Research on inducement to accident/incident of civil aviation in southwest of China based on grey incidence analysis

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Abstract

Southwest region of China is covered with mountains and plateaus vastly. Terrain and climate of this area is complex exceedingly. Many airports are plateau ones. All of these features make it difficult and high-risk to develop civil aviation. With the propelling of development of the west regions, more plateau airports and airlines will be built in the southwest. What was worse, more and more safe flights will make our nation’s safety management face rigorous test. Firstly, this paper analyzed features of the southwest and accidents or incidents of this region recent ten years; Secondly, it indicated four inducements, including bird strike, crews, the mechanical and general aviation; Lastly, this paper built a grey incidence analysis model to analyze all kinds of inducement. This final result will tell us one inducement has badly affected safety of China’s civil aviation, and some government or airline has to take some measures to prevent this kind of accident or incident.

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Keywords: aviation safety management; grey incidence analysis; risk analysis; accident/incident; plateau airport

1. Introduction

By the end of 2009, civil aviation of China had owned 38 airlines[1]; average increment speed of air transportation had been up to 7.2 percent. More and more airlines have acquired certificate to fly on plateau airports. Annual gross of safe flights reached 21.33 percent in one year. As Chengdu Shuangliu airport is becoming the core of southwest, air transportation net has covered other regions, including Yunnan, Guizhou, Xizang and Qinghai province. All of these regions are covered with high mountains and plateaus, you can hardly find more persons in this vast area. So, developing air transportation can save more money than building highway or railway, and it will prevent earthquake and mud-rock flow effectively. Meanwhile, with the deeply development of west regions, civil aviation of southwest will face bigger development.

As the feature of our nation’s geography, all of 17 plateau airports were put together in the west. It is more difficult and costly for airlines to operate flights on plateau, which has lower pressure, complex climate and rough topography [2]. Hump airline during World War II was the lifeline of China. Because of the difficulties and dangers of high altitude flights, the America Air Force lost a total of more than 400 aircrafts and 1,500 pilots. Modern aircraft flight performance has been greatly improved. The aircraft can be very easy to fly over high mountains [3]. All of these improvements have promoted plateau flights’ margin of safety. But wicked flight conditions still make rate of accident or incident on the high level. All in all, researches on all kinds of inducements to accidents or incidents can make a big difference for ensuring safety management of civil aviation in southwest.

2. Characteristics of civil aviation in southwest of China

Southwest of China is vast and it has owned many airlines, and it is also abundant in tourism resources and flight
trainings. Because of complex terrain and wired climate, safe flights in this area are facing difficult and dangerous conditions. However, all of these inactive external pressure have affected aircrafts, crews and airports badly.

2.1. Airports

By the end of 2008, southwest of our nation has owned 16 airlines and 33 airports. Civil Aviation Administration of China has defined common plateau airports as some airports whose elevation range from 1500 to 2560 meters. So those airports which are higher than 2560 meters will be called high plateau airport [4]. According to statistics, southwest owns 6 high plateau airports and 8 common plateau airports, as shown in Table 1.

| Table 1. Statistics of civil airports in southwest |
|-----------------------------------------------|
| High Plateau Airport | Common Plateau Airports | Common Airports | Amount |
|----------------------|------------------------|----------------|--------|
| Quantity             | 6                      | 8              | 19     | 33     |
| Percent              | 18.18%                 | 24.24%         | 57.57% | 100%   |

From the table above, we can learn that this area has 14 high plateau airports, accounting for 42.42 percent. These high plateau airports concentrate on Xizang province, western region of Sichuan and northwest of Yunnan. With the development of west region, government has planned to build 23 more airports, many of them will be built on plateau and other complex terrain [5]. These factors have made it more difficult to safety management. So it is necessary to improve high plateau airports’ safety management.

2.2. Airline

Southwest owns 10 airlines, 170 airplanes, 881 captains and 787 copilots. Among them, Air China Southwest Branch, Air China Chongqing Branch, China Eastern Yunnan Branch and Sichuan Airlines are large-scale. These airlines have 144 airplanes, which occupy 84.71 percent. While other 6 airlines’ scale is relatively small, they have only 26 airplanes, as shown in Table 2.

| Table 2. Statistics of airline fleet in southwest |
|-------------------------------------------------|
| Air China Chongqing Branch | Air China Southwest Branch | China Eastern Yunnan Branch | Sichuan Airlines | Others |
| Quantity | 18 | 56 | 34 | 36 | 26 |
| Percent | 10.59% | 32.94% | 20% | 21.18% | 15.29% |

2.3. Meteorological support

Both ICAO and FAA published some data about accident and incident. In recent 20 years, as manufacturing technique of aviation improved prominently, aircraft flight performance had been greatly improved; accident or incident rate had been dropping and death toll had been low. But the rate of accidents or incidents caused by meteorological support is still very high [7]. In recent 10 years, analysis of inducements to accidents and incidents suggests that the rate of accidents or incidents caused by meteorological factors can account for about 30 percent.

Because of the complex terrain of southwest, such as plateau, hills and basins. It is much more difficult for an aircraft to take off from and land at a plateau airport than at a common one. Weather of southwest are complicatedly; diversified and wind shear is very common and site selection of airports are unscientific. All of these factors had affected flight safety of southwest badly. So it is essential to ensure better meteorological support.

Meteorological supports of southwest are lack of experience, this chapter analysis characters and shortness of meteorological supports on plateau airports in “Men-Airplane-Condition-Management” [8]. Firstly, this area is lack of meteorological staffs, and they can hardly be competent with this job; Secondly, as terrain is very complex, meteorological devices can not be built correctly, then most of them can hardly operate efficiently, and wind shear warning system can not be popular, detect correctly and most technique of them is immature. These devices usually provide false alarm and bring psychological pressure to crews. Thirdly, physical features of plateau are low-pressure, low-oxygen, strong-radiation, wired
weather. While aviation collect and research little information about plateau weather so it is difficult to evaluate variation and regularity of plateau weather. Lastly, Aviation meteorological security organization is lack of special agency which is used to manage and research Aviation climate characteristics of plateau, basins and hills, and it is also lack of connection and share with the national meteorological department and academy.

2.4. ATC and Navigation

Southwest of China is consist of Tibet Plateau, Sichuan Basin, Qinba mountain and most part of Yungui Plateau. Tibet Plateau is usually called “airspace reservation”, and airlines on this area are most dangerous in the world. Southwest of China is also abundant in tourism resources and flight trainings [9]. However, many technical issues for flight in this area have not been resolved, and then margin of safe flight is relative small. In order to ensure flight safety on plateau and produce more profit, CAAC, airlines and Boeing carried out RNP/RNAV. This item will lay foundation for flight safety on plateau.

CAAC introduced RNP/RNAV in recent years, but it has been spread to plateau airports successfully. With the huge economic growth of southwest, requirements for air transportation will sharply increase, and RNP/RNAV technique will certainly ensure flight safety immensely; reduce operating cost; improve economic benefit.

3. Accidents or Incidents of Civil Aviation Analysis in Southwest of China

Civil aircraft incident was defined as events which happen at the stage of flight or in some airports can hardly become accidents by CAAC [9]. As our nation’s safety level is already very high in recent 10 years, accidents can merely happen and it is also unpractical to improve safety management through accident investigation. So it is important for us to analyze all kinds of incidents intensively. Civil aircraft accident was defined as events which happen at the stage of flight or in some airport had caused some persons dead or injured badly and aircrafts damaged or have to replace some major parts [9]. Aviation accidents will cause huge damage and affect sustained and sound development of civil aviation.

3.1. Some data about accidents or incidents

Inducements to accidents or incidents of southwest include bird strike, weather, machinery, crews, maintenance personnel, controllers, ground support, general aviation and runway overrun. The statical data is shown in Table 3.

| Bird Strike | Weather | Machinery | Crew | Maintenance | Controller | Ground Support | Others | General Aviation | Overrun |
|-------------|---------|-----------|------|-------------|------------|----------------|--------|-----------------|--------|
| 1           | 1       | 0         | 4    | 3           | 3          | 0              | 0      | 1               | 0      |
| 2           | 1       | 0         | 3    | 3           | 1          | 0              | 0      | 0               | 0      |
| 3           | 2       | 0         | 2    | 4           | 1          | 1              | 0      | 0               | 1      |
| 4           | 10      | 1         | 1    | 0           | 1          | 1              | 0      | 6               | 1      |
| 5           | 6       | 2         | 4    | 7           | 1          | 0              | 1      | 0               | 5      |
| 6           | 0       | 1         | 2    | 3           | 1          | 3              | 1      | 0               | 2      |
| 7           | 8       | 0         | 3    | 4           | 0          | 0              | 2      | 0               | 1      |
| 8           | 3       | 1         | 5    | 6           | 2          | 0              | 0      | 0               | 1      |
| 9           | 21      | 0         | 4    | 1           | 1          | 1              | 1      | 2               | 0      |
| 10          | 11      | 1         | 1    | 3           | 1          | 0              | 0      | 0               | 2      |
| 11          | 3       | 0         | 5    | 3           | 1          | 1              | 1      | 0               | 0      |
| 12          | 2       | 0         | 2    | 3           | 0          | 0              | 1      | 1               | 2      |
| Tale        | 68      | 6         | 36   | 49          | 14         | 5              | 8      | 3               | 22     |

This Table state that 189 accidents and incidents happened in 10 years, and most of them occurred from April to October. Bird strike, crews, machinery and general aviation mainly caused these accidents and incidents. So this paper will pay more attention to analysis these four factors.
3.2. Inducements to accidents or incidents

- First point-- Bird strike

The bird strike is the abbreviation of the collision of aircraft and birds. Exploring the relationship between aircraft and birds and preventing by scientific means gradually formed the aviation ornithology. The southwest region is located in the western bird migratory and central migratory routes. So the frequent bird activities will cause bird strike easily.

The survey showed that the bird strikes mainly occurred in April, May, July, September and October, which account for 82% of total events; the events happened in spring and autumn account for about 72%; in evening and twilight the number is 52%; bird strike occurred easily before the rain and after the rain. 75% of the bird strike occurred in height of less than 60 meters, while 20% happened in height of 60-1000 meters \cite{10}. So majority of bird strikes occurred below 1000 m. According to the statistics of GE, bird strike occurred during take-off phase account for 40% and the landing phase account for 35% divided by flight phases, and the crawling stage is 13%.

In southwest, there are good vegetation and the ecological environment around the airports, which is very suitable for the birds multiply, and the old bird repeller can hardly make any difference. While the new bird repeller is not yet mature and bird-penetrating radar and other new technology is still at researching stage. So it is difficult to play a decisive role.

- Second point --Crew

During flight, it is necessary for crews to coordinate economical efficiency and security in the complex process. However, people always make mistakes, well-trained operators engaging in repetitive operations will take error rate of 0.5%-1% in a complex environment. Crews will carry out tens of thousands of behavior (including language, motion, visual, listening, making decision) in every flight. So in one flight hours, 1 to 10 errors will occur. Each error will make one flight unsafe or costly \cite{11}. Accumulation of errors can usually lead to serious consequences. So it is particularly important for the study of human factors.

Mistake or error caused by human factors can be prevented or corrected before it produces consequences. The human factors is the biggest hidden trouble to civil aviation safety today, and it is also an effective means to improve economy of flight operations. According to statistics, accidents / incidents caused by human factors accounted for about 60 percent of commercial jet aircraft accidents. Geographical environment of Southwest is wired and affect status of crews immensely. Such an environment can easily make crews produce high-altitude flatulence, decompression sickness, and overall temperature range of the southwest region is very large. The complex weather will impact crews largely and it will lead to colds, fever and other symptoms easily. Then crews may fly with illness and sub-health state.

- Third point-- Machinery

With the development of modern aircraft design and manufacturing technology, security and reliability of the aircraft has reached a very high limit, but accident / incident caused by mechanical factors still account for a high proportion. Accidents caused by machinery failure has been remaining at about 25% from the relevant data.

The proportion of accident / incident caused by mechanical incentive has been very high in Southwest. Southwest special environment affects all aspects of the aircraft, and aircraft repair and maintenance compared to the low-altitude airport becomes more difficult. Pressure of the region is quite different from the plateau to the basin. Hydraulic system failure appears in the plateau low-pressure and engine performance degradation reduces the aircraft's maneuverability. Aircraft may be lack of oxidant during altitude flying, which can affect engine power and working properly. Temperature is very low in winter in southwest so the aircraft is easy icing, frosting, which can serious damage the aircraft configuration and reduce the aircraft aerodynamic performance. The harsh operating environment of southwest airport, such as the more sand and dust. So aircrafts in southwest, needs large engine power, long run, which makes the engine more easier to damage than in other regional airports. The material may also lead to lubrication failure, causing the oil filter clogging. Pollution hazards fuel could easily lead to fuel instructions swing. So researches about mechanical failure caused the accident/incident still need to be strengthened in the southwestern region.

- Fourth point-- General aviation

In recent 30 years, our nation’s air transportation acquired huge development and it had also been the second biggest aviation system in 2005. On the other hand, general aviation also developed rapidly. Compared to air transportation, growth rate of general aviation only reached 12.3%. Development of one nation’s general aviation had been seen as an important symbol. General aviation should be the base of nation’s civil aviation, but its structure presents “inverted pyramid” style obviously.

Many factors had restrained development of general aviation and some of them had threatened flight safety. Statute guarantee system about general aviation is still backward. Airspace is also limited and general aviation airlines can hardly
survive as operating cost is very high. Government can not pay more money on research about general aviation and these airlines’ safety management is not enough. All these factors had led to the deformed development of general aviation without safety and profit.

4. Researches on inducements to accident or incident of civil aviation in the southwest of China based on grey incidence analysis

This paper analyzed every factor causing accidents or incidents. In this way, government or airlines can determine which the main inducement is, and this will also improve safety management. The data about inducements is shown in Table 4.

| Year | Bird Strike | Weather | Machinery | Crew | Maintenance | Controller | Ground Support | Others | General Aviation | Overrun | Tale of Every Year |
|------|-------------|---------|-----------|------|-------------|------------|----------------|--------|-----------------|---------|-------------------|
| 1999 | 6           | 10      | 7         | 2    | 1           | 0          | 3              | 1      | 2               | 0       | 30                |
| 2000 | 6           | 3       | 3         | 2    | 0           | 0          | 0              | 0      | 4               | 0       | 14                |
| 2001 | 3           | 4       | 4         | 0    | 0           | 0          | 0              | 0      | 2               | 1       | 11                |
| 2002 | 9           | 5       | 2         | 3    | 0           | 0          | 0              | 0      | 1               | 2       | 19                |
| 2003 | 4           | 1       | 1         | 2    | 0           | 0          | 1              | 0      | 1               | 0       | 9                 |
| 2004 | 9           | 10      | 5         | 1    | 2           | 3          | 0              | 0      | 2               | 5       | 30                |
| 2005 | 7           | 4       | 3         | 0    | 0           | 0          | 1              | 0      | 2               | 2       | 15                |
| 2006 | 5           | 2       | 7         | 1    | 2           | 1          | 0              | 0      | 3               | 1       | 18                |
| 2007 | 10          | 3       | 3         | 1    | 1           | 1          | 0              | 1      | 0               | 1       | 20                |
| 2008 | 9           | 7       | 1         | 2    | 2           | 1          | 0              | 1      | 5               | 2       | 23                |
| Total| 68          | 49      | 36        | 14   | 8           | 6          | 5              | 3      | 22              | 14      | 189               |

This paper analyzed some relative information [12], combined some safety data and referred to some experts. Inducements to accidents or incidents are consist of $X_1$(Crew), $X_2$(Machinery), $X_3$(Bird Strike), $X_4$(General Aviation). This chapter will analyze inducements to accidents or incidents with grey incidence model. The initial data is shown in Table 5.

| Year | $X_1$ | $X_2$ | $X_3$ | $X_4$ |
|------|-------|-------|-------|-------|
| 1999 | 10    | 7     | 6     | 2     |
| 2000 | 3     | 3     | 6     | 4     |
| 2001 | 4     | 4     | 3     | 2     |
| 2002 | 5     | 2     | 9     | 1     |
| 2003 | 1     | 1     | 4     | 1     |
| 2004 | 10    | 5     | 9     | 2     |
| 2005 | 4     | 3     | 7     | 2     |
| 2006 | 2     | 7     | 5     | 3     |
| 2007 | 3     | 3     | 10    | 0     |
| 2008 | 7     | 1     | 9     | 5     |
Because these data have different dimensions, this part will conduct these data. New data is shown in Table 6.

Table 6. Results of index non-Dimensionalization

| No | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|----|------|------|------|------|------|------|------|------|------|------|
| $X_1$ | 2.0408 | 0.6122 | 0.8163 | 1.0204 | 0.2041 | 2.0408 | 0.8163 | 0.4082 | 0.6122 | 1.4286 |
| $X_2$ | 1.9444 | 0.8333 | 1.1111 | 0.5556 | 0.2778 | 1.3889 | 0.8333 | 1.9444 | 0.8333 | 0.2778 |
| $X_3$ | 0.8824 | 0.8824 | 0.4412 | 1.3235 | 0.5882 | 1.3235 | 1.0294 | 0.7353 | 1.4706 | 1.3235 |
| $X_4$ | 0.9091 | 1.1812 | 0.9091 | 0.4545 | 0.4545 | 0.9091 | 0.9091 | 0.9091 | 1.3636 | 0 | 2.2727 |

Put these new data shown in Table 6 into equation (1).

$$
\Delta_i(k) = \left| x_0(k) - x_i(k) \right|
$$

(1)

Now, new result is shown in Table 7.

Table 7 Data of $\Delta_i(k)$

| No | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|----|------|------|------|------|------|------|------|------|------|------|
| $X_1$ | 0.4535 | 0.1285 | 0.2343 | 0.0151 | 0.2721 | 0.4535 | 0.0227 | 0.5442 | 0.446 | 0.2116 |
| $X_2$ | 0.3571 | 0.0926 | 0.5291 | 0.4497 | 0.1984 | 0.1984 | 0.0397 | 0.9921 | 0.2249 | 0.9392 |
| $X_3$ | 0.7049 | 0.1416 | 0.1408 | 0.3182 | 0.112 | 0.2638 | 0.2358 | 0.2171 | 0.4124 | 0.1066 |
| $X_4$ | 0.6782 | 1.0774 | 0.3271 | 0.5507 | 0.0216 | 0.6782 | 0.1154 | 0.4113 | 1.0582 | 1.0558 |

Analyze data of $\Delta_i(k)$, combine them with equation (2) and (3), we can get the result: $\Delta_{\text{min}} = 0.0151, \Delta_{\text{max}} = 1.9841$.

$$
\Delta_{\text{min}} = \min_{i,k} \Delta_i(k)
$$

(2)

$$
\Delta_{\text{max}} = \max_{i,k} \Delta_i(k)
$$

(3)

Average the data of $\Delta_i(k)$, and put it into equation (4), we can get $\Delta_v = 0.4697$. Put these data into equation (5), we can also get $\delta_\Delta = 0.2367$.

$$
\Delta_v = \frac{1}{m \cdot n} \sum_{i=1}^{m} \sum_{k=1}^{n} \left| x_0(k) - x_i(k) \right|
$$

(4)

$$
\delta_\Delta = \frac{\Delta_v}{\Delta_{\text{max}}} \left( \Delta_{\text{max}} = \max_{i,k} \Delta_i(k) \right)
$$

(5)
Determination method of $\rho$ (resolution ratio) is shown in equation (6) and (7).

$$\Delta_{max} > 3\Delta_v, \quad \delta_\Delta \leq \xi \leq 1.5\delta_\Delta \tag{6}$$

$$\Delta_{max} \leq 3\Delta_v, \quad 1.5\delta_\Delta < \xi \leq 2\delta_\Delta \tag{7}$$

As $\Delta_{max} > 3\Delta_v$, we should use equation (6), and $\xi = 1.5\delta_\Delta = 0.3551$, then we get the equation (8) to calculate relevancy.

$$L_{qi}(k) = \frac{0.3551 \max \max \Delta_i(k)}{\Delta_i(k) + 0.3551 \max \max \Delta_i(k)} \tag{8}$$

At last, we put $\Delta_i(k)$ into equation (8) and get the final correlation coefficients, as shown in Table 8.

| No | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|----|------|------|------|------|------|------|------|------|------|------|
| $X_1$ | 0.1433 | 0.0185 | 0.0545 | 0 | 0.0692 | 0.1433 | 0.0001 | 0.1795 | 0.1402 | 0.046 |
| $X_2$ | 0.1038 | 0.0094 | 0.1736 | 0.1418 | 0.0412 | 0.0412 | 0.0011 | 0.3316 | 0.0509 | 0.316 |
| $X_3$ | 0.2395 | 0.0223 | 0.0221 | 0.0878 | 0.0141 | 0.0659 | 0.0551 | 0.048 | 0.1265 | 0.0127 |
| $X_4$ | 0.23 | 0.3554 | 0.0914 | 0.1821 | 0.0001 | 0.23 | 0.015 | 0.126 | 0.3502 | 0.3495 |

Finally, we must put data of Table 8 into equation (9) and get new results which are shown in Table 9.

| Degree of Association | $X_1$ | $X_2$ | $X_3$ | $X_4$ |
|-----------------------|------|------|------|------|
| 0.9108 | 0.8900 | 0.9167 | 0.8611 |
| Order | 2 | 3 | 1 | 4 |

According to the fundamental of grey incidence analysis [13], we can get the degree of association. What is more, we can also learn that the management order: $X_3$(Bird Strike)$> X_1$(Crew)$> X_2$(Machinery)$> X_4$(General Aviation).

5. Conclusions

The result suggests that bird strike and crew is the most important inducement. So government or airlines of southwest should pay more attention to prevent airplanes from bird strike and take some effective measures to train crews. As general aviation of southwest is well developed, these general airlines should improve their safety management. Complex terrain and climate make it necessary for airlines of southwest to introduce new aircrafts which can apply to plateau airports better.

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