Study on Considerations for Bicycle and Pedestrian Passage in Municipal Road and Bridge Design

Pingping Zhang

Suyi Design Group Co., Ltd. Anqing Branch, Anqing, Anhui, 246000, China

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Abstract: Modern urban construction development actively promotes the concept of green travel, where cycling and walking have become primary low-carbon and environmentally friendly transportation modes, occupying an important position in the urban transportation system. However, some cities inadequately consider bicycles and pedestrians in municipal road and bridge design, leading to restricted passage space for non-motorized vehicles and pedestrians, causing safety issues and poor travel experiences. This paper will focus on the field of municipal road and bridge design, point out the considerations and problems regarding bicycle and pedestrian passage in such designs, propose scientific and reasonable design optimization strategies, and provide a strong reference for the sustainable development of urban transportation systems.

1. Introduction

Municipal roads and bridges are core components of the urban transportation network, and their design quality is closely related to urban traffic operation efficiency. Against the backdrop of actively promoting green travel concepts, cycling and walking have become low-carbon and environmentally friendly travel modes, widely recognized by people. In the vast majority of large and medium-sized cities in China, cycling and walking have become popular, but some municipal road and bridge designs still prioritize motor vehicle passage needs, with insufficient consideration for bicycles and pedestrians, limiting the active promotion of green travel modes. Therefore, in-depth exploration of bicycle and pedestrian passage paths in municipal road and bridge design is of significant practical importance.

2. Considerations for Bicycle and Pedestrian Passage in Municipal Road and Bridge Design

2.1 Spatial Path Planning

Spatial path planning for bicycles and pedestrians in municipal road and bridge design must adhere to the principles of safety and comfort, establishing a multi-dimensional collaborative passage system based on road functional positioning. Among these, the independence of the passage path is the primary principle. Municipal engineering construction units need to install physical separation facilities between bicycle lanes and pedestrian walkways. Simultaneously, at key design nodes such as bridge intersections and approach ramp slopes, optimization of turning radii and gradient design should be considered. In areas with limited land, a shared board design mode for motorized and non-motorized traffic can be chosen, using different materials and colors of pavement to demarcate space and prevent motor vehicles from encroaching on passage channels.

2.2 Safety Protection

The safety protection of the bicycle and pedestrian passage system in municipal road and bridge design requires the construction of a multi-dimensional protection system. Specific design aspects should consider continuous guardrails or green belt design to achieve separation between motor vehicle lanes, non-motorized vehicle lanes, and pedestrian walkways. The height of guardrails

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should exceed 1.2m, with high baffles at the bottom to prevent children from climbing or objects from rolling off. Anti-skid paving and vibrating markings should be installed in speed change areas such as bridge approach slopes and tunnel entrances/exits. When the gradient exceeds 2.5%, anti-skid grooves should be added. Pedestrian walkways need to maintain a continuous ramp design, with double-layer handrails installed at key nodes. Bridges and connecting roads must be equipped with sufficient and uniform lighting facilities to avoid glare and shadows, ensuring pedestrians and cyclists are visible at night. Furthermore, the overall design should maintain a continuous, flat passage plane, avoiding steep slopes and sharp bends. Intersections should achieve zero-height difference transitions and be equipped with tactile paving systems and tactile warning tiles. Where bridge deck width allows, lanes and pedestrian walkways can be further separated to reduce pedestrian-vehicle mixing interference.

2.3 Environmental Integration

The planning of bicycle and pedestrian passage systems in municipal road and bridge design needs to be deeply integrated into the urban ecological and humanistic environment. At the ecological level, green permeability should be strengthened. Native weather-resistant plants should be selected to form ecological corridors. Vertical greening modules should be set on bridge piers, and rainwater collection systems should be utilized for automatic irrigation, forming dynamic ecological landscapes. The application proportion of permeable paving materials should be above 70%, combined with sunken green space design to give hard road surfaces rainwater storage and regulation functions, maintaining the regional hydrological cycle. At the cultural expression level, regional genes can be implanted. Traditional architectural elements can be extracted and modernly translated. Environmentally friendly building materials such as recycled aggregate concrete and bamboo-steel composites can be prioritized, conveying the concept of sustainable development through material texture. Integration at the cultural and social level should create rich interactive spaces, transforming transportation functions into positive social interaction experiences and enhancing community cohesion.

3. Common Problems in Bicycle and Pedestrian Passage Design of Municipal Road and Bridge Engineering

3.1 Unreasonable Space Allocation

The problem of unreasonable space allocation for bicycle and pedestrian passage in municipal road and bridge engineering design is becoming increasingly prominent. Some roads and bridges are designed with severely insufficient planning for bicycle lanes. On some busy sections, the width of the bicycle lane can barely accommodate one bicycle passing through. If a cyclist stops briefly or gives way, it can cause traffic congestion [1]. Furthermore, some municipal road and bridge designs have blurred boundaries between pedestrian and bicycle passage space. Pedestrians often have to avoid fast-moving bicycles while walking, increasing the risk of accidents. Cyclists also have to frequently brake and change lanes, reducing passage efficiency. From a spatial layout perspective, the design of bicycle and pedestrian passage areas in some municipal roads and bridges lacks coherence. Pedestrian walkways may also be blocked by various obstacles, forcing pedestrians to detour, adding extra travel distance and time costs. Additionally, the slow-traffic space in some road and bridge projects does not fully consider the special needs of groups such as the elderly, children, and people with disabilities. This design flaw not only reduces inclusivity but also exacerbates the chaos in space usage.

3.2 Signal Control Needs Optimization

Currently, the timing of traffic lights on some roads and bridges lacks scientific planning. During periods of low traffic volume, bicycles and pedestrians still have to wait for red lights for long times. This unreasonable timing seriously reduces the passage efficiency of bicycles and pedestrians, wasting their time. During peak hours, the green light time might be too short, preventing large numbers of bicycles and pedestrians from crossing the intersection within one signal cycle, causing them to accumulate in the middle of the intersection, affecting traffic order and increasing safety hazards. Simultaneously, the intersection traffic lights in some road and bridge designs do not fully consider the passage characteristics of bicycles and pedestrians. Bicycles and pedestrians interfere with each other during passage. Intersections without dedicated bicycle traffic lights force cyclists to follow motor vehicle signals, posing significant challenges to cycling safety. The intelligence level of signal triggering mechanisms has much room for optimization. Intersections often use fixed timing plans, lacking real-time perception and response capability to pedestrian and bicycle flow. Although some grade-separated crossing facilities achieve pedestrian-vehicle separation, problems like unclear signal indications and long waiting times reduce facility utilization rates, leading to frequent jaywalking.

3.3 Insufficient Accessibility Facilities

The problem of insufficient accessibility facilities in the bicycle and pedestrian passage design of municipal road and bridge engineering is quite prominent. From the bicycle passage perspective, some roads and bridges lack continuous, standardized dedicated bicycle lanes. On some road sections, bicycle lanes are occupied by parked motor vehicles or lack effective separation from motor vehicle lanes, forcing cyclists to frequently avoid motor vehicles, posing significant safety hazards. Bicycle lanes at intersections lack reasonable guidance signs and transition areas, causing cyclists to easily lose direction when turning. The inadequacy of accessibility facilities for pedestrian passage is even more common. The ramp design in some municipal road and bridge projects does not meet standards, making passage extremely inconvenient for people with disabilities. Tactile paving in some municipal roads and bridges is often treated as "decoration," not fulfilling its functional advantages. Issues during installation include sudden interruptions, unreasonable detour planning, and even blockage by fixed or temporary obstacles like street light poles, distribution boxes, and shared bicycles [2]. For visually impaired individuals, this can become misleading and a trap.

3.4 Traffic Organization Needs Improvement

Problems exist in the actual operation of bicycle and pedestrian passage design projects in municipal road and bridge construction regarding traffic organization that needs improvement. In terms of path planning, there is mixing of bicycles and pedestrians, which not only reduces passage efficiency but also increases collision risks, threatening the safety of pedestrians and cyclists. In the design of crossing facilities, there are still instances of shared use by bicycles and pedestrians, without fully considering their different needs. Some road and bridge projects have relatively complete slow-traffic systems designed on the bridge itself, but there are disconnections in the linkage with surrounding roads, communities, or public transportation stations. This lack of systematic traffic organization reduces the overall service capability of the slow-traffic system, making it difficult to form a continuous, friendly travel network. Furthermore, some roads and bridges lack physical separation between bicycle lanes and pedestrian walkways, relying only on markings to differentiate functions, making it difficult to effectively prevent motor vehicle encroachment or non-motorized vehicle boundary crossing. Problems like insufficient nighttime lighting and missing warning signs increase nighttime passage risks.

4. Optimization Strategies for Bicycle and Pedestrian Passage Design in Municipal Roads and Bridges

4.1 Implementing Spatial Separation and Functional Optimization

Optimization of bicycle and pedestrian passage design in municipal roads and bridges should adopt strategies of spatial separation and functional optimization. In the spatial separation phase, independent bicycle lanes and pedestrian walkways should be reasonably planned based on pedestrian and traffic flow data. For new road and bridge projects, physical separation methods can be used, such as setting green belts or guardrails of different heights, so that bicycle and pedestrian spaces do not interfere with each other. On broad urban arterial road bridges, bicycle lanes and pedestrian walkways can be set on both sides, separated by green belts in the middle. Functional optimization should focus on improving facility guidance and comfort, enhancing the passage experience from a systemic level. During this process, a continuous, unified guidance system should be established, using colors and textures to guide visually impaired persons, ensuring all users can clearly anticipate the path. Rest seats should be set in pedestrian gathering areas and separated from the passage space to avoid stationary crowds blocking the passageway. In periods or sections with high traffic flow and conflict risk, pilot installation of intelligent sensing systems can be considered. Dynamic safety reminders can be provided to users through sound and light warning devices, information screens displaying real-time traffic flow, etc.

4.2 Optimizing Intelligent Signal Control

Bicycles and pedestrians are important participants in the municipal road and bridge traffic system. Optimizing their passage design and implementing intelligent signal control are necessary conditions for improving traffic efficiency and safety. Engineering construction units should integrate traffic signal systems, monitoring equipment, and mobile terminals to build a unified information interaction platform. Using roadside sensors, information such as the flow, speed, and location of bicycles and pedestrians can be collected in real-time and uploaded to the platform. Mobile apps or smart wearable devices can provide travelers with real-time information such as traffic signal status and road congestion, enabling them to plan routes in advance [3]. Intelligent communication terminals should be added at key nodes of municipal road and bridge projects to convey traffic instructions and safety reminders to cyclists and pedestrians. For example, traffic lights with voice prompts can be installed at intersections, emitting warning sounds when the green light is about to end, enhancing the intuitiveness of traffic information communication. Furthermore, municipal road and bridge construction units should actively carry out humanized and interactive communication design, establish intelligent human-computer interaction systems, and improve passage experience and safety. Interactive traffic lights or large LED displays can be installed to provide clear countdowns for remaining waiting time and passage status prompts for waiting pedestrians and cyclists. Designers should set request priority buttons for special groups or high-demand scenarios. Upon receiving a request, the system will reasonably evaluate it in the next cycle and grant appropriate green light extension, reflecting humanistic care.

4.3 Implementing Accessibility and Humanized Design

The optimization of bicycle and pedestrian passage design in municipal roads and bridges should implement accessibility and humanized design, establishing an all-age-friendly passage system with continuous accessibility facilities covering the entire path. Anti-slip ramps should be set at bridge connection points. Height difference points should adopt gentle slope transitions, avoiding steps or steep slopes that could hinder vulnerable groups. On this basis, compound design should be actively promoted, expanding pedestrian passages to over 3 meters, and clearly demarcating walking paths

and rest areas. The entire design process should emphasize the transmission of humanized details. Signs should uniformly use Chinese-English bilingual comparison and international universal symbols. The height of sign placement should ensure visibility for wheelchair users at eye level, promoting the upgrade of municipal roads and bridges from passage function to service experience. A comfortable, accessible urban slow-traffic system should be established.

4.4 Optimizing Traffic Organization

The optimized design of the bicycle and pedestrian passage system in municipal roads and bridges should achieve synergistic improvement of safety and efficiency through multi-dimensional traffic organization strategies. In terms of spatial layout, a layered design concept should be implemented. Main roads should use colored anti-skid pavement combined with three-dimensional markings to clarify the boundaries of dedicated bicycle lanes, physically separated from motor vehicle lanes by permeable concrete isolation belts [4]. Pedestrian passages should be equipped with flexible facilities to form independent spaces. Key areas should adopt double-layer corridor systems to achieve three-dimensional separation of pedestrians and vehicles. In terms of signal control optimization design, engineering construction units should build a composite control system combining inductive and coordinated control. Deploy geomagnetic sensors and video detectors at arterial road intersections to collect bicycle flow data in real-time and dynamically adjust green light duration. Set up independent dedicated bicycle signal phases at large intersections or mixed-use squares, completely separated in time from pedestrian crossing signals. IoT technology can also be utilized to deploy sensors and warning devices at key conflict points. When high-speed bicycle approach or collision risk is detected, warnings can be issued simultaneously to cyclists and pedestrians through ground flashing warning lights and sound alert devices, enhancing situational awareness for both parties.

5. Conclusion

In summary, reasonable planning of bicycle and pedestrian passage paths in municipal road and bridge engineering can meet the positive concept of green travel in the new era. In the design phase, municipal road and bridge construction units need to implement spatial separation and optimization, optimize intelligent signal control, carry out accessibility and humanized design, and optimize traffic organization. This provides strong support for creating a comfortable and convenient travel environment for urban construction and promotes the development of transportation planning and construction towards sustainability.

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