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Bus anti-harassment design based on natural surveillance theory innovative exploration of spatial layout and product service system

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Abstract. Enhancing the social inclusivity of public transportation from a perspective of gender equality has become more significant in the context of China's rapidly expanding urbanization. However, female commuters' personal safety is severely impacted by sexual harassment, which is pervasive in public transportation, especially during the summer and rush hours in densely populated first- and second-tier cities. The challenges confronting efforts to address this issue are manifold, including insufficient law enforcement, the particular spatial constraints of public transportation, and people's weak awareness of protecting women's rights. This study focuses on the prevention of sexual harassment on buses from the perspective of spatial design to address the behavioral patterns and psychological needs of female commuters and proposes a product-service system based on the theory of natural surveillance. Consisting of a spatial layout design module, three product modules, and a software module, the system improves natural surveillance within the space to deter potential offenders by optimizing the arrangement of hardware facilities, guiding passenger orientation, and improving visibility. Its overall design centers on spatial layout and integrates functions of products and service to prevent crimes before they start. Furthermore, this study innovatively introduces crime prevention theories in environmental design to propose high-quality and visually appealing solutions as alternatives to traditional defensive measures. In addition to being applicable to public transportation, the research findings may also be applied to other public areas to improve the protection of women.

Keywords: public transportation product design, sexual harassment prevention, natural surveillance theory, environmental facility spatial design, women's safety system design

1. Introduction

1.1. The importance of urbanization and public transportation systems

Public transportation systems play a crucial role in enhancing urban mobility and promoting social interaction in light of rapid urbanization and pervasive use of smart technologies. However, due to the closeness, high passenger mobility and difficult supervision in public transportation spaces, these systems have become hotspots for crimes like sexual harassment.

1.2. Current situation and impact of sexual harassment on buses

In China, female passengers are frequently the main victims of sexual harassment on buses, which is also a global issue that affects many countries. Large cities are the most impacted places, and the summertime and rush hours are particularly high-risk periods for such incidents. Sexual harassment is often covert with difficulties to obtain evidence, and the legal sanctions are relatively weak, hence this type of crime continues to exist [1]. Moreover, sexual harassment not only causes psychological trauma and affects interpersonal relationships for the victims but also lifts their sense of avoidance towards public places [2], and in turn, confines their employment opportunities, social engagement, and the overall stability of society [2, 3].

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1.3. Research objectives and significance

This study aims to optimize the spatial layout and security systems of buses based on CPTED (Crime Prevention Through Environmental Design) theory, in order to minimize sexual harassment incidences by improving natural surveillance using environmental design approaches.

The primary objective of the research is to improve bus safety by minimizing opportunities for crimes through reasonable spatial design and technological interventions. Additionally, the study seeks to optimize the internal layout and service systems of buses, thereby enhancing female passengers' overall experience during their commutes and safeguarding their security.

Furthermore, being applicable to the public transportation environment in China, this research also provides a theoretical foundation and practical guide for future development of public transportation safety systems.

2. Analysis of sexual harassment in public transportation

2.1. Research background of sexual harassment issues

Sexual harassment on buses is a global social issue, particularly prominent in densely populated urban areas [4]. Survey data reveals that 24% of female passengers have been sexually harassed on buses, with 84% of the victims being between the ages of 15 and 30. The incidence of sexual harassment is closely related to passenger density, and the crimes exhibit a bimodal distribution. Overcrowding at peak hours gives offenders more opportunities, while a lack of surveillance raises the danger.

Instances of sexual harassment often occur near the doors and around the handrails in the middle of the bus during busy times, with incidents of harassment directed at the buttocks being particularly common. In contrast, harassment in the seated areas is more frequently during off-peak hours, and it is more often hand based.

2.2. Factors influencing the occurrence of sexual harassment

Studies show that multiple factors contribute to the occurrence of sexual harassment, primarily including the following:

2.2.1. Passenger density

High passenger occupancy on buses during rush hours creates a congested atmosphere that offers covert opportunities for sexual harassment; thus, it is difficult for victims to recognize or resist the harassment. Despite that passenger flow is lower during off-peak hours, the sparse distribution of passengers on buses makes it easier for offenders to find opportunities to harass.

2.2.2. Gender ratio

Survey data indicates that the incidence of sexual harassment increases with the number of male passengers in the vicinity. A higher proportion of male passengers can make offenders feel more secure and less likely to be reported.

2.2.3. Cabin environment

Environmental factors such as lighting and noise within the bus can also influence the occurrence of sexual harassment. According to the research, 70% of victims reported that the cabin was noisy when they were harassed, while 40% stated that the lighting was normal. This suggests that environmental factors are not the sole determinants, however, a noisy atmosphere may make nearby passengers less vigilant, thereby increasing the possibility for harassment to occur.

2.2.4. Sociocultural factors

Sociocultural factors including gender inequality and women's disadvantaged social position are considered as underlying causes of sexual harassment. Female victims often choose to remain silent because of societal stereotypes about women and their high tolerance for sexual harassment incidents, hence the similar cases continue to occur due to such cultural acceptance and the absence of social condemnation.

2.3. The unique nature of bus spaces

Buses are a confined public space with the following special features:

2.3.1. Limited space

The space inside a bus is confined, particularly during peak hours, when physical contact between passengers is inevitable, fostering an atmosphere that is conducive to sexual harassment. Victims find it challenging to distance themselves from the offenders throughout the trip because buses usually only have one compartment.

2.3.2. Blind spots

The seating arrangement and handrail design inside buses may result in areas that become blind spots, particularly in crowded situations, in which natural surveillance becomes nearly ineffective, facilitating the concealment of criminal activities.

2.3.3. High passenger mobility

A bus is a highly mobile space, allowing perpetrators to quickly get on and off, making it challenging to track them after they escape, which increases the difficulty for victims in seeking assistance or pursuing legal action.

2.4. Passenger density and time factors (peak hours vs. off-peak hours)

2.4.1. Peak hours

Sexual harassment often takes place during peak hours in the congested space in the middle of the bus and close to the doors, as the large number of passengers results in frequent physical contact between commuters. Victims in such dense crowd are often unable to immediately notice or resist the harassment, and the other passengers' distracted attention makes it difficult for them to offer effective assistance. The crowded conditions create an environment where offenders can more easily engage in inappropriate behavior without being detected or confronted.

2.4.2. Off-peak hours

Sexual harassment usually occurs in the seating areas during off-peak hours when there are fewer passengers. Perpetrators can more easily target victims since passengers are more sparsely distributed, and the relative isolation of the victim makes it difficult for them to receive support from surrounding passengers. In these less crowded conditions, offenders may feel emboldened by the lower chance of immediate intervention or detection.

2.5. Ineffective law enforcement and weak awareness of women's rights

Despite the frequent occurrence of sexual harassment, there are still significant issues with law enforcement and awareness of women's rights, which hinder the reduction of the incidence of sexual harassment.

2.5.1. Ineffective law enforcement

Survey data reveals that the main reasons why over half of victims decide not to assert their rights include insufficient evidence, distrust in the judicial system, and fear of retaliation. Additionally, the problem is further exacerbated by the lack of effective reporting systems on buses, which make it more difficult for victims to receive timely assistance. This deficiency in law enforcement and support mechanisms discourages victims from taking legal action and allows perpetrators to harass with impunity.

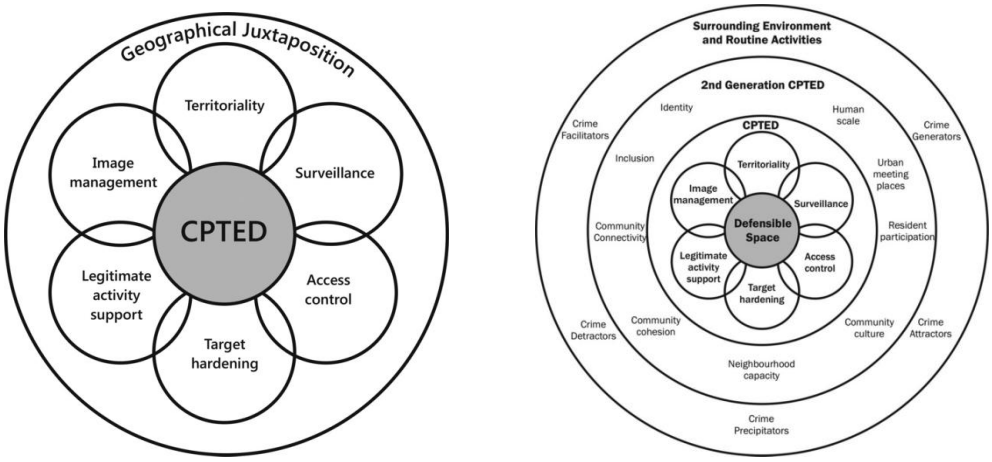
2.5.2. Weak awareness of protecting women's rights

Sexual harassment is widely tolerated in society, and victims often decide to keep quiet out of fear of shame or blame. Survey data shows that 58% of victims believe there is insufficient evidence to prove the harassment, 38% do not trust the judicial system, and 26% face obstacles when seeking help from bus security personnel. In addition to discouraging victims from seeking justice, the lack of awareness and support for women's rights perpetuates the cycle of silence and impunity.

3. Overview of natural surveillance theory

3.1. Basic concepts of natural surveillance theory

Natural Surveillance, which seeks to decrease crime opportunities by optimizing spatial design to improve visibility and observability in the environment, is one of the core concepts of Crime Prevention Through Environmental Design (CPTED). The fundamental principle of natural surveillance to deter crimes through increasing the number of watchers and broadening their vision scope, which can make potential offenders feel a higher risk of being watched. In contrast to typical methods to keep security like cameras or guards, natural surveillance emphasizes enhancing the ability of legitimate users to monitor a space through design measures, such as adjusting spatial layout, increasing lighting, and minimizing blind spots [5]. Figure 1 illustrates the seven concepts of CPTED and its dynamic integration model [6].



(a)The seven principles of CPTED (b)The dynamic integration model of CPTED

Figure 1. System construction of CPTED theory

3.2. Application of natural surveillance in crime prevention

The following aspects demonstrate how natural surveillance theory is applied in crime prevention:

3.2.1. Enhancing visibility

Optimizing spatial layout and reducing blind spots might make potential offenders feel more at risk of being watched.

3.2.2. Guiding foot traffic

Spatial design is adopted to direct people's sightlines and movement patterns, increasing surveillance of key areas.

3.2.3. Enhancing users' sense of security

Increasing natural surveillance helps legitimate users feel more secure and reduce their fear of crime.

3.2.4. Deterring crime

By increasing the number of and expanding the scope of observers, criminal acts can be suppressed since potential offenders perceive a higher probability of being reported or apprehended [5].

3.3. Case analysis of current public space crime prevention design

Natural surveillance theory is typically applied in the following approaches in current public space crime prevention design cases:

3.3.1. Optimizing lighting

Illumination is increased in public spaces to reduce dark corners and improve visibility.

3.3.2. Reducing obstacles

Objects that obstruct sightlines are removed or minimized to increase the openness of the space.

3.3.3. Guiding sightlines

Spatial design is used to direct people's sightlines toward key areas, such as entrances, exits, and aisles.

3.3.4. Increasing surveillance points

Features such as windows and transparent partitions are added to make activities within the space more observable [7].

4. Proposal for bus anti-harassment design

Based on the theory of natural surveillance, the proposal for bus anti-harassment design primarily focuses on optimizing three modules: spatial layout design, product and service systems, and software service support. As shown in Figure 2, Figure 3, and Figure 4.

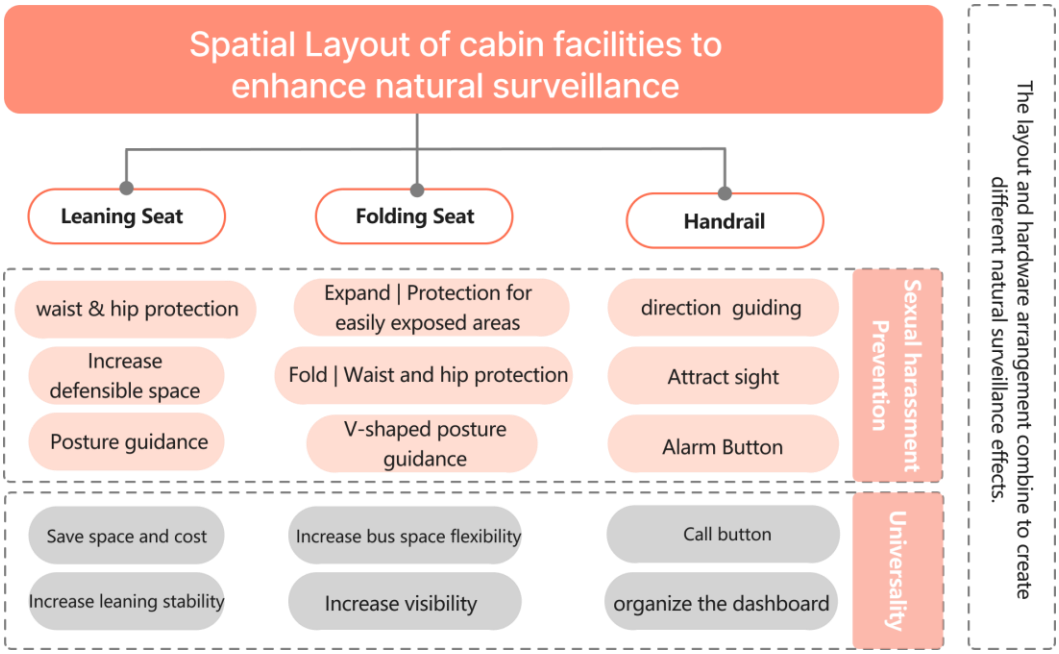


Figure 2. Module functional architecture

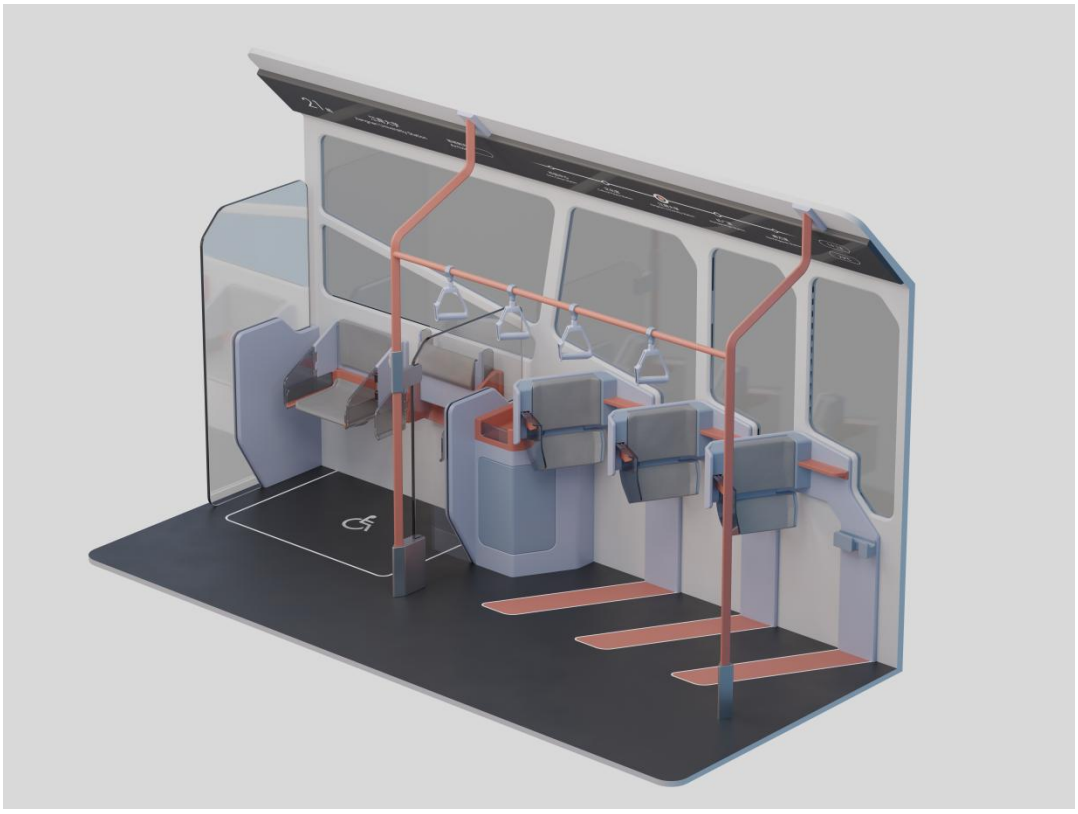


Figure 3. Overall view of the public bus sexual harassment prevention product system

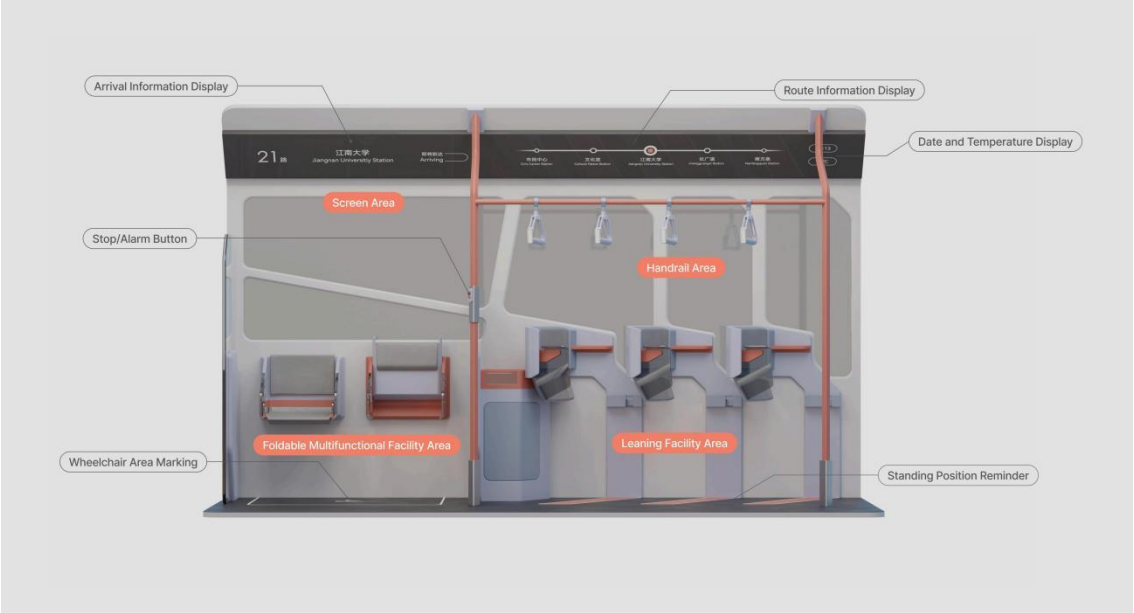


Figure 4. Product layout

4.1. Spatial layout design module

Optimization of seat and handrail arrangement: By adjusting the arrangement of seats and handrails, the design increases visual crossovers between passengers and reduces blind spots. For example, placing seats at a 45° angle can avoid passengers' discomfort caused by directly facing each other, while enhancing natural surveillance. As shown in Figure 5, Figure 6, Figure 7 and Figure 8.

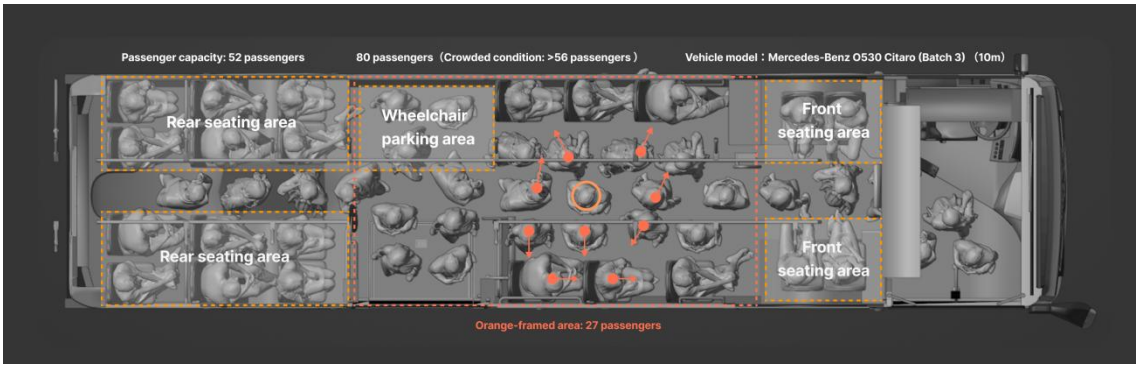


Figure 5. Current public bus natural surveillance layout

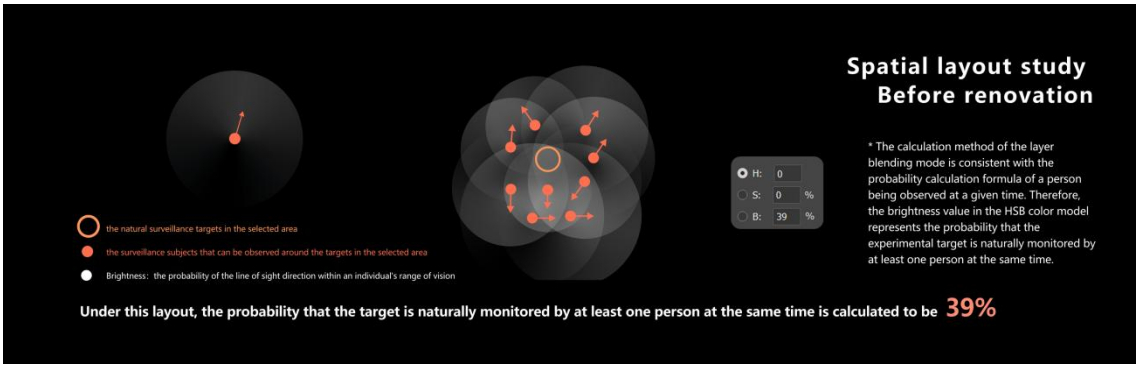


Figure 6. Natural surveillance visualization calculation(current public bus)

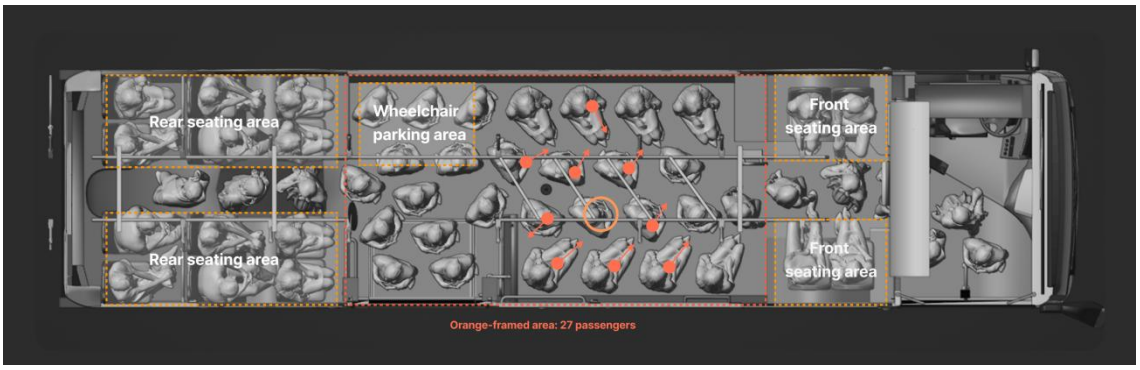


Figure 7. Optimized spatial arrangement for natural surveillance layout

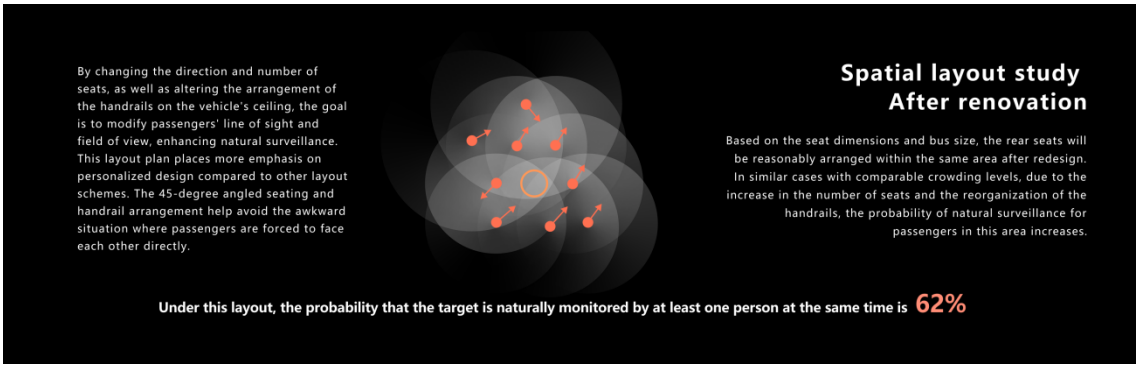


Figure 8. Natural surveillance visualization calculation (optimized spatial arrangement)

4.1.1. Passenger orientation guidance design

Seating and standing are designed to direct passengers' posture and orientation, guiding their sightlines toward key areas of the bus, such as doors and aisles, in order to improve surveillance of potential criminal activities. As shown in Figure 9, Figure 10 and Figure 11.

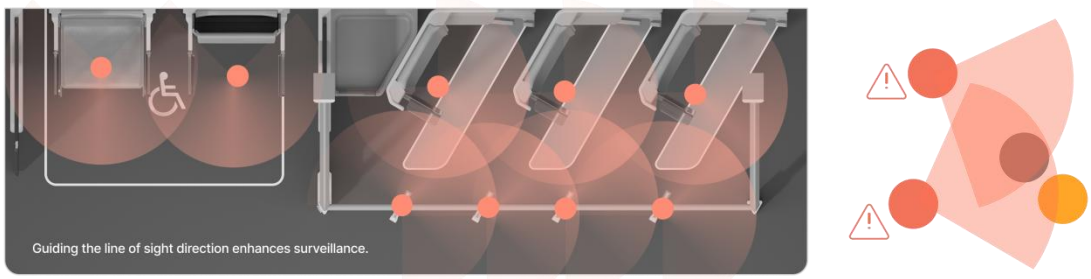


Figure 9. Sight guidance diagram for product area

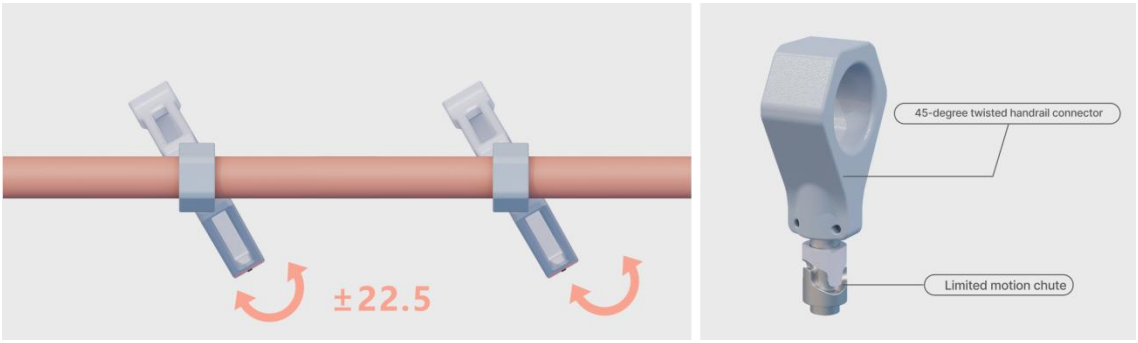


Figure 10. Standing direction control:angle-limited handrail

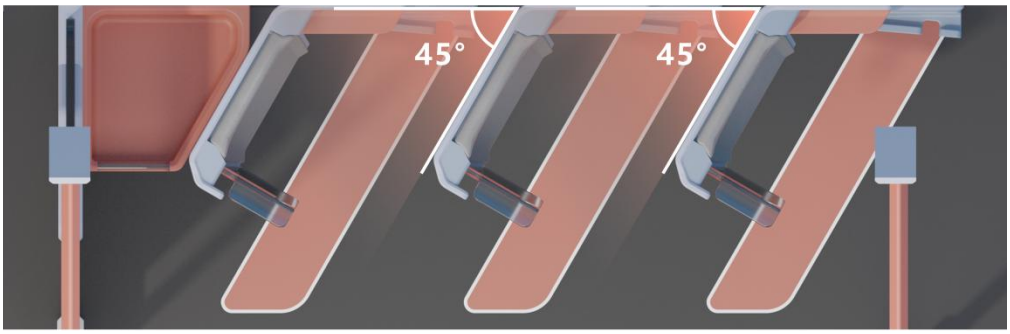


Figure 11. Seated position direction control: seat position angle layout

4.1.2. Increasing visibility of key areas (e.g. doors)

The chance of criminal activities is decreased by adding transparent partitions, mirrors, and other design elements to make key areas such as bus doors more visible increase the visibility of key areas such as bus doors. As shown in Figure 12, Figure 13 and Figure 14.

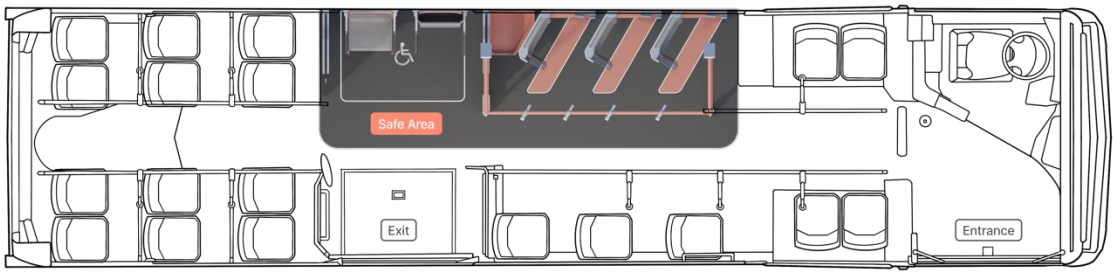


Figure 12. Key area

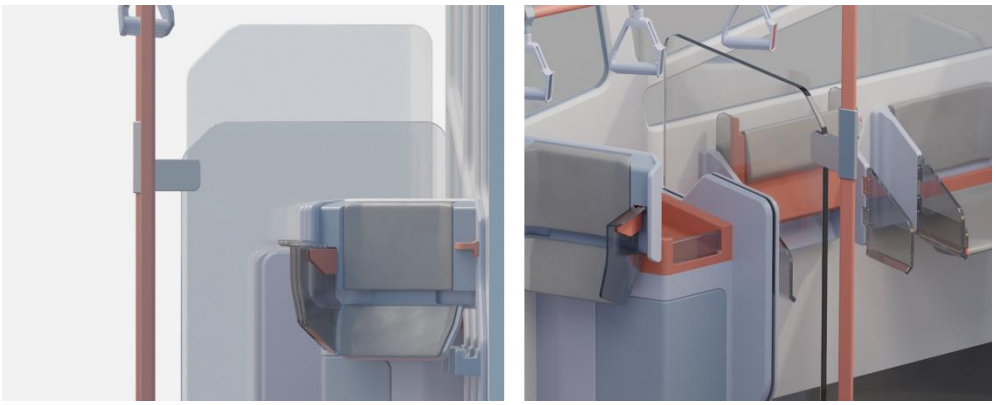


Figure 13. Transparent partition: visibility increase

Figure 14. Reflective mirror: reduce blind spots

4.2. Product and service system module

4.2.1. Physical protection devices

Designing foldable and supportive multifunctional facilities that protect waist and hip by covering vulnerable areas can expand the space for defense, which increases passengers' sense of security. As shown in Figure 15, Figure 16, Figure 17 and Figure 18.

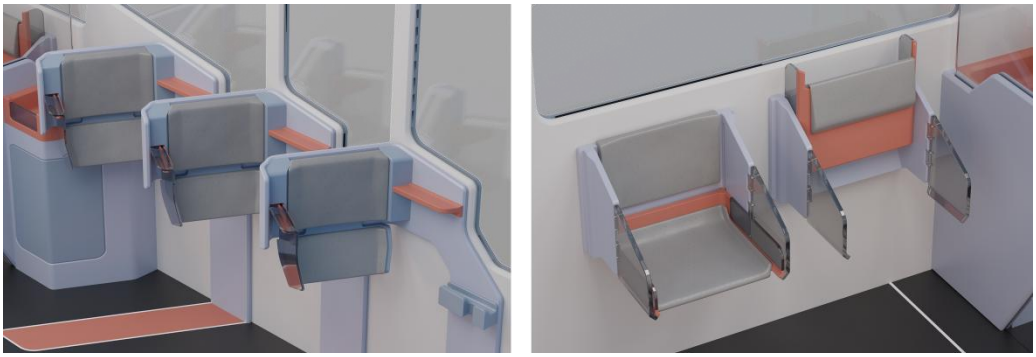


Figure 15. Leaning hardware & folding hardware render

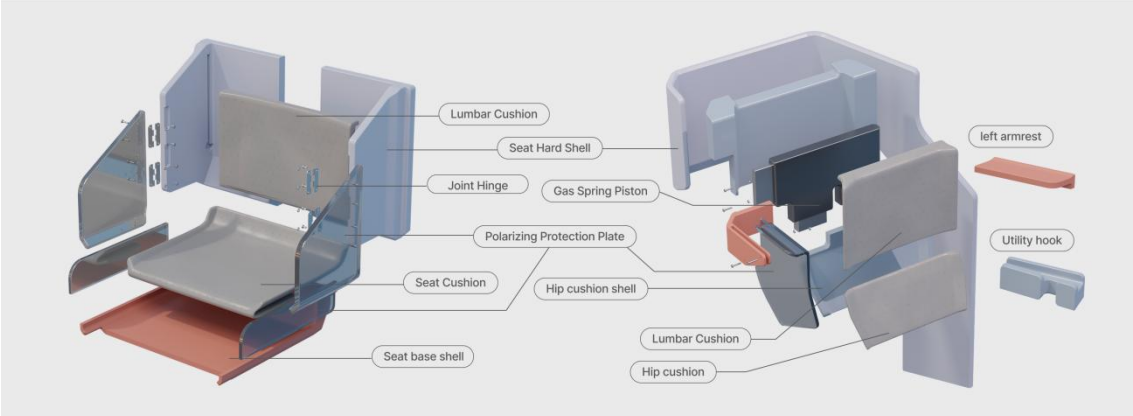


Figure 16. Leaning hardware & folding hardware exploded view

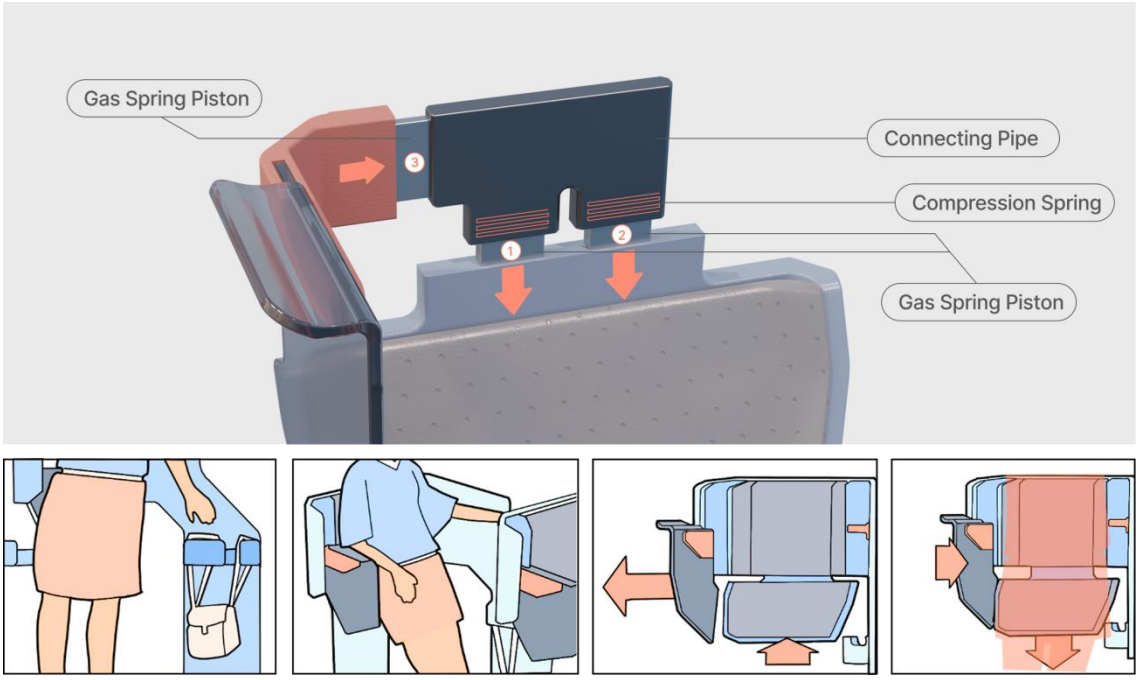


Figure 17. Leaning hardware principle and usage introduction

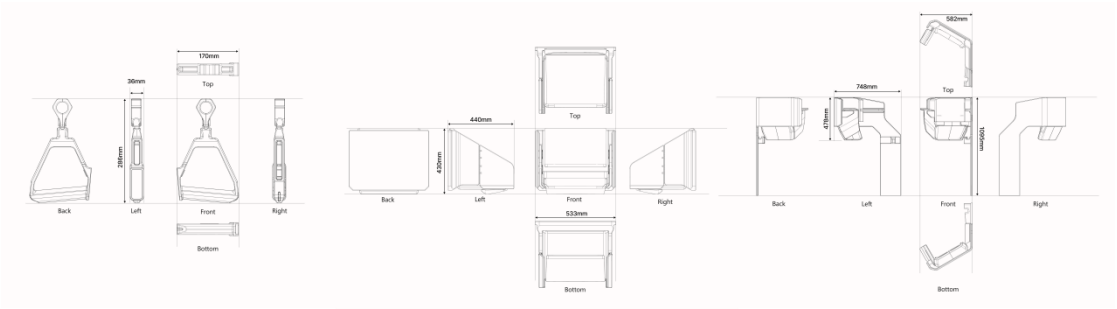


Figure 18. Six views and dimensions

4.2.2. Surveillance and alarm system optimization

Installing alarm buttons and surveillance equipment inside the bus allows passengers to promptly report harassment and obtain aid when needed. As shown in Figure 19-20.

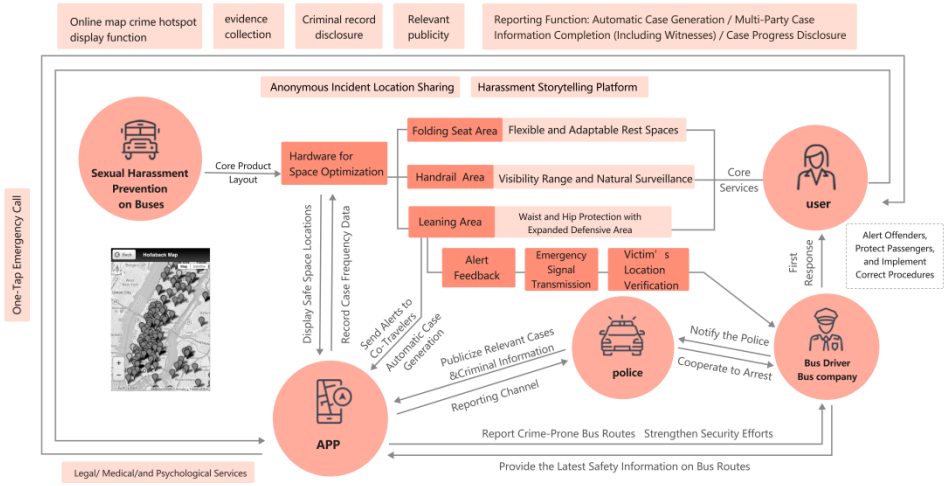


Figure 19. Police-community linked alarm system

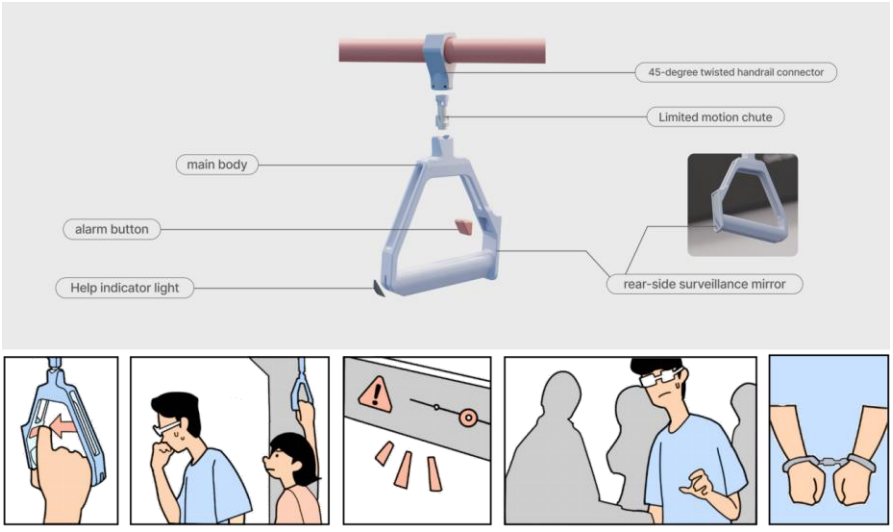


Figure 20. Handrail alarm button & cabin monitoring alarm

4.2.3. In-vehicle information guidance system

In-vehicle display screens, or mobile apps are employed to provide passengers with information on safety advice and crime prevention, enhancing their awareness of security. As shown in Figure 21.

Figure 21. Information guidance system

4.3. Software service support module

4.3.1. Passenger assistance and reporting system

Passengers can use the app platform to report sexual harassment instantly and receive assistance from nearby passengers. The app also provides features such as incident reporting and information disclosure to make passenger feel more secure. As shown in Figure 22 and Figure 23.

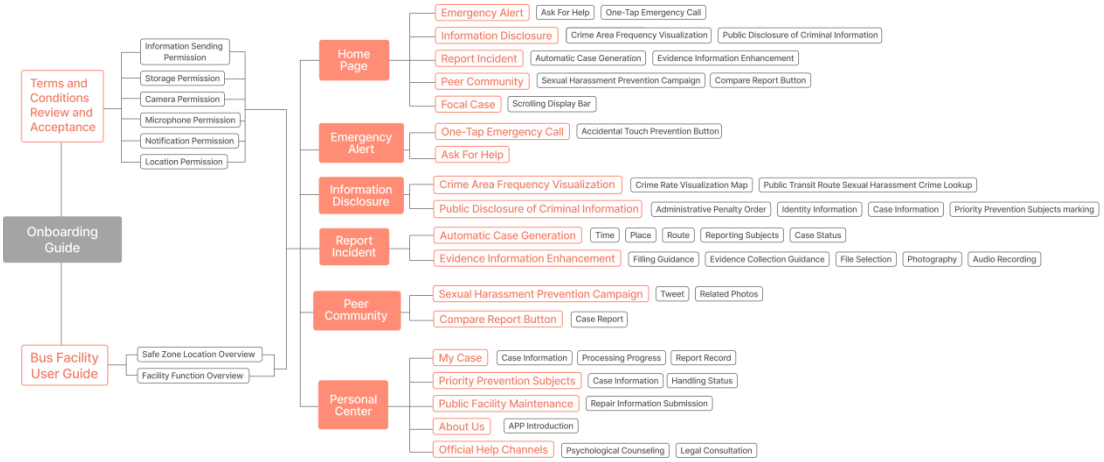


Figure 22. App information architecture

(a)

(b)

(c)

Figure 23. App high-fidelity display

4.3.2. Data analysis and dynamic adjustment plan

By collecting and analyzing data on sexual harassment incidents, the bus layout and safety measures can be dynamically adjusted to optimize the anti-harassment strategy.

5. Innovation and practical application

5.1. Innovative features of the design proposal

5.1.1. Innovative application of natural surveillance theory

The design proposal optimizes the bus interior layout by introducing natural surveillance theory to improve visibility and monitoring capabilities within the bus. For example, arranging seats and handrails can increase the visual intersections between passengers and reduce blind spots, which may deter potential sexual harassment.

5.1.2. Integration of visual aesthetics and high-quality spatial design

The design proposal focuses on visual appeal and high-quality spatial design in addition to functionality. Neutral colors and shapes are used to ensure that it is non-invasive while improving passengers' comfort and security. For example, the polarized film of the foldable multifunctional facilities provides protection while maintaining visual transparency within the bus.

5.1.3. Application of gas spring technology and polarized film

Gas Spring and polarized film technologies are creatively incorporated in the design proposal. Gas spring technology applied in the supportive facilities achieves an automatic reset function through pressure linkage to improve the functionality and comfort of the facilities. Polarized film technology is applied to the foldable multifunctional facilities, adjusting light permeability to protect privacy while maintaining visibility inside the bus.

5.2. Feasibility and promotion value of the proposal

5.2.1. Feasibility analysis

The design proposal is based on current well-developed and easily implemented gas spring and polarized film technologies. Prototype test and user feedback show that the design has demonstrated excellent performance in terms of functionality and user experience, making it highly feasible.

5.2.2. Promotion value

This proposal is not only applicable to buses but can also be extended to other means of public transportation and public spaces, such as subways, shopping malls, etc. It has extensive marketing potential due to its modular design and adaptable functionality, which can meet the specific needs of different spaces.

5.3. Recommendations on future implementation and optimization of bus systems

5.3.1. Recommendations on implementation

First of all, a pilot program should be conducted on selected buses to collect user feedback and make necessary optimizations and gradually expand the implementation across the entire bus network. Secondly, both bus drivers and passengers should be instructed on how to properly use the new facilities and safety precautions to ensure the smooth implementation of the plan. Finally, a regular monitoring and maintenance system should be established to ensure the long-term effective operation of the facilities.

5.3.2. Recommendations on optimization

Firstly, a user feedback system should be set up to regularly collect passengers' opinions and suggestions, which ensures ongoing optimization of the design. In line with future technological advancements, gas spring and polarized film technologies can be continuously upgraded to enhance the intelligence and automation level of the facilities.

5.4. Applicability expansion to other public spaces

5.4.1. Subway

In subway, similar natural surveillance designs can be applied by optimizing the arrangement of seats and handrails to improve inside visibility, which will lessen the chances for crimes by reducing blind spots and ensuring clear sightlines[8, 9].

5.4.2. Shopping malls

Polarized film technology can be applied in public rest areas and corridors of shopping malls to protect privacy while maintaining the openness of the space, which will increase customers' sense of security by protecting their privacy without compromising visibility and surveillance within the space.

5.4.3. Other means of public transportation

Similar design solutions can be used at airports, trains, and other public spaces to improve passengers' comfort and make them feel more secure, while reducing the occurrence of sexual harassment incidents [8].

6. Conclusion and outlook

In this study, a bus anti-harassment design is established based on spatial layout and product service systems by innovatively combining natural surveillance theory with gas spring and polarized film technologies. In addition to improving passengers' comfort and safety on buses, the design demonstrates strong feasibility and promotion potential. This approach can be extended to other public spaces with progress implementation and optimization, providing a safe and comfortable travel environment for more passengers and contributing favorably to the protection of women.

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