Improving Civil Aviation Service Risk Management with FMEA

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Abstract. The civil aviation industry has always been an important strategic industry for China's economic and social development. The increasing popularity of air travel has made passenger needs more diverse, which has made passengers pay more attention to the overall service quality of aviation. This change makes civil aviation service need to pay attention to risk management, need to change from post-management to pre-management, so it can also improve the level of service quality. The civil aviation industry is relatively mature in safety risk research and control technology, but civil aviation enterprises are in the initial stage for service risk. FMEA(Failure Mode and Effects Analysis) is widely used in aviation manufacturing, finance, automotive industry, medical industry and other industries. Combined with the characteristics of civil aviation service process, this study discusses how to use FMEA to manage civil aviation service risk. The application example of an airport proves that FMEA tool can improve the airport service risk management and the service level. FMEA can be applied to service risk management in the entire civil aviation industry.

Keywords: Service risk management·, FMEA ,·Failure mode

1. Background

With the rapid economic development, the global industrial structure has changed from "industrial economy" to "service economy". In 2015, the contribution rate of China's service industry to the national economic growth reached 53.7%, breaking through the 50% mark for the first time, marking China's entry into the service economy era. As an important strategic industry[1] in China's economic and social development, the civil aviation industry has always played a basic and leading role in China's economic and social development. At the beginning of 2023, China has issued an outline to improve the overall quality of its economy amid efforts to promote high-quality development. The outline clearly pointed out that the civil aviation industry needs to "Promote the upgrading of life service quality, promote airlines and airports to establish comprehensive passenger service quality management systems to improve aviation service capabilities and quality."[2] Establish service quality management system, improve civil aviation service capabilities and quality must adhere to risk prevention and control, civil aviation service quality management concept from "post-management" to "pre-management" change.

At present, China's civil aviation enterprises are in the initial stage of service risk, and there are problems in how to comprehensively identify related risk sources and analyze service quality risks by combining qualitative and quantitative methods. Every Civil aviation enterprise need

ICEMME 2023, November 17-19, Beijing, People's Republic of China

DOI 10.4108/eai.17-11-2023.2342695

to establish service management sysytems which is data-driven management mechanism and combines with qualitative and quantitative analysis. Through dynamic management of service quality risks, it can reduce uncertainties in the service process in advance, avoid service quality risks caused by service failure, reduce service quality loss costs, maintain the company's brand image, and maintain the effectiveness and foresight in enterprise management. FMEA is a tool that can anticipate failures and avoid the occurrence or recurrence of failures. It is useful for identifying potential process failures, estimating the relative risk of failure occurrence, evaluating current control plans, and identifying priority process areas for improvement. FMEA is more suitable for civil aviation enterprise risk management, so it is necessary to study the application of FMEA in civil aviation service risk management.

2.FMEA introduction

Failure Mode and Effect Analysis (FMEA) is a reliability analysis technique used to identify, verify and eliminate known or potential failures and problems in systems, designs, processes and services. It is a systematic and preventive reliability analysis tool in the system, thus providing help for developing risk management strategies. FMEA plays an important role in new product development, system design and service quality assurance. FMEA was proposed by the National Aeronautics and Space Administration (NASA) to meet the requirements of the aerospace industry on safety and reliability.[3] At present, FMEA is widely used in aviation industry[4], finance[5], medical treatment[6-7], automobile industry[8], etc., but FMEA is rarely used in civil aviation services. Some scholars or researchers only apply some partial functions of FMEA[9], and fail to achieve all functions of FMEA tools for risk management and control capabilities.

3. Civil aviation industry characteristics

From the perspective of passenger demand, civil aviation transport provides passengers with services that can quickly reach their destinations. As the typical service industry, the process of providing services by airlines is the delivery process of intangible products, which has characteristics such as heterogeneity, intangibility, perishability and synchronicity. Just because of these characteristics, once a service occurs, the service audience will have an evaluation of the quality of the product. If the service fails, it is possible to recover it through very large remedial costs.

Different from the general service industry, civil aviation enterprise services have the long chain, high technical requirements, operating environment changes, so that there are many participants in the entire service process, including airlines, ticket agents, airport management agencies, ground agents and other direct passenger service internal and external institutions or departments. It also includes departments that provide indirect services to customers such as information, maintenance. The operation has a high degree of uncertainty for such a huge system, and if any link goes wrong, it may bring service quality risks and even induce unsafe incidents. Unprofessional communication, inappropriate service standards, inadequate maintenance and other reasons are important causes of passenger complaints, property losses, personal injuries and so on. How to use FMEA in civil aviation enterprises is the problem solved in this thesis.

4. FMEA tool application

FMEA method mainly explores the potential failure modes in the process by comparing and analyzing the potential failure modes and their possible effects by cross-functional team members. The main steps are as follows: First, draw the service process, determine the key process and key contact points in the service process, and establish a cross-functional team; Second, collect relevant data, decompose service process, comprehensively identify service quality risk sources from human, machine, material, law, environment etc. through internal and external data and channels, confirm possible risk failure modes in each task, and analyze their causes and consequences. Third, Analyze failure mode and according to the evaluation criteria, determine ach risk failure mode by three risk factors:(Severity, S; Occurrence, O and Detection)[10]. Fourth, calculate each the risk coefficient RPN for each risk . Fifth, according to the size of RPN, determine the different levels of risk, propose appropriate risk mitigation or control measures, and form FMEA files. Finally, follow-up and effect verification of improvement measures, so that the risk can closed-loop manage, continuous monitoring of risks, periodic review and update of risk sources. The basic FMEA analysis process is shown in Figure 1.

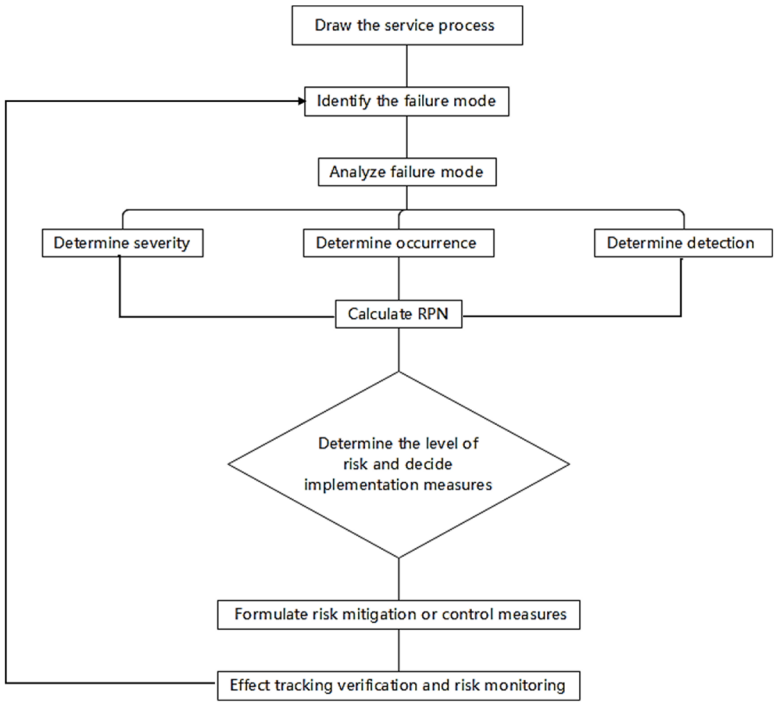

Fig.1 FMEA method flow chart

4.1 Draw the service process

The chain of civil aviation service process is relatively long, and service blueprints can be used to sort out service flow charts. Service blueprints is a graphical tool that converts service

processes into service delivery in a direct and clear form. From a functional perspective, service blueprints can be divided into two types: conceptual blueprints and detailed blueprints. The former is an overall description of the total system, while the latter is a detailed description of specific parts of the total system. The service blueprint can make the interactive service process visible which include different personnel, thus reducing the work difficulty caused by the intangible service product. Drawing the service blueprint can first draw the conceptual blueprint from a macro perspective, then assign each process to the main responsible department to complete FMEA. According to the process, relevant departments and relevant department will form cross-functional teams to complete FMEA activities, and experts can be added if necessary. FMEA cross-functional teams subdivide each sub-process to create detailed blueprints. The drawing of detailed blueprints is particularly important. Process refinement helps the team to understand the process more clearly and to identify risks more comprehensively.

4.2 Identify the failure mode

Service quality risk source refers to any source that may cause service product problems, service quality decline, cause passenger complaints, affect enterprise brand image, and any source that may cause service quality risk in the service process. Service quality risk refers to the uncertain consequences that may be caused by the source of service quality risk. FMEA application must be based on process facts and actual situation. The team needs to gather processes data and documents involving laws and regulations, customer needs (expectations) (internal and external customers), requirements, previous experience with similar service processes, etc. External data and the internal data are crucial to identify the service quality risk sources, External data include past passenger complaints, satisfaction evaluation result, and internal data include the operator feedback and service inspection. Relying on data drive, judge the regularity of event occurrence, systematically identify the risk source of service quality, and establish the risk source database. Teams can identify the risk patterns and consequences that may arise in each process by using brainstorm mode and summarizing past data.

4.3 Analyze failure mode

The key to risk management is how to judge SOD ratings. Many researchers only use FMEA to study SO ratings. The detectivity (D) in FMEA refers to the difficulty of indicating whether the risk can be found by current control methods. Service products and physical products have essential differences, Service products has the characteristics of synchronization, production and consumption are synchronized, so many researchers think the detectability (D) can not apply to service products. But the degree of service risk cannot only be considered from the dimension of passenger satisfaction, which can be used as a dimension of risk source identification. The relationship between customer satisfaction and service risk degree is not equal, but inclusive. In service risk management, certain data can be obtained from customer satisfaction, but it does not represent all. Service is the process of providing to customers, it also includes the service facilities, service personnel skills, service attitude and etc. Service satisfaction index can also be transformed into internal control index. For example, the comfort for the terminal building light can be translated into the lighting illuminance control standard. Table 1 is an example of Example of Service quality risk Severity criteria (S) based on passenger experience, Property lose or compensation and negative impact; Table 2 is an example of Service quality risk

occurrence criteria (O) based on qualitative and quantitative descriptions of occurrence probability; Table 3 is an example of service quality risk about detection criteria (D).

Table 1. Example of service quality risk about severity criteria (S)

Severity Rating		Severity determinant standard		
		Customer experience	Property lose or compensation	Negative impact
1	Slight	Cause individual customer complaints, through on-site communication, satisfaction survey feedback passenger comments	The amount of money is less than 1000 RMB	Minimal or no impact
2	Normal	Cause individual customer dissatisfaction, through telephone, mail and other company channels feedback service complaints or the same incident caused more than 5 people in a group incident	The amount of money is between 1000 (include)~5000 RMB	Caused media attention reports, result the internal negative impact
3	Serious	Cause serious customer dissatisfaction, through the Civil Aviation Administration, provincial, municipal government channels service complaints or the same incident caused more than 10 people in a group incident	The amount of money is between 5000(include)-10000 RMB	Attract media attention and reported, make negative impact in regional; attract regional administration attention
4	Very serious	Cause serious customer dissatisfaction or lead to customer injury, illness and other emergency medical events; or customers through the Civil aviation administration, provincial and municipal government channels to conduct complaints, reports	The amount of money is between 10000(include)-50000 RMB	Arouse media attention and report leads to a wide range of negative effects; arouse the attention of the Civil Aviation Authority
5	Extremely serious	The responsibility causes the death of the customer or the customer reports through the central government channels	The amount of money is above50000(include)	Arouse media attention and report leads to national or foreign media attention; Attract the attention of leaders at the national level

Table 2. Example of service quality risk about occurrence criteria (O)

Occurrence Rating	Occurrence	Qualitative	Quantify
1	Highly unlikely	Not happened in 5 years	Predictably, not going to

			happen
2	Unlikely	Not happened in 2 years	Predictable, low probability
3	Occasional	Happened above once in a year	Predictable, will happen
4	Several	Happened above once in a month	Predictable, easy to happen
5	Frequently	Happened above once in a week	Predictable, it will happen

Table 3. Example of service quality risk about detection criteria (D)

Detection Rating		Detection method maturity	Detection opportunity Description
1	Very high	The detection method can always detect the failure mode or cause by practice.	A service product or service process is designed to be error-proof without failure modes. For example, the service product design audit and service management audit confirm that the design (service product or service process) can be error-proof, and failure modes will not occur.
2	High	The detection method has been proved to be effective or reliable by practice: experience in detection methods and error proof measures; Experience in testing or probing methods for the same process with acceptable measurement repeatability and reproducibility.	On the current service node, the device automatically detects the failure mode or the cause to prevent further expansion and deterioration. Failure modes will be monitored within an effective system and will not cause passengers to experience poor service. Such as "machine-to-machine" contact service mode, inspected/tested by automated equipment
3	Middle	The test or inspection method has been proven to be effective and reliable: experience in the test or inspection method, experience in similar process testing or detection methods, measurement repeatability and reproducibility of results are acceptable.	There are devices at subsequent service nodes to automatically detect their failure modes or causes, or semi-automated devices at current or subsequent service nodes to avoid further expansion and deterioration of failure modes. Failure modes will be monitored in an effective system and will not cause passengers to experience poor service. Such as "human-machine" contact service mode, there are semi-automated equipment inspection/testing services
4	Low	Tests or inspection methods have not been proven to be effective and reliable in practice: no or little experience in testing or inspection methods; The results of quantitative repeatability and reproducibility analyses for similar processes or this	Manual inspection (visual, tactile, auditory) methods that can detect failure modes or causes, or methods that should be measured by manual instruments (counting or metering). Services such as person-to-person contact, using mystery travelers (unannounced visits); Customer Survey (Functional perception)

		procedure are close to the margin, etc.	
5	Very low	No test or test method has been established or known; Failure modes cannot be detected by the test or inspection method.	Failure mode cannot be detected or don't have test method.

4.4 Calculate RPN

The traditional FMEA method uses the risk coefficient RPN to evaluate the risk level, and the RPN value is the value obtained by the product of S, O and D. RPN indicates the level of risk caused by failure mode. That is, the higher the risk coefficient, the higher the risk. The traditional FMEA method has been widely used in various fields because of its advantages of simple calculation, easy understanding and easy operation.The risk coefficient calculation is shown with formulas (1):

$$RPNi=Si*Oi*Di \quad (1)$$

RPN_i- Coefficient risk of service risk i;

S_i - Severity of service risk i;

O_i - Occurrence of service risk i;

D_i - Detection of service risk i.

In the application of various industries and enterprises, according to their own needs, the calculation of RPN value can also consider the weight of S, O and D risk factors. The methods of determining the weight of risk factors are mainly divided into subjective weight method and objective weight method. The commonly used subjective weight determination methods include direct evaluation, analytic Hierarchy Process (AHP), Delphi method, etc. The commonly used objective weight determination methods are ordered weight operator (OWA), data envelopment method (DEA), minimal cut set and so on. For civil aviation enterprises to use FMEA risk analysis, it is recommended to use the traditional FMEA for RPN calculation and risk evaluation, establish the risk database. In the later stage, the risk SOD weight will be considered according to the actual application situation.

4.5 Risk level and mitigation measures

Service risk judgment level can be mainly defined from the aspects of compliance with the requirements of laws and regulations, service policies, service quality objectives and the general acceptance degree of passengers. Service quality risk is divided into three levels: Level 1 service risk (green), level 2 service risk (yellow) and level 3 service risk (red). The acceptable degree of risk corresponds to acceptable, acceptable to a certain extent and unacceptable. Table 4 shows an example of determining risk levels.

Table 4. Example of Service quality risk level criteria

Risk level	Risk coefficient range	Acceptability	Warning
Level I Risk	1 score ≤ Risk coefficient <30 score	Acceptable	Green
Level 2 Risk	30score ≤ Risk coefficient < 40 score	Acceptable to a certain extent	Yellow
Level 3 Risk	40 score≤ Risk coefficient	Unacceptable	Red

4.6 Effect tracking verification and risk monitoring

Evaluation of the effectiveness of service risk control and mitigation action after completion; if the effect is not good or do not meet the expectations, need to rearranged the control action. For service risks that need to be included in long-term monitoring, corresponding monitoring indicators and monitoring frequency should be set according to the actual risk situation, and dynamically adjusted.

4.7 Application Examples

The following table 5 is an example of FMEA application in the passenger check-in process of a southern airport, and one failure mode is selected for analysis to explain how to determine SOD rating and calculate RPN.

In the following table 5, for the check-in queuing process, long queuing time is one of its failure mode , which causes delays in passenger time and makes passengers impatient. One of the potential reasons is that the flow of people is concentrated and not dispersed. The current preventive measures are to set boundary points in the queue, and the detection method is to inspect the mobile personnel, and determine whether to open more check-in counters or guide them to other counters according to the situation. According to SOD evaluation criteria, use the formula (2) to calculate RPN :

$$RPN_{i\ before} = S_{i\ before} * O_{i\ before} * D_{i\ before} = 3*3*4 = 48 \quad (2)$$

Failure mode i: The queue lasts a long time

$S_{i\ before}$ - Delay passenger time, cause passenger impatience, passenger complaints to the Civil Aviation Administration, so S value is 3;

$O_{i\ before}$ - Current preventive measures: make a queue alert points; Frequently occurs, so O is 4;

$D_{i\ before}$ - Detection mode: mobile personnel perform visual inspections, so D is 4

According to table 4 :48>40 , this failure mode is an unacceptable risk and action need to be taken. The corrective action is to increase the electronic system monitoring, statistics and early warning of passenger queuing time. If there is an early warning, the system will have a alarm, and the staff will open more check-in counters or divert to other counters. After corrective action: Calculate the risk coefficient using the formula (3):

$$RPN_{i\ after} = S_{i\ after} * O_{i\ after} * D_{i\ after} = 2*3*3 = 18 \quad (3)$$

$S_{i\ after}$ - the device has effective early warning, the delay time of passengers is shortened, if be delay, individual passengers complain to the airport, so the value of S is 2.

$O_{i\ after}$ - electronic system monitoring, statistics and early warning; Occurrence frequency id occasional, so the value of O is 3.

$D_{i\ after}$ - Electronic system monitoring, statistics, and early warning, which is semi-automatic monitoring, D is 3.

According to table 4:18<20, it is reduced to acceptable risk, and this failure mode is valid after later verification. Risks are effectively controlled.

Table 5. The FMEA example of an airport

No	Process Step definition	POTENTIAL FAILURE		Severity	Potential Cause of failure	Occurrence	Process controls		Detection	RPN	Recommended Corrective Actions	Review			
		MODE	EFFECT				Prevention	Detection				S	O	D	RPN
1	Look for the check-in counter	Find the wrong area	Delay passenger time	2	Partition sign LED screen is not displayed	2	Start shift check, TPM maintenance	Start/middle /Last shift check	4	16					
		The late traveler got the wrong counter	Delay passenger time	2	Late arrival counter sign LED screen not displayed	2	Counter display captioning reminder; Check in area set up staff turnover patrol reminder	Passenger visual identification, counter signs use color reminder	4	16					
2	Queue up	Long queue time	Delay passengers' time and cause passengers to be impatient;	3	The flow was concentrated, not dispersed	4	Line up and set up alert points	Mobile personnel visual inspection	4	48	Add the electronic system to monitor and do early warning the queuing time	2	3	3	18

				3	Check-in staff operate slowly	2	Compile SWI and operate according it	Monitor make an inspection tour	4	24				
				3	Equipment breakdown	2	TPM maintenance	Start/middle /Last shift check	4	24				
		The temperature in the check-in area is high	Affect passenger comfort	3	The air conditioner temperature is improperly set	4	Start shift check, TPM maintenance	Start/middle /Last shift check	4	48	Add automatic air condition system to monitor, control and adjustment the temperature.	3	2	2	12

5. Conclusion

This paper mainly studies a method of service quality risk management. Civil aviation enterprises apply FMEA method to identify and manage risks, improve the ability of service risk control, and achieve "pre-management" of service management. This method FMEA will identify and control service risks from the severity, occurrence and detection, and conduct quantitative evaluation according to various dimensions of risk. Manage risks along the same dimensions and identify opportunities for improvement. FMEA can be digitally driven, based on the whole process of service analysis, qualitative and quantitative combination, comprehensive SOD evaluation, dynamic service risk management, and risk control of the whole process of service.

In the application of FMEA, it is necessary to enhance the awareness of risk prevention and pay attention to service detection. Avoid recurrence of service quality problems through prevention. Pay attention to detection, improve service quality monitoring, inspection and detection capabilities. According to the above analysis, if the service risk detection relies on manual inspection (visual, tactile, auditory), the detection degree is low; the service evaluation is also "post-evaluation", the detection level is low; Civil aviation service risk. At present, civil aviation enterprises mainly carry out service quality management through passenger service evaluation, expert service evaluation and passenger complaints. All civil aviation enterprises need to realize

the importance of detection to civil aviation service quality, accelerate the construction of smart civil aviation, and improve automatic monitoring capabilities to reduce service risks.

The risk management of civil aviation service is in the initial stage, and the S,O and D evaluation criteria given in this paper are given by the author according to the characteristics of the industry and own experience, and each enterprise can formulate or supplement it according to its risk bearing ability and situation.

To sum up, this paper puts forward the application of FMEA to service risk management, the method in the civil aviation has a certain promotion value.

Acknowledgments: This work is supported by central basic research funds of Castc (x222060302544).

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