User Engagement Through Perception of Vertical Greenery: A Case Study in Milan

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Abstract. The fast urbanism activities increase the impacts of challenges that are faced in the built environment include environmental, economic, and social problems. These problems have made sustainability an obligation, and Nature-based Solutions (NbS) and people engagement keys factor for mitigation. Together with Green Infrastructures (GI), NbS can offer several benefits to help multi-scalar impacts reduction in urban areas. Both horizontal and vertical surfaces of a building i.e., green roofs and green walls respectively, are recently considered among GI. Vertical Green Structures (VGS) is relatively new and still under development. Hence, more research is needed on these systems to understand the benefits better and to highlight the existing the research needs. These VGS can offer both direct and indirect versatile benefits with the potential to contribute to robust and resilient cities through improvement of human health and well-being. This study focuses on perception of wellbeing deriving from a VGS installed in a case study in Milan i.e., at two university buildings in the campus. A questionnaire is prepared and circulated among the users of these buildings to understand how they interact with the installed Vertical Green Structures, as well as how they perceived and understand the VGS. The stages of social involvement and social benefits in relation to the installation of VGS are discussed with the outcomes from the survey analysis.

Keywords: User Engagement, Vertical Green Structures, Questionnaire, social perception, social awareness.

1 Introduction

It is well known that, over 50% of the population currently lives in urban areas globally. This trend is expected to increase more, with the urban population more than doubling its current size by 2050 with the consequence of 70% of the population living in urban areas [1]. This increase in population in cities caused the fast urbanism activities that accelerated the impacts of climate change, health issues, and environmental pollution. In urban areas, these challenges have such environmental, economic, and social

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repercussions to require sustainability targets as an obligation. In this framework, Nature-based Solutions (NbS) can offer multi-scalar beneficial impacts and people engagement can become the key for their successful implementation. Buildings are started to be included among Green Infrastructures (GI) when their skins constitute the GI by itself. They can be both green roofs and green walls from horizontal and vertical planes, respectively. The latter, the Vertical Green Structures (VGSs) are a relatively new technology still under development that need more research to understand the benefits and possible drawbacks. In the framework of urban regeneration, VGSs can foster sustainability in urban areas currently facing a lack of horizontal land surfaces to design novel green parks and gardens. They can be installed indoors as well as outdoors since there are different available typologies in the market [2].

Living plants, hence VGSs, can provide several social benefits i.e., the focus of this study. Firstly, they can be elements of a GI network in a way that such decentralized network of smaller green elements makes easier for residents to breathe nature with important physical and mental health benefits [3]. This potentiality of the VGSs attracted more attention especially after the pandemic. A recent study [4] -targeted staff for surveys- done during the pandemic showed that physical and even only visual interaction with living plants is beneficial for mental health of hospitalized users. Another study [5] focused on residents during the pandemic used a questionnaire to evaluate the impact of both indoor and outdoor plants on their emotional welfare and came up with similar results. [6] specifically mentioned VGS as a green element in this social context looking at biophilia theories. Other studies also investigated the VGS's impact on human health (both mental and physical) and well-being through emotional effects [7]; on comfort level through decreasing noise level [8] and providing shadow effect [9]. All the mentioned social and well-being benefits are promising, however, the feedback from users themselves is crucial to understand the perception of VGSs impact.

Even the effort in the literature to evaluate the VGS's perception is limited, there are a few studies mainly focusing on indoor VGSs installations focused on educational environments catering to students across different age groups. For instance, following a pilot project with the aim to improve the indoor environmental quality of the schools, VGS are placed in classrooms in two elementary schools in Haarlemmermeer (Netherlands) [10]. In these schools, a controlled evaluation study is conducted and the authors compared the cognitive performance, well-being, and classroom evaluations of students in classrooms with and without VGS through attentional tests and self-report questionnaires. This study found that students in classrooms with VGS scored better on a test for selective attention and had higher classroom evaluations. These findings suggest that VGS can have a positive impact on users' cognitive performance and well-being in educational places.

In another survey conducted prior to the installation of VGS among students of Vrije Universiteit Amsterdam, van den Bogerd et al. [11] aimed to understand the perceptions of greenery in university restoration. The results showed that students expressed a preference for interior spaces featuring a nature poster, a VGS, or a combination of a VGS and interior plants over spaces with standard designs and colourful posters. Additionally, the survey indicated that students rated the restoration outcome of outdoor spaces with greenery more favourably than those without. Similar to the previous study, these

findings underscore the positive impact of greenery on students' preferences and perceived restoration likelihood in education environments, they both highlight the potential value of integrating GI to enhance the overall campus experience.

In a related study conducted in a university cafeteria, Kim and Tong-Mahn [12] utilized both behavioural observations and questionnaires to analyse users' perceptions. The results revealed that while participants expressed a desire to sit near the VGS, behavioural observations indicated a different pattern, with no discernible preference for seating proximity to the VGS and no significant difference in sitting times. However, the observations did show a higher percentage of female users near the VGS. These findings shed light on the complexities of user behaviour and preferences in indoor environments with VGS, emphasizing the importance of considering diverse factors that may influence user interactions with VGS in university dining spaces.

This study has the aim to contribute the knowledge of VGS with a focus on social behaviour and wellbeing. The objective of the present study is to understand what is the existing level of user's knowledge and awareness of VGSs and what is the level of expectation of future installation of VGS at the university campus. In the following chapter (i.e., Materials and Methods) the structure of the VGS and the questionnaire design are explained. In chapter 3, Results and Discussion, answers of each question's cluster are reported. Eventually, in the conclusion, the key findings, challenges, lessons learnt, and future needs are presented.

2 Materials and Methodology

A questionnaire was prepared in both Italian and English languages and circulated among the users of two buildings in the Leonardo campus of Milan Polytechnic University to understand how the users interact with such installed VGSs, as well as to evaluate their existing knowledge and future installation or spread expectations. The users target group was constituted mainly by students from master and bachelor levels of the following disciplines: architecture, landscape architecture, urbanism, and construction engineering.

2.1 The VGS installed in the campus.

The campus is the *Leonardo* campus (figure 1a) of Milan Polytechnic University (Politecnico di Milano-POLIMI), located in the east of historic city centre called *Città Studi* area. The two VGSs were constructed on the façades of building 9 (figure 1c) and 10 (figure 1b). Building 9 is next to the parking zone and has classrooms inside. Whereas building 10 faces transit of vehicles, cycles, and pedestrians and it is strongly linked to other building which has classrooms inside. Both walls are constituted of 4 modular panels and belongs to the living wall typology. Specifically, they are the products called Zero Gravity Eden and produced by ITALMESH [13].

Fig. 1 (a) The VGS location in POLIMI campus: on the façades of building 9 and 10. **(b)** VGS on building 10. **(c)** VGS on building 9.

2.2 Questionnaire design and distribution

In designing the questionnaire (Appendix 1), careful consideration was given to ensuring a comprehensive exploration of participants' perspectives on VGS. The prepared questionnaire has in total 21 VGS dedicated questions. Beside them, two additional questions to get the respondents informed consent were not included in this count and are provided at the beginning of the questionnaire (section 0).

The questions are clustered in five main sections (figure 2a) to systematically address different aspects. The first section aims to understand the demographic background of the participants to provide valuable context for the subsequent sections. The next sections have the scope to understand general knowledge level on vertical greenery within the broader context of sustainability and NbS (section 2); emotional perception to provide insights into the affective aspects associated with VGS (section 3); and future respond and expectations to understand the anticipated engagement with VGS (section 4), respectively. Section 2, served as a foundation for assessing participants' awareness and understanding of VGS. Eventually, the last section (section 5) contains an open question that asks if any participant has further comment or insights to share beyond the structured questionnaire.

The questionnaire is consisted of 6 multiple-choice questions, 8 yes-no questions, 5 open-ended questions, and 2 rating scale questions (figure 2b) to ensure a varied and completed data collection.

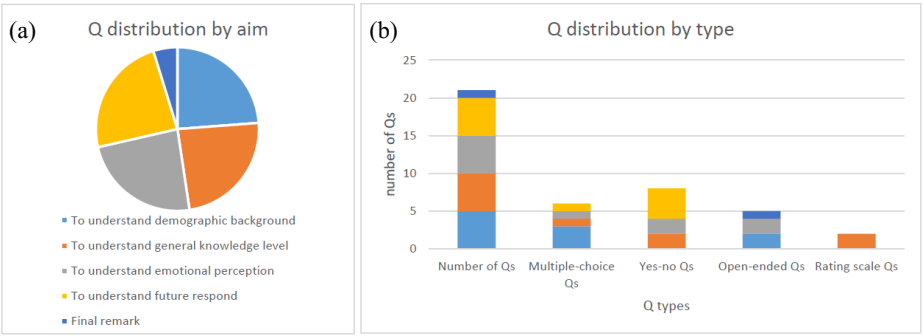
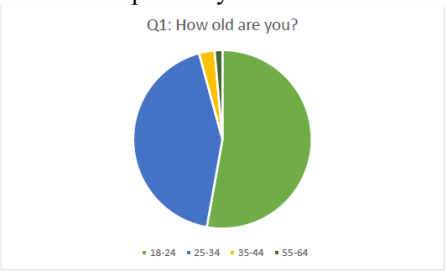


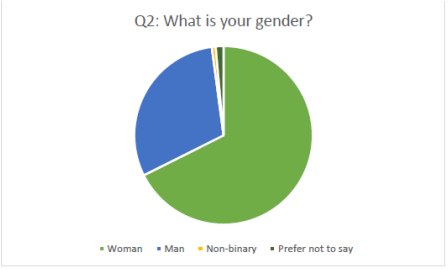
Fig. 2. Questions distribution sections based on (a) the aim of the questionnaire. (b) the type of questions.

The questionnaire was distributed among students during the lessons both sharing the link, and the QR code in the screen since the lessons were in hybrid mode. The data collection was mainly conducted in week 18 (from 2 May 2022 to 6 May 2022, except weekends). However, the questionnaires remained active till week 23 (10 June 2022).

3 Results and Discussion

The total number of respondents were 142. In figure 3, the answers to demographic background (section 1, colour blue in figure 2) constituted by five questions are represented. The respondents were mainly in the age range of 18-24 with 52,45%, the range of 25-34 follows it with 42,65% (question 1). This age distribution suggested a significant representation of younger individuals, indicating potential generational trends and preferences in their responses. The gender was constituted mainly by women with 67% (question 2). This gender distribution is a relevant factor to consider when examining perceptions and preferences related to VGS, as gender dynamics can influence individuals' interactions with urban environments. Italy was the main nationality of respondents followed by China and Iran regarding (question 3). Understanding the geographic diversity of our respondents is crucial for contextualizing the results, as cultural backgrounds may influence attitudes and perceptions towards VGS. 124 respondents among 142 were master students (question 4) who studies Architecture, Landscape Architecture, Urbanism, and Construction/Building Engineering with ratios of 65%, 46%, 28%, and 16% respectively.





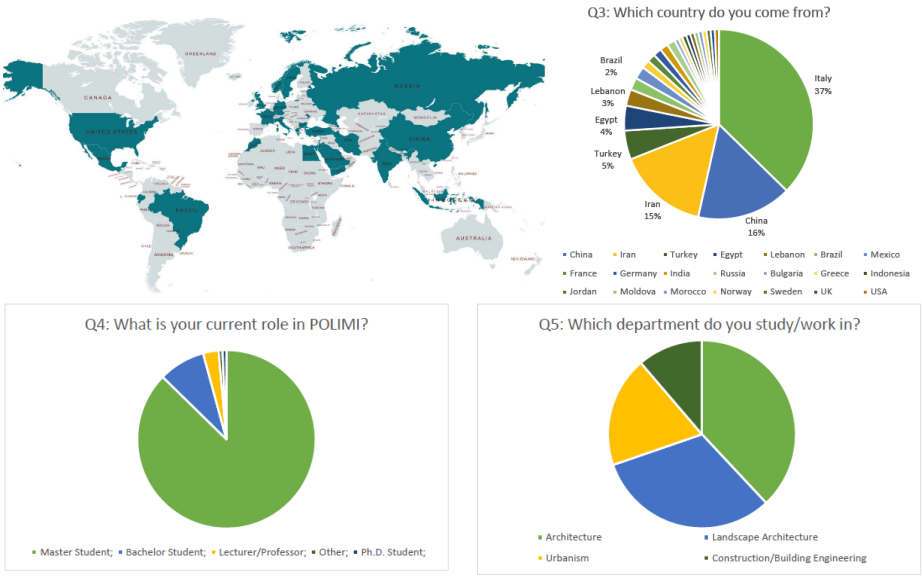


Fig. 3. Overview of the results from section 1 of the questionnaire i.e., demographic background (5 questions)

The following figure 4 shows the answers which explored the knowledge level of respondents (section 2, colour orange in figure 2) with questions ranging between 6 and 10. Questions 6 and 7 rate the level of knowledge (from 1 to 5, where 5 is maximum) about sustainability and NbS respectively. The score decreased when the topic is NbS. Whereas questions 8 and 9 ask if respondents are aware of any examples of VGSs both known from literature (theoretic example) or from practical examples (i.e., VGSs installation in cities they live in or they visited). The answers to these two questions suggested that the students know VGSs only by hearing them from literature without knowing them from practical experience. Also, it may indicate a potential gap in understanding or awareness specifically related to NbS among the respondents. Next question started to go deeper on VGS and asked some terminologies to understand which terms are well-known. 'Vertical garden', i.e., the most well-known way to call a VGS by the non-experts, was the first, followed by the term 'green wall'. The term 'living wall', was detected by the questionnaire as the most trend spreading term to define VGS nowadays, and also the technical term to define the typology of the VGSs constructed in the campus had a very low rate of knowledge. This observation raises questions about the accessibility and dissemination of technical terminology within the respondents.

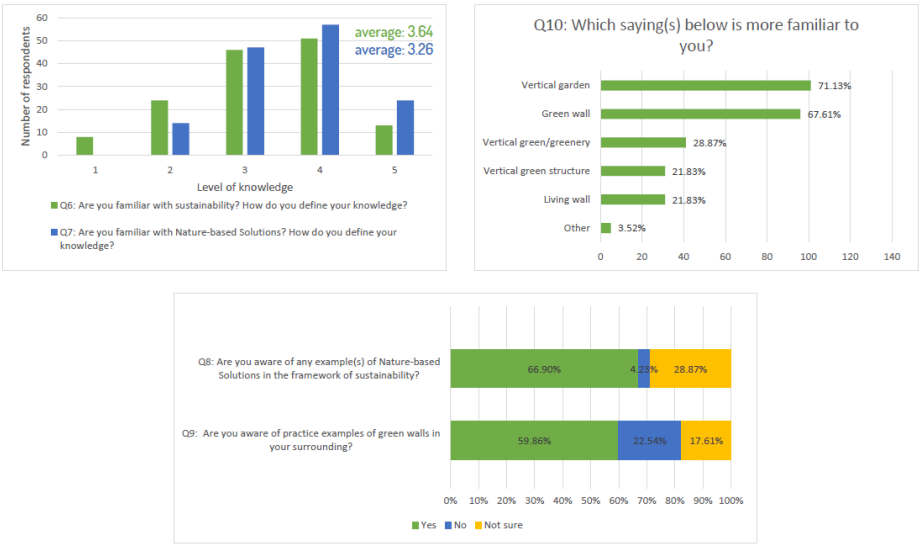


Fig. 4. Overview of the results from section 2 of the questionnaire i.e., general knowledge level (5 questions)

Most respondents answered positively to the section 3 of the questionnaire related to emotional perception (section 1, colour grey in figure 2). Figure 5 shows the answers to these dedicated questions i.e., 11, 12, and 13. Most respondents stated that the VGS attracts their attention in comparison to a bare wall (question 11) and have impacts on the environmental perception (question 12). Besides, most of them stated that they feel close to nature and relaxed. The following two questions were open questions which asked to write down 3 words to describe emotionally this environment (question 14) and the VGS (question15) respectively. The most written 5 words for the environment were as the following: ecology, relaxing, nature, air quality, sustainable. The words written for the VGS were biodiversity, clean, aesthetic, natural, comfortable. These themes in participants' responses highlight the positive emotional associations linked with both the environment and the VGS, emphasizing the importance of these green features in contributing to a sustainable, aesthetically pleasing, and emotionally enriching built environment.

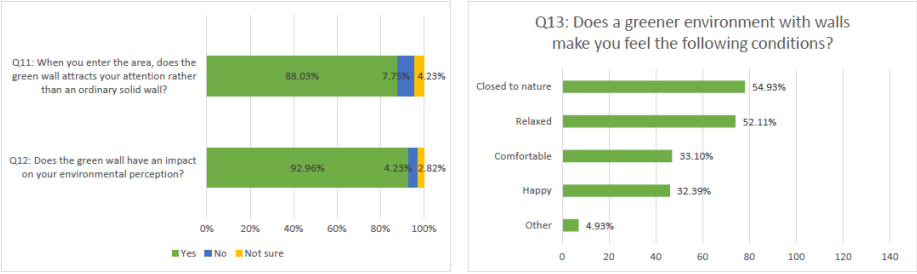


Fig. 5. Overview of the results from section 3 of the questionnaire i.e., emotional perception (3 answers among 5 questions)

The following section (section 4) was related to future expectation (section 1, colour yellow in figure 2) when dealing with VGSs and it is constituted of a multiple-choice question with the possibility of choosing more than one choice, and 4 yes-no questions (figure 6). The question 16 listed down VGS' benefits and asks if the respondents are aware of them. More than half respondents stated that they are aware of the following benefits: "to provide shade", "to create aesthetic", "to improve air quality", "to benefit mental health", "to enrich biodiversity", "to reduce noise levels", "to provide shade for comfort". All these benefits were mostly the ones they can experience with their personal observation/practice. However, the other benefits that were mainly not selected by students require more expertise and/or interest. They were energy efficiency benefits or water management contributions that unfortunately remained as sort of 'hidden benefits' for the respondents even if they were the ones which would have high potentiality in helping in combating economic and environmental problems. The following question (17) mainly aimed to understand the expectation of respondents on the willingness to be informed on VGS. The answer to his question is promising for the future integration and utilization of VGSs, indicating a potential for widespread interest and adoption within the academic community. More than half was aware of some negative aspects. Even if the sample of respondents were not too big to generalize the results, it could be said that a widespread research/design/usage of VGS in future is possible since 86% of students who studies relevant field are willing to be educated on VGS. The last two questions (19 and 20) in this section asked if the respondents prefer to have VGSs in their environments indoors and outdoors respectively. They preferred such installation more outside then inside, which was mostly caused by the concerns about insects/bugs as they indicated in the next question. Similarly, as [5] included VGS in their survey besides single plants, the results showed these structures were considered as advantageous for increasing indoor vegetation, but they were also associated with technical and economic issues.

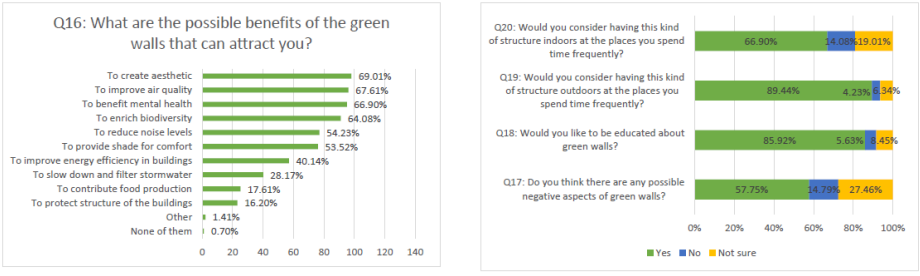


Fig. 6. Overview of the results from section 4 of the questionnaire i.e., future respond (5 question)

Question 21 was the last open question (section 5, colour dark blue in figure 2) to ask for the final remark. Although 57% of the respondents answered as no, there were

some replies which helped to understand the aspects that are overlooked during the questionnaire design, as well as to considered for the future development of VGS. The selected replies were directly copied and presented below:

‘Depends on the kind of green but you may have bugs problems or foliage problems during autumn’
‘Green walls have pros and cons that offer some great benefits, but they also present some challenges because choosing the right types of plants is important. Fast-growing, invasive plant species and some climbing vines can quickly grow out of control if left unchecked’
‘I think green walls are a good opportunity to have green also in vertical spaces, and they can/should be use’
‘In my hometown (Iran), there are some natural green walls with natural Bindweeds in a humid context which people consider a nice area and take care of that plats. It is a kind of traditional greenwall which I experienced and love it’
‘it would be interesting to actually learn about this subject and how to use it especially in my masters for instance where architecture is combined with landscape to create the paesaggio. i find important to be able to know how to merge different elements together , their place and importance such as green walls , knowing what they can offer ...’
‘Vertical Garden is one of the smart solutions for sustainable architecture. I am so interested in their effects ecologically and psychologically on the building and its users’

The respondents mostly appreciated VGS for aesthetical values, however, they were also aware of a possible negative aspect e.g., attracting bugs/insects. This was probably the main reason why more of them replied as ‘no’ to question 20 more than question 19 where they were asked their willingness to have VGS indoors and outdoors respectively. A few of them stated the importance of plant selection. This question showed that the acceptance of the VGS by people is up to cultural background as well in case people are used to have these structure in their hometown.

4 Conclusions

This study used a questionnaire to evaluate the knowledge level, perception, and the future potentiality of VGSs installation in university campus. The respondents mostly consisted of high-level education students from Milan Polytechnic University campus in Milan, Italy. The results showed that although most of the respondents consider themselves knowledgeable in sustainability, however, this score decreases when the scale of topic is narrowed down to both NbS and VGS. On the other hand, participants who state they have high level of knowledge on NbS, are more aware of VGS. The participants who consider themselves with high knowledge, are mostly aware of the main benefits VGSs contribute to, except their functions in food production, protecting skin on wall surface, storage (or demanding) water system, and in enhancing thermal insulation. Students stated that they would like to be trained more on the topic of VGS.

The questionnaire was designed to be as objective as possible by providing participants with clear and unbiased questions. However, there is always a possibility that

subjective factors, such as personal preferences or prior knowledge, may influence responses. To mitigate this, the questionnaire included a variety of questions to assess these subjective factors. This triangulation of data helps to provide a more comprehensive understanding of the target audience's views.

The findings may indicate that a small percentage of respondents considered VGSs as less pleasing or practical compared to plain wall surfaces. This could be attributed to factors such as the initial cost of installation, the potential for maintenance issues, the risk to attract the insects, or the lack of knowledge of potential benefits of VGS. In future studies, it would be valuable to explore these perceptions in more depth to understand the underlying reasons and address any concerns that may hinder VGS adoption.

The result of this analysis helps to understand the target group's interest and experience of vertical greenery as well as their future expectations from it. It is crucial to acknowledge that the respondents primarily belong to the Built Environment professionals, including students and a few teachers and professionals from the courses of Architecture, Landscape Architecture, Urbanism, and Construction/Building Engineering. Therefore, the conclusions drawn from this study should be interpreted within the context of this specific professional universe. In addition, it reinforced the trend of campus greening [14–16] through increasing the amount of green in educational buildings since the students, i.e., main users of these areas are willing to have VGSs for their well-being. With considering the limited places to plant brand new vegetation, these structures are offering a flexible solution to green the campuses.

However, this study has the limitation of generalizing conclusions beyond this specific universe. The participants' unique background in spatial issues and training within the Built Environment does not necessarily represent broader societal awareness.The VGS technology should improve looking at the ways users -from broader scales- are experiencing (or not-experiencing) the existing VGSs to make steps forward towards the optimization of social benefits.

Since this is ongoing research, the future aims of this work are both to enlarge the pool of target groups participating the questionnaire and to create new sections for assessing the awareness of benefits - nowadays still hidden - in the use of vertical greenery as well as to explore how to use VGS in an unconventional and possible even more economic sustainable way.

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