TECHNICAL SOLUTIONS APPLY FOR THE DESIGN OF SPACE ON BOTH SIDES OF STREET AXIS WITH PRIORITY FOR PEDESTRIANS AND SUSTAINABLE INFRASTRUCTURE (IN CASE OF THE STREET AXIS OF NGUYEN THE LOC AND YEN KHE 1)

Tran Dinh Hieu[1]*, Nguyen Quoc Truc[2]

[1]*The University of Danang - University of Science and Technology, Vietnam*
[2]*Thu Dau Mot University, Ho Chi Minh City, Vietnam*

*Corresponding author: tdhieu@dut.udn.vn

(Received: March 28, 2026; Revised: May 06, 2026; Accepted: June 05, 2026)

DOI: 10.31130/ud-jst.2026.24(7B).592E

Abstract - When the streets system are new upgraded, renovated, expandable and built, especially the space on both sides of the street axis in the areas of centre and canal has not been designed according to technical requirements in accordance with the function, deficiency of diversity and aesthetics should be affecting to spacial quality of street. The design of this space needs to be suitable for each area, guaranteeing technical requirements, and following the orientation to apply sustainable infrastructure facilities, with infrastructural equipment that meets usable requirements will create: High space order, friendly environment; To increase pedestrian safety; To increase aesthetic value; To increase convenience and improve the quality of the modern urban environment. The research content focuses on technical solutions to design these spaces in a way is compatible with each segment on each street; The propose for to integrate sustainable infrastructure engineering solutions and pedestrian safety engineering.

Key words - Walking sidewalk; sidewalk space; sidewalk design; sidewalk engineering

1. Introduction

1.1. Overview of spaces along both sides of the street corridor

1.1.1. The perspective of urban space

- In the context of ongoing urban development, the modernization of transportation spatial systems in Vietnamese cities in general, and in Da Nang in particular, has become an urgent requirement. Developing well-organized spatial structures along transportation corridors is therefore essential to improving urban functionality and overall spatial quality.

- Sidewalks are an important component of urban space and perform multiple essential functions. Therefore, sidewalks should be properly designed and managed to meet the following requirements:

+ Serving as public interaction spaces for social activities and community engagement.

+ Providing pedestrian circulation space, while accommodating the need for bicycle and motorcycle parking, as well as access for cars, buses, and other forms of public transport.

+ Functioning as corridors for urban technical infrastructure, including the installation of utilities, street trees, and other urban amenities.

+ Supporting economic activities and cultural-social interactions among urban residents.

+ Contributing to the urban landscape of the city [1].

- Such approaches should also align with the long-term development orientation of Da Nang toward becoming a green and ecological city in the future.

1.1.2. The perspective of technical safety

- According to Dr. Angela Pratt - the representative of the World Health Organization in Vietnam: “During the period 2011–2021, pedestrian fatalities increased by 42% in the Southeast Asia region, while cyclist fatalities rose by approximately 88% in the Western Pacific region. However, only about 0.2% of streets worldwide are equipped with dedicated bicycle lanes, and many areas still lack sidewalks and safe pedestrian pathways”.

- Technical solutions for organizing spaces along street corridors should satisfy several key criteria, including safety, aesthetics, connectivity, primary and extended functional requirements, and environmental considerations (green infrastructure), etc. Specifically, these include:

+ Appropriate dimensions of sidewalk space, technical facilities, and frontage areas in front of townhouse facades;

+ Universal accessibility provisions, such as curb ramps, suitable surface conditions, clear spatial separation between pedestrian and vehicular areas, and safe corner configurations at intersections and public transport stations;

+ Ensure the continuous connectivity of pedestrian and bicycle routes, integrated with public transportation systems, so that these modes of mobility become more convenient and accessible for residents;

+ Clear signage providing necessary information, pedestrian traffic signals, and adequate public lighting;

+ Promote interaction between people and urban space through attractive environments, appropriate vegetation, and well-designed urban furniture;

In addition, given the high level of motorcycle usage, appropriate measures are required to prevent motorcycles from encroaching upon spaces designated for pedestrians and cyclists.

1.1.3. The perspective of environmental sustainability and urban public health

- Walking and cycling provide numerous health benefits, contributing to the reduction of cardiovascular diseases, respiratory illnesses, cancer, and diabetes. In addition, these modes of transport help reduce daily travel costs for urban residents.

Walking and cycling, which pose minimal risk to other road users and do not generate air pollution, are among the major environmental concerns in contemporary cities and simultaneously reduce the costs associated with road construction and maintenance.

- From an economic perspective, the increasing number of immigrants to large cities has placed growing pressure on urban transportation networks, particularly road-based transport systems. Therefore, promoting walking and cycling can simultaneously enhance safety, improve public health, and contribute to more sustainable transportation, environmental quality, and economic development. Some studies have shown that walkable and bicycle-friendly urban environments can increase retail sales for local businesses, generate employment opportunities, and promote tourism.

- A well-balanced integration between motorized and non-motorized transport modes can ensure more equitable access to urban mobility for all users. This approach can also raise public awareness and encourage changes in attitudes and behaviors among road users, thereby fostering safer and more responsible travel practices.

1.2. Current situation and technical design requirements for sidewalk space in Da Nang

1.2.1. Spaces along both sides of transportation corridors in newly redeveloped areas and in the study area

a. Newly redeveloped areas within the city

- Since 2024, according to the Department of Construction of Da Nang, the city's project management boards have been implementing 10 investment projects for the renovation and upgrading of sidewalks using new structural systems along 59 streets, with a total length of approximately 73 km. The projects for the improvement and upgrading of urban roads and sidewalks across the city have a total investment of over VND 1.7 trillion.

- According to Decision No. 2030/QĐ issued by the People's Committee of Da Nang, sidewalks will be paved with high-strength interlocking concrete pavers (30 × 60 × 6 cm). Besides, tactile paving strips will be installed along sidewalks to support visually impaired pedestrians. Existing curbs will be upgraded and replaced with chamfered high-strength precast concrete curbs with anti-slip surface treatment, while damaged curb foundations will be repaired or replaced. In addition, tree pits will be newly designed to match the existing sidewalk dimensions. Longitudinal drainage channels and manholes will be upgraded to align with the finished sidewalk elevation. Furthermore, odor-control flap valves and debris screens will be installed. The project also includes the renovation and underground installation of telecommunication infrastructure.

- The new interlocking concrete pavers used in the sidewalk renovation offer three major advantages:

+ Good drainage capacity, helping to prevent water accumulation on the surface;

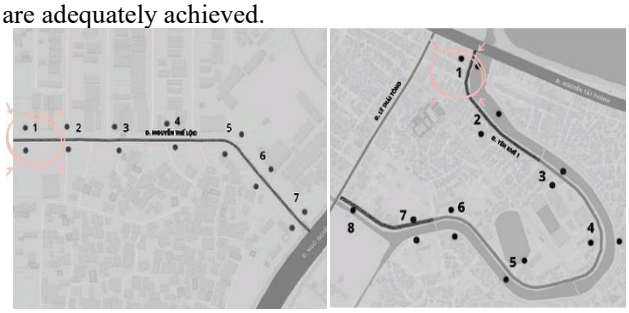
+ Higher load-bearing capacity compared with conventional concrete paving tiles, making them suitable for conditions where vehicles frequently mount and descend the sidewalks in front of residential buildings;

+ Ease of removal and reinstallation when underground infrastructure requires maintenance or repair, as the pavers can be dismantled without breaking concrete, thereby significantly reducing maintenance costs.

- However, in practice, the construction process has encountered numerous difficulties due to unstable subgrade conditions, with some areas being damp, others dry, some affected by tree root systems, and others obstructed by existing telecommunication infrastructure and street lighting utilities. The current construction method allows only a layer of crushed stone bedding beneath the pavers, without the use of concrete as a binding layer. As a result, after heavy rainfall, the crushed stone layer can be washed away, causing the paving blocks to lose stability. Following heavy rain events, many sidewalk pavers no longer maintain their initial cohesion or appearance. In several locations, stepping on the surface causes water to splash from the joints, while the pavement shows clear signs of displacement and unevenness, with pavers at different elevations, widened joints, and some blocks becoming loose or displaced from their original positions [2].

b. The study area

1. Based on field surveys of existing conditions, several general technical parameters were assessed, including: the overall sidewalk width; the width of the pedestrian walkway; the width of tree pits and planted areas; and the sidewalk slope; curb height; the frontage width of buildings; the number and types of business activities; the number of building access points; and the number of other types of buildings. The survey results indicate that many of these parameters do not meet the required technical standards, particularly as the overall sidewalk width is generally limited, ranging from 1.5 m to 2.7 m, which can be considered relatively narrow for accommodating pedestrian circulation and related activities. The surveyed locations show that only 20-30% of the required elements are adequately achieved.



Nguyen The Loc.St *Yen Khe 1.St*

Figure 1. *30 locations of field survey along the two streets (Source: Author)*

2. Nguyen The Loc. St and Yen Khe 1. St

- Nguyen The Loc. St has a long and continuous frontage, no landscape gaps, and the slope of the road greatly affects the user experience.

- Yen Khe 1. St has the advantage of a well-developed tree system in some sections, especially along the canal, contributing to creating shade and improving microclimate conditions. But the spatial relationship between the two sides of the street has not been exploited effectively: One side has potential the landscape opens to the water, while the other side is gendered limited by long, closed fences, creating a feeling of monotony and lack of vitality.

- General assessment for two streets

+ For spatial organization:

Sidewalks on both sides of streets have not been clearly defined using functions, leading to overlap between walking, business and parking spaces. Small retail activities (shops, carts, tables and chairs) occupy most of the sidewalk, while motorbikes are parked everywhere, significantly narrowing the path. Direction pedestrian movement is interrupted, lacks continuity and convenient access for all subjects cannot be guaranteed.

+ For surface quality: The sidewalk surface is mainly concrete bricks but there are signs of uneven deterioration with some places showing subsidence, peeling or height differences. Some manhole covers and technical pits are not arranged synchronously with the sidewalk-bed bricks elevation, making it unsafe to move. The guide strip for the visually impaired is present but is interrupted or obscured by obstacles, reducing effectiveness of use.

+ For landscape and microclimate: The tree system along the street have an active role in creating shade and improvement climate improvement, but not yet organized synchronously. But the tree stump are uprooted affects the structure of the sidewalk-bed surface. Temporary roofs, business utensils and tangled electrical wires reduce the overall aesthetic quality.

+ For technical infrastructure and safety: Infrastructure equipment such as electrical cabinets, light poles, cables are scattered, lacking overall planning, obstructing circulation and posing a potential safety risk.

1.2.2. Principles for sidewalk space design

General principle: Sidewalk space should ensure easy access and mobility for all users, particularly the elderly, children, and people with disabilities. It should maximize the possibility of continuous pedestrian movement along sidewalks, without requiring pedestrians to step down onto the carriageway or climb stairs. In addition, sidewalk design should also ensure aesthetic quality, through elements such as paving materials, street trees, and planting beds, which contribute to creating a positive visual impression and improving the microclimate of the urban environment.

a. Sidewalk surface space

- The sidewalk surface should be non-slip and kept free of obstacles, while ensuring adequate protection from potential hazards posed by motorized vehicles such as cars and motorcycles. Street furniture and traffic-related infrastructure, including street lighting poles, utility poles, traffic signs, directional signs, planters, and decorative sculptures, should be appropriately arranged to avoid safety risks. In addition, movable signage, banners, and advertising boards should not be placed on sidewalks or roadways, except for advertising structures installed in accordance with approved urban advertising plans.

- The minimum sidewalk width should accommodate at least two pedestrian lanes (equivalent to 1.5 m or more), and sidewalks should ideally be wide enough to support multiple functions. In cases where sidewalks are constrained, a minimum pedestrian clear width of 1.2 m may be provided.

Table 1. *Capacity of a single walking lane ([3])*

Walking condition	Capacity (persons/lane·h)
Sidewalks adjacent to buildings	700
Sidewalks separated from buildings	800
Sidewalks within green belts	1000
Promenade/recreational walkway	600
Pedestrian crossing strip	1200

Table 2. *Minimum cross-section dimensions of urban streets (Excerpted from Table 3 [3])*

Road Type	Number of lanes (two-way)	Width per lane (m)	Minimum road width (m)
9. Bicycle lane	2	1.50	3.00
10. Pedestrian path	2	0.75	1.50

b. Vertical clearance space

- Vertical clearance refers to the safe spatial limit above the roadway or pedestrian surface within which no obstacles are permitted, including road-related structures such as traffic signs, lighting poles, or other installations that may obstruct the clearance envelope.

- For spaces designated for bicycles and pedestrians, the required minimum vertical clearance is 2.5 m at certain localized locations, such as turning areas, vehicle U-turn points beneath bridges, and pedestrian underpasses [4].

- The installation of signboards must comply with regulations regarding their dimensions, as follows:

+ For horizontal signboards, the maximum height is 2 m, and the length must not exceed the width of the building frontage;

+ For vertical signboards, the maximum width is 1 m, and the maximum height is 4 m, but it must not exceed the height of the building floor where the signboard is installed;

+ Signboards must not obstruct emergency exits or firefighting access, and must not encroach upon sidewalks or roadways or otherwise interfere with public traffic [1].

c. Frontage zone

- The design of sidewalks should be compatible with the functional characteristics of each street, for example, commercial and service streets, hotel streets, or residential streets, while ensuring connectivity with public transport facilities, such as bus stops, taxi waiting areas, and pedestrian crossings.

- For sidewalks located in front of government offices or public buildings, the spatial organization should depend on the specific conditions of each street, including factors such as sidewalk width, the arrangement of street trees, and the placement of utility poles, to appropriately allocate space for pedestrian movement. For these streets, areas for commercial or street-trading activities should not be permitted.

Table 3. *Usable width allocation of sidewalk space ([1])*

Sidewalk width (m)	Pedestrian zone adjacent to building frontage (m)	Parking zone adjacent to curb (m)	Notes
< 3	1.5	(0 - 1.5)[a]	No commercial activities
3 - 4	1.5	1.5 - 2	No commercial activities
4 - 6	2	2	Commercial activities [b]
6 - 9	3	2	Commercial activities [b]
> 9	5	2	Commercial activities [b]

Notes: [a] Where the sidewalk width is insufficient, parking spaces shall not be allocated.

[b] Except for streets where the use of sidewalks for business activities, street trading, or individual commercial activities is prohibited, as specified of Decision No. 08/2023/QĐ-UBND, 23 Feb. 2023 and Decision No. 55/2014/QĐ-UBND, 31 Dec. 2014, issued by the People's Committee of Da Nang City.

d. Curbside zone

The curbside zone is the area where the sidewalk meets the roadway, typically with a width of approximately 0.5 m. The sidewalk elevation should not be higher than 0.15 m above the road surface. The use of stone curbs is encouraged, preferably with a beveled face of less than 30 degrees.

At access points to residential areas, the curb height should range from 5 cm to 8 cm, using beveled curbs. For internal roads or streets undergoing renovation and upgrading, the curb height may be reduced when considering the existing ground elevation of residential areas, but it should not be lower than 8 cm [3].

- Within the intersection area, depending on pedestrian crossing demand and the specific characteristics of the intersecting roads, pedestrian crossing arrangements should be designed to ensure pedestrian safety [5].

- Solutions for the development of bicycle and pedestrian transport in the central area of Da Nang City [5]:

+ Width of bicycle is 1.5 m/lane (2 lanes for two-way streets and on sidewalks; 1 lane for one-way streets);

+ Width of Pedestrian is 0.75 m/lane (on sidewalks);

+ Arrangement of bicycle lane: On two-way streets: two bicycle lanes with car parking prohibited during certain hours or on alternating odd-even days. On one-way streets, one bicycle lane is provided. Where sidewalks are wider than 6 m, bicycle lanes may be arranged on the sidewalk;

+ Arrangement of pedestrian lane: Located on the inner side of the sidewalk, adjacent to building frontages.

1.2.3. Technical requirements

a. Requirements for the sidewalk surface

- The pavement structure should be constructed using drainage-permeable materials, such as crushed stone and sand, to ensure adequate water drainage. Currently, high-strength interlocking concrete pavers are widely used for their durability, resistance to detachment, and low abrasion rate. The paver surface should be flat to prevent water accumulation and textured to provide slip resistance.

- After paving is completed, the base surface should be compacted using a plate compactor to ensure that the pavers are properly rearranged and interlocked, resulting in a flat and even sidewalk surface [6].

- The above-mentioned sidewalk paving solution has several advantages, including moderate investment cost, simple structural composition, and convenient construction. It also provides high load-bearing capacity, reducing the risk of breakage when cars mount or descend the sidewalk, while creating a textured surface to improve slip resistance. In addition, this method allows surface water to infiltrate through the sidewalk into the underlying soil, as no concrete bedding layer is used. This contributes to urban drainage and helps reduce pressure on the stormwater drainage system.

- Technical guidelines should clearly specify requirements regarding materials and construction procedures, including quality control from the factory stage, and strict adherence to the construction sequence without omitting any steps.

b. Thermal requirements for sidewalk surfaces

- Urban areas absorb more heat from solar radiation than rural areas and also emit more heat due to the concentration of built structures. Therefore, the impact of urban heat accumulation can be mitigated through several measures, including: minimizing the extent of paved surfaces; reducing heat emissions from architectural structures; using permeable paving materials; applying reflective paving materials; selecting materials with low thermal conductivity; reducing smooth surfaces with high heat conductivity and instead using rough-textured materials such as gravel or small stones, or prioritizing sawn or split cubic stone blocks; avoiding thick paving materials with high heat retention capacity (e.g., stone paving installed over concrete bases); and increasing green coverage, including street trees and rooftop vegetation.

Based on the solutions above, it is recommended to use light-colored surface materials and permeable materials in urban environments.

c. Technical requirements for spatial organization

Sidewalks can be organized in the following forms:

+ Pedestrian movement on sidewalks without physical separation or protective measures from motorized traffic should only be permitted on streets with design speeds of 60 km/h or lower.

+ Dedicated pedestrian walkways located along roadside verges or sidewalks and separated from vehicular

traffic by guardrails, barriers, or planted buffer strips are typically provided along major streets (Figure 2).

Figure 2. *Types of urban street spaces (Source: Author)*

2. Research methodology and survey results

2.1. Research methodology

Field survey method: Survey was conducted along both sides of Nguyen The Loc.St (0.5 km) and Yen Khe 1.St (2 km) including 30 locations were surveyed. The locations were measured, drawed, and assigned codes (NTLA-1…/NTLB-1…/YK1A-1…/YK1B-1…).

Sociological survey method: Questionnaires were distributed online based on pre-established survey contents. (115 respondents for 20 questions are reliable)

Diagramming and modeling method: Based on field survey results, diagrams, tables, and drawings were used to support analysis, evaluation, and the proposal of appropriate technical solutions.

Analysis and Synthesis Method: Results obtained from the above methods were analyzed and synthesized to conclude.

2.2. Survey results

2.2.1. Survey on the quality of sidewalk of four space for usage needs

Table 4. *Survey for four spaces on 115 people for contents in 1.2.1.2 (a). (Author)*

Four sidewalk spaces	Sidewalk surface	Vertical clearance space	Frontage zone	Curbside space
The quality of space	Sidewalk environment is assessed as satisfaction (3)	Structures encroaching of advertising signs and billboards is Average (2)-(52.2%)	Building gates opening and entrances and exits causing interruptions is Average (2)-(46.1%)	Parked cars obstructing the movement of motorcycles, bicycles and walker
The quality of material	Cracked & Warped paving tiles is Average (2)-(47%)	Structures encroaching of temporary awnings is Average (2)-(59.1%)		
The quality of safety	Even paving tiles is Average (2)-55.7%	Structures encroaching of electrical wires and cables is Average (2)-(53%)	Minimally encroach of steps or ramps from buildings and Areas adjacent to rivers equipped with protective railings is satisfaction (3)-(62%)	Properly arranged curb ramps connecting the roadway is satisfactory (3)-(58.3%)

Note: Online survey subjects: The people who directly use it in Da Nang City include: laborers, office workers / employees, students, and tourists / visitors.

2.2.2. Survey based on elements improving the quality of sidewalk space for usage needs

Table 5. *Survey for 09 elements on field by 30 form with codes (NTLA-1…/NTLB-1…/YK1A-1…/YK1B-1…) in 30 locations of survey and drawing (Author)*

Elements	Nguyen The Loc.St	Yen Khe 1.St
Accessibility	(2)-Average	(2)-Average
Safe connection	(1)-Weak	(1.5)
Clearly signage	(0)-Does not meet requirements	(2.25)
Security guaranteed	(2)-Average	(2)-Average
Attractive space	(0.5)	(1.7)
Specific space	(1.71)	(2)-Average
Suitable size	(3)- Satisfaction	(2)-Average
Surface quality	(3)- Satisfaction	(2.5)
Drainage efficiency	(3)- Satisfaction	(3)- Satisfaction

Note: Base on four elements of 1.2.1.2 - The study area (b) for Spatial organization; Surface quality; Landscape and microclimate; Technical infrastructure and safety. Evaluative application of four level including: (0)-Does not meet requirements, (1)-Weak, (2)-Average, (3)- Satisfaction, (4)-Pattern for Table 4 and 5.

3. Result and discussion

3.1. Factors affecting the space along both sides of the traffic corridor

3.1.1. Effects to design solutions and construction techniques

a. Ground conditions and construction techniques are two main causes of sunken or displaced paving tiles and uneven sidewalk surfaces.

- If the filled subgrade is inadequately compacted, heavy rainfall may lead to water infiltration, resulting in soil settlement, sliding, uneven pavement surfaces, displaced paving tiles, and water ponding after rainfall.

- If paving tiles are not properly jointed or adequately compacted during construction, they may fail to interlock firmly. Even small gaps around tree pits or manholes can cause sections of paving to shift, and grass may grow through the joints.

- The main challenge is ensuring a stable base beneath paving tiles when the foundation consists only of soil subgrade and crushed stone. If permeable pavement is required, the base materials must be carefully evaluated, as water-saturated clay has low strength and stone or sand layers may be washed away under heavy rainfall [6].

b. Common problems for technical solutions

- In urban areas, where most houses are located along main streets and cars frequently access properties, traditional tile-laying methods are often unsuitable and prone to detachment.

- When using interlocking paving tiles, the standard procedure requires spreading fine sand into the joints after laying the tiles, followed by vibratory compaction so that the sand fills the gaps and stabilizes the pavement surface.

- Quality control during construction is essential. Technical procedures must be strictly followed, particularly in stages prone to tile displacement.

Alternative base materials, such as granular layers beneath the tiles, should also be considered to improve structural stability.

Figure 3. *Sidewalk paved with interlocking tiles showing unevenness and displacement (Source: Author)*

3.1.2. Effects to environmental and climatic factors

The main causes of sidewalk defects and damage include slow-draining subgrade conditions, improper technical design of tree pits relative to root systems, ground settlement, substandard installation, and poor surface finishing due to inadequate quality control.

During use, sidewalks may deteriorate due to factors such as slow drainage affecting soil conditions, tree root growth, and structural deterioration. These factors may cause the sidewalk to heave or tilt due to subgrade expansion, temperature fluctuations, or the thermal expansion of concrete slabs. Deformation may occur due to tensile stresses caused by soil shrinkage as moisture decreases. Uneven slab movement related to subgrade conditions may result in deflection or settlement, while swelling of clayey soils at slab edges can lead to longitudinal cracking. Conversely, upward warping may occur when clay expansion at the slab center exceeds that at the edges, causing vertical movement. This deflection may also lead to longitudinal cracking.

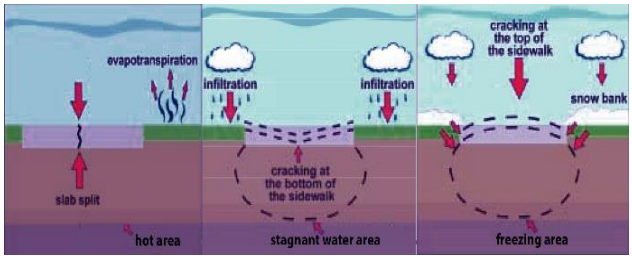


Figure 4. *Causes of sidewalk surface damage (Source: Author)*

3.2. Technical solutions

3.2.1. Spatial design solutions

a. Sidewalk surface space

Appropriate paving techniques can create visually appealing patterns and colors, contributing to aesthetic harmony while improving pedestrian comfort.

Currently, paving materials are generally flat and smooth, whereas in the past, a wider variety of surface textures, such as river cobblestones, were commonly used. In practice, textured sidewalk surfaces provide better balance and slip resistance, particularly for elderly pedestrians.

1. Unit paving layers

- Unit paving materials include fired clay bricks, concrete pavers, ceramic tiles, natural stone, cobblestones, and precast concrete slabs.

- Paving techniques including:

Paving design should consider both the pattern and orientation of paving units. In practice, joint lines are typically arranged transversely, as longitudinal layouts make irregularities more noticeable. Transverse arrangements also allow paving units with the same width but varying lengths to be used, helping to reduce costs and minimize material waste.

The herringbone paving pattern, when laid on a sand bedding layer, provides strong interlocking and distributes loads more effectively in the horizontal direction than other paving patterns.

Harder and thicker paving units should be installed on a sand bedding layer to create a flexible sidewalk structure and clearly define the joint patterns.

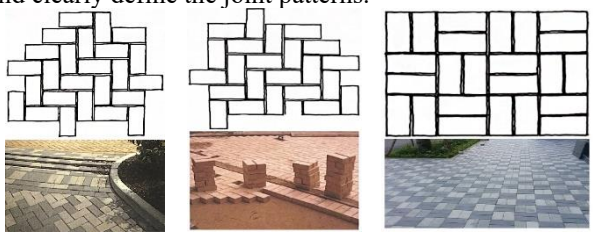


Figure 5*. Square unit paving technique (Source: Author)*

2. Flexible pavement layer

Gravel is a traditional and widely used flexible paving material. In general, gravel paving layers are permeable. However, some self-binding paving materials contain clay, which, when properly compacted, may form a relatively impermeable surface.

Crushed stone, often used as an alternative to gravel, forms a stable surface that allows drainage along the curb edges, thereby reducing the risk of pavement cracking. Crushed stone mixed with a transparent epoxy resin binder may also be used, allowing the natural color and texture of the aggregates to remain visible.

Flexible pavement layers are typically low-cost, simple, and quick to construct while providing adequate structural stability. They also allow slight movement of the subgrade and base layers, and can be used immediately after installation. Furthermore, they are relatively easy to adjust or excavate for the installation of underground utilities in the future.

3. Permeable pavement layer

Most conventional paving materials are designed to drain water across the surface while preventing infiltration. Natural processes may damage the surface layer, the paving layer, and the underlying structural layers. Concerns over declining groundwater levels as well as reduced flows in rivers and streams have led to the development of permeable paving materials, including unit paving systems and resin-bound crushed stone. Common permeable surface materials include permeable concrete blocks, permeable clay pavers, permeable crushed stone, resin-bound crushed stone, grid paving systems, no-fines concrete, and porous concrete.

Permeable paving units typically have wide joints to facilitate water infiltration. These units should be laid on a

coarse aggregate bedding layer sized 2-6 mm, while the upper 100 mm of the base layer should consist of coarse crushed aggregates sized 5-20 mm. The aggregates must be durable to prevent fragmentation; therefore, granite or basalt is recommended. The jointing material, applied during compaction, should be compatible with the base material. The use of coarse aggregates in the base layer increases the void ratio, allowing the base to function like a sponge for water storage and infiltration.

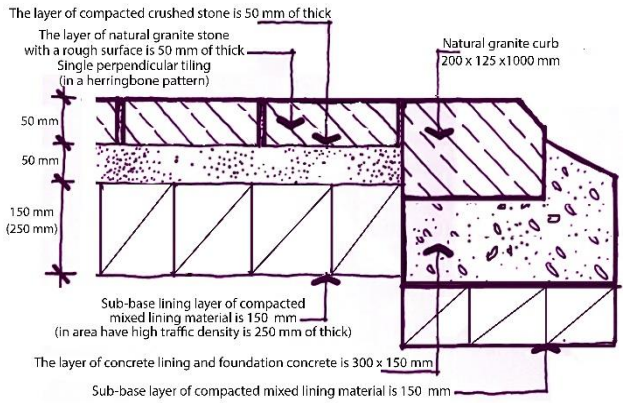


Figure 6. *Technical cross-section of unit paving*

(Source: Author, [7])

b. curbside space

Curbs are used to provide a level transition between different components of the street. The curb top elevation should be at least 12.5 cm higher than the road surface edge and may be adjacent to drainage channels or grates.

- The selection of curb types should be based on the traffic characteristics of the adjacent carriageway and the intended use of the sidewalk. Curbs can be classified into three types:

+ Vertical curb / barrier curb: the outer face is nearly vertical, preventing vehicles from crossing over or deviating from the roadway.

+ Semi-mountable curb: the outer face is slightly inclined, allowing vehicles to cross when necessary.

+ Mountable curb: the outer face is inclined, enabling vehicles to pass over easily.

- Curbs may be integrated with drainage grates or longitudinal drainage channels, or constructed as separate elements. They are typically made of cement concrete, natural or artificial stone, or other materials. Curb materials should have a compressive strength of at least 25 MPa, and higher-strength curbs with anti-slip surface treatment are recommended. Proper connections to surface drainage channels should also be provided.

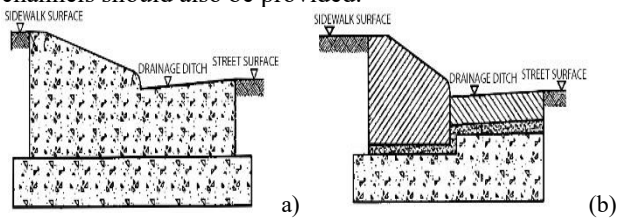


Figure 7. *Concrete curb cross-section (a) and natural stone curb cross-section (b)*

(Source: Author, [4])

Common curb materials include B22.5 grade cement concrete with 2 × 4 cm crushed stone aggregates, cast integrally with drainage channels, (Figure 7a) or natural stone blocks measuring 26 × 23 × 100 cm connected to drainage channels, with a slope angle of less than 30%, (Figure 7b).

c. Frontage zone

Canopies are provided over sidewalk areas adjacent to building frontages to shelter pedestrian walkways. The design should comply with the required clear height and the minimum pedestrian walkway width along the building frontage (Table 3).

d. Vertical adjacent to buildings

This space should be integrated with the building-adjacent space, while incorporating street trees and greenery within architectural elements in accordance with the characteristics of each street. Moreover, the vertical clearance zone must remain free of any obstructions, such as traffic signs, lighting poles, and other street facilities.

3.2.2. Green infrastructure integration solutions

- Vegetation cover can protect surfaces such as asphalt pavements and architectural structures. In public spaces and streetscapes, vegetation can also contribute to increased pedestrian activity and urban vitality.

- The use of bioretention systems

Bioretention structures use soil and vegetation to retain and infiltrate rainwater and surface runoff. These systems typically require a soil depth greater than that of conventional drainage channels to reduce runoff volume and flow rate. The systems can significantly improve stormwater quality by removing pollutants through filtration and treatment by plant species adapted to local climatic conditions.

Bioretention systems may be applied in various spaces, including parking areas, median strips and alleyways, pedestrian-priority zones in commercial or industrial areas, vacant sites, sidewalks, and public squares.

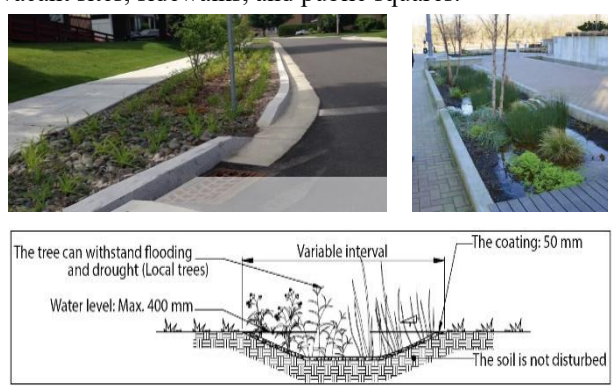


Figure 8. *Technical solutions of bioretention systems*

(Source: Author)

4. Conclusions

Based on the results of field surveys and assessments, together with the application of design principles, technical requirements, and influencing factors affecting the spaces along both sides of the street corridor, the

sidewalk environment can be analyzed through four fundamental spatial components for: *The quality of space, the quality of material and the quality of safety (Table 4) and 09 elements: Accessibility, safe connection, clearly signage, security guaranteed, attractive space, specific space, suitable size, surface quality, drainage efficiency (Table 5).* So technical solutions to improve and enhance space quality:

a. Spatial organization

Suitable size: The sidewalk width should accommodate at least two pedestrian lanes (approximately 1.5 m or more). Sidewalks are recommended to have sufficient width to support multiple functions.

b. Surface quality

- Accessibility and the quality of material: These include unit paving systems, which should incorporate appropriate patterns and orientation of paving units. Joints are typically arranged transversely to ensure visual consistency and allow paving units with the same width but different lengths to be used, thereby reducing costs. Other solutions include flexible paving systems and permeable pavement materials (Figure 6).

- Attractive space and specific space: The paving surface should be aesthetically harmonious and provide comfort for pedestrians. Effective paving techniques can create visually appealing patterns and colors, enhancing visual interest and contributing to the overall aesthetic quality of the space.

c. Landscape and microclimate

- Canopies are provided over sidewalk areas adjacent to building frontages to shelter pedestrian walkways. This space should be integrated with incorporating street trees and greenery.

- Green solutions should be integrated, such as the use of permeable paving materials with high reflectivity and low thermal conductivity. Smooth surfaces with high thermal conductivity should be minimized.

d. Technical infrastructure and safety

- Drainage efficiency: The extent of green spaces should be increased, including street trees and rooftop vegetation. In addition, bioretention structures should be incorporated to retain and treat stormwater (Figure 8).

- Safe connection, clearly signage, security guaranteed and surface quality: The sidewalk surface should be non-slip and free of obstacles, while ensuring protection from potential hazards posed by motorized vehicles such as cars and motorcycles. Street furniture and traffic-related infrastructure, including street lighting poles, utility poles, traffic signs, directional signs, and decorative sculptures, should be appropriately arranged to avoid safety risks.

REFERENCES

[1] Danang City People's Committee, "*Use sidewalks through marking lines on the sidewalks of streets in wards and communes in Da Nang city*", Decisions No: 97/2024/QĐ-UBND, 2024.

[2] N. D. Cuong, "The trillion-dollar sidewalk that has just been completed is already bumpy, and Da Nang requires a complete solution", *www.nguoiduatin.vn,* Dec 05, 2025. [Online] Availbe: https://www.nguoiduatin.vn/via-he-nghin-ty-vua-lam-xong-da-gap-ghenh-da-nang-yeu-cau-xu-ly-dut-diem-20425120513595525.htm, [Accessed: Feb 07, 2026].

[3] Construction ministry, "*National Technical Regulation on Technical Infrastructure System - Urban Transportation Works*", QCVN 07-4:2023/BXD, 2023.

[4] Construction ministry, "*Urban Roads - Design Requirements*", TCVN 13592:2022/BXD, 2022.

[5] N. T. Thai, P. C. Tho, and T. T. P. Anh, "Development of bicycle and pedestrian system in urban areas of Vietnam toward green and sustainable transport", *The University of Danang - Journal of Science and Technology*, vol. 11, no.120.3, pp. 71-75, 2017.

[6] C. Khanh, ""Verification" sidewalk improvement projects with new design solution in Danang", *cadn.com.vn,* Dec 03, 2025. [Online] Availbe: https://cadn.com.vn/tam-soat-cac-du-an-cai-tao-via-he-bang-giai-phap-thiet-ke-moi-cua-da-nang-bai-cuoi-phu-hop-xu-the-nhung-can-co-dieu-chinh-de-toi-uu-post323414.html, [Accessed: Feb 07, 2026].

[7] R. Holden and J. Liversedge, "*Landscape architecture techniques"*, Tonghop HCM city Publisher, Translation by D.H. Son, 2020.