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Insight into vegetation inclusion along urban roads: A pilot study on the preferences of expatriate roadside users in downtown Doha, Qatar

Abstract

Physical Activity (PA) is vital for health and well-being. Automobile-oriented urban development hinders PA in rapidly urbanized cities. In this regard, Complete Streets' is an emerging design approach to provide equitable services for all road users while promoting PA. Qatar is introducing 'Complete Streets' as part of an urban beautification project in which trees are an integral design element. In the capital city of Doha, expatriates constitute a large portion of the resident population; and primary roadside users due to their dependence on public transportation like the Metro rail. Using a quantitative survey, this pilot study conducted in a typical road segment of downtown Doha investigated the preferences of expatriate roadside users for ecosystem services (ES) offered by the street vegetation, the four potential roadside vegetation types, and the associated reasons. The results revealed that the top two preferred ES were the benefits of street vegetation in the aesthetic enhancement of streets and microclimate regulations. The vegetation type that was perceived to have more greenery was most preferred. The perceived 'restorative' benefits of street vegetation mainly influenced the preferences. The findings of this study provide insight into the inclusion of vegetation along roads under the beautification projects in downtown Doha by the Public Works Authority, Ashghal. It is the first study in Qatar that focuses on the preferences of expatriate roadside users for the ES offered by street vegetation and street vegetation types.

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1 Introduction

Today, almost 55% of the world's population is urbanized; and expected to increase to 68% by 2050 (UN 2019). Rapid urbanization leads to environmental degradation, such as air, water, and soil pollution (Cui et al. 2019), which risks the health and well-being of urban dwellers (Barker & Fisher 2019). In addition, the loss and unavailability of natural areas also negatively affect mental health and well-being (de Vries et al. 2016). Further, economic prosperity, technological advancements, and extensive use of private automobiles contribute to physical inactivity and chronic diseases such as obesity, diabetes, and heart disease (Al-Hazzaa 2022). The Millennium Ecosystem Assessment 2005 (MEA 2005) aims to reverse the degradation of the ecosystem while meeting the increasing demand for services. MEA 2005 defines Ecosystem Services (ES) as *"the benefits people obtain from ecosystems."* The ES concept is gaining popularity in spatial planning, particularly with Green Infrastructure (GI) implementation (Ersoy Mirici 2022). GI is a network of natural and semi-natural areas managed to provide ES (Monteiro et al., 2020).

Urban Green Spaces (UGS) are part of GI and are defined as *"all urban land covered by vegetation"* by the World Health Organization (WHO). WHO recognizes UGS as an essential source of health and well-being (WHO 2017). As part of ES, UGS provides recreational and social opportunities that help reduce sedentary leisure time by increasing UGS visits (Storgaard et al., 2013). Walking for recreation and social opportunities benefits physical and mental health (Sugiyama et al. 2008). Facilities such as playgrounds, a fitness area, and pathways encourage PA (Kaczynski et al. 2014). Further, UGS have 'restorative' potential. Stress Recovery Theory by Ulrich et al. (1991) suggests that natural views such as greenery and water features have the potential to recover people from emotional, attentional, and physiological stress. Attention Restoration Theory by Kaplan & Kaplan (1989) proposes that exposure to landscape features such as water, vegetation, wildlife, sounds, and textures can restore cognitive functioning by drawing involuntary attention that replenishes directed attention. In this regard, the four key features of restorative landscapes described by Kaplan & Kaplan (1989) as being away, soft fascination, extent, and compatibility provide a framework for designing and managing landscapes. A natural environment, such as a forest or a park, offers a sense of 'being away' via features that promote involuntary attention, such as vegetation and natural water features, which can help replenish directed attention and promote psychological restoration. 'Being away' provides a sense of psychological escape and a break from routine and everyday demands. 'Fascination' capture and hold our attention, providing visual interest and variety. For example, the presence of birds and butterflies can significantly enhance the overall aesthetic quality of an environment and contribute to a greater sense of tranquility (Herzog et al. 1997). Also, people prefer birds and butterflies with bright colors and distinctive movement patterns out of their fascination (Daniel et al. 2012). 'Extent' is the feature that enables a familiar environment and helps immerse in nature. 'Compatibility' refers to the characteristic of landscapes that meet the needs and preferences of the people who use them.

Due to the restorative qualities, exercising in a natural environment is better than in built environments for mental health (Mitchell 2013). In other words, aesthetically pleasing and engaging elements can support physical activity through psychological recovery. For example, the 'green' color positively contributes to green exercise by alleviating mood and reducing perceived exertion (Akers et al. 2012). The presence of natural elements, such as vegetation and water, positively influences perceptions of thermal comfort during green exercise (Brown et al. 2014). Studies show a positive association between the restorative quality of the UGS and the frequency of UGS visits. For example, Niu et al. (2022) found that large tree-shaded areas, pavilions, and fitness trails during summer increased physical activity frequency in an urban park in Chongqing, China. Fongar et al. (2019) found that positive association between Norwegians' positive perception of the quality of green spaces and the frequency of visits. Street vegetation can help create a conducive environment for pedestrians and cyclists by offering aesthetic, environmental, safety, and functional benefits. Street greenery played an important role in enhancing health and

well-being during the confinement period of the COVID-19 pandemic due to the imposed restrictions on visiting urban parks and gardens (Fischer & Gopal 2021; Shentova et al. 2022). Attractive street greenery was proven to be as significant as a garden with diverse plants for mental health during the pandemic (Shentova et al. 2022). Street greenery during the pandemic was used widely for PA, such as walking, jogging, and cycling (Fischer & Gopal 2021). State-of-the-art studies on the perception of or preference for street vegetation have focused on one or more benefits of street vegetation (Table S1). However, there are no studies on the preferences of expatriate roadside users for the ES offered by street vegetation or street vegetation types.

According to a study by Madureira et al. (2015) conducted in two cities in Portugal and France, participants' ethnic backgrounds influence their preference for ES offered by UGS. A study by Collins et al. (2022) showed that UGS is an essential health resource for students and expatriates to mentally recover from the long-term impact of the COVID-19 pandemic in Berlin, Germany, due to the uncertainty and constraints in their everyday lives brought about by the enforced lockdown measures. Hence, investigations on the expatriate and roadside users' preference for street vegetation are crucial in cities where a large section of the population is expatriate.

In recent years, the 'Complete Streets' design approach has gained much importance in automobile-oriented cities to integrate pedestrians and cyclists into urban roads. One of the primary focuses of Complete Streets is to contribute to public health by supporting physical activity (Anderson et al. 2015). Qatar is introducing 'Complete Streets' as part of a road beautification project in which trees are an integral design element. Downtown Doha predominantly consists of expatriate households (PSA 2020). Expatriates are the primary roadside users and users of the Mero rail in downtown Doha. This pilot study investigates expatriate roadside users' perception of and preference for ES and potential street vegetation types and the associated reasons to support physical activity in downtown Doha, Qatar.

This study addresses the following questions:

1. What is roadside users' preference for the ES offered by street vegetation?
2. How do roadside users perceive potential roadside vegetation types?
3. How can the roadside vegetation in downtown Doha support physical activity?

2 Material and methods

2.1 Study context

The Gulf Cooperation Council (GCC) countries have rapidly urbanized since the 1970s. The urban population consists of 90% of the total population in Bahrain, 85% in Saudi Arabia, 87% in the United Arab Emirates (UAE) and Oman, 99% in Qatar, and 100% in Kuwait (Group, 2023). Urbanization is mainly driven by the oil and Liquefied Natural Gas (LNG) economy (El-Arifi 1986). Expatriates outnumber the citizens due to the dependency on the foreign workforce in the GCC (Hertog 2012). Economic prosperity, urbanization, and technological advancements have led to a reliance on private automobiles, resulting in physical inactivity in the GCC countries (Al-Hazzaa 2022). Physical inactivity among adults is higher in these countries than the global average, with Kuwait having the highest prevalence at 67%, followed by Saudi Arabia at 53.1%, the United Arab Emirates (UAE) at 41.4%, Qatar at 36.8%, and Oman at 32.9% (WHO 2019). Physical inactivity in adults is less than 150 minutes of weekly moderate physical activities or less than 75 minutes of high-intensity physical (WHO 2018a). Physical inactivity is concerning because it increases the risk of non-communicable diseases such as hypertension, diabetes, and coronary heart disease (WHO 2018a). Non-communicable diseases account for 69–83 percent of all deaths in the GCC states (WHO 2018b). Those who are insufficiently active have a 20% to 30% higher risk of death than those who are sufficiently active (WHO 2018a).

There are several possible impediments to accommodating Physical Activity (PA) in the urban fabric of the GCC. Firstly, the roads in most cities are unfriendly for pedestrians and cyclists. For example, the percentage of pedestrian deaths in Qatar is 32%, Oman is 23%, and the UAE is 24%, all of which are significantly higher than in other high-income countries such as the United States (15%) and Canada

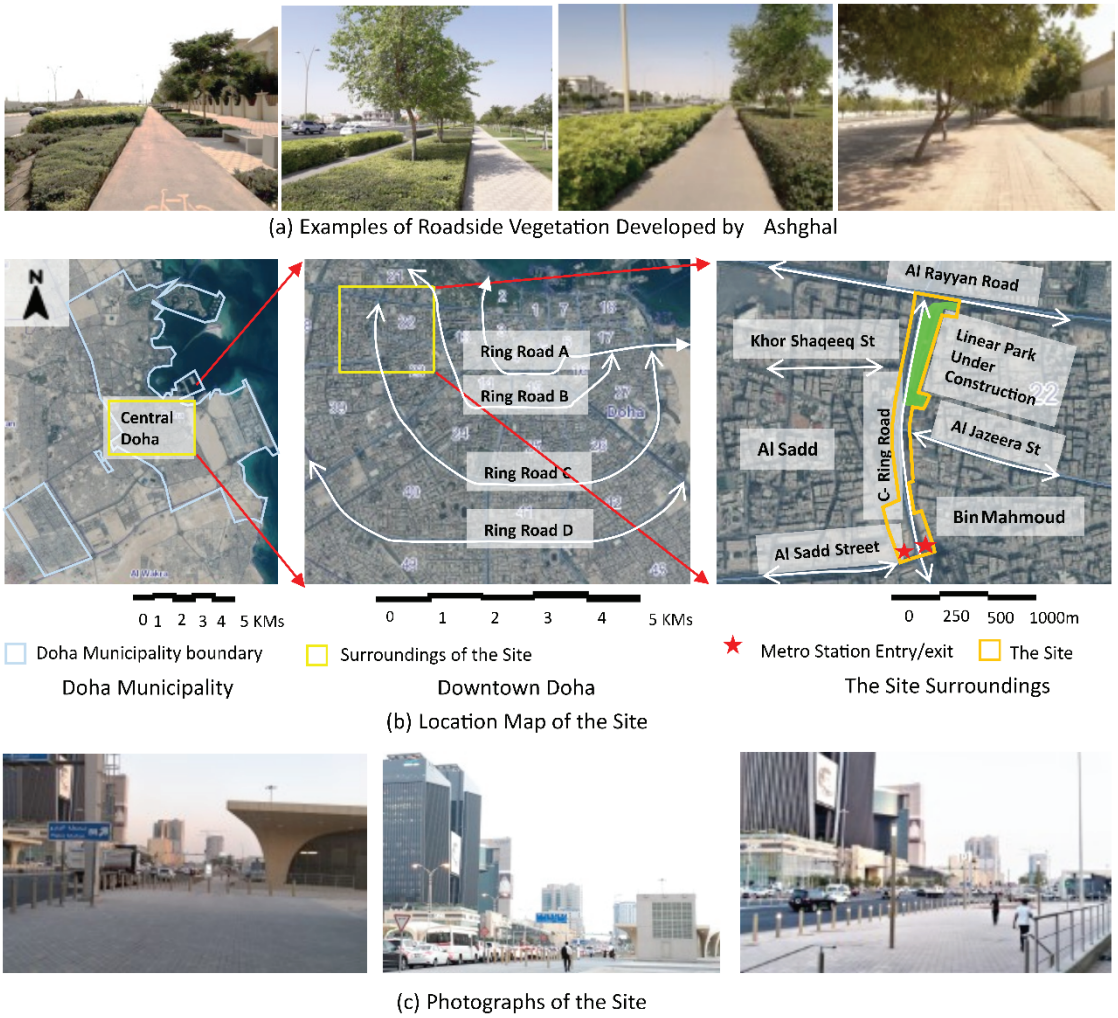

Figure 1. Location and surroundings of the site. Map Source: CGIS. Accessed on 20 August 2022. Photographs: the authors

(15%) (WHO 2018b). Secondly, the region belongs to the hot desert climate (BWh) zone of the Koppen Geiger Climate Classification (Kottek et al. 2006). Hence, it has long summer seasons, and the temperature in July can occasionally reach 50 °C. A hot and long summer can make outdoor activities very challenging. Thirdly, the cities of the GCC have poor ambient air quality caused by both natural and anthropogenic sources (Farahat 2016, 2022). Poor ambient air quality can discourage outdoor PA (An et al. 2018). Therefore, creating a conducive environment is necessary to support outdoor PA in the region.

Incorporating vegetation into complete streets can contribute to the quality of life by supporting PA. Vegetation can provide shade and improve air quality, making outdoor activities more appealing, especially during the hot summer, which can help reduce reliance on private automobiles. In Doha, Qatar, the Public Works Authority, Ashghal, is implementing the 'beautification of roads and public places in Qatar' project to promote walking and cycling using the "complete streets" approach. The project aims to enhance roads leading to bus stops and newly built metro stations with bicycle lanes, pedestrian paths, street furniture, decorative lighting, and trees (QNMP 2019). Some of the streets beautified under the project in Doha municipality are shown in Figure 1a. Within this context, this study was conducted to provide insight into the inclusion of vegetation in urban streets to support PA in downtown Doha.

2.2 Study site

The downtown is at the heart of the Doha municipality, surrounded by four ring roads (Figure 1b). It has medium to high-density mixed land-use development. It mainly accommodates expatriate households (PSA 2020). This pilot study chose the C – Rind Road segment, which reflects the land use charac-

teristics of road segments in the downtown (See Supplementary Figure SF1). The site surrounds two high-density neighborhoods, Al Sadd, and Bin Mahmoud, occupied 99.48% by expatriate households (PSA 2020). Buildings such as offices, hotels, commercial complexes, apartments, bus stops, and two exit/entry points of the metro station are along the site (Figure 1c). Ashghal was constructing a roadside linear park at the north end of the site as a part of the beautification project during this study.

2.3 Questionnaire design and data collection

The English language is familiar to the public in Doha; hence, the questionnaire was written in English. A trial was carried out to check the reliability of the questionnaire for the language and the time needed for completion. It involved sharing the hard copies of the questionnaire with eight family members and friends of the researchers who were also frequent pedestrians in the study area. Based on the feedback received, the questionnaire was modified.

The questionnaire consisted of three parts: 1) Characteristics of the respondents; 2) Respondents' preferences for the ES offered by street vegetation to support their PA in the urban roadside environment; and 3) Respondents' preferences for potential street vegetation types and the associated reasons.

2.3.1 Characteristics of the respondents

The questionnaire collected demographic information such as gender, age, nationality, education, work status, and place of residence. The preference participants for outdoor physical activities with options, walking to destinations, playing sports, mobile and stationary exercises, walking or playing with children or pets, strolling, and a write-in option for other activities was asked.

2.3.2 Preferences for ES offered by roadside vegetation

The second part of the questionnaire consisted of a 5-point Likert scale question on the preference for ES offered by urban roadside vegetation for conducting PA like walking, jogging, cycling, walking with kids or pets, and exercising. The list consisted of eight ES that contribute to user comfort as follows: 'producing shade and reducing heat;' 'reducing dust exposure;' 'balancing O_2 and CO_2;' 'reducing traffic noise;' 'reducing glare from vehicles' headlights;' 'reducing storm water run-off;' 'enhancing the beauty of streets;' and 'attracting birds and butterflies.' The Likert scale options were 'highly beneficial,' 'beneficial,' 'neutral,' 'not beneficial,' or 'not at all beneficial.' There was no choice between the ES (See Supplementary Appendix B, Question 8).

2.3.3 Preferences for potential roadside vegetation type and the associated reasons

The third part had an image-choice question followed by a multiple-choice question. The image-choice question included four options of roadside vegetation types that included trees (Figure 2) since trees are an integral element of roads under the road beautification project (QNMP 2019). 'I like more greenery'; 'I feel safe because of the road visibility'; 'It is safer to walk with kids or pets'; 'I get more shade'; 'It secludes me from road vehicular

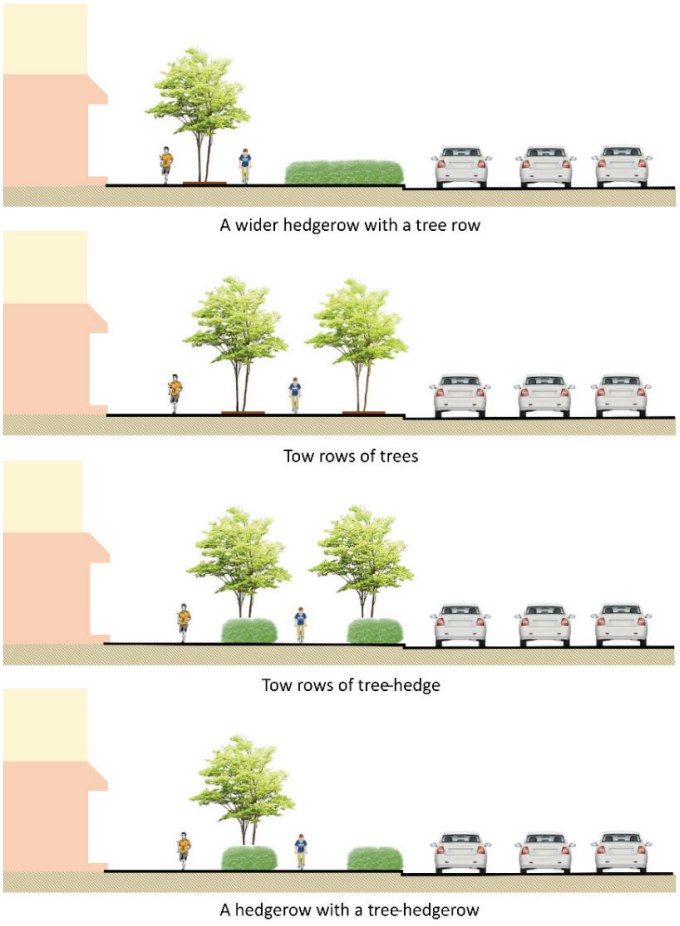

Figure 2. Potential roadside vegetation types presented in the image-choice question. Photographs: the authors

traffic'; 'It looks good'; and a write-in option for other reasons. Participants could select up to three reasons based on their priorities (See Supplementary Appendix B, Questions 9 and 10).

2.3.4 Sample size determination

One of the main issues was determining the sample size in this study. There is no data on the number of people who walk, cycle, or exercise in the study area. Hence, the population of this study is unknown. Therefore, using the G* Power Software (Version 3.1.9.7) to determine the sample size based on the effect size and the power. Information on the G* Power Software is available in Faul et al. (2007).

Cohen (1977) provided benchmark values for effect sizes: 0.5 for a moderate effect size, 0.2 for a small effect size, and 0.8 for a large effect size. The smaller the effect size, the smaller the distance between the means. Hence, a large effect size is more desired. A power of 0.80 is the recommended minimum, and 0.95 is more desirable. This study considered the effect size of 0.4 and the power of 0.8 for sample size calculation in this study, which is acceptable. Table 1 provides the G* Power Software input values and the output. The sample size of this survey is 55, which is higher than the estimated sample size of 52 (Table 1). Hence, the sample size of this study was considered sufficient.

Table 1. Input values used for sample size calculation in G* Power Software and the output.

Analysis	A priori: Compute required sample size – given α, power, and effect size	
Input	Tails	two
	Effect size dz	= 0.4
	α error probability	= 0.05
	Power (1-β error probability)	= 0.8
Output	Non-centrality parameter δ	= 2.8844410
	Critical t	= 2.0075838
	Degrees of freedom	= 51
	Total sample size	= 52
	Actual power	= 0.807787

2.3.5 Participant recruitment

The survey took place between November 2020 and March 2021 on six weekdays and three weekends from 5 p.m. to 8 p.m. Each site visit involved the distribution of 25 questionnaires between November 2019 and December 2020. Roadside construction hindered pedestrian movement during the last five site visits in January, February, and March 2021. As a result, the number of potential participants approached was reduced to almost half of what had been planned. A total of 150 questionnaires were distributed, and 55 responses were received, with a response rate of 36.67%. The samples of the questionnaires were collected from four survey spots: two at the edge of Al Sadd and two at the edge of Bin Mahmoud neighborhoods. The survey spots, Spots 1 (25.2821 N, 51.5060 E) and Spot 2(25.2825 N, 51.5065 E), were located at the metro stations, and Spots 3(25.2858 N, 51.5060 E) and Spot 4(25.2882 N, 51.5057 E) were at the crossroad intersection areas (See Supplementary Fig. SF2). Survey Spot 3 had a high level of pedestrian activity due to the presence of supermarkets, vegetable and fruit shops, sweet shops, bakeries, and restaurants at the crossroad connecting C-Ring Road.

A systematic sampling procedure, as explained in Sekaran & Bougie (2016), was adopted for sample recruitment. The first potential participant was a random roadside user; afterward, every fifth roadside user was approached and informed of the survey's objective. If the potential participant was disinterested in participating in the survey or had a language barrier to participation, the next fifth roadside user was approached. The sampling excluded those who were 18 years old and below and tourists. To avoid prolonged and direct contact and the exchange of physical materials between the surveyor and the potential participants due to the restrictions imposed during the COVID-19 pandemic, a web-based survey platform, Google Forms, was used to distribute the questionnaires. Potential participants at the site were asked for their email addresses or WhatsApp numbers to distribute the questionnaire.

3 Results

3.1 Characteristics of the respondents

All survey respondents were expatriates, with more male than female respondents. Most were full-time employees with at least a bachelor's degree, resid-

Table 2. Characteristics of respondents

	Characteristics of respondents	Number of respondents
Nationality	Qatari	0
	Non-Qatari	55
Gender	Male	34
	Female	21
Age	18-30	17
	31-40	26
	41-55	12
	56-70	0
	Above 71	0
Educational Qualification	Did not go to school	0
	Less than Highschool	2
	Highschool and equivalent	7
	Bachelor's degree	31
	Master's degree and above	10
	Do not wish to specify	0
	Other	1
Employment Status	Employed full-time (40+ hours a week)	44
	Employed part-time (Less than 40 hours a week)	2
	Looking for a job	1
	Not looking for a job	2
	Student	4
	Retired	0
	Self-employed	1
	Unable to work	0
Residence Location	Adjacent neighborhoods	31
	Other neighborhoods in the downtown (Supplementary Fig. SF3)	12
	Other neighborhoods in Qatar	12

ing in high-density areas in downtown Doha. Table 2 details the respondents' nationality, age, employment, and residential information.

Walking to the destination is the most frequent outdoor PA performed by the respondents. Walking or playing with children is the least common outdoor PA among the respondents (Figure 3).

3.2 Respondents' preferences for ES offered by street vegetation

The mean and standard deviation values of the ES indicate that the top five ES offered by roadside vegetation preferred by the respondents are: 'enhancing the beauty of the streets'; 'producing shade and reducing heat'; 'reducing dust exposure'; 'balancing O_2 and CO_2'; and 'attracting birds and butterflies;' respectively (Figure 4). The highly preferred ES by the respondents is 'enhancing the beauty of the streets' with the highest mean value. The standard deviations for the top five ES preferred by the respondents are between 4 and 5 points on the Y-axis, which is the 'beneficial' to 'highly beneficial' range on the Likert scale. The standard deviations for the bottom three ES preferred by the respondents are between 3 and 5 points on the Y-axis, which are in the range of 'neutral' to 'highly beneficial' on the Likert scale. The least preferred ES by the respondents is 'reducing glare from the vehicles' headlights, with the lowest mean value.

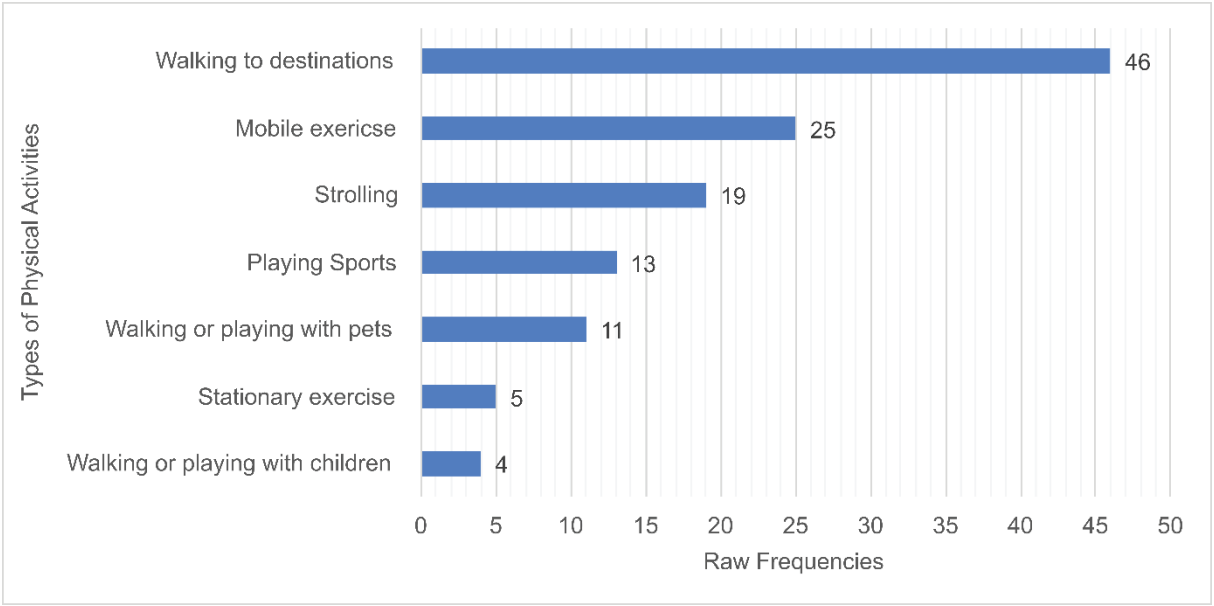

Figure 3. A bar chart showing the frequencies of physical activities carried out by the respondents.

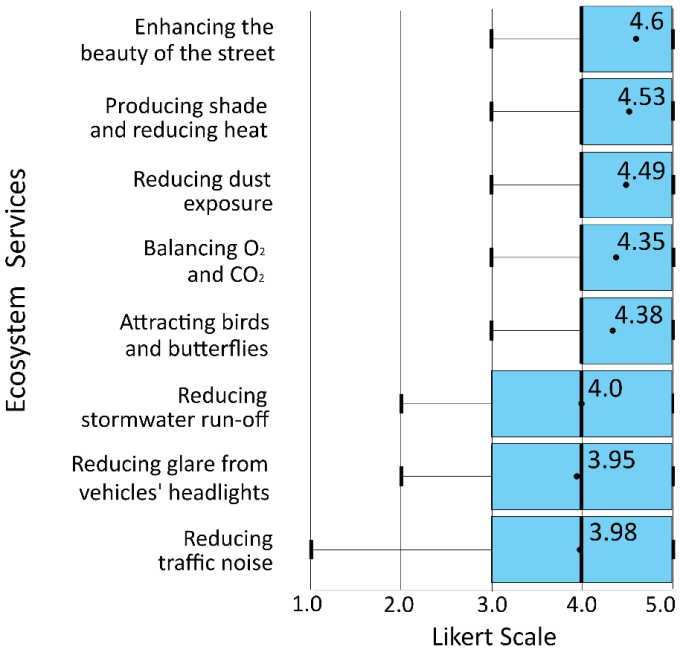

Figure 4. A boxplot analysis for the respondents' preferences for ecosystem services offered by roadside vegetation on a 5-point Likert scale (Total number of respondents, n=55).

3.3 Respondents' preferences for roadside vegetation types and the associated reasons

Among 55 respondents, 42 preferred the 'two rows of tree-hedge' vegetation type. The vegetation types 'two rows of trees' and 'a wider hedgerow with a tree row' received 6 responses each. One respondent liked the 'a hedgerow with a tree-hedgerow' type, which is consequently anomalous. The 'two rows of tree-hedge' and the 'two rows of trees' vegetation types are preferred mainly for the 'I like more greenery' (Table 3). The 'a wider hedgerow with a tree row' vegetation type is preferred mainly for the 'I feel safe because of the road visibility.' The responses received for the reasons show that the perceived greenness, perceived ability to provide shade, and perceived ability to provide safety for children and pets are the top three reasons for the vegetation preference.

Table 3. The number of responses received for the reasons for selecting the roadside vegetation type.

Reasons	Roadside Vegetation Types			Total Responses
	Two rows of tree-hedge	Two rows of trees	A wider hedgerow with a tree row	
It looks good	14	1	1	16
I like more greenery	31	6	3	40
I get more shade	25	4	1	30
It is safer to walk with children and pets	19	3	3	25
It secludes me from road vehicular traffic	7	2	3	12
I feel safe because of the road visibility	11	0	5	16
Other	2	0	0	2
Total Responses	109	16	16	141
Total respondents	42	6	6	54

4 Discussion

4.1 Preference for ES offered by roadside vegetation

The result of this study showed that despite the region having a long and hot summer season which can make outdoor PA challenging, the benefit of street vegetation in 'enhancing the beauty of the streets' is highly preferred by roadside users. A study by Graça et al. (2018) in Porto, Portugal, showed a higher preference for 'air quality regulation' than 'aesthetic pleasure' and 'microclimate regulation.' One of the main differences between this study and the Graça et al. (2018) is the nationality of the participants. All the participants in this study are expatriate roadside users, unlike Graça et al. (2018), in which all participants were citizens.

The data collection in this study was around the time of the COVID-19 affected period. Hence, the preference for 'enhancing the beauty of the streets' to 'providing shade and reducing heat' could be in response to the perceived mental health benefit associated with the UGS at the time as discussed by Collins et al. (2022). Another reason for the difference in the results of this study and the study by Graça et al. (2018) could be because of the difference in the ethnicities of the participants as mentioned in the study by Madureira et al. (2015).

Further, the benefit of street vegetation in 'reducing dust exposure' and 'balancing O_2 and CO_2' are related to air quality enhancement and the third and fourth highest preferred ES, respectively. Preference for air quality enhancement could be their negative perception of ambient air quality in the region. The literature demonstrated that the perception of better air quality in UGS motivates people to visit them

(Fongar et al. 2019). Hence, the preference for enhancing air quality is justifiable.

Followed by street vegetation benefit in 'enhancing the beauty of the streets,' 'providing shade and reducing temperature was the second highest preferred ES. As mentioned earlier, the region has a long summer season, sometimes temperatures crossing 50° C, which makes outdoor PA challenging. Hence, the preference for 'providing shade and reducing temperature is justifiable. As mentioned earlier, vegetation is perceived to provide thermal comfort (Brown et al. 2014; Niu et al. 2022).

The 'reducing storm water run-off' and 'reducing glare from the vehicles' headlights' are within the bottom three ES preferences. Considering Doha belongs to the hot desert climate zone, it naturally has less rainfall. Hence, to find less desire for 'reducing storm water run-off' is not surprising. Further, less importance for vehicle-light glare reduction could be because it is hazardous mainly for drivers.

The last preference for 'reducing traffic noise' is surprising, particularly in the heavy traffic roadside green spaces. As mentioned earlier, traffic noise can negate the restorative potential of the landscape (Uebel et al. 2022). However, the study by Graça et al. (2018), and Madureira et al. (2015), also showed that noise mediation by UGS is less preferred than other ES. The less preference for the noise abatement benefit could be because people accept traffic noise as a common issue in roadside urban environments.

Overall, roadside users' preference for ES offered by street vegetation emphasizes the aesthetic quality enhancement of streets. Preference for aesthetic quality enhancement of streets indicates that the mental health benefit of street vegetation is most important to roadside users in downtown Doha.

4.2 Preference for roadside vegetation types and the reasons associated

The 'two rows of tree-hedge' vegetation type was most preferred, followed by 'two rows of trees' and 'a wider hedgerow with a tree row.' The vegetation types 'two rows of tree-hedge' and 'two rows of trees' were preferred mainly for perceived greenness. The study by Lindal and Hartig (2015) showed that restoration likelihood increases with an increase in the number of street trees. The difference between the two is the additional two hedgerows with two rows of trees in the 'two rows of tree-hedge.' Perceived greenness is positively associated with a restorative effect (Ulrich et al. 1991; Ulrich 1984). It shows that low-level vegetation with trees along the streets contributes to the perceived greenness, thus, the restorative quality of the streetscape.

Both the 'two rows of tree-hedge' and 'two rows of trees' are preferred for providing shade. It is a general notion that shade is mainly associated with trees. The highest preference for 'two rows of tree-hedge' shows that hedgerows under tree rows might enhance the perception of thermal comfort. The study by Klemm et al. (2015) also showed a higher preference for street vegetation having both trees and low-level vegetation for perceived thermal comfort.

The 'a hedgerow with a tree-hedgerow' type was preferred the least. The absence of a tree row on the road verge in the 'a hedgerow with a tree-hedge' differentiates it from the highly desired 'two rows of tree-hedge' vegetation type. A study by Lusk et al. (2020) conducted in Boston, MA, showed that the presence of trees with bushes at the road verge was preferred highly for benefits in perceived benefits in thermal comfort, air pollution exposure reduction, and blocking the sight of traffic. Hence, the highest preference for the 'two rows of tree-hedge' type is possibly the presence of trees with low-level vegetation on the road verge. However, in this study, the list of reasons associated with the vegetation type preference did not include air quality enhancement in specific.

Furthermore, 'It is safer to walk with children and pets' is one of the top three reasons associated with roadside vegetation preference. The 'two rows of tree-hedge' type received the highest response for 'safer to walk with children and pets.' Except for the least preferred 'a hedgerow with a tree-hedge row' vegetation type (anomalous preference), the other two vegetation types did not have a hedgerow between the pedestrian path and the bicycle lane. It shows that including a hedgerow between the pedestrian path and the bicycle lane can enhance pedestrians' perception of safety concerning accidents involving pedestrians and cyclists. Among the four

vegetation types, the 'a wider hedgerow with a tree row' had a wider buffer from the roadway. A study by Kweon et al. (2021) in Texas, USA, also showed that pedestrian safety perception is higher when a wider buffer between the roadway and the pedestrian route. It indicates that wider hedgerows at the road verge can effectively enhance the perceived safety of roadside users concerning accidents involving road vehicles and roadside users.

4.3 Insight into inclusion of vegetation on the urban roads in downtown Doha

Key insights on the preferred street vegetation types and ES for roadside users in downtown Doha include (Figure 5):

1. Street vegetation benefits in enhancing the aesthetic of streets, providing shade, and reducing temperature are top preferences.
2. The 'two rows of tree-hedge' is preferred due to the higher perceived greenness compared to the other three types of street vegetation.
3. Two rows of trees positively contribute to perceived thermal comfort; low-level hedgerows under trees can enhance perceived thermal comfort.
4. A wider hedgerow at the roadside verge enhances the perception of safety concerning accidents.
5. Low-level hedgerows between pedestrian and bicycle lanes enhance the perception of safety against accidents involving bicycles and pedestrians.

These insights can guide road beautification projects in downtown Doha for supporting PA.

4.4 Limitations

This pilot study provides an initial analysis for vegetation inclusion along roads to support PA in downtown Doha, Qatar. However, this study has several limitations. Firstly, the study is spatially limited to a segment of the road in downtown Doha. Secondly, sample collections along roads in various neighborhoods with different ratios of citizens and expatriates can be more insightful as that allows comparing the ethnic groups, including Qatari citizens. A study of such nature could reveal more nuanced and detailed information.

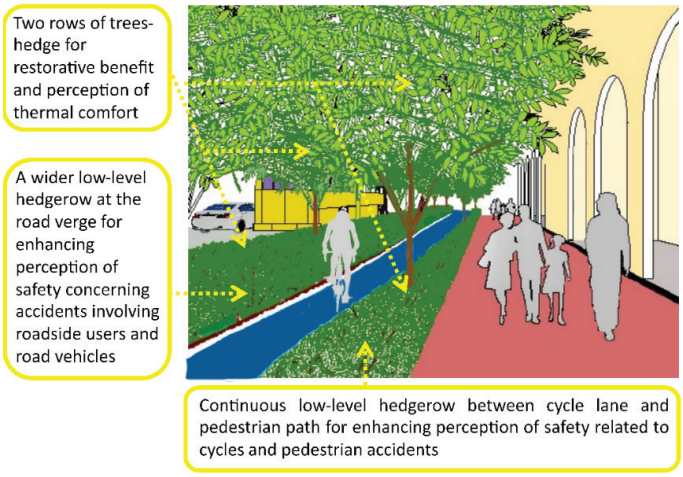

Figure 5. A graphical abstract of insight into roadside vegetation to support PA in downtown Doha. Source: the authors

Another limitation of this study is the person jogging in the image-choice question is not at the same distance from the vegetation and building in all images. Perception may vary depending on one's position shown in the images (Ennis et al. 2011). Future studies should ensure that the distance from the vegetation and building is consistent across all images to avoid any potential biases in the data. Furthermore, this study did not consider all possible combinations of vegetation, such as the preference for a tree-hedge with a hedgerow. It also did not examine the perception of vegetation screens and green facades. Since space is often scarce for greening on urban roads, such research is worthwhile. Future studies could investigate the perception of these types of vegetation.

Moreover, the study did not examine the preferences of roadside users for vegetation texture, color, and flowers. Although the study found that roadside users highly preferred the aesthetic benefits of roadside vegetation, a more thorough investigation of urban roadside users' preference for the aesthetic benefits of roadside vegetation is worth considering. A detailed understanding of the preferences of roadside users for different vegetation types could inform urban planning and design, as well as improve the overall well-being of citizens.

Finally, this study did not investigate the perception of the benefits of roadside vegetation types concerning air quality enhancement, even though Doha has high ambient particulate matter. Given that the

study showed that roadside users preferred air quality regulation services offered by street vegetation, further research on the perception of vegetation types for air quality enhancement benefits could provide more insight into vegetation inclusion along urban roads.

Overall, this study provides useful insights into the perceptions of street vegetation for PA, but future research should address the limitations outlined above to gain a more comprehensive understanding of roadside users' preferences for different types of street vegetation.

5 Conclusions

This study has provided insight into vegetation inclusion in the complete streets design in downtown Doha, Qatar. This is a unique study that focused on expatriate roadside users' preference for street vegetation. To the best of our knowledge, this is the first study conducted in the GCC region to provide insight into vegetation inclusion on urban roads to support PA based on the 'preference' approach. This study suggested that the benefit of street vegetation in aesthetic enhancement of the street and micro-climate regulation are most important to roadside users. The vegetation type, which has the highest amount of perceived greenery and perceived thermal comfort, was most preferred.

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Declaration of Competing Interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper."

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Appendix A: Supplementary Figures

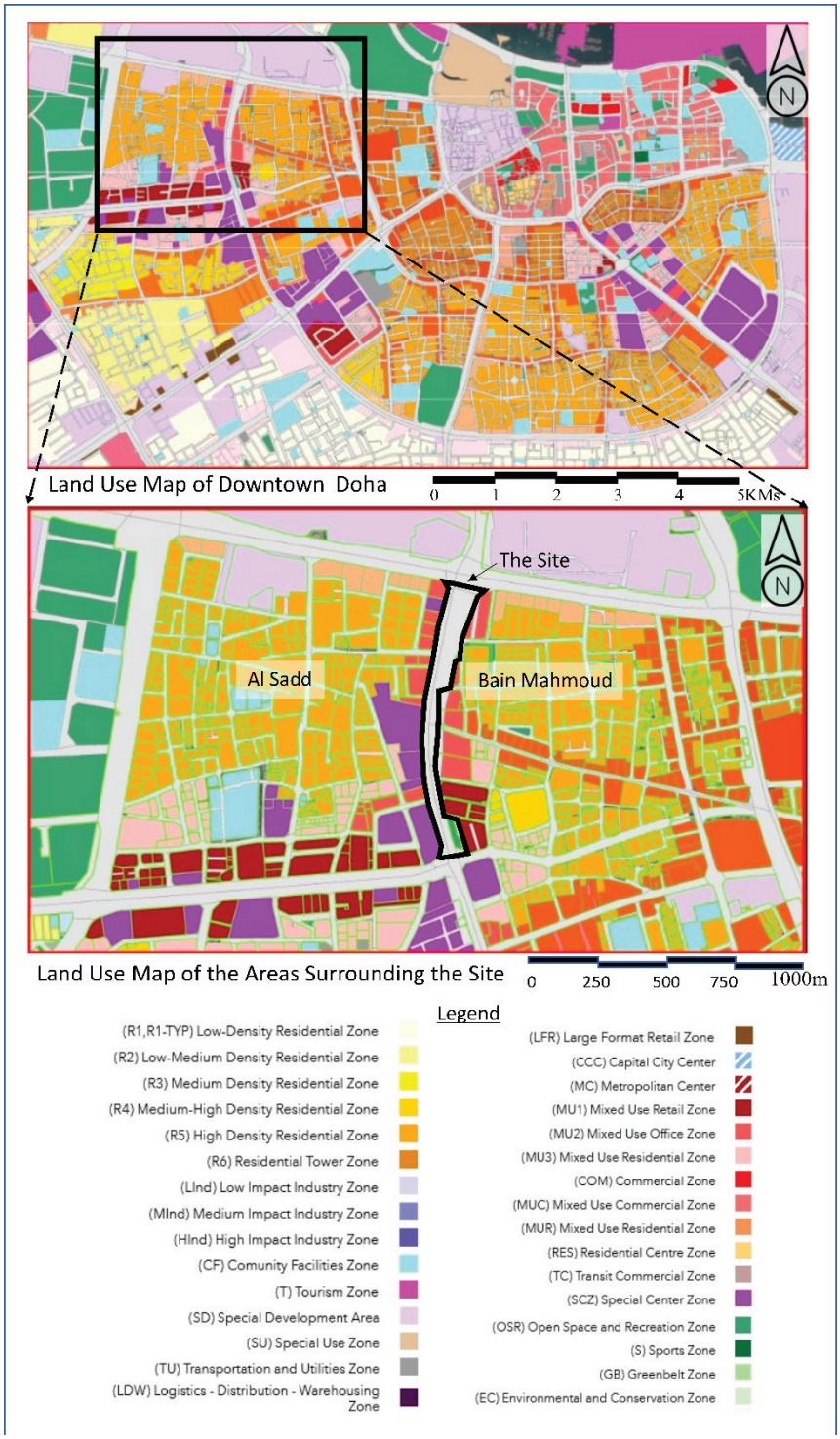


Figure SF1. Land use map of downtown Doha and the surroundings of the site. Map Source: QNMP GIS Portal. Accessed on 30 October 2022

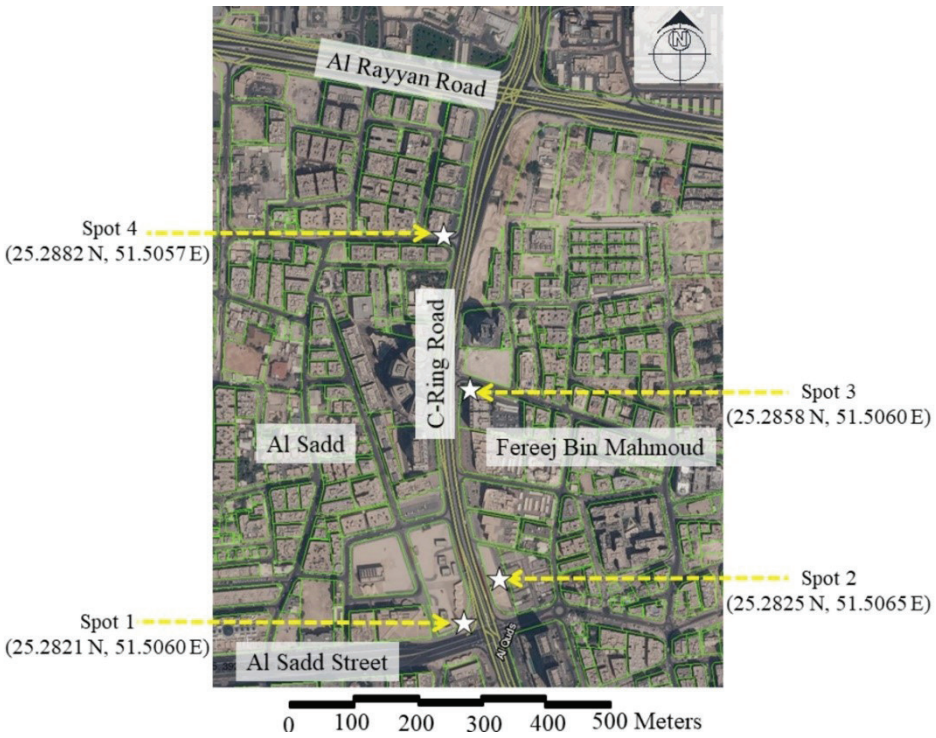


Figure SF2. The four survey spots. Map Source: CGIS. Accessed 07 June 2021.

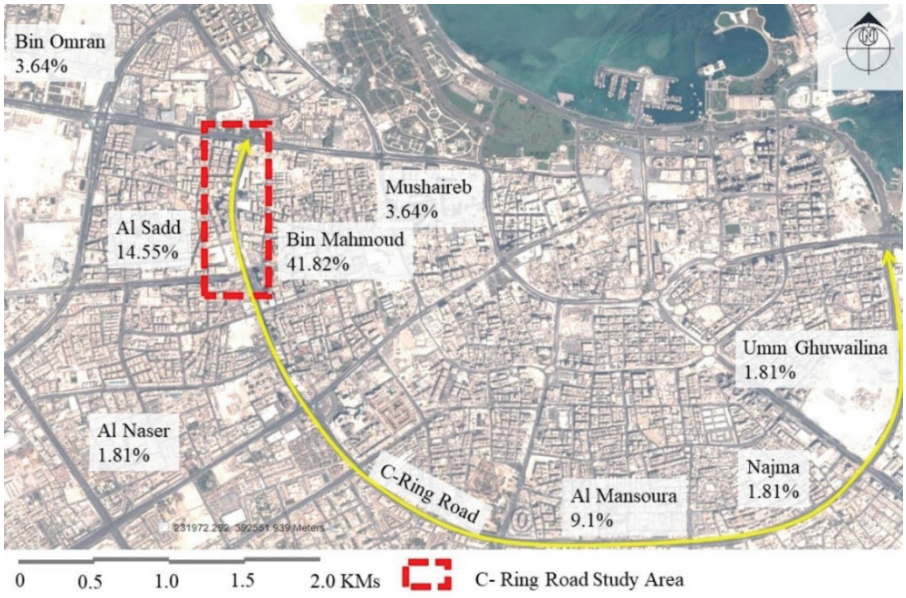


Figure SF3. Residential locations of the respondents (n=43) in downtown Doha. Map: Google Pro. Accessed 14 October 2021.

Appendix B: Survey Questionnaire

Part-A

1. To which age group do you belong?

- 18-30
- 31-40
- 41-55
- 56-70
- Above 71

2. Please select your gender

- Male
- Female

3. Please select your nationality

- Qatari
- Non-Qatari

4. Please select the highest degree or level of education you have completed.

- Did not go to school
- Less than Highschool
- Highschool and equivalent
- Bachelor's degree
- Master's degree and above
- Do not wish to specify
- Other. Please specify here……

5. Please select your current employment status

- Employed full-time (40 or more hours per week)
- Employed part-time (Less than 40 hours per week)
- Self-employed
- Looking for a job
- Not working
- Student
- Retired

6. Where do you reside in Doha? Could you please write the name of your neighbourhood here.

……
……

7. What kinds of outdoor activities do you participate in when you are outdoors? You may choose a maximum of 3 answers.

- Walking to destinations (metro, shops, school, office, park etc.)
- Playing sports
- Mobile exercises like walking, jogging, and cycling etc.
- Stationary exercises like body workout, outdoor gym, and yoga etc.
- Walking or playing with children
- Walking of playing with pets
- Strolling
- Other. Please specify here…….

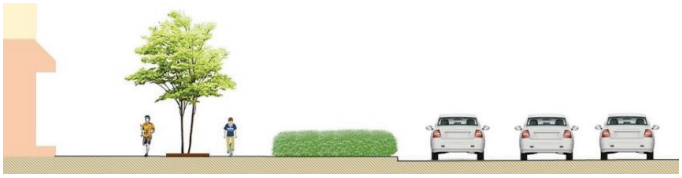
Part-B

8. For you to enjoy and spend more time on various physical activities (walking, jogging, cycling, exercising, walking with kids, walking with pets, etc.) in roadside greenery, how do you rate the below services provided by roadside vegetation?

Ratings / Benefits	Highly Beneficial (5)	Beneficial (4)	Neutral (3)	Not Beneficial (2)	Not at all Beneficial (1)
Producing shade and reducing heat	❑	❑	❑	❑	❑
Reducing dust exposure	❑	❑	❑	❑	❑
Balancing O2 and CO2	❑	❑	❑	❑	❑
Reducing traffic noise	❑	❑	❑	❑	❑
Reducing glare from vehicle headlights	❑	❑	❑	❑	❑
Reducing storm water runoff	❑	❑	❑	❑	❑
Enhancing the beauty of streets	❑	❑	❑	❑	❑
Attracting birds and butterflies	❑	❑	❑	❑	❑

Part-C

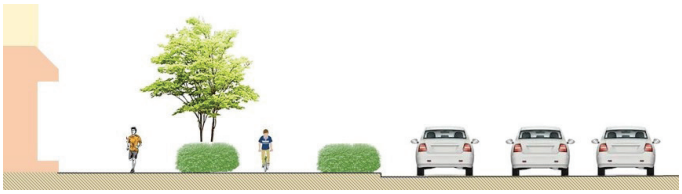
9. For you to enjoy and spend more time on various physical activities (walking, jogging, cycling, exercising, walking with kids, walking with pets, etc.) in roadside greenery, which of these roadside vegetation types do you prefer the most?



- A wider hedgerow with a tree row

- Two rows of trees

- Two rows of tree-hedge



- A hedgerow with a tree-hedge row

10. What is the reason for choosing the above vegetation type? You may choose a maximum of 3 answers.

- I like greenery
- I feel safe because of the road visibility
- It is safer to walk with kids or pets
- I get more shade
- It secludes me from road vehicular traffic
- It looks good
- Other. Please specify here ……

Appendix C: Supplementary Table

Table ST1: State-of-the-art literature on perception of or preference for street vegetation

Studies	Topics	Participants	Sampling Location	Focus
Graça et al., (2018)	Preference for ES offered by street vegetation	Citizen Roadside users	Porto, Portugal	ES management
Koyata et al. (2021)	Perception of street trees for ES offered	Roadside users	Yokohama, Japan	ES management
Weber et al. (2014)	Perception of wild and cultivated street vegetation for ES offered	Residents	Berlin, Germany	ES management
Klemm et al. (2015)	Preference for street trees with and without the frontal garden	Roadside users	Utrecht, the Netherlands	Thermal comfort and aesthetic appreciation
Lusk et al. (2020)	Preference for street vegetation with combinations of trees and bushes between on-street parking, bicycle lane, and pedestrian path	Roadside users	Boston, MA	Aesthetic benefits, perceived environmental comfort (thermal comfort, air quality, sight of traffic), and functional benefits
Dobbie & Farrelly (2022)	Preference for rain garden	Residents	3 Suburbs of Melbourne, Victoria, Australia	Retrofitting rain gardens
Todorova et al. (2004)	Preference for trees and trees with possible elements such as soil, grass, hedge, and flowers.	Residents	Sapporo, Japan	Aesthetic benefit, function benefit, and maintenance benefit
Lindal & Hartig (2015)	Preference for vegetation	Citizen Residents	Iceland	Aesthetic benefits
Hidalgo (2021)	Perception of street vegetation	Residents	Calgary, Canada	Aesthetic benefits
Nawrath et al. (2019)	Preference for street vegetation with different levels of greening and types of cycling infrastructure	Residents	Berlin, Germany	Aesthetic and functional benefits
Van Dongen & Timmermans (2019)	Preference for street vegetation arrangements with possible combinations of trees, hedges, and grass	Citizens	4 cities in the Netherlands	Aesthetic benefits
Kweon et al. (2021)	Preference for vegetation	Parents	College Station and Bryan, Texas	Safety
Botes & Zanni (2021)	Preference for street vegetation and cycling and walking infrastructure	Road users	Taipei, Taiwan.	Aesthetic, functional, and economic benefits
Coleman et al. (2021)	Preference for trees	Pedestrians	Chicopee, Holyoke, and Springfield in Massachusetts, U.S.	Safety