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The Application of High-Visibility Colors in the Uniforms of Urban Rail Transit Maintenance Personnel

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ABSTRACT

This paper delves into the application of high-visibility colors in the uniforms of urban rail transit maintenance personnel. By analyzing the characteristics of the rail transit working environment, the principles of color psychology, and the performance of colors under different conditions, it proposes a high-visibility color design scheme for such uniforms. The study reveals that well-selected and matched colors can significantly enhance the visibility of maintenance personnel in complex environments, ensure operational safety, and strengthen corporate image and employee identity. The findings offer a scientific basis and practical guidance for designing more efficient and innovative uniforms.

KEY WORDS: Urban rail transit maintenance personnel uniforms; High-visibility colors; Color application; Uniform design

1. Introduction

Urban rail transit is a key mode of urban transportation. Its safe and efficient operation relies on the hard work of maintenance personnel. Their uniforms are not only essential for work but also a vital part of a transit company's image. In complex working environments like tunnels, platforms, and track areas, high-visibility colors in uniforms are crucial for safety, work efficiency, and corporate image enhancement. They allow maintenance personnel to be easily noticed by colleagues, train drivers, and other staff, improving communication and collaboration and reducing misunderstandings and delays caused by visibility issues.

At the same time, the uniforms of maintenance personnel serve as a showcase for a transit company's image. Unified and highly visible uniforms can act as a mobile business cards, conveying the company's professional and reliable image to the public and boosting its social recognition and reputation. Well-designed uniform colors can reflect the company's professionalism and cultural values, enhancing employee identity and pride and strengthening the company's cohesion.

However, there has been relatively little research on the application of high-visibility colors in the uniforms of urban rail transit maintenance personnel. Although progress has been made in fields like color psychology and optical contrast principles, how to systematically apply this knowledge to uniform design remains a topic that needs further exploration. Factors such as

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regional cultural backgrounds, environmental characteristics, and international industry standards impose varying requirements on uniform color design.

This paper will explore this field in depth. By integrating color psychology, optical contrast principles, and international standards, it aims to propose a high-visibility color design scheme for urban rail transit maintenance uniforms, providing valuable references for uniform design and offering significant practical implications.

2. Research Questions

i. What factors in the rail transit working environment significantly affect the color visibility of maintenance personnel uniforms?
ii. How to choose and match colors to achieve high visibility for urban rail transit maintenance uniforms?
iii. What is the significance of applying high-visibility colors in urban rail transit maintenance uniforms for operational safety and corporate image?

3. Literature Review

3.1 Design of Urban Rail Transit Maintenance Uniforms

The design of urban rail transit maintenance uniforms must consider a multitude of factors, such as the working environment, safety requirements, and corporate image, while also incorporating regional cultural integration and color psychology principles to achieve comprehensive optimization. Wang (2020) notes that occupational uniforms play a pivotal role in shaping a company's image and must align with its business processes, product features, cultural philosophy, and employee needs. In the rail transit industry, uniform design must meet basic safety requirements and showcase the company's professional image and cultural values. Chang (2019), using chameleons as an example, provides solutions for optimizing the design of special-sized chameleons through statistical analysis, offering insights for incorporating traditional clothing elements into rail transit uniforms. Sun (2024) points out that under the backdrop of Chinese modernization, the occupational uniform industry is being propelled by policies, with market demand shifting toward professionalization and high quality, and scenario-based perspectives becoming a new trend in design. However, current occupational uniform design faces challenges such as homogenization, lack of innovation, and functional impracticality.

In terms of color design, Li (2020) explores the application of traditional Chinese colors in rail transit uniforms, emphasizing the importance of color in conveying cultural meanings and enhancing visual visibility. Reasonable color selection and matching can improve the visibility of maintenance personnel in complex environments and reflect regional cultural characteristics. For instance, Zhengzhou Metro adopts stone green and ochre, which not only offer high visibility but also embody local culture. Color psychology research indicates that red has strong warning properties and can quickly attract attention in complex environments, while yellow offers high visibility in low-light conditions, and the proper use of these colors can enhance operational safety.

In terms of regional cultural integration, the color design of rail transit maintenance uniforms is increasingly incorporating regional cultural elements, reflecting local culture and enhancing the cultural significance and visibility of uniforms. Studies show that color brightness and purity directly impact visibility. Low brightness (e.g., dark blue) combined with high purity (e.g., ochre) can create visual layers, providing a scientific basis for color matching in rail transit maintenance uniforms. The application of reflective materials is also crucial, as they ensure high visibility in low-light conditions and further enhance operational safety.

In terms of future research directions, with continuous technological advancements, intelligent color-changing materials are emerging. These materials can automatically adjust their color or reflective properties based on environmental light and temperature, further improving safety. In design applications, 3D printing technology is beginning to be used in uniform insignia production, enabling more complex and personalized high-visibility pattern designs and bringing new possibilities to the high-visibility color design of rail transit maintenance uniforms.

In summary, the design of urban rail transit maintenance uniforms is a complex process involving multiple disciplines. Through in-depth research and practice, uniform design will continue to improve, providing strong support for the safe operation and sustainable development of the rail transit industry.

3.2 Application of High-Visibility Colors

Zuo (2022) indicates that 3D body measurement technology is widely used in the clothing industry and is particularly important for special-sized consumers. Taking ladies' convex abdomen dresses as an example, the study explores the allocation patterns of 3D body measurement data in key areas of clothing, addressing technical challenges in pattern making for special-sized and custom-made garments. Luo (2022) investigates the morphological characteristics of young women with special body shapes, obtaining data through 3D body scanning and image processing software. The study analyzes different body shape features, optimizes prototype structures, and combines visual illusion techniques for innovative design, making clothing patterns conform to human body structures and improving visual effects. Chen & Hou (2022) note that with improved living standards, the body shapes of middle-aged and elderly women are changing, forming special-sized groups. There is a limited market supply of clothing suitable for this group. Through the method of correcting three-dimensional cutting with a mannequin, a well-fitting garment prototype can be obtained, providing an effective approach for the structural design of special-sized occupational clothing for middle-aged and elderly women and meeting their demand for well-fitting occupational uniforms.

The application of high-visibility colors is also significant in the design of urban rail transit maintenance uniforms. Li (2020) explores the application of traditional Chinese colors in rail transit uniforms, emphasizing the role of color in conveying cultural meanings and enhancing visual visibility. Reasonable color selection and matching can improve the visibility of maintenance personnel in complex environments and reflect regional cultural characteristics.

Color psychology research provides theoretical support for the application of high-visibility colors. Hivizology (2021) points out that different colors have varying visual effects and psychological impacts under different environmental conditions. For example, red has strong warning properties and can quickly attract attention in complex environments, while yellow offers high visibility in low-light conditions. Keith Shiggins (2023) also emphasizes the safety and standards of color selection, noting that reflective materials can provide greater visibility at longer distances in low-

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light conditions, while fluorescent colors offer higher visibility during the day.

In practical applications, the color design of urban rail transit maintenance uniforms must consider multiple factors. Sun (2024) notes that under the backdrop of Chinese modernization, occupational uniform design is increasingly moving toward professionalization and high quality, with scenario-based perspectives becoming a new trend in design. This means that uniform design must not only meet safety requirements but also consider the diversity and complexity of working environments. By integrating 3D body measurement technology and color psychology principles, uniforms that conform to ergonomics and feature high visibility can be designed. This comprehensive design approach can significantly enhance the visibility of maintenance personnel in complex environments, reduce safety risks, and strengthen the company's professional image and social recognition.

3.3 Rail Transit Working Environment and Color Psychology

Rail transit maintenance work is highly hazardous, with maintenance personnel required to operate in complex light and dynamic environments. Studies show that the visibility of uniform colors directly impacts operational safety: a 15% increase in visibility can reduce accident rates by 22% (Flatscher, 2025). The rail transit working environment is complex and diverse, primarily including tunnels, platforms, and track areas. Factors such as light conditions, background colors, and personnel activities in these environments can all affect the visibility of maintenance uniforms. Color psychology research indicates that different colors have varying visual effects and psychological impacts under different environmental conditions. For example, red has strong warning properties and can quickly attract attention in complex environments, while yellow offers high visibility in low-light conditions. Proper color selection and matching can effectively enhance the visibility of maintenance personnel in complex environments and ensure operational safety.

In tunnel environments, where light is dim and backgrounds are predominantly gray or black, the use of fluorescent yellow or fluorescent orange uniforms can effectively improve the visibility of maintenance personnel. Although the effectiveness of fluorescent colors may decrease in low-light conditions, reflective materials can provide greater visibility in such environments. Therefore, maintenance uniforms for tunnel work should combine fluorescent colors with reflective materials to ensure high visibility under different light conditions (Alsco, 2023).

On platforms, where light conditions are generally good but environments are crowded with diverse background colors, the colors of maintenance uniforms need to form a strong contrast with the background for quick identification. For instance, fluorescent yellow or fluorescent orange uniforms can quickly attract attention in well-lit platform environments, thereby improving work efficiency and safety (Keith Shiggins, 2023).

In track areas, light conditions vary significantly, with ample sunlight during the day and reliance on lighting equipment at night. During daytime operations, fluorescent colors can provide high visibility, while in nighttime or low-light conditions, the use of reflective materials becomes crucial. By properly combining fluorescent colors with reflective materials, maintenance uniforms can maintain high visibility under different light conditions, reducing the risk of accidents (Hivizology, 2021).

In summary, the diversity and complexity of rail transit working environments require that the color design of maintenance uniforms comprehensively consider factors such as light conditions, background colors, and personnel activities. By properly selecting and matching colors and leveraging the characteristics of fluorescent colors and reflective materials, the visibility of maintenance personnel in complex environments can be significantly enhanced, ensuring operational safety. Additionally, the application of color psychology provides a scientific basis for uniform design, ensuring that uniforms meet safety requirements while considering visual effects and psychological impacts.

4. Research Methods

This paper adopts a research approach combining literature analysis and case studies. By analyzing existing literature, it outlines the design process of urban rail transit maintenance uniforms, the characteristics of working environments, and methods for applying high-visibility colors. The research subjects are urban rail transit maintenance personnel, and high-visibility color design schemes are proposed through analysis of their actual working environments.

5. The Application of High-Visibility Colors in Urban Rail Transit Maintenance Uniforms

5.1 Analysis of Rail Transit Working Environments

The rail transit working environment is complex and diverse, primarily comprising the following scenarios:

Table 1: Analysis of Different Rail Transit Working Environments

Environment Name	Light Conditions	Background Colors	Personnel Activities	Scene Image
Tunnel Environment	Dim light	Gray or black	Maintenance personnel must work in confined spaces	

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Platform Environment	Good light conditions	Diverse colors	High personnel density	
Track Area	Light conditions vary significantly	Track and equipment colors	Maintenance personnel must work between moving trains and equipment.	

Source: Drawn by the researcher.

Image Source: Shenzhen Metro Official Website（https://www.szmc.net/）

The working environment in urban rail transit is diverse and complex. In tunnels, lighting is dim, with backgrounds predominantly gray or black, and maintenance personnel must work in confined spaces, making them easily overlooked. At platforms, lighting is better, but the area is densely populated with diverse background colors, requiring maintenance personnel uniforms to be quickly identifiable. In track sections, lighting conditions vary significantly—bright sunlight during the day and reliance on lighting equipment at night—with backgrounds primarily consisting of track and equipment colors, posing higher safety risks for maintenance personnel working in these areas (see Table 1).

5.2 Selection and Matching of High-Visibility Colors

Based on the characteristics of rail transit working environments, the following factors should be considered when selecting high-visibility colors:

Table 2: Selection and Matching of High-Visibility Colors

Consideration Factor	Color Effect	Color Matching
Color Visibility	Select colors that maintain high visibility under different light conditions, such as fluorescent yellow and fluorescent orange. Fluorescent colors may have reduced effectiveness in low light, while reflective materials provide greater visibility in such conditions.	Low light + reflective materials; High light + fluorescent materials
Contrast	Choose colors that form a strong contrast with background colors to enhance the visibility of maintenance personnel. For example, in tunnels with gray or black backgrounds, fluorescent yellow or fluorescent orange uniforms can effectively attract attention.	Gray/black background + fluorescent yellow or fluorescent orange
Psychological Impact	Select colors with warning and safety properties, such as red and yellow, which can psychologically alert surrounding personnel to the presence of maintenance personnel.	Red, yellow, etc.

Source: Drawn by the researcher.

In the urban rail transit work environment, selecting high-visibility colors requires consideration of multiple factors. Color visibility is critical; fluorescent yellow, fluorescent orange and similar colors offer good visibility under various lighting conditions. In low-light environments, reflective materials can be combined, while fluorescent materials are used in high-light environments. Color contrast is also important. Colors like fluorescent yellow or fluorescent orange, which contrast sharply with gray or black backgrounds, can enhance the visibility of maintenance personnel. Additionally, the psychological impact of colors should be considered. Colors like red and yellow, which have warning and safety connotations, can psychologically alert surrounding personnel to the presence of maintenance personnel (see Table 2).

5.3 Integration of Regional Culture and Color Design

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Table 3: Integration of Regional Culture and Color Design

Case	Case Source	Color Scheme	Case Image
China Case	Zhengzhou Metro Official Website	Orange work-wear combined with gray functional dividing lines, incorporating regional cultural elements.	
	Hangzhou Metro Official Website	"West Lake Blue" paired with red, white, and blue scarves and ties.	
	Tianjin Metro Official Website	Light blue uniforms with yellow stripes.	
	Nantong Metro Official Website	Dark gray base with red reflective strips.	
International Case	Deutsche Bahn Official Website	Red and white combination with horizontal color bands to enhance contour recognition. Uniforms match the company's color scheme.	
	Moscow Metro Official Website	Blue base with red reflective strips.	

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	Indian Metro Official Website	Light color base with red reflective materials.	

Source: Drawn by the researcher.

Indian railway worker studies indicate that yellow, symbolizing "sacredness" locally, has a lower hazard perception score than international standards (Borade et al., 2008). This contrasts with China's high-speed rail adoption of "azure" to convey a sense of technology (Huang et al., 2020), illustrating that color design must align with regional cultural symbolism.

In summary, these cases demonstrate the practical application of high-visibility colors in the design of urban rail transit maintenance uniforms, highlighting their importance in enhancing operational safety, shaping corporate images, and integrating regional culture. By properly selecting and matching colors and leveraging the characteristics of fluorescent colors and reflective materials, the visibility of maintenance personnel in complex environments can be significantly improved, ensuring operational safety. Additionally, the application of color psychology and regional culture provides a scientific basis and cultural significance for uniform design, ensuring that uniforms meet safety requirements while considering visual effects and cultural characteristics (see Table 3).

6. Research Findings and Discoveries

6.1 Effects of High-Visibility Color Application

By incorporating high-visibility colors into the uniforms of railway maintenance personnel, visibility in complex environments can be significantly enhanced, thereby reducing the risk of accidents. Relevant research and practical applications have demonstrated that after adopting uniforms featuring high-visibility colors compliant with standards, the incidence of accidents caused by visibility issues has notably decreased, resulting in more effective safeguarding of maintenance personnel safety.

6.2 Color and Corporate Image Building

The application of high-visibility colors not only enhances operational safety but also strengthens the image of rail transit enterprises. Uniform and high-visibility uniforms serve as the enterprise's mobile business card, conveying a professional and reliable brand image to the public, thereby enhancing the enterprise's social recognition and reputation.

6.4 Technological Applications and Innovation

With the continuous advancement of technology, the application of high-visibility colors in railway maintenance personnel uniforms is also undergoing continuous innovation. In terms of material research and development, smart color-changing materials are beginning to emerge. These materials can automatically change color or reflectivity based on environmental light and temperature, further enhancing safety performance. In terms of design application, 3D printing technology is now being used in the production of uniform logos, enabling more complex and personalized high-visibility pattern designs.

7. Discussion

7.1 Future Development Directions

Future research can further explore how to integrate artificial intelligence, big data, and machine learning technologies more deeply into the design of high-visibility colors for urban rail transit maintenance uniforms. For example, by developing more precise color recognition systems, real-time monitoring and analysis of different light conditions and background colors in working environments can be achieved, allowing automatic adjustment of uniform color matching to maintain high visibility in various complex environments. Additionally, research on intelligent materials is becoming a hotspot. Intelligent color-changing materials can adjust their color or reflective properties based on environmental light and temperature, offering new directions for uniform design. By combining intelligent materials with digital design, dynamic color changes in uniforms can be realized to adapt to different tasks and scenarios.

7.2 Application Prospects of Intelligent Color-Changing Materials

Intelligent color-changing materials have broad application prospects. These materials can automatically adjust their color or reflective properties in different environmental conditions, such as appearing in regular colors during the day and enhancing reflective effects at night or in low-light conditions. This ensures that uniforms maintain high visibility across different time periods and environments, further improving operational safety. However, the application of intelligent color-changing materials also faces challenges, such as material stability, cost control, and durability. Currently, the high cost of intelligent color-changing materials limits their widespread use in urban rail transit maintenance uniforms. Future research needs to address these issues to promote the practical application of intelligent color-changing materials in uniform design.

7.3 Innovative Applications of 3D Printing Technology

The application of 3D printing technology in uniform insignia production offers new possibilities for high-visibility pattern design. Through 3D printing technology, more complex and personalized pattern designs can be achieved, enhancing the visual effects and visibility of uniforms. 3D printing technology allows precise control over the size and shape of patterns, making uniform insignia design more flexible and diverse. Additionally, 3D printing technology offers advantages in rapid prototyping and customized production, meeting the personalized needs of different companies for uniform design. However, the application of 3D printing technology in uniform design is still in its early stages and requires further optimization of printing materials and processes to improve the durability and wear resistance of patterns. Currently, the durability of 3D printing materials needs improvement, which may affect the lifespan of uniforms. Future research should focus on developing more durable 3D printing materials to promote the widespread use of this technology in uniform design.

8. Conclusion

This paper systematically studies the application of high-visibility colors in urban rail transit maintenance uniforms and comprehensively analyzes their significant effects in improving operational safety, enhancing corporate images, and promoting

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technological innovation. The findings reveal that proper color selection and matching can significantly enhance the visibility of maintenance personnel in complex environments, reduce accident risks, and strengthen the company's professional image and social recognition. With continuous technological advancements, innovative applications such as intelligent color-changing materials and 3D printing technology will offer more possibilities for the high-visibility color design of urban rail transit maintenance uniforms. Future research should further explore how to integrate these new technologies with traditional design approaches to achieve more efficient, safer, and innovative uniform designs. Through ongoing research and practice, the application of high-visibility colors in urban rail transit maintenance uniforms will continue to improve, providing strong support for the safe operation and sustainable development of the rail transit industry.

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