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Strategies to Promote Greenery in Urban Boundary Wall Facades: A Case Study in Residential Areas of Colombo district, Sri Lanka

W.C.M.S. Madushanka
Faculty of Graduate Studies, University of Sri Jayewardenepura, Gangodawila, Nugegoda, Sri Lanka

G.N. Samarasekara
Faculty of Engineering, University of Sri Jayewardenepura, Gangodawila, Nugegoda, Sri Lanka

K.C. Ellawala
Faculty of Engineering University of Ruhuna, Hapugala, Galle, Sri Lanka

ABSTRACT

Understanding the public perceptions towards green infrastructure can be instrumental in identifying effective strategies for greening. This research focuses on the less exploited green boundary walls among the different green infrastructure options. A questionnaire survey was conducted among three hundred twenty-eight residents in residential areas of Colombo district, Sri Lanka, to understand the public perceptions that affect green urban boundary walls. Using Likert scales, participants expressed their perception of benefits and challenges related to greening boundary walls along with socio-economic data. Relaxation effects, improvement of aesthetic appearance, becoming close to nature, and improving air quality were among the highest-rated benefits. Lack of knowledge and time and money requirement was identified as significant challenges. Misconceptions about property damages and nuisance to the owner are demotivators for nearly 38% of the sample as determined by the cluster analysis. Interventions such as providing relevant knowledge on methods of green wall construction and maintenance methods and subsidies can be recommended. Raising awareness through pilot programs and opportunities for experience sharing may motivate people towards greening boundary walls. The study concludes with strategies applicable in motivating residents towards greening their boundary walls.

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Corresponding Author Contact:

gangas@sjp.ac.lk

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1. Introduction

1.1 Background

Increasing the urban population in developing countries leads to increasing building footprint at the cost of green areas (Brochu et al., 2022). Lack of green spaces and removal of green spaces are significant issues related to urban densification (Haaland and van den Bosch, 2015), thus calling for an increase in green infrastructure (Jim, 2015; Hall et al., 2012; Chaudhuri and Kumar, 2022). Recent studies highlighted the importance of maintaining equity for greenery in countries of the global south (Rigolon et al., 2018; Elgizawy, 2016)). Mitigation of the urban heat island effect has become an urgent need for Asian countries (Borzino, 2020; Yang and Santamouris, 2018) while some nations around the world are already succeeded in securing reasonable levels of green coverage, some other countries with decreasing

levels of greenery are pressed to find innovative and strategic ways to guarantee safer levels of vegetation in urban areas.
Colombo city, the commercial capital of Sri Lanka, irrespective of its history of being one of the first garden cities, is one of the cities experiencing a decline in green spaces. The green areas in Colombo city have reduced from 31.0 km^2 in 1980 to 5.02 km^2 in 2015. Colombo city's per capita green space was 7.16m^2 in 2015, and it is below the WHO standard level of 8 m^2 per person (Li and Pussella, 2017).

Reduction of urban green spaces due to unplanned urban growth calls for better planning for green spaces. (Senanayake et al., 2013). Li and Pussella (2017) suggest that efforts to increase green spaces in Colombo should focus on smaller administration units. High dense space scared urban areas like Colombo and should look for innovative green infrastructures such as green walls and green roofs to increase green spaces. Green buffers, instrumented through urban planning regulations, have been proposed to core parts of Colombo under Megapolis regulations (Jayaweera et al., 2018). Colombo has joined the trend of constructing green walls, increasingly appearing in clients' requirements (De Silva et al., 2021). As highlighted by the above publications, and in the context of scarce land plots and the suggestion to focus on smaller administrative units, Colombo's effort to increase greener should focus on vertical greening at the household level. According to Rathnasiri et al. (2021), only 15% of the Sri Lankan participants who do gardening practice vertical gardening. This shows a substantial unutilized potential for increasing vertical greenery for Colombo. It further calls for careful effort at the hand of urban planners to increase urban greenery based on a proper understanding of motivators and barriers for greening as well as effective interventions for such.
Research studies from other countries give evidence for attempts to understand citizen perceptions about green infrastructures in urban areas to support the process of increasing urban greenery (Tsantopoulos et al., 2018; Jim and Chen, 2006). Tsantopoulos et al., (2018) proposed some strategies to improve urban greenery in Athens in Greece by understanding people perceptions about benefits, challenges, interventions, and sources of information related to green infrastructure.

The research reported here also attempted to study people perception of one such resident maintained vertical greening option: the green road facades of roadside boundary walls. Citizen perception of greening boundary walls was explicitly understood in terms of benefits and challenges in order to identify effective strategies towards increasing greenery in boundary wall facades.

1.2 Literature review

1.2.1 Multiple Options Of Green Walls As Green Infrastructure

The increase of green space can be materialized through different forms of green infrastructure. Tzoulas et al. (2007), after reviewing previous research on green infrastructure, identified eight options: green roofs; urban parks; green corridors; encapsulated countryside; derelict land; housing green space and domestic gardens; churchyards, cemeteries, and school grounds; open standing and running water. Focusing on green infrastructure at the household level, Tsantopoulos et al. (2018) identified the options such as green roofs, green walls, and green balconies. Historically, green walls, living walls, and green roofs have been used at the building level as passive techniques which adopt the natural cooling mechanism. While the green roofs have been actively promoted in many areas, adoption of the green walls is happening slowly (Jim, 2015). The potential of green walls or vertical green systems remains high in the context of space availability lesser plant requirements. However, this potential has not been fully exploited (Radić, et al., 2019).

A range of options is available for adopting green walls. A green wall may be constructed as a living wall or a green façade (Papadopoulou, 2013), which may not be fixed to a wall or building façade (Francis and Lorimer, 2011). Further, these can be varied according to the growing method, supporting structure, location, the material employed for construction and type of vegetation (Dunnett and Kingsbury, 2008). Jim (2015), based on his review of published materials and applications, has presented his classification based on three factors: growth form, training/ substrate system, and substrate. Based on the observations of existing green facades in Western Province, Sri Lanka, Madushanka et al., (2019), identified 12 configurations of green boundary walls which citizens successfully adopted.

1.2.2 Benefits of green walls and other green infrastructure as motivators for greening

A large mass of literature focusing on different green infrastructure options has been built over the last decades, highlighting multiple motivators behind introducing green to urban areas. People install green infrastructure to receive various benefits. Akreim and Suzer (2018), reviewed 32 studies and identified 26 factors that motivate green buildings. They have classified these factors into environmental, economic, and social motivators. Sheweka and Magdy, (2011) also, classified benefits of living walls into the same three categories. Radić et al. (2019), who reviewed the benefits, identified thermal performance, air pollution, noise pollution, hydrological, social, visual, educational, habitat, and economic benefits. These can also be categorized as environmental, social, and economic benefits. The benefits of green walls and other green infrastructure are thus discussed below by classifying them into environmental, economic, social, personal, aesthetic, and psychological benefits. In the absence of much research on green boundary walls, the benefits arising from green walls and other green infrastructure are reported here.

Peck et al. (1999) have comprehensively reviewed a series of qualitative and quantitative studies on green roofs and green walls to identify a range of benefits. As reviewed by those authors, the environmental benefits of green walls included improved air quality, climate change mitigation, temperature regulation, insulation of buildings, moderation of urban heat island effect, CO_2 and O_2 exchange, stormwater exchange, water filtration, and sound insulation. Oberndorfer et al. (2007) and Teotónio et al., (2021) also suggested other benefits, including increasing biodiversity, noise reduction, and mitigating the urban heat island effect. The environmental benefits through green spaces Mitigation of climate change by sequestering, carbon emissions and reduction in air pollution are benefits of urban greening (Ramaiah and Avtar, 2019).

Green plants reduce air pollution by taking up gaseous pollutants through leaf stomata and convert to acids and other chemicals (Dennis et al., 1987). Green walls can improve air quality by controlling air movement and especially the movement of dust and dirt particles (Peck et al., 1999). Greenery plays a significant role in maintaining atmospheric carbon dioxide balance by absorbing carbon dioxide for photosynthesis and releasing oxygen. Thermal comfort by greenery results from the evapotranspiration cooling and shading effect of green plants. Plants absorb water from roots, and a large portion of them again is released into the atmosphere as vapours. This process absorbs surrounding heat energy resulting in cooler conditions (Shashua-Bar, et al., 2011; Gates, 1968). An experimental study done in Colomobo, found that *Sansevieria trifasciata* has a temperature reduction potential of up to 2.3ºC (Jayasundara et al., 2017). A technical review using literature and case studies conducted to build a greener London has highlighted that green roofs can bring some improvements. These include the thermal performance of buildings, reducing the urban heat island effect, absorbing rainfall, enhancing biodiversity, providing residents' amenities, and improving the appearance (Greater London Authority, 2008). Green walls have a sound-absorbing impact (Azkorra et al., 2015). Veisten et al., (2012) estimated that a green wall with a height of 9.2 m could reduce the noise level by 4.1 dB.

Green infrastructure and green walls can bring economic benefits by increasing property values, reducing energy requirements in the associated building while becoming a food source, as presented following literature. Economic benefits include increased property value due to aesthetic quality (Peck et al., 1999). Energy savings for winter heating and summer cooling and the increase of durability of building facades can be considered personal economic benefits (Rosasco, 2018). Vertical green layers can enhance building performance creating an air layer between the building envelope and green layer (Perini et al., 2011) and reducing the 50% of energy requirement for air conditioning in the Mediterranean climate (Mazzali et al., 2012). The green wall concept can be used for urban agriculture to produce high-quality fruits and vegetables in a limited space available in urban areas (Papadopoulou, 2013). Since some of the intangible benefits of green infrastructures, such as those generated by biodiversity, don't have a formal market, researchers have attempted to evaluate those based on non-marketed valuation techniques (Collins et al., 2017). Gao and Asami (2007) have applied hedonic pricing to evaluate green walls, and they have found that an increase in greenery would increase land price 1.4% in Tokyo 2.7% in Kitakyushu of Japan.

Increase environmental quality by reducing greenhouse gases, heat island phenomena reduction, better air quality due to abatement of pollution indoor and outdoor comfort improvement and increase of biodiversity will result from green walls. These would be social benefits since the beneficiaries are humans in society (Rosasco, 2018).

The psychological and aesthetic benefits of urban greenery have been extensively studied by researchers in environmental psychology, especially in the 20th century. White and Gatersleben (2011) have summarized the key trends associated with urban greenery. They suggested that those areas with vegetation and nature are perceived as more positive than those without. Further, they highlighted that natural and vegetated regions have higher preferences than built areas. At the same time, they are perceived as more aesthetically beautiful and evoke more positive emotions while having more restorative effects. Green roofs improve visual and aesthetic appearance in urban areas (Fernandez-Cañero et al., 2013). Buildings vegetated with certain types of vegetations appeared to be aesthetically pleasing and restorative than those without vegetation (White and Gatersleben, 2011). However, the authors also presented another argument that some of the generalizations from landscape research may have validity issues when applied to natural residential settings where the resident perception may vary if their houses vary from a standard house. A study done in Germany on people perception about roadside greenery revealed the presence of positive perceptions related to "Plants are important for the quality of life", "nature in the city", "it lifts the spirit", "aesthetic value", "wellbeing" and without plants everything grey and ugly. Roadside greeneries enhance the bonds with nature (Weber et al., 2014). According to Tsantopoulos et al. (2018), for people in Athens in Greece, the most important benefit from constructing green infrastructure is the improvement of aesthetic properties and improvement of quality of life of tenants.

1.2.3 Challenges And Demotivators For Green Walls And Other Green Infrastructure

Challenges faced in installing and maintaining green infrastructure may keep the residents from adopting such. As detailed in the studies presented below, these problems include lack of knowledge related to installation, possible plant species, and maintenance is the main challenge. Costs at various stages, issues such as insects and diseases, or the time commitments for installation and maintenance are among others. Limited knowledge of officials and developers responsible for city planning, barrier issues in cost and unfamiliarity, and lack of incentives cause to limit the vertical greening systems in Texas (House, 2009). Past failures, the absence of design guidelines, and limited local expertise on the green roof are the main obstacles in implementing the vertical greening system (Zahir et al., 2014). A study in Cairo, Egypt, revealed that people who preferred vertical green infrastructures were more familiar with the system. The study showed that people's main concerns are maintenance, insects, installation cost, and irrigation. They are also concerned about the lack of technical understanding on plant selection and orientation, soil stabilization, impact on building envelope while worrying about maintenance problems such as falling of leaves. According to (Koraim and Elkhateeb, 2017) prior knowledge can affect on residents' concerns related to greenery.

A study by Papadopoulou, (2013) reveals people consider construction and maintenance cost, lack of knowledge, problems with irrigation, mould and moisture problems, damage to the wall, salt accumulation, attraction of insects, and excessive pollen as challenges for greenwalls.

1.2.4 Interventions And Incentives To Encourage Green Walls And Other Green Infrastructure

Different forms of interventions such as providing subsidies, can increase green infrastructure. Government interventions and incentives as well as contributions in the form of money, tax reductions support for installations, may encourage more green infrastructure as described in the studies below.

A study in Germany revealed that most people believed roadside greeneries are planted either by municipal action or by private initiatives, which indicates the need for interventions at the municipal level or as private initiatives (Weber et al., 2014). Amsterdam, Netherlands, and Shanghai, China are two examples. Residents of Amsterdam can apply for a subsidy of 50 €/m² up to a maximum of 50% of the total installation costs. A maximum of 20,000€ assistance were to be awarded for each project. The Shanghai Municipal Afforestation and City Appearance and Environmental Sanitation Administration has introduced a subsidy for the total green area of their city (Papadopoulou, 2013).

The studies mentioned above on green infrastructure provide evidence on how the residents perceive benefits and challenges. It is necessary to consider citizens' views and attitudes when planning cities integrated with vertical greenery systems through urban planning strategies (Tsantopoulos et al., 2018; Jim and Chen, 2006). In the absence of a comprehensive study on resident perception on green facades of Colombo, this study aims to explore views of people about roadside green facades. It includes benefits arising from the roadside green facades, challenges people to face when and after installation. Further, to support greening initiatives, effective and applicable strategies in Sri Lanka would be proposed based on the perceptions identified in the study.

2. Methodology

2.1 Study Area

Colombo district is the commercial capital and most densely populated district of Sri Lanka. Several high dense residential areas within the district were selected to carry out this study which included Rathmalana, Dehiwala, Mt. lavinia, Kesbawa, Piliyandala, Maharagama, Moratuwa, Malabe, Kaduwela, Kotte and Homagama. Data collection was done by using a structured questionnaire (Balram and Dragićević, 2005). Using a random sampling approach, research data was collected through a google form. Three hundred twenty-eight (328) questionnaires were collected from participants of the areas mentioned above of the Colombo district.

Questions related to socio-economic characteristics and whether they have a green wall, perceived cost and time to construct and maintain green walls, were raised in Section A. In Section B, the public perception on greening the boundary walls was evaluated along with two facets, namely perceptions towards benefits of green walls and challenges of adopting green walls. A set of representative variables was first identified for each of these facets based on a pilot study conducted using a qualitative approach. This set was further enriched with relevant variables identified from the above literature review especially based on the study of Tsantopoulos et al. (2018). The variables were presented to the participants in the form of Likert scale-based statements, and the participants rated each statement for the degree of agreement. As an example, data for benefits arising from the construction of a green boundary wall was obtained by getting them to evaluate the benefit variables on a 5-point Likert scale of 1 (do not agree as a benefit) to 5 (strongly agree as a benefit).

2.2 Data Analysis Approach

Data of Section A on socio-economic factors, perceived cost and time requirements and presence of green boundary wall were analyzed using descriptive statistics. The representative variables for both benefits and challenges were first analyzed using descriptive statistics to identify trends of resident perception for green boundary walls. Two distinct factor analyses were conducted to find out underlying factors which represent the relationships among benefits and challenges. K modes clustering method was used to identify different clusters within the sample based on perceived challenges for adopting green walls. All analyses were carried out in R statistical software package.

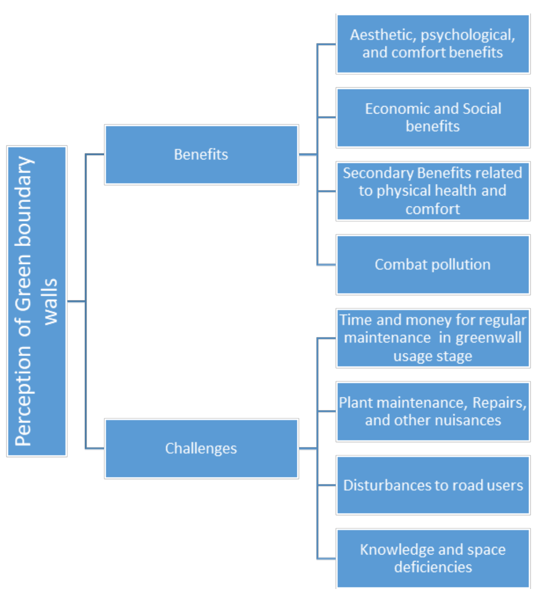

Figure 1 Underlying factors for benefits and challenges of public perception towards green boundary walls

3 Results and Discussion

3.1 Sample demographic characteristics and presence of green boundary wall

The study sample consisted of 328 participants, 51% males and 49% females. Care was taken to have participants representing different age groups, income levels and education levels. Only 15% of the participants of this study had a green boundary wall in their houses.

3.2 Benefits from green boundary walls

The percentage of people agreeing on the benefits is nearly 90% for most benefit variables (Table 1). All the variables had their mean values above 3.50, while many exceeded 4.00. With Likert scale value 3 indicating the neutral opinion, these values indicated participants agreed to the benefits of green walls.

Among the benefits, a higher level of agreement was observed for, "Seeing green make me relaxed" (4.58), "Improve the aesthetic of property" (4.49), "I can feel close to nature" (4.47), "Improve the air quality/purifies air" (4.46), "Growing plants is good for health" (4.41), and "Improves thermal comfort" (4.40). All the first 11 variables had a mean score above 4 and proved that participants strongly agree with the multiple benefits of façade greening. The remaining ten variables still showed mean values greater than 3.50, indicating participant agreement for those. The least values of these were "Safeguard wall against weather" (3.60), "Reduction of energy requirement" (3.59), "Sources of food" (3.58) which were related to material benefits.

The factor analysis revealed four important factors that explain 60.79% of the total variance (a-Cronbach=0.925; Keiser-Meyer-Olkin = 0.923; χ^2 =3239.978; df=210; $p<0.001$). As detailed in Table 2, four major factors were identified as deterministic factors for benefits. The first factor was named as "aesthetic, psychological, and comfort benefits". This had a higher loading from variables, I can feel close to nature; seeing green make me relaxed; Improve the air quality/ Purifies air; Growing plants is good for health; Effective use of available limited space; Enhance the image of the area; hiding artificial elements; improve the aesthetic of property and improve thermal comfort.

Table 1 . Level of the agreement for the perceived benefits arising from green boundary walls

		Percentage of participants expressing different opinions		
	Mean	Agree	Neutral	Disagree
Seeing green make me relaxed	4.49	92	4	4
Improve the aesthetic of property	4.48	93	4	3
I can feel close to nature	4.46	92	5	3
Improve the air quality / Purifies air	4.45	92	5	3
Growing plants is good for health	4.42	90	7	3
Improve thermal comfort	4.39	91	5	4
Effective use of available limited space	4.39	92	6	2
Biodiversity enhancement	4.26	88	7	4
Enhance the image of the area	4.22	84	12	5
Hiding artificial elements	4.19	87	8	5
Improve the microclimate	4.11	83	11	6
Reduction of dust and vehicle smoke	4.10	82	9	9
Creation of shade	4.02	77	13	10
Improve the quality of life of tenants	3.89	71	19	10
Help me to be physically active	3.8	68	22	10
Increase the property value	3.69	62	26	12
Creation of a setting to have a social interactions	3.62	57	30	12
Reduction of energy requirement	3.58	58	27	15
Safeguard wall against weather	3.58	60	24	16
Reduction of noise pollution	3.57	57	28	15
Source of food	3.57	57	31	13

Table 2. Rotated component matrix for value variables related to benefits

	Factor			
	Aesthetic, psychological, comfort, benefits	Economic and social benefits	Secondary Benefits related to physical health and comfort	Combat pollution
I can feel close to nature	0.816			
Seeing green make me relaxed	0.809			
Improve the air quality / Purifies air	0.772			
Growing plants is good for health	0.710			
Effective use of available limited space	0.697			
Enhance the image of the area	0.687			
Hiding artificial elements	0.655			
Improve the aesthetics of the property	0.628			
Improve thermal comfort	0.564			
Improve the quality of life of tenants		0.781		
Increase the property value		0.685		
Reduction of energy requirement		0.596		
Creation of a setting to have social interactions		0.580		
Source of food			0.788	
Safeguard wall against weather			0.616	
Creation of shade			0.561	
Help me to be physically active			0.532	
Reduction of noise pollution				0.833
Reduction of dust and vehicle smoke				0.713
Percentage of variance explained by the component	26.6	13.2	10	9.8
Cumulative percentage explained by the component	26.6	39.8	49.8	59.6

The second identified factor was "Economic and social benefits". This was loaded from the variables Improve the quality of life of tenants; Increase the property value; Reduction of energy requirement and Creation of settings to have social interactions. The third factor was "Secondary Benefits related to physical health and comfort". It was loaded by the variables Sources of food; Safeguard wall against the weather; Creation of shade and Help me to be physically active. The fourth factor is named "Combat pollution" with the higher loading of variables "Reduction of noise pollution" and "Reduction of dust and vehicle smoke". Consistent observations can be done for outcomes of factor analysis, whereby the first factor related to Aesthetic and Psychological benefits explained higher variance than the fourth factor on combatting pollution.

Similar observations have been made by Tsantopoulos et al. (2018), in a study on green infrastructure in Greece. Accordingly, people have recognized aesthetic value, improvement of tenants' quality of life, and leisure areas as significant benefits of green roofs. On the other hand, interest in financial investment, suitable space for environmental education increase the building value, and biodiversity enhancement were perceived as less important (Tsantopoulos et al., 2018). De Silva et al., (2021), who studied six vegetated building facades in Colombo and their Contribution to Environmental Sustainability concluded that such green walls have achieved aesthetic aspects and provided psychological benefit.

Irrespective of higher appreciation levels of benefits of green walls, the aforementioned statistics on green wall presence in Colombo (15%), indicates the presence of some other factors which inhibits people from adopting green walls. Therefore, challenges associated with the creation and maintenance of green walls may lead to lower levels of green wall adaption was studied next.

3.3 Challenges For Installation And Maintenance Of Green Boundary Walls

According to the results on perceived challenges shown in Table 3, the agreement levels reveal that except for a few challenge variables, the participants' perceptions of challenges varied across the sample.

As per the results on agreement levels, most participants perceived Initial cost as a challenge to have a green wall. The variables which had higher agreement levels across the sample were "Lack of knowledge about construction and planting methods" (3.73), "Lack of knowledge about suitable plants" (mean 3.69), "Requires time for maintenance/pruning/shaping" (3.62), "Requires money and time for maintenance" (3.53). These variables in total, describe challenges related to knowledge gaps for construction and time and monetary demands for maintenance.

People may be receptive to advise on construction and maintenance and to receive monetary or material subsidies such as plants. The Residents of Amsterdam, Netherlands, has been provided with the incentives of receiving subsidies for initial construction (Papadopoulou, 2013), which shows their desire to receive direct financial support. Interventions in indirect support such as property tax reduction are less familiar instruments in Sri Lanka where direct interventions such as plants and fertilizer. However, indirect support such as property tax reduction is less familiar in Sri Lanka and may not be effective since the property tax for houses remains at significantly lower levels.

Table 4 gives the results of the Factor analysis for challenges. The Factor Analysis with Varimax rotation of factorial axis to variables related to challenges revealed four important factors giving an approximately equal contribution to explaining a total variance of 53.79%. (a-Cronbach=0.863; Kaiser-Meyer-Olkin = 0.816.; χ^2 =2495.754; df=210; $p<0.001$).

The first factor identified was "Demand for time and money for regular maintenance in green wall usage stage". It was loaded from the variables, require money for agrochemicals and fertilizer; Requires money and time for maintenance; Requires time for application of agrochemicals and fertilizer, and Requires time for maintenance/pruning/shaping. "Fear of nuisances to the owner" was identified as the second factor which had higher loading from Damages to the wall; Problems with regular replanting; The presence of insects; Blocks daylights; Limitations by powerlines and require frequent watering. The third identified factor was "Disturbances to road users" which was loaded from variables Disturbance to pedestrians; Disturbance to the road; Disturbance by fallen leaves and another part. "Knowledge and space deficiencies" was identified as the fourth factor. It was loaded through variables Lack of knowledge about suitable plants; Lack of knowledge about construction and planting methods, and Limited space for planting. The underlying components behind the perceived benefits and challenges towards installing green boundary walls are summarized in Figure 1.

Stakeholders for green roof establishment have identified four types of barriers: Lack of knowledge and awareness, Lack of incentives for implementation, cost-based barriers, and technical issues and risks associated with uncertainty (Peck et al., 1999). Tian et al., (2012) have identified a shortage of knowledge, Lack of interest shown by public entities, and ineffectual institution and legacy of the government as challenges for making Hong Kong greener. The present study also showed similar results on perceived challenges. Thus, irrespective of the type of green infrastructure, challenges related to knowledge gaps and technical issues are common for establishing urban greenery.

Table 3: Level of the agreement for the perceived challenges arising from green boundary walls

		Percentage of participants expressing different opinions		
	Mean	Agree	Neutral	Disagree
Lack of knowledge about construction and planting methods	3.72	70	16	14
Lack of knowledge about suitable plants	3.69	68	18	14
Requires time for maintenance/pruning/shaping	3.65	67	19	14
Requires money and time for maintenance	3.54	62	23	15
Requires money for agrochemicals and fertilizer	3.5	60	23	17
Requires time for application of agrochemicals and fertilizer	3.44	56	25	19
Presence of insects	3.44	57	22	21
Initial cost (only for greening an already constructed wall)	3.41	53	30	18
Require regular watering	3.28	51	25	24
No time for making a green wall	3.26	50	24	27
Limited space for planting	3.23	48	24	28
Damages to the wall	3.19	44	28	28
Problems with regular replanting	3.13	42	29	29
Hiding place for intruders	2.99	34	33	33
Disturbance by fallen leaves and other parts	2.96	37	25	37
Limitations by powerlines	2.93	34	33	34
Damages to the pipes	2.77	27	32	41
Blocks daylights	2.64	23	29	48
Disturbance to the pedestrians	2.52	22	24	54
Disturbance to the road	2.43	18	26	57
Looks ugly	1.87	10	13	77

Table 4. Rotated component matrix for Challenges for green boundary walls

	Component			
	Time and money for regular maintenance in green wall usage stage	Plant maintenance, Repairs, and other nuisances	Disturbances to road users	Knowledge and space deficiencies
Requires money for agrochemicals and fertilizer	0.898			
Requires money and time for maintenance	0.862			
Requires time for application of agrochemicals and fertilizer	0.853			
Requires time for maintenance/pruning/shaping	0.566			
A hiding place for intruders				
No time for making a green wall				
Damages to the wall		0.643		
Problems with regular replanting		0.631		
Presence of insects		0.628		
Blocks daylights		0.620		
Limitations by powerlines		0.610		
Require regular watering		0.596		
Damages to the pipes				
Disturbance to the pedestrians			0.867	
Disturbance to the road			0.855	
Looks ugly			0.655	
Disturbance by fallen leaves and other parts			0.459	
Lack of knowledge about suitable plants				0.848
Lack of knowledge about construction and planting methods				0.823
Limited space for planting				0.549
Initial cost (only for greening an already constructed wall)				
Percentage of variance explained by component	15.8	13.4	13.2	11.2
Cumulative percentage explained by component	15.8	29.2	42.4	53.6

Table 5 : Cluster modes identified with K-modes clustering

	Cluster		
	1	2	3
Cluster size	29%	38%	33%
Initial cost (only for greening an already constructed wall)	4	4	3
Lack of knowledge about suitable plants	4	4	4
Lack of knowledge about construction and planting methods	4	4	4
Limited space for planting	4	4	3
No time for making a green wall	4	4	3
Requires time for maintenance/pruning/shaping	4	4	3
Requires time for application of agrochemicals and fertilizer	4	4	3
Requires money for agrochemicals and fertilizer	4	4	3
Requires money and time for maintenance	4	4	3
Hiding place for intruders	2	4	3
Disturbance to the road	2	3	1
Disturbance to the pedestrians	2	3	1
Disturbance by fallen leaves and other parts	2	4	3
Presence of insects	2	4	4
Looks ugly	1	1	1
Problems with regular replanting	2	4	3
Damages to the pipes	2	4	3
Damages to the wall	2	4	3
Require regular watering	2	4	3
Blocks daylights	2	4	3
Limitations by powerlines	2	4	3
Note: Cell values denote the mode value of the perceived challenge			

Table 6. Perceived money and time required for construction and maintenance of green wall among participants of different clusters

Challenge cluster		The perceived initial cost for construction of a green wall (LKR)	Perceived monthly maintenance cost of a green wall (LKR)	Perceived time required for construction of a green wall (Hours)	Perceived time required for maintenance of a green wall (Hours per month)	Greenwell ownership within the cluster	Size of cluster
1	Mean	36902	3361	25	24	22%	29%
2	Mean	37323	2727	39	16	10%	38%
3	Mean	50825	2468	25	19	12%	33%
1	Minimum	2000	500	1	1		
2	Minimum	2000	50	1	1		
3	Minimum	2000	100	1	2		
1	Maximum	300000	50000	365	200		
2	Maximum	500000	10000	1000	90		
3	Maximum	500000	12000	240	192		
	Estimated cost *	37000	1630				
*Cost estimated (using standard rates) for cost associated with green wall (for a 6m long 2m high wall with climber support fence)							

In the presence of variations in agreement levels of perceived challenges, the possible existence of distinct user groups within the sample was explored through cluster analysis. Three distinct clusters were identified, and their perception profile can be understood in Table 5. Accordingly, people belonging to Cluster 1 placed a higher emphasis on the challenges related to Lack of time, money and knowledge. However, they neither perceived green walls as a nuisance for themselves and road users nor worried about the potential of property damages due to green walls. This cluster is nearly 29% of the sample.

People of Cluster 2 also identified Lack of time, money and knowledge as the challenges. In addition to those, they perceived green walls might damage the property or become a nuisance within their property. Further, they are neutral about the possible disturbances to the other road users. Except for Lack of knowledge about green wall constructions and plants, members of Cluster 3 take many challenges as neutral. People of cluster 3 appears to be passive/ or unconcerned about having a green wall.

Table 6 details the perceived money and time required for constructing and maintaining green walls among participants of different clusters. Further, an estimation of the cost of construction and maintaining a typical green wall was done for comparison purposes. In terms of the initial cost of construction of a green wall, members of Clusters 1 and 2 have mean values closer to each and the estimated cost value. However, members of cluster 3 perceived this need of higher investment in comparison to other clusters and the estimated cost. All three clusters have a perceived maintenance cost that is higher than the estimated maintenance cost. Further, the perceived time for maintenance for all clusters remains in the range of 30 to 45 minutes per day.

The percentage of members of cluster 1 owning a green wall was 22%, which is a notably higher value compared to the other two clusters.

3.4 Strategic Implications Of The Study To Promote Green Boundary Walls

Based on the findings of this study, the following strategies focusing on the public can be recommended to increase green facades in Colombo and similar areas.

- Knowledge on construction methods of green walls and planting such as different optional configurations should be easily available for residents who are considering incorporating façade greenery. Further, the details about the method and cost of construction and sample drawings would be helpful to install such configurations. Also making ready-made/ easy to install options available either directly or through landscape service providers may also be effective.
- Effort and money spent on maintenance may be holding people back from greening the boundary walls. Enhanced knowledge and technology on easy maintenance methods, especially for automating the plant nutrient and water level monitoring and delivery, and market availability of such devices can be proposed to overcome challenges related to maintenance.
- The residents should be educated with knowledge on how to plant and maintain a green façade what kind of fertilizers should be applied at which intervals. An online database providing the above information for potential species could be proposed.
- Subsidies for agriculture has been effective in Sri Lanka. Similarly, subsidies in the form of money, plants and fertilizer could be provided to those who adopt green walls.
- Local authorities can adopt options such as the provision of support to construct walls. Also, free or discounted distribution plants, fertilizers and agrochemicals can be recommended. Financial subsidies may also be effective, and the data on estimated costs can be referred to in deciding the values of such subsidies.
- Further interventions such as pilot programs can be introduced at local authority level with the support of volunteers youth groups. Such programs could be structured based on an understanding of the three user group clusters identified above.

Members of cluster 1 should be the first group to be motivated through a pilot program and the focus of such a program could be to improve the knowledge on practical implementation.

Those of cluster 2 have perceived additional challenges in terms of misconceptions on property damages and maintenance requirements in addition to the challenges perceived by cluster 1 members. Thus the interventions for this cluster should additionally focus on improving the awareness on above-mentioned misconceptions. Sharing the experience of green wall owners using multiple means could be effective in this regard.

Members of clusters 1 and 2 in total amount to 67% of the sample and the above measures would be able to motivate a substantial majority.

While the outcomes of the study directly apply to Colombo, other developing countries in the South Asian region with the same tropical climate may be able to use this knowledge to improve their urban greenery through boundary wall greening.

4 Conclusions

Proper understanding of public opinion is vital to encourage urban greening through green walls. Such knowledge will pave the way for better decision-making by policymakers, urban planners, and related business owners leading to more effective outcomes from greening for Colombo and similar places.

The present study showed only a marginal number of residents (15%) already have green in their boundary walls. These findings indicate a significant opportunity for greening within the remaining population. The outcomes revealed that residents place a higher value on intangible benefits such as aesthetic appearance, feeling relaxed and less weight on tangible benefits such as the source of food or energy savings.

Participants perceived Lack of knowledge of construction and planting methods of green walls as challenges. They also perceived the time and money spent on maintenance as a challenge. Three distinct clusters can be identified based on the way of perceiving challenges. Support to overcome challenges such as Lack of knowledge and time and money requirement may effectively move the members of first cluster to adopt greenery in their boundary walls. Experience sharing sessions can be recommended to encourage members of the second cluster along with support measures provided to first cluster members. Members of the third cluster are passive over adopting green walls, hence, motivating them towards green wall adoption will be more challenging. The strategies applicable to promote green walls are proposed based on the study results.

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