear trouble at the first time, so the betweenness centrality value of V19 is the largest among all risk event nodes, which is completely in line with the reality.

V19 and V1 play an important role in the evolution of flight conflict scenarios on the intersecting runway.

5.3. Closeness Centrality of Nodes. The 12 nodes in Table 7 had the highest closeness centrality. The closeness centrality of nodes shows of the location of nodes in the network. The

Table 3: Risk factors (nodes).

Numbers	Risk factors	Degree
V1	Abort approach	38
V2	Go-around	9
V3	Rainfall	2
V4	Turbulence	3
V5	Reapproach	13
V6	Flap fault	2
V7	Bird strike	3
V8	Runway suspended	7
V9	Avoid	5
V10	Ground proximity warning	3
V11	Crossing the runway waiting line	4
V12	Conflict	10
V13	TCAS warning	1
V14	Conflict warning	2
V15	PTCAS	1
V16	Blind approach	14
V17	Waiting in place	3
V18	Controller briefing	33
V19	Inspect	18
V20	Safe landing	11
V21	Approach coordination	3
V22	Normal approach	6
V23	Continue approach	5
V24	Run off the runway	9
V25	Alarm elimination	2
V26	Suit of pavement	3
V27	Change runway to land	4
V28	Glide back	25
V29	Take-off interrupted	21
V30	Automatic pressurization system failure	1
A1	Wind shear	3
A2	Turbulent flow	3
A3	Thunderstorm	1
A4	Unable to see the runway	1
A5	Excessive tailwind	1
A6	Excessive gust	1
A7	Orders plane to slow down	12
A8	Causes of runway configuration	1
A9	Failed to get off the runway in time	1
A10	Unable to see the front plane	9
A11	Still has catch-up trend	3
A12	Under the wake interval	9
A13	Overweight	2
A14	Continue to catch up with the front plane	7
A15	Catch up with the front plane	7
A16	Dissatisfaction landing interval	2
A17	There is a trend of catching up	6
A18	Unstable approach	3
A19	Bias navigation	3
A20	Crosswind	1
A21	Frost fog	1
B1	Repair	2
B2	No foreign matter was found	1
B3	The equipment is normal	3
B4	Departure aircraft waiting	1
B5	The course signal is normal	3
B6	Confirm whether the blind drop signal is stable	2
B7	Course stability	2
B8	Fragments	1
B9	Plastic bag	1

Table 3: Continued.

Numbers	Risk factors	Degree
B10	Course signal instability	3
B11	Course instability	5
B12	The one minute vector line swings left and right	3
B13	The course signal is unstable	2
B14	Signal instability of glide path	2
B15	The radar signal swings left and right	1
B16	Radar track swing	2
C1	MSAW alarm	1
C2	Descent height	2
C3	Stop descent	2
C4	Alarm release	1
C5	Unidentified vehicle	2
C6	Controller call field service assistance handling	2
C7	Radio jamming channel	2
C8	Get off the runway	1
C9	Deviation taxiway	2
C10	Guided vehicle passes the waiting point without permission	1
C11	Runway intrusion warning	2
C12	Controller verification	2
C13	The guide car exits outside the waiting point	1
C14	Breaking the command height	1
C15	Keep going up	2
C16	Controller command descent	2
C17	The height setting is correct	1
C18	Flight procedure error	1
C19	Upwind not turning according to the procedure	2
C20	Deviation from procedure	2
C21	Rejoin the correct take-off procedure	1
C22	Conflict resolution	6
C23	No TCAS alarm	1
C24	Controller asked if it could be visualized	2
C25	Visualization	2
C26	Keep visualization	2
C27	Converging flight at the same altitude	1
C28	Converging flight	2
C29	Slow down	1
C30	Under the regular interval	1
C31	Waiting outside the runway	1
C32	Drive-bird car for road inspection	1
C33	Waiting on taxiway	2
C34	Delay	1
D1	Drone	5
D2	Tower verification to crew	4
D3	Not found by the crew	5
D4	The operation was not affected	2
D5	Departure aircraft affected	1
D6	Approach aircraft affected	1
D7	The moving direction is uncertain	1
D8	Balloon	4
D9	Crew visual balloon activity	1
D10	Kite	1
D11	Floater	1
D12	Laser irradiation	1
E1	Airforce activities	1
E2	Reasons for passengers	1
E3	Mechanical fault	1
E4	Aircraft fault	1
E5	Fuel leakage	1
E6	Pollute taxiway	2
E7	The reason of frontier defense	1

Table 3: Continued.

Numbers	Risk factors	Degree
E8	Crew timeout	1
E9	The visual range of runway is lower than its landing standard	1
E10	Pavement icing	1
E11	Flight control system fault	1
E12	Weather radar fault	1
E13	Aircraft technical reasons	1
E14	Front wheel turning fault	1
E15	Engine core de-icing component fault	1
E16	Departure time limit	1
E17	There are approaching planes on final	2
E18	Oil replenishment	1
E19	Abnormal front tire pressure display	1
E20	Hit by a special vehicle	1
F1	No impact on runway	1
F2	The tower asked if there was any hydraulic oil leakage	2
F3	No hydraulic oil leakage	2
F4	Need rescue service	2
F5	Suspension of subsequent take-off activities	2
F6	Further confirm the fault information	1
F7	Apply for glide back	2
F8	Uncertain whether there is any abandoning and scattering objects	2
F9	No service is required	1
F10	Recovery of runway	2
F11	Coordination of relevant airport departments	1
F12	The rear cargo door warning light extinguish	2
F13	RebJoting	2
F13	The rear cargo door is closed	1
F14	The push back light is on at the same time	2
F16	The computer shows that the hydraulic pressure is low	1
F17	Lost GPS signal	1
F18	Rear gate light on	1
F19	Rear cargo door warning light on	1
F20	Rear passenger compartment gate warning light on	1
F21	Fire engine in place	2
F21	Warehouse fire	1
F22	Fire emergency	2
F24	There is no smoke or fire outside the engine room	2
F25	The fire engine taxied behind	1
F26	There is no abnormal phenomenon in the fire report	1
F27	Right engine fault	1
F28	Oil leakage may occur	1
F29	Hatch open	1
F30	Cockpit voice recorder fault	1
F31	Computer fault	1
F32	Configuration alert	1
F33	Take-off configuration alert	1
F34	Front door of engine room not opened	1
F35	Air-brake fault	1
F36	Left side engine fault	1
—	—	—

closer the node is near the network center, the more important is the node.

Go-around (V2) and conflict resolution (C22) are the key risk factors related to the occurrence of flight conflict events at Daxing Airport, and their closeness centrality is high.

The warning light off (F12) of the rear cargo door and interphone card group channel (C7) are both related to equipment failure. The inspection (V19) node is the node with the greatest median centrality, while the equipment failure-related node is closely related to V19.

The description of deviation procedure (C20) in the case is that the pilot did not operate according to the prescribed procedure to cause deviation procedure, which is a human factor. The whole process of flight conflict in actual operation cannot be separated from human behavior.

Suspend of subsequent take-off activities (F5), maintain visual (C26), stop descent (C3), controller verification (C12),

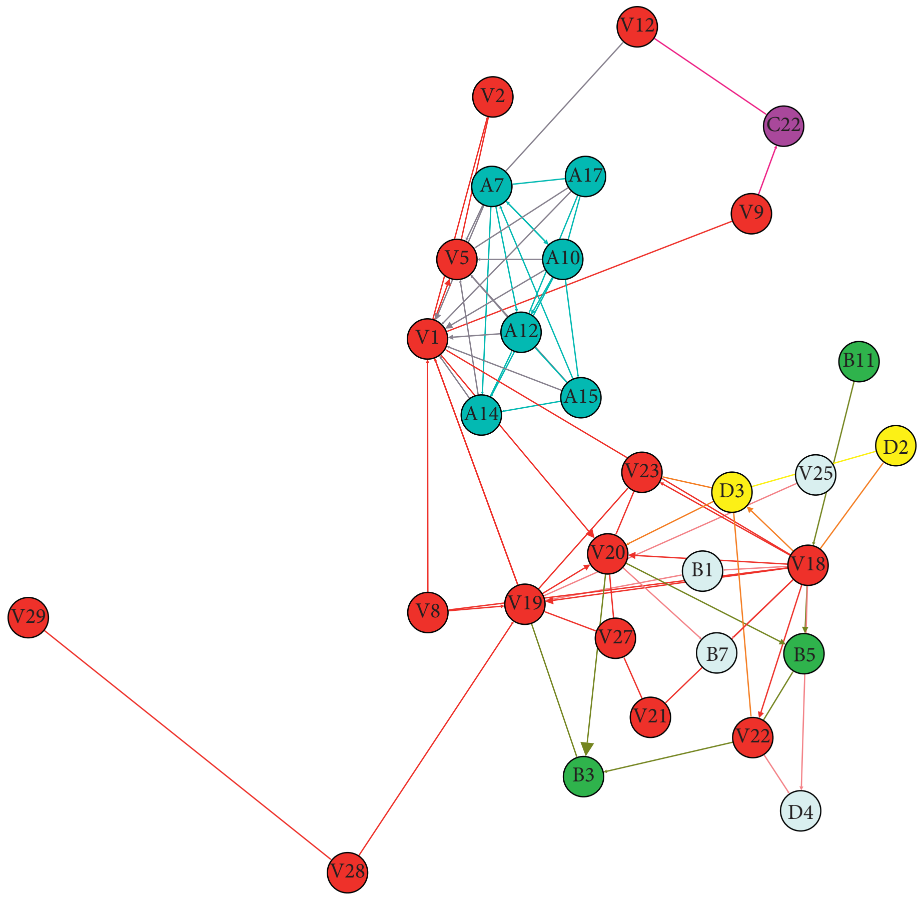

Figure 2: Complex networking graph of flight conflict in the intersecting runway. Note: only nodes with the node degree greater than or equal to 3 are retained in the figure, while nodes with the low connectivity degree are not shown in the figure.

Table 4: Parameters of the network.

Parameter name	Value
Number of nodes	169
Number of edges	263
Network density (directed)	0.009
Network average degree	1.556
Network average weighted degree	20.337
Network diameter	9
Network average clustering coefficient	0.097
Network average path length	3.143

Table 5: Distribution of nodes' degree values.

Number	Nodes	Degree	Degree centrality	In-degree	Out-degree
1	V1	38	0.2262	32	6
2	V18	33	0.0536	15	18
3	V28	25	0.0774	22	3
4	V29	21	0.0417	15	6
5	V19	18	0.0595	7	11
6	V16	14	0.0833	1	13
7	V5	13	0.1964	13	0
8	A7	12	0.1071	4	8
9	V20	11	0.0655	8	3
10	V12	10	0.0357	8	2

Note: only the top 10 nodes are shown in the table.

and controller instruction descent (C16) are all belong to the node that describes the state, not risk factors, which carry the transmission of risk factors.

Since there is no flight accident in the case set in this paper, the closeness centrality of safe landing (V20) is 1.

5.4. The Comprehensive Value of the Node. According to the relevant research results [15], the importance of nodes is determined to be described by comprehensively considering the relevant parameters. In this paper, the comprehensive value of nodes is defined as the average value of the sum of degree centrality, betweenness centrality, and closeness centrality. The importance of each node in the network is described by the comprehensive value, as shown in Table 8.

From the result of the comprehensive value, the case set of unsafe events adopted in this case did not cause serious consequences, so the safe landing (V20) can be eliminated. At this time, the comprehensive value of go-around flight (V2) is the largest, indicating that go-around flight is the most critical factor leading to flight conflict. Conflict relief (C22), rear cargo door warning light off (F12), suspension of subsequent take-off activities (F5), visual maintenance (C26), and other nodes have significant influences on flight conflict, and the conclusions obtained from the analysis are also consistent with the actual situation.

Table 6: Betweenness centrality distribution of nodes in networks.

Number	Nodes	Betweenness centrality
1	V19	0.0493
2	V1	0.0430
3	V28	0.0337
4	V18	0.0262
5	V29	0.0219
6	F21	0.0100
7	F24	0.0072
8	V20	0.0070
9	V24	0.0050
10	F7	0.0045

Note: only the top 10 nodes are shown in the table.

Table 7: Closeness centrality distribution of nodes in networks.

Number	Nodes	Closeness centrality
1	V2	1.0000
2	F5	1.0000
3	C3	1.0000
4	C7	1.0000
5	V20	1.0000
6	C12	1.0000
7	C16	1.0000
8	F12	1.0000
9	C20	1.0000
10	C22	1.0000
11	C26	1.0000
12	C33	1.0000

Table 8: Comprehensive value distribution of nodes in networks.

Number	Nodes	Comprehensive value
1	V20	0.3575
2	V2	0.3512
3	C22	0.3454
4	F12	0.3385
5	F5	0.3375
6	C26	0.3374
7	C3	0.3373
8	C7	0.3373
9	C12	0.3373
10	C16	0.3373

Note: only the top 10 nodes are shown in the table.

5.5. Break Chain Control Strategy. Perform scenario analysis by using a large number of cases, find the key nodes that affect the outcome of the event as well as the correlation and logic among the key nodes, and then find out the prevention and control strategies. In this paper, V2 is the most critical factor, which can effectively prevent the occurrence of flight conflict by controlling it. By controlling the risk factors that lead to resort (V2), it can reduce the occurrence or improve the safety of go-around. For the field of civil aviation, the most effective strategy includes enhancing the capability of small-scale weather forecast in the airport area, improving the conflict resolution ability of flight crews and controllers in the go-around scenario, and developing equipment to provide the capability of conflict prediction in the airport terminal area.

6. Conclusion

(1) In this paper, the operational risk factors of the airport with intersecting runway configuration are identified, and the visual model characteristics and key nodes of flight conflict scenario evolution of civil aircraft in the approach phase are described.

(2) The evolution network model of the flight conflict scenario of civil aircraft in the approach phase is constructed, which includes 169 nodes and 263 edges. By analyzing the parameters of the network, the risk evolution path is given and the effectiveness of the network is verified.

(3) The mechanism of flight conflict scenario evolution and propagation has not been analyzed in detail, which will be the next research focus.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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