

## PLANNING AND DESIGN CRITERIA FOR SUSTAINABLE AND PANDEMIC-RESILIENT STREET FURNITURE: THE TEHERAN SCENARIO

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### ARTICLE INFO

#### Keywords:

COVID-19;  
pandemics;  
street furniture;  
sustainable design;  
urban design

### ABSTRACT

*Street furniture has always played a significant role as one of the major determinants of the urban environment's quality. In Iran, the importance of street furniture, as an influential factor in increasing urban sustainability have received less attention and focus. Also, the recent COVID-19 pandemic has significantly endangered global health and public safety, leaving a noticeable impact on Iran's urban environment. As a component of the urban environment, street furniture plays a crucial role in reducing the risk of infection. This article aimed to identify local performance criteria for sustainable and pandemic-resilient street furniture in 17th district of Teheran. The study employed both qualitative (field observation, interviews) and quantitative methods (questionnaire) employing tools such as indexing, reliability measurement, multivariate linear regression, and triangulation. Results suggested that improving urban design could enhance sustainability by 36%, while improving street furniture characteristics may increase sustainability by 66% in the district. Also, the 17th District suffers from significant deficiencies in sustainability and needs serious improvements, especially in the socio-economic category. Implementing the criteria outlined in this study can grant Tehran's 17th District street furniture a distinct identity, bolster pedestrian safety, and elevate sustainability levels.*

## 1. INTRODUCTION

“Urban Design” arose in the 20th century, notably from the 1956 Chicago Conference. Originally like “Civic Design,” it focused on civic buildings and expanded to include the interplay between city structures and public spaces (Carmona & Tiesdell, 2010). Urban design principles cover aspects like legibility, comfort, safety, and attractiveness (Rehan, 2013). The urban environment's quality significantly affects residents' well-being (Carmona, 2016). This includes designing urban elements such as street furniture, which greatly influences a city's sustainability (Kántor et al., 2018; Nasir et al., 2016).

The term “urban furniture” or “street furniture” appeared in the 20th century in Europe and North America, encompassing objects installed in streets, like trash bins, bus stations, signs, streetlights, and benches (Zhou et al., 2022; Soffritti et al., 2020) significantly influences daily activities (Arruda et al., 2017). In the contemporary world, sustainable design for urban areas and street furniture meeting social, economic, and environmental criteria enhances the quality of life and encourages long-term city planning (Xia et al., 2018). However, changing circumstances, like pandemics, lead to

new expectations regarding the quality and performance of street furniture (Liu et al., 2021).

Pandemics, with their disruptive impact on daily life (Jones, 2020), necessitate specific social actions such as travel restrictions, quarantine, and social distancing (Lekić Glavan et al., 2022; Kyriakidis et al., 2023). The lockdowns during COVID-19 highlighted deficiencies in the built environment (Pinheiro & Luís, 2020), leading to unemployment, economic decline, and mental health challenges (Bonaccorsi et al., 2020). During pandemics, street furniture use may decline due to limited access and safety concerns, underscoring the necessity for advancements to support people in managing these challenges (Liu et al., 2021).

Iran encountered its first COVID-19 case on February 19, 2020, triggering travel restrictions, quarantine measures, and job closures (Shaer et al., 2021). The country's economy, already facing inflation, ended its lockdown, leading to a surge in infections (Rezaeitavabe et al., 2021) and urban challenges in Iran's capital city, Tehran (Heidari et al., 2022). Managing waste, including medical waste, emerged as a significant environmental challenge during the pandemic

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(Rezaeitavabe et al., 2021; Zand & Heir, 2020). Moreover, in response to the pandemic, there was a substantial increase in private car usage, concurrent with a decline in the usage of public transport systems. These challenges, resulted in elevated pollution levels in Tehran and caused the limited outdoor activities that often serve as a refuge during lockdowns (Heidari et al., 2022; Rezaeitavabe et al., 2021). Therefore, prioritizing efficient urban waste management and advancing public transportation facilities are crucial for creating a resilient Tehran's urban environment during a pandemic.

The questions posed by this study were, "How does the planning and design of street furniture contribute to a sustainable urban environment?", "What is the actual state of street furniture in the 17th District of Tehran compared to a set of accepted worldwide design criteria?" and "What planning (location) and design criteria are suitable for sustainable and pandemic-resilient street furniture in the 17th District of Tehran?" Therefore, the studies on urban design, street furniture, and sustainability were reviewed and used to develop the evaluative criteria for assessing the street furniture in the 17th District of Tehran. Subsequently, the findings of the study enabled the development of the local performance design criteria for sustainable and pandemic-resilient street furniture.

The main objectives of this study are as follows:

- To investigate the interconnected impact of urban design and street furniture design on creating a sustainable urban environment.
- To understand the issues of the existing street furniture in the 17<sup>th</sup> District of Tehran by considering worldwide design criteria.
- To develop criteria for planning and design of sustainable and pandemic-resilient street furniture in the 17<sup>th</sup> District of Tehran.

The paper proceeds with Section 2, outlining the study's structure and scope, followed by a literature review in Section 3, a detailed presentation of the methodology in Section 4, data analysis in Section 5, further findings discussion in Section 6, and conclusion in Section 7.

## 2. THE STRUCTURE AND SCOPE OF THE STUDY

This study comprises three main components. Firstly, it reviewed international criteria and indicators for street furniture design, aiming to enhance sustainability and pandemic resilience. Secondly, the study assessed the street furniture in the case study area using field observation, interviews, and a questionnaire survey. Lastly, it proposed Local Performance Criteria (LPC) for street furniture design in the 17th District of Tehran.

This study was limited to benches and seating, bus stops, bicycle racks, shelters, trash receptacles, and bollards as part of street furniture.

## 3. LITERATURE REVIEW

### 3.1 Evaluative Criteria For Sustainable Street Furniture (ECSSF)

Sustainable design helps to achieve thriving environmental, economic, and social systems. The significance of physical planning (location), physical design, and socio-economic aspects of sustainable design for street furniture are highlighted by many planning documents and manuals (Abu Dhabi Urban Street Design Manual, 2014; San Francisco Better Streets Plan, 2010, 2018; Akadiri et al., 2012).

### 3.2 Planning of Street Furniture

The accessibility to various urban services and infrastructure is crucial for sustainable urban development (Cruz & Paulino, 2021). Street furniture, as part of urban infrastructure, should prioritize pedestrian needs and optimize environmental benefits while minimizing congestion (Ballarat urban design manual, 2013).

The planning of street furniture involves the strategic placement of various elements, each serving specific functions. Bus stops adapt to traffic arrangements (APTA Standards Development Program, 2012, 2019), and trash receptacles are strategically located near transit stations, intersections, and bustling pedestrian zones (Victoria West Neighbourhood Plan, 2018). Seats not only offer resting spaces but also accommodate landscaping or wheelchairs (London Borough of Richmond upon Thames, 2006, 2015). Bicycle racks are intelligently positioned to coincide with public transport stops, benefiting cyclists (Cruz & Paulino, 2021). Bollards function as barriers to prevent vehicle entry onto pedestrian or bike paths (Urban Street Design Guidelines for Pune, 2016), while shelters provide comfort and weather protection at specific locations (Harvey et al., 2015). These elements collaboratively contribute to an integrated and efficient urban design.





**Figure 1:** The “RAPID” station with different facilities provides comfort for pedestrians, Singapore (left) (Photo: Author, 2018). The bicycle station provides easy access, legibility, and safety for users, Mississauga, Ontario, Canada (right) (Photo: Mona Azizabadi Farahani, 2021).

### 3.3 Design of Street Furniture

Aesthetic street furniture fosters positive user connections (Liu et al., 2021), while consistency in quality and style builds area identity (London Borough of Richmond upon Thames, 2006, 2015). Prioritizing easy maintenance, safety, durability, sustainability, and local relevance in materials is essential (Urban Street Design Guidelines for Pune, 2016). Weather-friendly street furniture boosts user comfort and reduces long-term maintenance (Best Practices for Downtown Olympia, 2009, 2017).

Bus stops should include pedestrian access, seating, shade, route information, and supplementary amenities like trash bins, bicycle parking, lighting, and real-time bus arrival displays, natural or air ventilators (Urban Street Design Guidelines for Pune 2016, Best Practices for Downtown Olympia, 2009, 2017). The design of shelters should be affected by the local climate and can be included landscaping, pedestrian furnishings, and other identity-enhancing features (London Borough of Richmond upon Thames, 2006, 2015). The design for bus stops, shelters, and bicycle racks should ensure unobstructed pathways and include seats with armrests and backs for the elderly. Using low heat-reflecting and quick-drying materials, along with trash receptacles featuring separate compartments, are recommended (San Francisco Better Streets Plan, 2010, 2018; Urban Street Design Guidelines for Pune, 2016). Additionally, illuminating bollards in distinct colors aids nighttime visibility for the visually impaired (San Francisco Better Streets Plan, 2010).



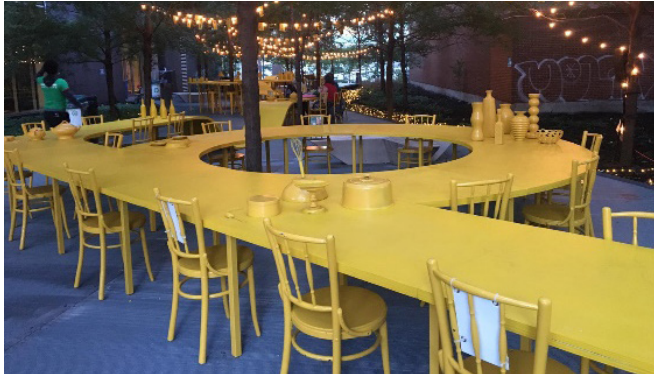
**Figure 2:** Attractive design for seats and benches., Montreal, Québec (left). Shelter with creative design and lively colour., Montreal, Québec (right) (Photo: Marie-Josée Roux, 2021). Trash Receptacle with Recycling Possibilities., Mississauga, Ontario, Canada (middle) (Photo: Mona Azizabadi Farahani, 2021).

### 3.4 Socio-Economic Aspects of Street Furniture

The design and distribution of street furniture are closely interrelated to safety and comfort (Ma et al., 2022; Zhou et al., 2022). Safety must be provided for all residents despite their disabilities, ages, and be recognizable to people with visual and mobility impairments at all hours of the day (Victoria West Neighbourhood Plan, 2018). Well-designed street furniture that embraces places to sit, stop, gather, and play provides social interaction opportunities (San Francisco Better Streets Plan, 2010, 2018). Designs should be developed upon the detail of the existing main furniture in the street space that is compatible with the historical identity of the area (Ballarat urban design manual, 2013).

Street furniture that encourage people to walk into neighbourhood shopping malls instead of driving to regional shopping malls could support local businesses. Strategic street furniture can drive local commerce, elevate property values, attract investment, and stimulate economic growth (San Francisco Better Streets Plan, 2010, 2018). The long-term success of places depends on their visual appeal and durability. High-profile areas usually need higher quality and more durable elements; thus, the costs may be higher (Scotland’s best streets, 2010).





**Figure 3:** Street furniture as a public art and landmark., Montreal, Québec, (Photo: Marie-Josée Roux, 2021).

### 3.5 Potential Measures To Control Pandemics

The 19th-century industrial revolution brought unsanitary conditions to cities, fueling disease transmission. This prompted a pivotal reexamination of urban planning, advocating for healthier urban environments (Kozlowski et al., 2021). In recent decades, humanity faced multiple devastating pandemics like the Spanish flu post-World War I, MERS-CoV, Ebola, SARS-CoV, and the 2009 H1N1 Pandemic. The latest COVID-19 pandemic inflicted a global catastrophe, profoundly impacted social safety and the economy (Liu et al., 2021).

The built environment greatly influences disease transmission and health practices (Pinheiro & Luís, 2020). In cities, dense populations create prime conditions for the spread of contagious diseases (Neiderud, 2015). Street furniture design vastly impacts social interaction and social activities between people. Therefore, street furniture design can be a vital element in improving public health and safety (Pinheiro & Luís, 2020). Table 1 outlines criteria for diminishing infections and advancing public health during pandemics through the planning and design of street furniture.

*Table 1: Street furniture design criteria for the pandemic scenario*

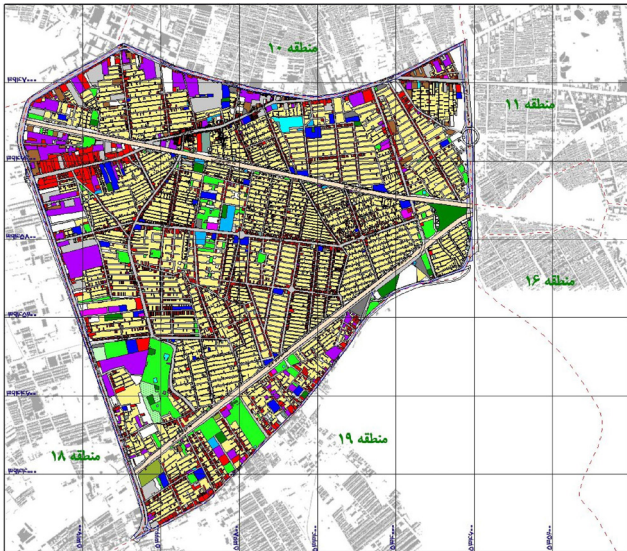
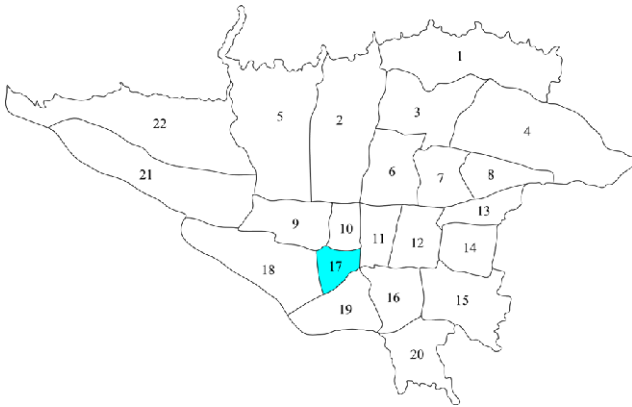
Street Furniture	Criteria	COVID-19 Benefits
<b>Bus stops</b>	Automatic (Hands-free) doors (European Commission, 2020; Preiss, 2011)	Prevents contact with common surfaces
	Distinguish between entrance and exit doors (Lekić Glavan et al., 2022; European Commission, 2020)	Prevent people from crossing with one another
	Safety distance indicators at stations, seats and waiting zones (Larsson, 2020; Eykelbosh, 2020)	- It allows social distancing - Prevent the spread of viruses
	- Hand sanitary facilities and signs for the obligation to use a face mask (European Commission, 2020) - Disinfectant containers or systems (Liu et al., 2021)	Public hygiene
	Public awareness of the new infection risk by employing Information Technology methods (Pinheiro & Luís, 2020).	Risk recognition and potential decrease in transmission via more information
	- Larger size and higher distribution of bus stops - Providing attractive view (Lekić Glavan et al., 2022)	Positively affect psychological health (Ko et al., 2020)
	Natural ventilation at closed bus stops (Lekić Glavan et al., 2022; Pinheiro & Luís, 2020)	air renewal to reduce the likelihood of virus resistance (Kurnitski, 2020)

Street Furniture	Criteria	COVID-19 Benefits
	- Smart technologies and systems - Thermal sensors (Alaloul et al., 2020; Nassar et al., 2019)	Identify the infected person
	A reliable power supply	Provides proper operation requirements
	- Maximize the greenery (Lekić Glavan et al., 2022; Tang et al., 2021) and Provide access for pedestrians to the parks	Improve public health (Van Den Bosch & Ode Sang, 2017)
	- Modern and Minimalist design (Ko et al., 2020) - Use of sustainable, durable, easy-to-clean, and easy-to-sanitize materials (Lekić Glavan et al., 2022) (Applies to other street furniture)	- Decreasing places of contamination - Easy to eliminate COVID-19 and other pathogens (Pinheiro & Luís, 2020)
	Selection of substances that reduce the residence time of the virus (van Doremalen, 2020; Chatterjee et al., 2021)	Positive to reduce the residence time of COVID-19
	Allocation of the extra open areas in front of bus stations	- It allows social distancing
<b>Shelters</b>	Sunlight (achieves through orientation) (Schuit et al., 2020)	Some viruses are sensitive to sunlight
	Ensures easy cleaning solutions - Promoting free and reliable Wi-Fi and lighting in shelters - necessary tools for students and micro-business owners to study and work outdoors (Oren, 2020)	Reduces the risk of contamination Permits for safe activities between people in open areas (Oren, 2020)
	Greenery in surroundings (Lekić Glavan et al., 2022)	- Improve public health
	Larger size, Higher distribution (Lekić Glavan et al., 2022) and regular layouts (Pinheiro & Luís, 2020)	- It allows social distancing - Reduces the risk of cross-contamination
	Hand sanitary facilities at shelters	Public hygiene
<b>Cycle racks</b>	- Increasing cycle racks (World Health Organization, 2020) - Allocate additional space between bicycle racks	- Prevent people from crossing with one another
	- Free water for cyclists and walkers (Ravenscroft T. Weston Williamson + Partners, 2020)	Motivates and supports active mobility.
	Public awareness of the risk of new infections by Information technology methods at bicycle stops	Risk recognition and potential reduction of transmission
	Free Wi-Fi (Gangneux et al., 2022)	Provide services for all
<b>Sitting and Benches</b>	Safety (distance) stickers on benches	Permits for safe distances between people
	Protective barriers (Semple & Cherrie, 2020)	Physical protection to prevent social contact
	- Locating seats in natural zones with attractive views - Mixing green features with design (Abraham, 2010)	Green space provides health and much-needed stress relief (Pinheiro & Luís, 2020)
	- Larger size (Lekić Glavan et al., 2022) and higher distribution of seats and benches - Creation of more space between seats and benches (Pinheiro & Luís, 2020; Oren, 2020)	- It allows social distancing - Reduces the risk of cross-contamination
<b>Trash receptacles</b>	- Provision of trash receptacle for sanitary wastes - Separated and isolated bins for sanitary waste such as gloves and masks - Incineration and strict disinfection of trash receptacles	The virus can stay on plastic and other surfaces for several days. Garbage bags can be potential ways of transmission. (Nghiem, 2020)
<b>Bollards</b>	- Closure of public spaces and high-risk areas - Movement restrictions (Pinheiro & Luís, 2020)	Permits for safe distances between people
	- Determine the separation distance protocols	Permits for safe distances between people

Source: Author

#### 4. THE RESEARCH METHODOLOGY

The capital city of Tehran, serving as Iran's political, economic, and communication hub, is home to 8,693,706 residents and holds an irregular urban layout (Moghbel et al., 2020; Zand & Heir, 2020; Ministry of Housing and Urban Development - Tehran Municipality, n.d.). Situated in Tehran's southern region, the 17th District suffers from an inadequate and unsafe urban environment, characterized by poor-quality street furniture and unsustainable environmental conditions (Bigdeli Rad, 2019). Known as "self-growing" in urbanism, the district's expansion occurred without prior planning, evolving in line with urban economic growth (<https://region17.tehran.ir/>) (see Figure 4).



**Figure 4:** The Location of the 17th District in Map of Tehran, (left) (Source: Bigdeli Rad, 2019). Land use map of the 17th District of Tehran, reflecting the study area (right) (Source: Ministry of Housing and Urban Development - Tehran Municipality, n.d.).

The study, conducted in Tehran's 17th District, used a mixed methodology—qualitative (field observation, in-depth interviews) and quantitative (questionnaire survey). The district spans 8.22 square kilometers with a population of 278,354 (2021 Iran census) (<https://region17.tehran.ir/>). Specific locations were chosen to represent varied urban settings: YaftAbad Street, Golchin Street, Khazaneh Garden Street, and Azari Street, representing a major shopping city street, a residential street, an urban park, and a civic plaza. To ensure validity and reliability, five experts, including

the author and professionals with significant experience and grade licenses 3 to 1 from the Tehran Construction Engineering Organization, assessed the case study area using the ECSSF checklist based on the provided photographs (see Figure 5). Additionally, eight experienced individuals in the field of urban planning in the city of Tehran involved in designing and implementing the urban schemes within the Tehran master plan were interviewed. Lastly, a questionnaire survey was completed by 305 respondents in the 17th District. The formula,  $\text{Sampling Error} = \sqrt{\frac{p \times (1-p)}{\text{sample size}}}$ , was applied with a 5% assumed P value, resulting in a sampling error of less than 5% and a 95% confidence level (Mitra & Lankford, 1999; De Vaus, 2001). The survey evaluated various demographic aspects such as gender, age, marital status, education, workplace, income, and primary mode of transport.

#### 5. DATA ANALYSIS OF THE CASE STUDY AREA (THE 17TH DISTRICT OF TEHRAN)

Three methods of site observation, interview, and questionnaire were used to find the issues of street furniture in the 17th District of Tehran and the relationship between urban design, street furniture, and sustainable design. The study conducted the impact of the Evaluative Criteria for Sustainable Street Furniture (ECSSF) on the urban environment of the district. Also, the economic, social, and environmental factors and their contribution to achieving a more sustainable urban environment in Teheran were identified and studied.

##### 5.1 Field Observation

In site observation, the ECSSF Criteria was applied to assess the case study areas based on a rating scale (Zikmund, 2000). The evaluation involved a measurement scale from 0-10, categorizing areas as satisfactory (fully complying with the evaluative criteria), partially satisfactory (partially complying), or unsatisfactory (not meeting the evaluative criteria) regarding sustainable street furniture.



**Figure 5:** Supporting Images for assessment of street furniture in 17th District of Tehran (Photo: Author, 2020).

Subsequently, the indexing data utilized to identify the major street furniture issues in the selected areas. This technique of summarizing and presenting data at their rates helped to detect each category's mean (average) and discover shortcomings related to street furniture in the district (Creswell & Poth, 2016; Saldaña, 2021) (Table 2).

**Table 2: Composite sustainability index of 17th District of Tehran**

ECSSF Criteria	Street Furniture Elements to Assess	Mean rate (0-10)
Planning (Location)	Provisions of street furniture location, distribution, orientation, access to public transport, access for pedestrians, access for cyclists, proximity to car parking, proximity to recreational areas, surrounding areas, as well as weather and climate conditions	4.24
	Design	4.02
Socio-Economic	Provisions of street furniture safety and security, social interaction, culture, and identity	3.92
	Provision of the commercial context, eating places/shops, and maintenance	
Composite Sustainability Index	Total:	4.06

The socio-economic criteria carry less weight, demanding increased attention from governmental bodies and decision-makers. The district's average value, below five across all three categories, highlights a substantial gap between its current condition and the desired benchmark.

## 5.2 Interview

The interview protocol was developed based on the main and secondary questions that mirror the sustainable design aspects of street furniture. This protocol was created as a blueprint with a list of clear, guiding, and engaging questions, consistent enough to collect respondents' points of view and experiences (Merriam, 2009).

**Table 3: Interview Questions**

Main RQ	Sub-RQs	Interview Questions
How to improve the sustainability and pandemic readiness of street furniture in 17th District of Tehran?	How does the planning and design of street furniture contribute to sustainable urban design?	1- From your perspective, how can street furniture in 17th District of Tehran contribute to Tehran sustainable urban environment? 2- In terms of street furniture elements, what are the most important contributors to sustainable urban design?
	What is the actual state of street furniture in 17th District of Tehran compared to a set of accepted worldwide design criteria?	3- What are the current issues regarding street furniture placement in 17th District of Tehran? 4- What are the current obstacles in design of street furniture in 17th District of Tehran?
	What planning (location) and design criteria are suitable for sustainable and pandemic-resilient street furniture in the 17th District of Tehran?	5- Do you think the current criteria has to do with the level of sustainability and pandemic readiness in the process of street furniture planning and design? 6- What planning and design criteria for street furniture in 17th District of Tehran need to be changed or added?

As per Creswell (2013), a sample of eight (8) informants, selected from experienced experts in urban design, participated in interviews. Those with substantial experience in urban design were further questioned in alignment with the research focus. Urban Planners and Architects (UP/As) highlighted the furniture's impact on social interaction, pedestrian comfort, and cultural identity in the district. They stressed culturally fitting and visually appealing designs to promote social engagement and urban vibrancy. Moreover, they advocated for shelter provision to ensure pedestrian comfort in varying weather conditions. Safety, inclusivity, and fostering a sense of belonging were key concerns, with an emphasis on enhancing pedestrian safety, supporting cultural identity, and encouraging commerce. Overall, UP/As emphasized the need for sustainable designs that harmonize social, economic, and environmental aspects to create a more sustainable and pandemic-resilient urban environment.

## 5.3 Questionnaire Survey

In this study, a survey was conducted in the form of a self-administered questionnaire using the Likert scale (on a scale of

1 to 5) from strongly agree to disagree (Shiu et al., 2011). The questionnaire constructed by sets of questions about urban design principles (legibility, quality of space, and physical characteristics), street furniture, and Sustainability. Data collected in this study were analyzed by SPSS version 22.0 to evaluate current research objectives. To analyze data this study employed descriptive statistics to measure the central tendency and dispersion (mean and standard deviation) of continuous variables (namely; urban design, street furniture, and sustainable design) applied in the regression model. The study also used inferential analysis, which provides several procedures to explore the relationships between variables, including Cronbach's alpha, and multiple regression analysis.

### Descriptive Statistics & Reliability Measurement:

Descriptive statistics, as outlined by Guest (2019), serve as fundamental measures for survey data description. They encompass univariate analysis, summarizing individual variables and the survey sample. This analysis, detailed by Kaushik and Mathur (2014), organizes vast data volumes by portraying the distribution of variables, including measures like central tendency (mean, median, mode), dispersion (variance, standard deviation), and shape (skewness, kurtosis) (Wong et al., 2012).

According to descriptive statistics of each criteria, sustainable design with overall mean and standard deviation of 2 and 0.237 has the highest mean value among other factors. Descriptive statistics of its factors were socio-economic (with mean=1.89 and std=0.346), physical (mean=2.04 and std=0.32) and environmental (with mean=2.11 and std=0.43). Urban Design in second place had the mean and standard deviation of 1.88 and 0.26, respectively. Its criteria included Legibility (with mean=2.05 and std=0.21), Quality of space (with mean=1.87 and std=0.30), and Physical characteristics (with mean=1.79 and std=0.314). Lastly, the overall mean and standard deviation of street furniture were 1.82 and 0.16, respectively, and its factors, namely, detailed design (with mean=1.82 and std=0.153) and functionality (with mean=1.82 and 0.31) had the lowest mean value.

The research applied Cronbach's alpha to assess consistency among items, a measure of internal reliability (Shiu et al., 2011). According Ferrão (2019), the Cronbach's alpha ranged from "0 to 1", and the values between 0.58 and 0.97 indicated satisfactory internal consistency of reliability. The obtained Cronbach's alpha for each variable (Urban Design, Street Furniture, and Sustainable Design) exceeding 0.60, confirming their reliability for analysis (Table 4 to 6).

**Table 4: Descriptive statistics & reliability measurement of urban design's items**

Items	Mean	Std. Deviation	Cronbach's Alpha >0.58
Urban Design	1.88	.260	.818
Legibility	2.05	.209	
Q1: Along the pathways I could connect with all existing street furniture	2.10	.904	.847
Q2: Street furniture is highly identifiable because of its unique character (Texture, space, form)	2.04	1.052	.774
Q3: Street furniture allow different social experiences	2.10	.788	.847
Q4: The elements of the street furniture are very dominant as landmarks	1.94	.851	.776
Quality of space	1.8707	.29793	

Items	Mean	Std. Deviation	Cronbach's Alpha >0.58
Q5: Street furniture makes the street a good place for walking	1.92	.895	.845
Q6: Street furniture makes the street a good place for socializing	1.83	.766	.772
Q7: Street furniture makes the street a good place for a night out	1.87	.848	.847
Q8: street furniture creates safe and pandemic-resilient streets	1.72	.765	.770
Q9: Street furniture makes the street a relaxing place	1.95	.948	.845
Q10: Street furniture makes the street an attractive place	1.95	.887	.774
Q11: Street furniture makes the street more responsive in terms of social amenities	1.85	.951	.770
<b>Physical characteristics</b>	<b>1.7880</b>	<b>.31391</b>	
Q12: Street furniture design fits the Iranian culture	1.89	.824	.845
Q13: Street furniture embodies a modern aesthetic	1.70	.706	.770
Q14: Street furniture design is antiquated	2.19	1.028	.780
Q15: Street furniture design is very attractive	1.49	.634	.771
Q16: Street furniture design is responsive	1.74	.844	.845
Q17: Street furniture design fits with all users' needs	1.71	.795	.770

Table 5: Descriptive statistics &amp; reliability measurement of street furniture's items

Items	Mean	Std. Deviation	Cronbach's Alpha >0.58
<b>Street Furniture</b>	<b>1.815</b>	<b>.1564</b>	<b>.792</b>
<b>Planning &amp; Design</b>	<b>1.8147</b>	<b>.15316</b>	
<b>Benches</b>	<b>1.8852</b>	<b>.31090</b>	
F1: Are well located in the street	1.92	.759	.811
F2: Exists in sufficient number in the streets	1.76	.623	.757
F3: Is well oriented	1.89	.847	.774
F4: Has comfortable material	2.04	.775	.809
F5: Is well designed	1.81	.808	.784
<b>Bus stops</b>	<b>2.0990</b>	<b>.27488</b>	
F6: Have good pedestrian accessibility	2.42	1.020	.812
F7: Are well lighted at night	1.88	.888	.779
F8: Have clear signs	2.04	.814	.820
F9: Have enough seating	1.94	.829	.759
F10: Allow a well connection with the point of entry to the bus	2.22	1.155	.794
<b>Bicycle racks</b>	<b>1.3951</b>	<b>.35538</b>	
F11: Exist in sufficient number in the street	1.36	.628	.782
F12: Are safely accommodated, thus encourages bicycle use	1.41	.627	.797
F13: Is installed at a convenient location along the street	1.41	.612	.770
F14: Are high aesthetic value	1.41	.606	.753
<b>Shelters</b>	<b>1.6938</b>	<b>.34602</b>	
F15: Are comfortable	1.86	.965	.786
F16: Well covered from inclement weather	1.48	.693	.766
F17: Are safe	1.87	.850	.812
F18: Have an attractive design	1.52	.761	.773
F19: Are well positioned	1.74	.778	.786
<b>Waste receptacles</b>	<b>2.0270</b>	<b>.36708</b>	

Items	Mean	Std. Deviation	Cronbach's Alpha >0.58
F20: Are conveniently located	2.05	.891	.765
F21: Exist with sufficient quantity	2.22	1.016	.827
F22: Fit with the street landscape	1.76	.917	.771
F23: Are easy to use	2.09	.906	.791
<b>Bollards</b>	<b>1.7295</b>	<b>.31445</b>	
F24: Are well placed in the street and prevent the entrance of motorcycle	1.77	.831	.812
F25: Exist in sufficient number in the street	1.64	.967	.767
F26: Have an efficient design	2.15	.812	.772
F27: Are safe and pandemic-resilient	1.36	.568	.770
<b>Functionality</b>	<b>1.8172</b>	<b>.31017</b>	
F28: Street furniture remains well-maintained	1.88	.911	.810
F29: Street furniture is accessible	1.90	.929	.786
F30: Street furniture contributes to safety and resilience during pandemic	1.62	.654	.771
F31: Street furniture needs major improvement	1.88	1.096	.759

Table 6: Descriptive statistics &amp; reliability measurement of sustainable design's items

Items	Mean	Std. Deviation	Cronbach's Alpha >0.58
<b>Sustainability</b>	<b>2.003</b>	<b>.237</b>	<b>.681</b>
<b>Socio-Economic</b>	<b>1.8902</b>	<b>.34605</b>	
S1: Street furniture provide opportunities for businesses along the street	1.88	1.012	.658
S2: Street furniture cultural attachments and give me a sense of place in the street	1.84	.944	.608
S3: Street furniture encourage me to less use the car	1.86	.930	.771
S4: Street furniture encourage the outdoors activities (shopping, social interaction...)	1.95	1.113	.620
S5: Street furniture is pivotal for safety and pandemic readiness	1.90	.912	.651
S6: The existing street furniture encourage me to walk along the street more frequently	1.92	.939	.658
<b>Physical</b>	<b>2.0389</b>	<b>.31906</b>	
S7: Street furniture is an important elements of the urban environment	2.18	1.211	.753
S8: Street furniture is of good material (sustainable, recyclable, non-toxic and non-staining).	1.94	.970	.612
S9: Street furniture is an added value to the streets in terms of beauty and aesthetic	1.95	1.017	.568
S10: Street furniture provide safety and pandemic resilient	1.94	1.143	.641
S11: Street furniture constitute important landmarks and nodes along the street	2.43	1.255	.730
S12: Street furniture considerably participate to the street attractiveness	2.13	1.161	.737
S13: Street furniture is well maintained	1.70	.852	.617
<b>Environmental</b>	<b>2.1090</b>	<b>.43039</b>	
S14: Street furniture participate to the good visual quality of the environment	2.01	1.023	.588
S15: Street furniture help to sustain responsible and civil behaviour	2.18	1.139	.686
S16: Street furniture help to protect the quality of the environment	2.13	1.161	.668
S17: Street furniture improve the liveability of the urban area	2.12	1.194	.622

### Pearson Correlation Analysis:

The Pearson correlation ranges from -1 to 1, representing negative and positive linear associations. Cohen (1988) categorized an

absolute Pearson correlation of 0.1 as small, 0.3 as medium, and 0.5 as large. This study applied “Pearson Correlation” analysis to explore the relationship among variables (urban design, street furniture, sustainable design). The results indicated that all three factors were significantly correlated in 99% confidence interval (P-value<0.01). As it is shown in Table 7, sustainable design was strongly correlated with urban design  $\rho=0.727^{**}$  and  $\rho=0.736$  street furniture. In addition, the value of Pearson Correlation between urban design and street furniture is about 0.756. Therefore, this study was able to conduct regression analysis and identify the relationship between variables in the model.

Table 7: Result of Pearson Correlation

	Urban Design	Street Furniture	Sustainable Design
Urban Design	1	.756**	.727**
Street Furniture	---	1	.736**
Sustainable Design	---	---	1

\*\*Correlation is significant at the 0.01 level (2-tailed).

**Multivariate Linear Regression Model:**

For this study, Multivariate regression analysis was applied to identify the impact of urban design principles and characteristics of street furniture on the sustainability of the urban environment in 17th District of Tehran. According to Table 8, the value of R-Square = 0.61 showed that the model could explain approximately 60% of the variability of sustainability around its mean. The higher R-squared indicates the better model fit for the data and therefore, the data fitted the regression line closely.

Table 8: Result of Model Fit

Model Summary <sup>a</sup>	R	R Square	Adjusted R Square	Std. Error of the Estimate
	.781 <sup>a</sup>	<b>0.61</b>	0.607	0.1483

a. Predictors: (Constant), URBAN\_DESIGN, STREET\_FURNITURE  
 b. Dependent Variable: SUSTAINABLE\_DESIGN

Table 9: Result of ANOVA

Model	Sum of Squares	df	Mean Square	F	P-value
<b>Regression</b>	10.377	2	5.189	235.968	.000 <sup>b</sup>
<b>Residual</b>	6.641	302	0.022		
<b>Total</b>	17.018	304			

a. Dependent Variable: SUSTAINABLE\_DESIGN  
 b. Predictors: (Constant), URBAN\_DESIGN, STREET\_FURNITURE

Table 9 showed that the regression model in this study was significant with P-value=0.000<0.05. As a result, there was a linear relationship between sustainable design and two other independent variables, namely, urban design and street furniture. The multivariate linear regression model is identified as below:

$$y = \beta_0 + \beta_1x_1 + \beta_2x_2 + e$$

$$\text{Sustainability} = \text{Constant} + \beta_1 * \text{urban design} + \beta_2 * \text{street furniture} + \text{error}$$

However, it is necessary to measure the variance of the estimated regression coefficients compared to the predictor variables. For this reason, a multicollinearity test was also performed and the result is given in Table 10.

Table 10: Result of Regression Coefficients and Multicollinearity Test

Model	Unstandardized Coefficients		Standardized Coefficients		Collinearity Statistics	
	B	Std. Error	Beta	t	P-value	Tolerance VIF
<b>(Constant)</b>	.124	.101		1.231	.219	
<b>URBAN_DESIGN</b>	<b>.361</b>	.050	.397	7.233	<b>.000</b>	.429 2.333
<b>STREET_FURNITURE</b>	<b>.660</b>	.083	.436	7.945	<b>.000</b>	.429 2.333

Dependent Variable: SUSTAINABLE\_DESIGN

In the multicollinearity test, the value of tolerance for both independent variables (urban design and street furniture) was greater than 0.2; thus, the sustainable design can be predicted from urban design and street furniture. In addition, variance inflation factors (VIF) were greater than 1 and less than 5, then they are moderately correlated (Vrieze, 2012).

Estimated regression model:

$$y = 0.36 x_1 + 0.66 x_2$$

Y: SUSTAINABLE\_DESIGN

X1: URBAN\_DESIGN

X2: STREET\_FURNITURE

From the result of the multiple regression model, it is clear that both urban design principles and street furniture characteristics are significantly and directly influence the sustainability of the 17th District of Tehran urban environment (P-value=0.000 <0.01). According to Table 10, regression coefficients of urban design and street furniture were and , respectively. By improving urban design principles, sustainability will improve by 36% and by improving street furniture characteristics, sustainability will improve by 66% in 17th District of Tehran.

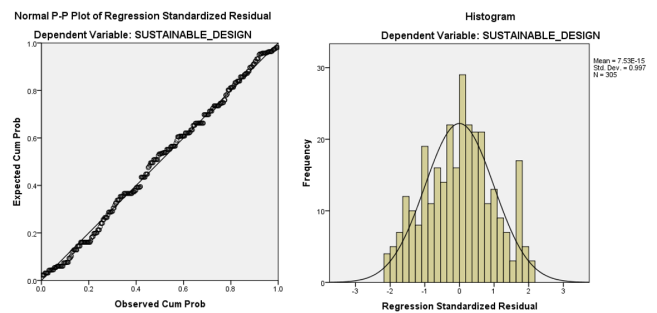


Figure 6: Histogram and Normal P-P plot of Residuals

To check the normality of regression residuals, a normal P-P plot and histogram are plotted (Chayalakshmi et al., 2018) (see Figure 6). Normal P-P plot (probability plot) of Residual in the regression model shows that the data are closely fit with the model. In addition, a histogram with a normal curve also indicates the residuals in the regression model are normally distributed.



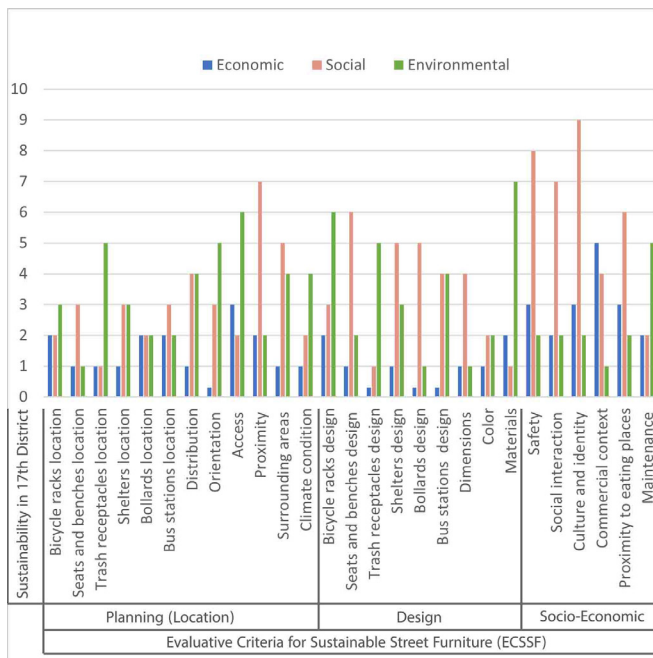
### Triangulation of the Data:

Triangulation is a strategy to validate findings by combining information from various sources (Denzin, 1994; Patton, 2002). Therefore, the data collected by observation, interview, and questionnaire is synthesized using Methodological triangulation to develop a comprehensive understanding of the phenomena.



**Figure 7:** Triangulation of data

The data underwent triangulation to ensure consistency and alignment of the research findings. Our findings indicate a crucial link: addressing larger street furniture issues significantly enhances the district's sustainability, whereas addressing smaller concerns has a comparatively lower impact. Figure 8 depicts the relation between street furniture improvements and sustainability in the 17th District of Tehran.



**Figure 8.** Anticipated Impact of Proposed Criteria on the Sustainability of Urban Areas in Tehran's 17th District.

The horizontal axis of the bar chart illustrates various data variables related to planning, design, and socio-economic factors. Meanwhile, the vertical axis measures the level of sustainability, ranging from low to high, with a scale from 0 to 10. This visual representation aims to demonstrate the expected impact or outcome within the 17th District of Tehran as a result of implementing sustainable street furniture criteria.

The charts show that street furniture design will positively increase sustainability in the 17th District of Tehran urban areas. Also, these charts present a comprehensive view of economic, social, and environmental sustainability levels, aiding in pinpointing areas for enhancement and shaping future development priorities. Notably, the proposed street furniture criteria exhibit a higher impact on social sustainability, followed by environmental and economic considerations.

The bar charts show that culture, social interactions, and security have a significant impact on social sustainability in the 17th District of Tehran. By designing safe furniture in harmony with the Iranian culture and considering the criteria that promote social interactions a high level of social sustainability can be achieved. The 17th District's environmental sustainability hinges on material selection, access, trash receptacles, and bicycle rack placement and design. Ensuring pedestrian-friendly access, climate-sensitive orientation, proper trash receptacles, and bicycle rack design significantly decrease environmental pollution, fostering a secure, clean, and accessible urban ecosystem.

The economic sustainability of the 17th District is significantly bolstered through strategic implementations aligned with business contexts, cultural integration, and user security. This synergy yields substantial benefits such as amplified job opportunities, economic growth, augmented commercial sales, and enhanced business promotion. Concurrently, it leads to notable reductions in transportation expenses, maintenance costs, and material procurement, contributing to a more sustainable economic environment in urban areas.

## 6. DISCUSSION

The development and use of the Evaluative Criteria of Sustainable Street Furniture (ECSSF) checklist in Tehran's 17th District aided in assessing subjective views of sustainability. This comprehensive approach, derived from a literature review on urban design, street furniture, and sustainability, revealed the direct influence of urban design principles and street furniture characteristics on sustainability in the district. Notably, enhancements in urban design could improve sustainability by 36%, while improvements in street furniture characteristics could elevate it by 66%. This study emphasized the interrelation between these factors and highlighted how enhancing street furniture quality can increase sustainability. These insights facilitated the creation of tailored local performance criteria for sustainable and pandemic-resilient street furniture, considering district-specific aspects like culture, climate, pedestrian needs, local materials, sustainable and pandemic-resilient design considerations.

## 6.1 Local Performance Criteria (LPC) for Sustainable and Pandemic-Resilient Street Furniture in the 17th District of Teheran

Recognizing the district's issues prompts the development of Local Performance Criteria (LPC) for Tehran's 17th District. Street furniture design significantly influences social interaction and can play a pivotal role in bolstering public health during pandemics (Lekić Glavan et al., 2022). In line with these criteria, the proposal includes health-centered design recommendations to mitigate the spread of infections.

### The LPC: Design Guidelines for Sustainable and Pandemic-Resilient Street Furniture:

To enhance street furniture in Tehran's 17th District, several guidelines are proposed:

- Accommodate the district's high population by adding bicycle racks, seats, and shelters.
- Place benches at shorter intervals, ideally within 5 meters, in crowded areas.
- Employ temporary and fixed bollards to restrict motorcycles from pedestrian walkways. Equip these with lights and paint for increased safety.
- Install shelters along sidewalks to shield pedestrians from summer sun and create pleasant environments, employing sustainable materials.
- Strategically position trash receptacles based on street types, especially in high-traffic areas. Remove or replace oversized receptacles.
- Infuse Iranian cultural elements into street furniture design, drawing inspiration from Iranian garden aesthetics.
- Use light-colored materials to reduce heat absorption and promote quick drying after rain.
- Preferably utilize Iranian building materials like stones, sand, bricks, timber, and lime.
- Harmonize street furniture colors with the district's historical architectural hues, such as earthy-brick, blue, and turquoise.
- Integrate new street furniture designs that align with existing historical elements such as break wall, detailed decoration, motifs, and arcs.
- Implement both fixed docking and free-floating bike-sharing designs for varied user preferences.
- Ensure proper street furniture placement to enhance safety against accidents, crimes, and adverse weather conditions.



**Figure 9:** Shelter design suitable for Tehran weather conditions based on Iranian cultural elements and materials (left) Sustainable bicycle station with solar panels and greenery (right) (3D & design by Author).

- Strategically place street furniture like seats to maintain social distancing protocols, employing bollards in crowded areas to prevent close contact.
- Emphasize the link between social distancing and interactions, promoting design that fosters harmony while adhering to distancing norms.
- Design more expansive street furniture to ensure proper distancing between individuals.
- Prioritize materials with shorter virus retention times and surfaces that are easily washable.
- Ensure continued accessibility to street furniture for people with disabilities while maintaining distancing measures.
- Incorporate disinfection features in street furniture, such as containers or systems for handrails and contact surfaces.
- Design trash receptacles to minimize workers' exposure to contaminated waste.
- Embrace minimalist street furniture designs that are both virus-resistant and adaptable.
- Consider factors like ventilation and natural lighting to reduce virus transmission in bus stops and shelters.
- Introduce green roofs for bus stops, shelters, and bicycle stations to enhance sustainability.
- Provide functional street furniture in local parks for work or study purposes.

- Incorporate smart technologies into street furniture, offering services like Wi-Fi, charging facilities, and environmental sensors for public use, particularly targeting young people and employees.



**Figure 10:** Innovative shelter design provides space between seats by plantation (left). Street furniture as a workplace in the open air provides a safe working environment (3D & design by Author).

## 7. CONCLUSION

The COVID pandemic has significantly affected Iran's cities, demanding fundamental changes in urban design. Embedding sustainable and pandemic-resistant street furniture stands as a crucial step in fortifying urban areas against future health crises. This study demonstrated the practical use of the Evaluative Criteria of Sustainable Street Furniture (ECSSF) for evaluating current street furniture in the 17th District of Teheran. Following this assessment, a customized set of local performance criteria (LPC) was proposed, specifically addressing the needs of the 17th District. The LPC comprised guidelines for street furniture design, encompassing culture, local climate, pedestrian preferences, street usage, district population, accesses, sustainable materials, and traditional design elements as key considerations. The findings of the study showed the various street furniture shortcomings and the need for more reforms in the socio-economic field. Engaging cultural elements in the district's street furniture design, and coordinating with existing historic buildings create legibility, identity, and a sense of place.

During the COVID-19 pandemic, challenges in the 17th District comprised public neglect, waste management, rising private car use, protocol uncertainties, and social-psychological concerns.

Therefore, the LPC particularly addressed design elements like waste bin placement, transit and bike station design, health-compliant seating areas, cultural integration, safety, tech incorporation, and community awareness. The street furniture design criteria incorporating traditional symbol preservation, local and sustainable materials choices, climate adaptability, user preferences, safety protocols, and local business support markedly affect the economic, social, and environmental aspects of sustainability. This study notably emphasizes the fundamental role of culture and identity in bolstering sustainability within the district. Furthermore, it presents the development process of the Local Performance Criteria (LPC) as a robust framework to achieve sustainable and pandemic-resilient street furniture, applicable not just locally in Iran but also on a global scale within urban areas. The LPC contributes to reducing the risk of infection and pursuing sustainability from a more comprehensive perspective. The key findings of this study serve as a foundational resource for designers, urban planners, policymakers, and leaders, facilitating the creation of more attractive, safer, and more sustainable cities.

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