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Research on Smartphone Function Improvement Based on FMEA

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Abstract: At present, research on smartphones mainly focuses on the hardware and partial systems of a single model of a particular brand, while comprehensive research on smartphones is scarce. In particular, when a sound set of mobile phone hardware produces different effects on different phone models, the available improvement methods are limited, and functional improvement research conducted on a single model of a particular brand affects only a small group of users. Therefore, improvement research on smartphones in a comprehensive manner has high research value. This paper applies FMEA to conduct a unified analysis of comprehensive smartphone products and to propose corresponding improvements. First, the content related to FMEA is introduced; then the functions and structure of smartphones, including hardware components and software systems, are analyzed. Subsequently, the potential failure modes of mobile phone hardware, software, and communication systems are identified, their impacts on user experience and performance are evaluated, and the causes of failure are analyzed. Finally, improvement measures and suggestions are put forward, providing a reference for smartphone quality improvement and risk control.

Keywords: Smartphone, FMEA, software failure, hardware failure, communication failure.

1. Introduction

In today's digital era, smartphones have become an indispensable tool in people's lives, and the diversity and reliability of their functions directly affect user experience and market competitiveness [1]. Ranging from convenient mobile communication to high-definition image capture, and from smooth gaming and entertainment to efficient office assistance, smartphones carry numerous complex and critical functional modules, the stable operation of which is essential to meeting users' growing demands [2].

However, with the rapid development of smartphone technology and the continuous expansion of the market, users' requirements for phone functions have become increasingly stringent [3]. In actual use, various functional failure problems have gradually become prominent, such as insufficient battery life, system lag, unstable signals, poor camera imaging quality, and abnormal heating [4]. These problems not only reduce user satisfaction but may also lead to user loss and damage to brand reputation [5]. Therefore, how to effectively identify and improve the functional failures of smartphones and enhance their overall reliability and performance has become a key issue to be addressed by mobile phone manufacturers and researchers [6].

Failure Mode and Effects Analysis (FMEA), a reliability engineering method widely used in the industrial field, provides a systematic and effective approach to solving this problem [7]. FMEA comprehensively identifies the potential failure modes of a product or system, deeply analyzes their failure causes and possible effects, and quantitatively evaluates the failure modes according to indicators such as severity, occurrence, and detection, so as to determine the Risk Priority Number (RPN), and then formulate targeted improvement measures to prevent or reduce the occurrence of failures [8]. Applying the FMEA method to research on smartphone function improvement can help us deeply explore the potential problems existing in each functional module of mobile phones and conduct comprehensive analysis from multiple dimensions, ranging from hardware design, software algorithms, and production processes to user usage scenarios, achieving precise optimization of smartphone functions and improvement of reliability, providing users with a more stable, efficient, and high-quality experience, while also injecting new vitality and competitiveness into the sustainable development of the smartphone industry [9]. This study aims to apply the FMEA method to deeply analyze the functional failure modes of smartphones and explore practical and feasible improvement strategies, in order to achieve research results with practical application value in the field of smartphone function improvement [10].

2. Overview of FMEA

FMEA, namely Failure Mode and Effects Analysis, is a systematic activity in which, during the product design stage and the process design stage, the subsystems and parts constituting products and equipment, as well as the various procedures constituting processes, are analyzed one by one to identify all potential failure modes and analyze their possible consequences, so that necessary measures can be taken in advance to improve the quality and reliability of products or equipment.

The elements of FMEA include quantitative risk assessment, listing causes/mechanisms, and seeking prevention/improvement. As an important management analysis method, FMEA uses several key parameters: Severity (S), Occurrence (O), Detection (D), and the Risk Priority Number (RPN).

2.1. Severity (S)

Severity (denoted as S) is an evaluation indicator of the degree of impact on product quality and customers when a certain potential failure mode occurs, as shown in Table 1.

Table 1. Severity Analysis Criteria

Effect	Evaluation Criteria	Severity
Hazardous without warning	Occurs without any warning sign of failure, endangers safety, violates relevant laws and regulations, and is of very high severity.	10
Hazardous with warning	Occurs with warning signs of failure, endangers safety, violates relevant laws and regulations, and is of very high severity.	9
Very high effect	The product loses its basic functions and customers are extremely dissatisfied.	8
High effect	The product remains usable but its performance declines, and customers are dissatisfied.	7
Moderate effect	The product functions normally, but comfort or convenience items fail, and customers feel uncomfortable.	6
Low effect	The product functions normally, but the performance of some comfort or convenience items declines, and customers are somewhat dissatisfied.	5
Very low effect	Items such as product appearance and packaging protection do not meet requirements, and most customers can detect these problems.	4
Slight effect	Items such as product appearance and packaging protection do not meet requirements, but the problem is not obvious and 50% of customers can detect these problems.	3
Very slight effect	Items such as product appearance and packaging protection do not meet requirements, but the problem is very slight and a small number of customers can detect these problems.	2
No effect	No impact whatsoever on product quality or customers.	1

2.2. Occurrence (O)

Occurrence (denoted as O) refers to the probability that a certain potential failure mode will occur; the higher the probability, the greater the likelihood. The criteria are shown in Table 2.

Table 2. Occurrence Analysis Criteria

Likelihood of Occurrence	Occurrence Rating
Very high; failure is almost unavoidable	10,9
High; failure occurs repeatedly	8,7
Moderate; failure occurs occasionally	6,5
Low; failure occurs relatively rarely	4,3
Very low; failure is unlikely to occur	2,1

2.3. Detection (D)

Detection (denoted as D) is an evaluation indicator of the probability that a potential failure can be detected according to existing control means and detection methods when it occurs. The evaluation criteria are shown in Table 3.

Table 3. Detection Analysis Criteria

Likelihood of Detection When Failure Occurs	Detection Rating
Very high probability that the failure is not detected	10, 9
High probability that the failure is not detected	8, 7
Failure occasionally not detected	6, 5
Low probability that the failure is not detected	4, 3
When failure occurs, it can almost certainly be detected	2, 1

The Risk Priority Number (RPN) is the result of multiplying the three indicators above, namely severity, occurrence, and detection. It refers to the likelihood and hazard degree of potential risks and represents a form of indicator; items with higher RPN values should be the focus of control. The determination of the RPN threshold X is related to the confidence level and the values of the above scores, as shown below:

$$X = MAX(S \times O \times D) - (MAX \times \alpha)$$

3. Analysis of Mobile Phone Functions and Structure

A mobile phone is composed of various hardware components, each playing a different role in the operation and use of the phone. Hardware damage will greatly affect the operation of the phone, and severe hardware damage may directly lead to the breakdown of the phone. Therefore, mobile phone hardware occupies an important position in the smooth operation of the phone. The main hardware of mobile phones and their principal functions are as follows:

3.1. Processor (CPU)

Core computing

The processor in a mobile phone is like the human brain, responsible for executing various instructions and data processing, such as running the operating system and applications. Its performance directly affects the operating speed and multitasking capability of the phone.

Scheduling management

It coordinates the work among the various hardware components of the phone and allocates resources reasonably to ensure the stable operation of the system. For example, when multiple applications are running simultaneously, the processor allocates corresponding computing power and memory resources according to the priority and resource requirements of the applications.

3.2. Graphics Processing Unit (GPU)

Graphics rendering

It is mainly responsible for processing graphics and image-related tasks, such as 3D modeling in games, animation effects, and the decoding and rendering of video playback. It can quickly convert graphics data into images visible on the screen, making the picture smoother and more delicate.

Image optimization

It performs post-processing on captured photos and videos, such as noise reduction, color correction, and image enhancement, to improve image quality. Meanwhile, in some image editing applications, the GPU can also accelerate the processing speed of operations such as filter effects, cropping, and rotation.

3.3. Memory (RAM)

Temporary data storage

It is used to temporarily store various data during the operation of the phone, including running applications and temporary files of the operating system. Like a temporary workspace, data here can be quickly read and processed by the processor to support the rapid launching and switching of applications.

Multitasking support

The larger the memory capacity, the more applications the phone can run simultaneously, supporting more efficient multitasking. For example, with sufficient memory, users can download files while watching videos, and at the same time open multiple web browsers for browsing without experiencing lag.

3.4. Display Screen

Image display

As the output device of the phone, it presents the image information processed by the processor and GPU to users in a visual manner. Different types of display screens, such as LCD and OLED, differ in color performance, contrast, resolution, and refresh rate, directly affecting users' visual experience.

Touch interaction

Most modern phone display screens adopt touchscreen technology, through which users can operate the phone, such as tapping icons, swiping the screen, and entering text, realizing human-computer interaction with the phone.

3.5. Camera

Image capture

It is used to take photos and record videos, capturing beautiful moments and various scenes in life. The parameters of the camera, such as pixels, aperture, focal length, and sensor size, determine the quality and effect of the photos and videos taken.

Image and video creation

It supports multiple shooting modes and functions, such as night mode, portrait mode, panorama mode, slow-motion shooting, and time-lapse photography, meeting users' creative needs in different scenarios and enabling them to easily take photos and videos of professional quality.

3.6. Battery

Power supply

It provides power support for the various hardware components of the phone, enabling the phone to boot normally and run various functions. The battery capacity determines the phone's battery life, generally measured in milliampere-hours (mAh); the larger the capacity, the relatively longer the battery life.

Charging management

The built-in battery management chip is responsible for managing the charging and discharging of the battery, ensuring safe charging and extending the battery's service life. Meanwhile, it supports different charging technologies, such as fast charging and wireless charging, providing users with more convenient charging methods.

3.7. Motherboard

Hardware integration

As the carrier of the phone's hardware, it integrates various hardware components such as the processor, memory, storage chips, power management chips, and communication modules, and realizes communication and collaborative work among them through circuit connections, forming a complete mobile phone hardware system.

Signal transmission

The circuits and solder joints on the motherboard are responsible for transmitting various electrical signals, including power signals, data signals, and control signals, ensuring accurate information exchange among the hardware components, thereby guaranteeing the normal operation of the phone.

4. Analysis of Potential Failure Modes and Causes of Mobile Phone Hardware, Software, and Communication Systems

4.1. Mobile Phone Hardware Failures and Cause Analysis

Common mobile phone hardware failures mainly include: screen damage; battery failure; camera failure; motherboard failure. The causes are analyzed as follows:

Screen damage: It may be caused by accidental drops or squeezing, leading to screen cracking, dead pixels, or touch failure.

Battery failure: For example, the battery ages too quickly and its battery life declines sharply; or the battery bulges under excessive temperatures, posing a safety hazard and potentially even causing an explosion.

Camera failure: A scratched camera lens affects photo quality; inaccurate focusing or image sensor failure leads to problems such as blurriness and color distortion in the photos or videos taken.

Motherboard failure: It may be caused by overheating, water ingress, or aging of electronic components, resulting in phone crashes, failure to boot, frequent restarts, or the unavailability of some functions.

Table 4. FMEA of Mobile Phone Hardware

Potential Failure Mode	Possible Causes	Potential Effects	S	O	D	RPN
Screen damage	Accidental drops and squeezing cause the screen to crack.	Dead pixels or touch failure occur.	5	3	4	60
Battery failure	The battery ages too quickly and its battery life declines sharply.	The battery bulges under excessive temperatures, posing a safety hazard and potentially even causing an explosion.	9	3	3	81
Camera failure	The camera lens is scratched or damaged, affecting photo quality; inaccurate focusing or image sensor failure.	It affects photo quality and leads to problems such as blurriness and color distortion in the photos or videos taken.	4	3	3	36
Motherboard failure	It may be caused by overheating, water ingress, or aging of electronic components.	It results in phone crashes, failure to boot, frequent restarts, or the unavailability of some functions.	9	3	3	81

4.2. Mobile Phone Software Failures and Cause Analysis

Common mobile phone software failures mainly include: operating system lag; application crashes; software update failure. The causes are analyzed as follows:

Operating system lag: As more applications are installed and usage time increases, system cache accumulates, leading to slower operating speeds, delayed app opening, and unsmooth app switching.

Application crashes: Some applications may be incompatible with the phone system or have their own vulnerabilities, suddenly closing during use and losing unsaved data.

Software update failure: When updating the system or applications, the update may fail to complete due to network problems or insufficient phone storage space, thereby affecting the normal use of related functions or putting the phone in an unstable state.

Table 5. FMEA of Mobile Phone Software

Potential Failure Mode	Possible Causes	Potential Effects	S	O	D	RPN
Operating system lag	As more applications are installed and usage time increases, system cache accumulates.	It leads to slower operating speeds, delayed app opening, and unsmooth app switching.	4	4	4	64
Application crashes	Some applications may be incompatible with the phone system or have their own vulnerabilities.	They suddenly close during use and lose unsaved data.	4	4	4	64
Software update failure	When updating the system or applications, it may be due to network problems or insufficient phone storage space.	It causes the update to fail to complete, thereby affecting the normal use of related functions or putting the phone in an unstable state.	4	3	4	48

4.3. Mobile Phone Communication Failures and Cause Analysis

Mobile phone communication failures mainly include: call interruption; SMS sending/receiving failure; mobile data connection problems. The causes are analyzed as follows:

Call interruption: It may be caused by poor signals, network fluctuations, or failure of the phone's communication module, leading to sudden disconnection during a call.

SMS sending/receiving failure: Similarly affected by signal and network factors, it may also be caused by incorrect SMS center settings, resulting in the failure to send and receive SMS normally.

Mobile data connection problems: Such as inability to connect to the mobile network or excessively slow network speeds, affecting the normal conduct of functions such as web browsing, online video playback, and application downloads.

Table 6. FMEA of Mobile Phone Communication

Potential Failure Mode	Possible Causes	Potential Effects	S	O	D	RPN
Call interruption	It may be caused by poor signals, network fluctuations, or failure of the phone's communication module.	It leads to sudden disconnection during a call.	4	4	4	64
SMS sending/receiving failure	Similarly affected by signal and network factors, it may also be caused by incorrect SMS center settings.	It results in the failure to send and receive SMS normally.	4	5	4	80
Mobile data connection problems	Such as inability to connect to the mobile network or excessively slow network speeds.	It affects the normal conduct of functions such as web browsing, online video playback, and application downloads.	5	4	4	80

5. Improvement Measures for Mobile Phone Hardware, Software, and Communication Systems

The trend of mass data in power system provides a basis for load characteristic analysis and prediction model establishment, but the classical load forecasting method can not afford such a huge time and computing resource consumption. The problem of over fitting in large sample set will affect the prediction accuracy. In this paper, a power load forecasting model is built by using the BP neural network model, making full use of the powerful data processing function of Clementine and preventing the over fitting function. The experimental results show that the BP neural network model has good predictability and robustness, and has a certain practical application value.

5.1. Mobile Phone Hardware Improvement Measures

(1) Screen damage improvement measures

Adopt higher-strength and more drop-resistant screen materials, such as Gorilla Glass.

A mobile phone screen is composed of a multi-layer structure. The bonding process should be improved by adopting high-precision, high-reliability vacuum bonding technology to ensure tight and gap-free bonding between the layers. This can prevent moisture, dust, and other impurities from intruding into the screen, avoid display abnormalities or damage caused by internal short circuits and corrosion, and also enhance the overall strength of the screen, reducing the probability of local damage caused by uneven force.

Optimize the appearance design of the phone and add protective measures around the screen, such as metal frames or rubber buffer strips.

(2) Battery failure improvement measures

Develop more efficient and safer battery technologies, such

as improved versions of lithium-ion batteries.

Reasonably design the matching relationship between battery capacity and phone power consumption to improve battery life. Add mobile phone battery management functions, such as smart charging and overcharge/over-discharge protection.

Reasonable battery layout: During the phone design stage, plan the battery position reasonably according to heat dissipation requirements and heat source distribution. Avoid placing the battery adjacent to heat-generating hardware (such as the processor) to reduce the impact of heat on the battery; optimize the battery compartment space and reserve sufficient heat dissipation channels to ensure that heat can be dissipated in time during battery operation, preventing high temperatures from accelerating battery aging and causing failures such as bulging.

(3) Camera failure improvement measures

Adopt higher-quality lenses and image sensors to improve photo quality. Optimize the camera's focusing algorithm to improve focusing speed and accuracy.

Develop optical glass with higher hardness and lower dispersion, or combine it with nano-coating technology to enhance the wear resistance and anti-fouling performance of the lens. For example, adopting a fluoride coating gives the lens surface a lotus-leaf-like "self-cleaning" property, making it difficult for water droplets and dust to adhere, and reducing failures such as imaging blurriness and glare caused by stain obstruction; at the same time, it enhances the scratch resistance of the lens, preventing scratches from hard objects such as keys and tabletops in daily use and maintaining stable optical performance of the lens.

(4) Motherboard failure improvement measures

Adopt higher-quality electronic components to improve the reliability of the motherboard. Improve the phone's heat dissipation design, such as adding heat sinks and optimizing heat dissipation channels, to prevent the motherboard from overheating.

Apply conformal coating on the surface of the motherboard to form a dense protective film that isolates moisture, dust, and salt spray corrosion, which is suitable for humid and dusty environments; add anti-static components, such as TVS (Transient Voltage Suppressor) diodes, to clamp instantaneous high voltages and prevent electrostatic discharge from breaking down sensitive chips and components, ensuring the electrical safety of the motherboard during daily use and the plugging and unplugging of interfaces.

5.2. Mobile Phone Software Improvement Measures

(1) Operating system lag improvement measures

Continuously optimize the code of the operating system to reduce the possibility of system cache accumulation.

Through forms such as built-in tutorials in the phone system, boot guidance screens, and popular-science articles on the official website, disseminate correct methods of using the phone to users. Inform users to regularly clean the cache and close infrequently used applications; remind them to avoid running high-load applications continuously for long periods; guide them to develop good charging habits to prevent system frequency reduction and lag caused by overheating; when the phone's battery is low and memory is tight, push prompt messages in time to help users optimize the operating state of the phone.

Develop a more efficient memory management mechanism to improve system operating efficiency.

(2) Application crash improvement measures

Strengthen quality control in the application development process and strictly review the code to eliminate vulnerabilities.

Precisely plan application memory usage, estimate memory requirements according to different functional modules, and reasonably allocate heap and stack space; for loading large resources such as images and videos, adopt caching strategies, set reasonable cache duration and size, and clean up expired and idle caches in time to release memory and prevent program crashes caused by memory overflow.

Improve the compatibility between applications and the system and conduct sufficient compatibility testing.

(3) Software update failure improvement measures

Improve network connection conditions, such as providing a better Wi-Fi environment or enhancing mobile data signals.

Optimize phone storage space management and promptly remind users to clean unnecessary files to ensure the space required for updates.

5.3. Mobile Phone Communication System Improvement Measures

(1) Call interruption improvement measures

Improve the performance of the phone's communication module and enhance its adaptability to signal and network fluctuations.

Improve the structure of the phone's built-in antenna, adopting a multi-band, high-gain antenna design to adapt to the needs of diverse network frequency bands; use new antenna materials to improve antenna radiation efficiency and reduce signal loss; optimize the antenna layout to avoid electromagnetic shielding effects from components such as the phone's metal casing and battery, ensuring smooth signal transmission and reception and reducing call failures caused by poor antenna performance.

Cooperate with telecommunications operators to optimize signal coverage and network quality.

(2) SMS sending/receiving failure improvement measures

Optimize the SMS center setting process to make it simpler and easier to understand, facilitating user operation.

Enhance the phone's adaptability to signal and network fluctuations.

The built-in SMS application of the phone system needs regular iteration to fix vulnerabilities and optimize the interface and operation logic. Add an intelligent retransmission function: when an SMS sending failure is detected, the message is automatically retransmitted according to the set interval and number of attempts; optimize the SMS storage mechanism to prevent a full local storage or database errors from affecting the reception of new SMS.

(3) Mobile data connection problem improvement measures

Optimize phone network settings to improve adaptability to different network environments.

Cooperate with telecommunications operators to improve network quality and increase network speeds.

6. Conclusion

This study explored the improvement of smartphone functions based on the FMEA method. Through precise identification of failure modes, detailed analysis of failure

causes, risk assessment, and the formulation and implementation of targeted improvement measures, remarkable results have been achieved and the expected research objectives have been fulfilled.

Through the FMEA process, numerous potential failure modes of smartphones in hardware, software, and communication were systematically identified, covering key functional areas such as the battery, motherboard, screen, camera, communication module, operating system, and various applications. In response to these failure modes, their root causes were deeply explored from multiple perspectives such as technical principles, design defects, production processes, usage environments, and user habits, and the various factors leading to functional failures were determined. Using the quantitative assessment system of severity, occurrence, and detection, the risk priority numbers were accurately calculated, and the key directions and priority order of improvement were clarified.

In the improvement measure stage, a series of practical and feasible solutions were formulated for the high-risk failure modes. In terms of hardware, the battery management system and charging technology were optimized, higher-performance chipsets and heat dissipation materials were selected, the manufacturing process and protective structure of the screen were improved, and the optical components and image processing algorithms of the camera were upgraded. In terms of software, the kernel code of the operating system was reconstructed to enhance stability and resource management efficiency, and the code quality and compatibility of applications were optimized. In terms of communication, the performance of the phone's communication module was improved, its adaptability to signal and network fluctuations was enhanced, and the structure of the phone's built-in antenna was improved by adopting a multi-band, high-gain antenna design to adapt to the needs of diverse network frequency bands.

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