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REVIEWING THE INTERVENTION OF LANDSCAPE IN VERTICAL GREENERY SYSTEMS (VGSS)

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ABSTRACT

Concern for green technologies with efforts to strive for the quality environment can be achieved via VGSs. The systems provide multiple benefits by restoring greenery in urban landscapes. In general, they help improving environmental, social, economic, and ecological values. Green technologies have been in the industry for more than a decade. However, the contribution from the landscape architecture circles is found insufficient. Hence, for a start, this paper reviews the intervention of landscape in VGSs from the aspects of system operation, plant component, and landscape maintenance. The aim is to create an eye-opener amongst the experts, whose expertise in similar studies can assist in sustaining the usage and lifecycle of the systems. Both reviews of literature and personal observations traced the necessary data having concentrated on green wall and living wall. Information on the operational nomenclatures of VGSs is useful to reduce confusion amongst researchers and academics. Simple insights of this study would encourage in-depth explorations in the areas of the landscape. Consideration to opt for local plant species of the tropical climate is a convincing topical topic suggested for future research.

Contribution/ Originality: This study contributes to the existing literature reviews the intervention of landscape in VGSs from the aspects of system operation, plant component, and landscape maintenance towards sustaining the usage and lifecycle of the systems. Information on the operational nomenclatures of VGSs is useful to reduce confusion amongst researchers and academics.

1. INTRODUCTION

It is forecasting that the world population may increase dramatically by 2050. The news suggests that sixty per cent of the population may choose to live in urban landscapes. In some cases, high urbanisation may tabulate unpleasant visual phenomena. These describe the conglomeration of high-rise, concrete jungles with dense physical developments, and drastic loss of green land use [1]. Similarly, developments with uncontrolled anthropogenic activities can lead to environmental degradation like pollutions, global warming, and climate change [1-4]. It is noted that massive land clearing for a similar purpose would contribute to Urban Heat Island (UHI) effects [5] and global warming. The reflection of solar radiation causes UHI on hardscapes when producing longwave radiation or heat effect [6, 7].

It is observed that demands for quality indoor and outdoor urban environments can be challenging because to restore greenery is harder than to dispose of it. For instance, the use of a mechanical solution to reduce the air temperature of a room has adverse effects; e.g., air conditioning releases toxins and increases air temperature. On the other hand, Vertical Greenery Systems (VGSs) are the technologies designed to reduce some of the undesirable effects [4, 6, 8]. The tools are originating from natural material of plant component. VGSs are globally recognized for mitigating UHI effect and energy crisis in a building [9, 10]. Assessments on the effectiveness of the intelligent systems demonstrate significant reduction of air temperature and heat flux as well as energy consumption in buildings [2, 11-15].

It is found that pioneers of VGSs have used several operational nomenclatures to describe the same system. For instance, some may coin *vertical greenery* as *vertical garden*, *living wall*, *green wall*, *green façade*, *bio-wall* or *vertical vegetation* [2, 6, 9, 16-18]. Thus, to identify the regular nomenclatures used in the study is necessary to reduce confusion or conflict in academic research. It is interesting to know that VGS is sometimes coined as a *Passive Energy-Saving System* [17, 19]. In summary, the review provides a clearer understanding of the subject and direction of the study. Notwithstanding, this paper has focused on the two branches of VGSs, which are *green wall* and *living wall*.

VGSs are part of Urban Green Infrastructure (UGI) network, where nature has significant implications on quality urban environment [7, 20]. The systems use landscape solutions to remedy a deteriorating urbanscape, in which plant is one of the essential components. In theory, the principle of VGSs is close to the principles of sustainability and ecology. The borrowed principles are amongst the tenets found in the landscape architectural profession. Reviews consistently identify the role of VGSs in restoring environmental integrity with sound ecology [21]. Besides that, the systems also enhance the visual impact of urban landscapes Nyuk, et al. [22]; Manso and Castro-Gomes [23]. Sheweka and Mohamed [6] further note the implications of VGSs on the aspects of social and economic. The review may philosophically suggest that the technologies have been regenerating from the principles of *sustainability* and *ecology* by borrowing the concept of '*bringing back nature into urban living*.'

Importantly, there is an agreement on the importance of plants in the operation of VGSs [17]. Perhaps, it would be wise to engage a horticulturist or landscape architect to address an issue concerning landscape elements. The selection of plant species and best landscape maintenance practices are necessary to sustain the lifecycle of VGS. Therefore, collaboration amongst the relevant professionals concerning the aspects of façade design, construction materials, plant selections, and maintenance would develop a more compelling environment with better ambience. With that, this paper reviews the intervention of landscape based on *green wall* and *living wall*. An overview of the operational nomenclatures and landscape issues was traced from reviews of literature and personal observations. The preliminary insights may enhance the research gaps through data sharing on live projects of VGSs of newly built buildings observed in a tropical region.

2. BACKGROUND STUDY

Some chronicles on the invention of *a green wall* can be traced in the works of Alabadla [12]; Dutta and Mani [4]; Hoong [24] and Timur and Karaca [25]. Perhaps, more credits should be given to the Mesopotamian for the creation of a *roof garden* dated sometimes in 2500 BC; e.g., the Hanging Garden of Babylon. The reviews suggest that the earliest intervention of landscape architecture in VGS can be evidenced since the civilisation. Apart from being a symbol of love, this wonder of the world can be accepted as the masterpiece of VGS in the history of landscape architecture. Perhaps unintentionally, between 3th. BC and 17th. AD, the Roman Empire had invented a system, which principle was idealised from a planting concept. The basis to Roman's *green wall* has idea borrowed from a grape vinery. The vinery was trained to self-climb on a façade of villas and trellises. Then, the concept of *the garden city* was developed in North America and Great Britain in the early 1900s. The era witnessed more exploration in the circles of landscape, where landscape furniture (e.g., trellis and pergola) and plants from self-climbing species were initially introduced.

Contemporarily, there is a significant improvement in the technique of installing plants in both *green wall* and *living wall*. For instance, cable and wire-rope systems, together with modular trellis panel are used for climbers to cling on. The approach allows plants to grow better. Thus, technologies of VGSs are becoming more sophisticated when the purpose of the installation is not only for aesthetic enhancement but also more on the environmental enlivenment of cities. Such rapid advancement of VGSs is due to the lack of green space available in urban areas. The situation can implicate the development of horizontal gardens [18]. Perhaps, the promotion of VGSs can be seen in the work of a French botanist named Patrick Blanc. He had successfully aroused the public's awareness of the implications of VGSs at public, private, and commercial buildings. The scenario describes the potential of regenerating healthy living by bringing back greenery into polluted urban landscapes. Perhaps, the use of VGSs would be more efficient in the tropical region because of one season climate and therefore, fewer issues to consider when selecting the plant component. Nevertheless, this is something to be rebutted in research since more empirical data with a methodical and thorough procedure are required to reveal the level of effectiveness claimed.

In summary, VGSs provide convenient visual and environmental tools because they suit to all urban environments. However, issues on site, location, local climate, plant component, supporting structure, irrigation system, sustainability, and maintenance may influence a successful operation. Still, more attention should be given to the aspect of plant selections [17] because they are an essential component of VGSs. The best selections of plant components may derive from the properties and characters. For sustainable usage and lifecycle of VGS, continuous research and development are needed [17]. So far, studies on plant materials and planting techniques of VGSs receive good responses amongst the contemporary researchers [17].

3. GENERAL INSTALLATION

VGSs can be installed on the walls of buildings located in multiple climates. In tropical regions, most buildings are exposed to heavy rainfalls and intense sunlight. Interestingly, the climatic situation does not implicate the operation because the systems are designed for buildings with zero climatic restrictions. A vegetated wall of VGSs can reduce the cost of paintings and decrease wall deterioration caused by UV (ultraviolet) rays. Many studies have supported the environmental outcomes of VGSs relating to air temperature and energy-saving building [2, 8, 17, 26-28].

It is observed that VGSs adopt the planting concept borrowed from several natural settings like a waterfall, riverbank, seeping rock, and cliff. In these ecosystems or landscape features, climbers are mostly relied on the natural vertical wall to grow. The planting principle of VGSs adopts a similar concept of vertical growth identified in the natural settings. Both *green wall* and *living wall* are the systems classified under VGSs. The human-made vertical structure of VGSs requires a feature like cladding element to support the growth of climbers [25, 28]. In principle, VGSs are friendly environmental tools that can be installed on both the interior and exterior of walls of the building [4].

There are cases where plant component is not installed on an envelope of a building but rather on a self-standing wall. The former explains the nature of using a *green wall* system, while the latter refers to the approach of a *living wall*. Generally, both systems use a specific vertical structure to support the growth of climbers, which technique was earliest practised by the Roman Empire. As described in Dutta and Mani [4] and Yuan [28] a *green wall* adopts a framework including mesh, wire or cable fixed to a wall for climbers to cling on and weave through. The followings are the contemporary installations of plant component under the *green wall* (*GW*) and *living wall* (*LW*) systems: i) Modular grid system (*LW*), ii) Trellis panel system (*GW*), and iii) Wire/rope net system (*GW*). Both climbers and creepers are the standard plant components of *a green wall*, while climbers and some potted plant species work effectively for a *living wall*.

4. LANDSCAPE INTERVENTION – OPERATIONAL COMPONENT

This study further describes the intervention of landscape in the operation of a *green wall* and *living wall*. Pérez, et al. [29] provide clear explanations on the operating methods of VGSs, though their studies have not explicitly focused on landscape issues. Similarly, a review of the literature reveals that very few research had explicitly discussed the aspects of landscape maintenance (e.g., soil fertilization, pesticide control/weeding, and pruning and irrigation) of both *green wall* and *living wall*. Meanwhile, [17] provide a lengthy discussion on the advantages and disadvantages of VGSs with focusing more on the issue of cost. The review suggests that some key issues should be considered when selecting a system. The following briefly summarises the operational aspects of a *green wall* and *living wall* from the perspective of landscape architecture.

i. *Green Wall*: The operation does not require a specific vertical feature attached to a wall when plants originate from a self-adhesive component (e.g., creepers). However, the structure is vital to the non-adhesive plant component (e.g., climbers). Here, the installation of the vertical feature is to assist and support the growth of tendrils and twinning stems. The structure is usually made of wire rope or cable to allow shoots to cling on for healthy growth. The system provides a planter box for efficient growth of plants and maintenance and roots protection. The planting technique is suitable for perennial species, while the generic operational systems of the *green wall* include the *support*, *planter*, and *pocket systems*.

ii. *Living Wall*: Normally, the operation involves intricate supporting features. Complexity may refer to the methodology of installing the plant. Step i) Pre-planting stage: Young plants are planted in a box, tube, or tray; Step ii) Planting Stage: Once reaching to a certain height, plants are transferred into a modular unit cladded to a wall. The vegetated wall can be vertical, angled, or horizontally designed. Plants are irrigated using a drip system and fertilized using organic or inorganic media. Similar irrigation and fertilisation exercises apply to a *green wall*. At this point, the operating system of the *living wall* only involves carrier/modular system. The modular units should encompass drip, geotextiles, polypropylene plastic containers, growing medium, and plant materials.

Table 1 summarises the planting operation of both *green wall* and *living wall* with brief descriptions of planting techniques [30]. Earlier, Chen and Hien [31] have suggested similar operation but using different nomenclatures to describe the system. Again, the information in Table 2 is useful to reduce uncertainty while conducting the study. Both Figure 1 and Figure 2 illustrate several images on the live project of VGSs in the newly built high-rises in the local context. Finally, Figure 3 illustrates the drip irrigation system of a *green wall*, which application is also applicable to a *living wall*.

Table-1. Types of operational systems in the *green wall* and *living wall* of VGSs [30, 31].

Operational of VGSs	Descriptions
Carrier System (CS) /LW	The carrier system comprises of several modular units of containers with a growing medium. They are connected to metal framings and attached on wall surfaces. The system is connected to a building façade.
Support System (SS) /GW	The support system consists of planters mounted on welded wire trellises. The trellis is suitable to climbers for a 'green screen' ambience. The system engages a wire-rope or cable for plants to climb up. A planter box is a container to protect the plant roots and secure an acceptable amount of water and fertilizer for healthy growth.
Planter System (PS1) /GW	The planter system consists of a single pot mounted on a structure. Draping plants are the medium used to produce continuity of a vertical garden. A planter box is provided at every level of a high-rise and attached to a façade of a building.
Pocket System (PS2) /GW	The pocket system consists of fabricated panels. A wired mat is attached to an inflexible backup for support. The pockets are designed at an external layer of a facade for planting purposes. The system uses both wire-rope and planter box at each level.

Notes: *GW=Green Wall*; *LW=Living Wall*; CS=Carrier System; SS=Support System; PS1=Planter System; PS2= Pocket System.

Both review and personal observations indicate that VGSs can be installed for all types of buildings, including hotels, offices, shopping malls, retail shops, residential, and institution. Despite that, selection of a system should consider the function of a building and reasons for installing one. For example, a *green wall* with a wire-rope system is more suitable for a high-rise building of multi-level parking lots. Here, such a system can reduce traffic pollutions and UHI effect of both buildings and parking lots. More importantly, the plant selections of VGSs should tolerate the local climate [6, 23]. Perhaps, the suggestion to use local species is due to ones' endurance and sustainability.

Table-2. Common operational nomenclatures of VGSs.

Green Wall		Living Wall	Reference
1.Wall-Climbing	2. Hanging-down	3. Module type	Chen and Hien [31]
1. Support System	2. Planter System	3. Carrier System	Allan and Kim [30]

Source: Allan and Kim [30]; Chen and Hien [31].

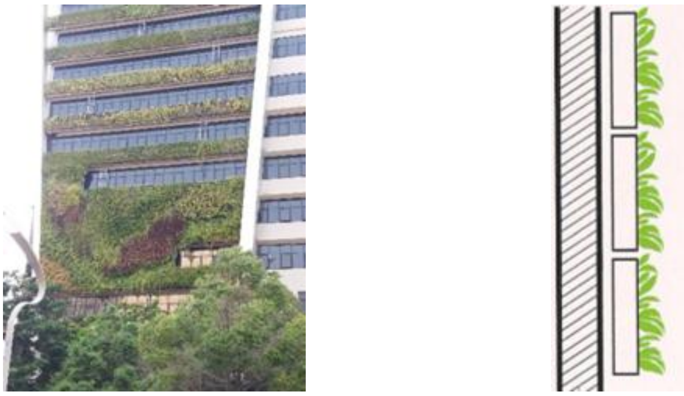

Figure-1. View of *living wall* using a carrier/modular type of operational system.
Location: Federal Territory Putrajaya, Malaysia.
Land use: Administrative
Source: Badrulzaman, et al. [26].

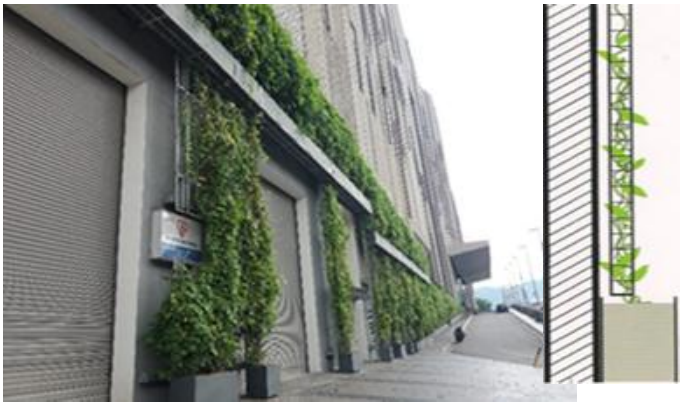

Figure-2. Views of *a green wall* using a support/wall-climbing operational system.
Location: Federal Territory Putrajaya, Malaysia
Land use: Commercial
Source: Badrulzaman, et al. [26].

Figure-3. Views of a *green wall* using a drip irrigation system.

5. LANDSCAPE INTERVENTION - PLANT COMPONENT

High-rise can be categorised as leisure, retail, industrial, healthcare, office, and residential buildings. Despite diversities in categories, VGSs are found suitable for all high-rises of urban environments [6]. Interestingly, Yeang [32] provides a basic understanding of the number of plants needed for a high-rise with different size of facades. His finding suggests that the ratio of the plant used can influence the function of VGSs. Another, a material used to construct a façade might be an issue when selecting the related plant species. Thus, the best plant selection should also consider the construction materials (e.g., steel, glass, brick or composite facades).

In short, plants have a significant influence on the performance of VGSs. No doubt, ones' exploitation in term of properties can enhance the sustainability of urban built environment [27]. The outstanding function of plant component is evidenced in a thermal behavioural effect of a façade of a building [33]. Most importantly, the thematic-benefit is subjected to the VGSs abilities to perform as an effective evapotranspiration and shading devices. It is agreed that plants have a significant influence on the energy-saving [17] and visual effects of an envelope of building [21]. Hence, to wisely manipulate plant component can produce multiple outcomes for the betterment of urban environments.

For a longer lifecycle and sustainable systems, the choice of plants should withstand local disease and climatic issues. For instance, a Blue trumpet vine (*Thunbergia grandiflora*) receives high preferences in the operation of a *green wall* of the tropics [34]. The use of native plant species is highly recommended as it can minimise landscape maintenance procedures and cost of maintenance [12]. A clustered shrub or ground cover with thick foliage would provide a denser growth that is more applicable to a *living wall*. The explanation may refer to potted species with herbaceous character. In contrast, mosses, lichens, creepers, and grasses, including perennial climbers, are the common species of *a green wall*.

Uncertainty in selecting viable species can complicate the operation of VGSs. Thus, making the appropriate decision in selecting ones can be challenging because there are constant issues like cost and maintenance to be considered along the process. Rayner, et al. [35] have addressed some of these issues in their work. For a convincing result, collaboration with the related experts (e.g., horticulturist, arborist, architect, landscape architect, and etcetera) is necessary. Parallel to that, Jain and Janakiram [18] provides a useful study on the plant component of VGSs having stressed on adoption of local species. Sometimes, the failure or success of a system can be associated with a plant component [2]. Thus, to achieve the most promising system is by optimizing the performance of the component.

Hunter, et al. [36] and Köhler [37] stress the importance of establishing a clear direction for future research of VGSs. Studies should dwell on how to develop sound environmental tools for building façades of urban environments. To sustain the application of VGSs using the local plant species with low maintenance is another potential research area of contemporary research. Discoveries would further complement the past studies that have highlighted the role of plants for efficient VGSs [16, 27, 38]. Indeed, more data on plant components may help sustaining the usage of VGSs.

6. LANDSCAPE INTERVENTION – MAINTENANCE COMPONENT

Landscape maintenance is one of the fundamentals of VGSs, which has long been discussed in the subject of landscape architecture. A study of Yuan [28] indicates that *a living wall* can accept varieties of plant materials because the system requires minimal plants maturing period. Similarly, the system may experience less wall surface damage risk.

Nonetheless, high maintenance exercise is required due to the complexity of certain plant materials. For instance, the difference in plant types and species requires a different technique of irrigation [15]. The good part is that the plants of VGSs can be naturally, manually, or automatically irrigated. By the principle of landscape maintenance, the systems are operating using mixed irrigations include drip, mist, or water hose. Apart from that, a pump is alternative irrigation used for daily basis.

A poly-pipe is used for automated irrigation. The pipe may run vertically or horizontally on a wall. The installation can be hidden or exposed to suit the design and function of a building. The source of water is stored at the top of a building and automatically distributed down to plants for every one to two hours using a drip or a mist irrigation system. For continuous watering, both systems should be gradually examined to certify the reliability of building material, speed of the water, and plant condition. Besides *irrigation*, landscape maintenance also includes *soil fertilization*, *pesticide and weed control*, and *pruning* exercises. In the case of *a living wall*, the pruning exercise requires exceptional equipment such as suspended platform, ladder, scissors, or lifts depending on the height of the wall.

On the other hand, a *green wall* may require more pruning exercise for adequate cooling, visual, and tidiness purposes. However, the maintenance of a *green wall* is considered lower than the *living wall* because there is less equipment required with an uncomplicated irrigation system [15]. Several considerations need to be taken into account in order to achieve the best maintenance practices. Successful maintenance may relate to the factors of building design and method of installing plant components. The factors are described in detail by previous researchers [6, 17]. Below is the summary of concerns for effective landscape maintenance:

i) To adopt the right selection of VGSs.
ii) To be able to estimate the extra structural loads required.
iii) To select proper plant species having concerned for good adaptation, maintenance, growth period, and lifecycle.
iv) To provide proper planting media and irrigation system.

7. CONCLUSION

At the local context, VGSs are visible at both newly built public and private buildings. Both government and non-government organisations are in favour of *green* and *green buildings*. Hence, the trend of VGSs become necessary environmental tools in some Malaysian cities. It is found that the *support* and *modular* features are the standard operating systems. So far, a drip system maintains relevant to both *green wall* and *living wall*. Insight suggests that early awareness of the usage of VGSs receives affirmative acceptance amongst the authority and developers. The scenario marks a sign for continuous application to the future high-rise here. However, the widespread of VGSs to the broader built environment circles could be challenging, due to long term cost incurred in landscape maintenance practices and refilling of dead plants.

Insight further suggests that best landscape maintenance practices and appropriate plant components may correlate significantly to sustainable VGSs. These would be under the preview of the landscape architecture discipline. However, reviews indicate that the contributions from such a profession are almost zero. Since the issues concerned are under the professional's jurisdiction, thus, experts from a similar field should take up the lead. Therefore, this study calls for continuous research, in which more landscape architects, horticulturists, and botanists should collaborate for further improvement of technologies, sustainability, the effectiveness of plant materials, and many more.

This study also points out the rationale of using local plants to suit to local climate and disease. Local species are favourable, due to ones' endurance and durability. The consideration would further influence the sustainability of VGSs and its application. The idea of adopting native climber and creeper (e.g., species of limestone) of local ecosystems may inject new ideas towards filling up the research gaps. Besides, insight suggests that an in-depth research exploration would require high funding. Potential research can be realised through active and selective collaborations. The paper suggests that discoveries on landscape issues are essential to assist in more successful applications.

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