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BARRIERS OF IMPLEMENTING GREEN WALLS IN THE URBAN ENVIRONMENT IN DEVELOPING COUNTRIES

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The purpose of this research is to determine the barriers of implementing green walls in the urban environment in developing countries. The built environment contributes to major global energy consumption and greenhouse gas emissions. Greenery systems such as green walls have been around for centuries and provide a sustainable solution to reduce and mitigate the negative impacts that the built environment has on the surrounding environment and biodiversity. Green walls could add a significant amount of vegetation in an environment without requiring any additional space. Green walls increase the albedo, lower temperatures, acts as an insulating layer, mitigate the heat island effect, lowers operational costs of building and saves energy, sequestrate carbon and capture pollutants, attenuate noise, increase positive emotions and is an aesthetic enhancement. Green walls are however, rarely seen in developing countries like South Africa. Green walls are defined as a greening vertical layer for adding greenery to the façade or internal walls of a building. A systematic literature review was done by researching all possible barriers and reasons for the lack of green walls in developing countries in journal databases and an online library database. The barriers identified includes lack of building regulations, lack of awareness of green walls, lack of standard costs, lack of understanding the benefits that comes with green walls, lack of knowledge in the construction industry and lack of emphasis on sustainability. By identifying the barriers in South Africa, recommendations are made in terms of addressing these barriers in order to accelerate and promote green walls within developing countries. Green walls can be categorised into green facades and living walls. Green facades can be sub-categorised into direct and indirect (with planter box or as double skin) green facades. Living walls can be sub-categorised into continuous living walls and modular living walls. Each type of green wall has certain advantages and disadvantages and costs that goes with it. To conclude, the direct green façade requires the least installation costs, expertise, maintenance and water usage and is the ideal starting point for developing countries. Even though there are numerous barriers to implement green walls in developing countries, there are solutions to overcome these barriers in order to promote and accelerate the implementation thereof.

Keywords: barriers, green building, green walls, sustainable, urban greenery

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INTRODUCTION

The United Nations Environment Programme (UNEP) reports that the built environment contributes approximately 40% to global energy consumption and approximately 36% in greenhouse gas emissions [1]. Johannesburg, a metropole in South Africa, has been ranked as one of the most polluted cities in the world. This is due to the heat island trapping dust from mining, carbon emissions form factories and vehicles, domestic coal burning and waste disposal and incineration [2]. According to the World Health Organisation, Pretoria is the second most polluted city in South Africa, followed by Cape Town and Durban [3]. Urban areas not only see an increase in the carbon dioxide emission and Urban Heat Island Effect, but also see a decrease in vegetation and biodiversity [4].

The increasing number of studies on living walls in the recent decade indicates the increasing interest regarding the environmental benefits of this greenery system [5]. Greenery systems such as green roofs and green walls have been around for centuries and provide a sustainable solution to mitigate the negative impacts that the built environment has on the surrounding environment [1]. Although they have been around for centuries, urban vegetation systems are a relatively new concept in South Africa, a developing country. Currently there is a demand for green urban systems in South Africa and the materials are readily available to have the systems constructed, however industry professionals lack knowledge thereof [6]. Developing countries like South Africa are facing certain barriers that demote the development of green walls. As South Africa has one of the most polluted cities in the world [2], it is imperative to develop green sustainable urban buildings, however the barriers needs to be overcome. Green walls are seen as a green sustainable development that could mitigate the negative effects of the built environment [1][5][7][8][9][10], and this study attempts to present green walls as a viable solution for developing countries.

The aim of this research is to determine the barriers of implementing green walls in the urban environment in developing countries. The objectives are to define and categorise green walls; investigate the advantages of green walls; determine the barriers for the implementation thereof; and finally present solutions for the barriers. A systematic literature review will be done in order to achieve the aim and objectives.

LITERATURE REVIEW

Defining green walls

A green wall is defined as a wall that is both partially or completely covered with greenery that includes vegetation and a growing medium e.g. soil, substrate and or water. Green walls have been around for centuries and date back to the Hanging Gardens of Babylon [1]. Green walls can be divided into two categories: green facades and living walls [7][8][9] as illustrated in figure 1.

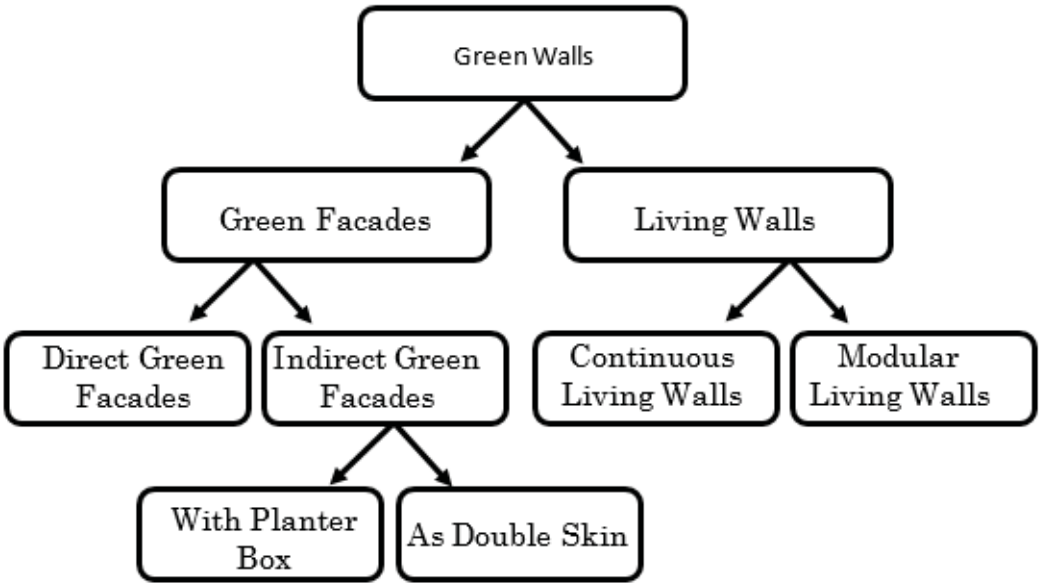

Fig 1: Categorisation of green walls

Green facades and living walls can further be divided into sub-categories. Green facades can be sub-divided into direct green facades, indirect green facades, indirect green façade with a planter box and indirect green façade as a double skin. A green façade is predominantly seen as an exterior application [8]. Green facades are generally characterized by a type of climbing plant that has been planted at the base of the building and left to climb the facade of the building [7][9]. The creepers can be either evergreen or deciduous and needs to be able to extend far enough in order to cover the entire wall. A hardy creeper is ideal as it will have greater success and requires less maintenance [5][17]. Indirect facades (planted at the base) and indirect facades with planter boxes are used in conjunction with an air barrier between them and the building. The indirect systems use a trellis or lattice structure to allow the plants to move vertically up with the building [7].

Living walls can be sub-divided into continuous living walls and modular living walls. The application of living walls may be either interior or exterior [8] and can include plants like perennials, ferns, shrubs, bromeliads and creepers. Plants that are hardy, needs little space to grow and has shallow roots are ideal for living walls [8][11]. Living walls are a newer innovation that step away from the traditional ways in which green facades are constructed; this system implements a continuous system modular planter box system that is equipped with an irrigation system and growing media. These living wall systems are then placed with a lattice like system, which is constructed alongside the façade of a building [11]. Figure 2 consists of three photos of examples of green walls. The photo on the left is of an indoor living wall. The photo in the middle is of an indirect green façade where you can clearly see the second skin mesh and the photo on the right presents a direct green façade.

Fig 2: Photo of a living wall indoors (left), indirect green façade (middle) and direct green façade (right)

Advantages of green walls

Green walls have various advantages depending on the type of green wall system. An experimental greenery system on an urban watershed was constructed in order to do a cost benefit analysis. From the experiment it is clear that the vegetation increases the albedo of the vegetation covered areas. Increasing the albedo of a surface allows for a greater amount of the incoming solar energy to be reflected rather than absorbed [12]. The size of the watershed is however smaller than the standard building and the experiment is limited to one climate. Nevertheless, green facades contributes to lower temperatures around buildings due to a higher albedo on the wall. Over and above the albedo effect, green walls create an insulating layer for the building, provides additional shading as well as evapotranspiration. A simulation study was done with the aim to determine the level of mitigation of heat stress by the addition of green walls. Is is found that green walls mitigate heat stress by 5-10% due to insulation, shading and evaporation [13]. The critic of the research is that it is only a simulation and real life measures should be done. Nevertheless, green facades leads to the mitigation of the heat island effect and the reduction of energy usage by the building, however the extent of the energy savings will differ with other climates. Djedjig, Belarbi and Bozonnet [14] did a comparative study on the energy savings potential between living walls and green facades. Both systems have a high potential of energy saving. The living wall system provided the highest cooling performance and achieved energy savings of 58.9% and the green facade reached an energy saving of 33.8%. Green walls thus contributes to the reduction of operational costs of a building [1]. Wind speeds are reduced between buildings [15]. Carbon sequestration occurs due to the vegetation that forms part of green walls [5]. This means that some carbon dioxide, a greenhouse gas, is taken out of circulation. In addition to the uptake of carbon dioxide, plants have long been observed to capture a variety of pollutants, and even partly bio-transform them with the aid of microorganisms that coexist in their microbiome [16]. Wolverton, Douglas and Bounds used a sealed experimental chamber with various plant types and various toxins and measured the amount of

toxins removed by the plants. The results showed that each plant type removed toxins from the sealed chamber, however the amount of toxins differed for each plant type. The roots of the plants and their associated microorganisms then destroys the toxins and eventually convert it into plant tissue [16]. Therefore, green walls contributes to better air quality. Plants attenuate noise by absorbing, diffracting, and reflecting sound. Vegetated installations have as a result been widely used as means to improve outdoor and indoor sound environments [17] [18]. Benedict and McMahon [19] identified a greater presence of birds due to green facades and Matt [20] found between 16 and 39 times more collections of diverse arthropods. A study of thirty-three sites in Paris by Madre et al. [21] characterised green facades as 'xerothermophilous' habitats comparable to cliffs, while continuous felt and modular substrate-filled living wall types were characterised as damp and cool habitats comparable to vegetated waterfalls. The latter modular system with its increased substrate depth was found to offer the highest diversity and abundance of species [21]. Greenery systems have thus a positive effect on biodiversity. The natural setting including plant life has been identified to increase positive distractions and emotions, promote restoration from illness and stress, and enhance the sociocultural climate [22] [23]. The contribution of plants to the aesthetic and wellbeing enhancement of cities is acknowledged in built environment discourse as biophilic design, which gathered interest and momentum in response to the need to alleviate symptoms of sick-building syndrome [24]. Vegetation on walls also increase the aesthetic enhancement of the surroundings [25]. The reduction of storm water run-off in cities is another advantage of living walls as reported by Byrne, Lo and Jianjun, who did a study on the role of green infrastructure for climate adaptation like flooding and the increased severity of storms [26].

Barriers to implementing green walls

Cost is a major factor hindering living wall installations [27]. Green facades, however, are more cost effective during the installation process, but have limited plants diversity [9][10]. There are no published costs in South Africa regarding living walls, as it is unfamiliar to the construction industry. Long-term maintenance costs are also problematic. A well-designed system with suitably selected plants relies heavily on maintenance for success [28]. Reducing maintenance may require more investment in the quality of the system, but could lead to a system's durability to be on par with the durability of the superstructure supporting it [29], in lieu of having a living wall system with a shorter life expectancy than the superstructure [30].

Living walls often have unsustainable water usage [31]. However, systems can be developed to reduce the overconsumption of drinkable water by harvesting rainwater and/or recycling water [24] [32], which can be concurrently advantageous for the management of storm water [33]. Unfortunately, most developments with living wall systems do not recover the wastewater. This is due to it being too expensive to collect and filter recycled irrigation water [34]. There are two living wall developments globally that have managed to solve this problem: The Rubens at the Palace in London [35] and the One Central Park project in Sydney, Australia by means of harvesting rain water and recycling water [36] South Africa has a water shortage problem [37] and unsustainable water usage from a green wall system is a major barrier.

The climate is the next difficult barrier to overcome. There are three climatic factors to take into consideration when designing green living walls: temperature and humidity levels; orientation; and wind [38]. Derkzen, van Teeffelen and Verburg [39] did a study on green infrastructure and concluded that people's awareness of climate impacts and their understanding of the benefits of green infrastructures, influence their preferences for green infrastructure measures. The general consensus remains that people are willing to support climate adaptation through green infrastructure as long as the green infrastructure is multifunctional, i.e., comes with recreational and aesthetic benefits. Lack of awareness and not understanding the benefits that comes with green walls serves as a barrier toward the implementation thereof.

Plants are dependent on light and the available light needs to be utilized effectively and the expected light conditions for living walls must be calculated prior to the plant selection. Light for plants is measured in terms of its quantity, quality and duration. The quality of light for plants is defined by its colour or wavelength. The quality of light is measured in lux and the duration of light is the amount of time per day that the plant has exposure to light [40]. Insufficient quantity of light is one of the drawbacks of living walls and the maintenance thereof.

It has been found that some cities have an uneven distribution of urban green infrastructure. Low green space cover have been linked to residents with lower socio–economic status of which includes Johannesburg in South Africa [41]; This is seen as a general challenge for future green infrastructure installations [42]. Unfortunately, the national building regulations of South Africa does not include any reference to green walls [43]. In South Africa, it is thus not compulsory by national regulations to develop and include greenery systems. This leads to slow adaptation and implementation.

Various benefits have been identified for sustainable development, nevertheless, stakeholders, especially in Africa, have not yet realised the claims as such [44] [45]. Barriers to implement green infrastructure in South Africa includes the perception of costs being higher than it actually are. Over and above that, the lack of incentives for greenery systems in South Africa contributes to this problem [46]. Urbanisation in Africa has generally been criticised for its perceived failure to contribute to sustainable development [47], however, limited guidance is available to African governments, planning institutions, and policy makers regarding how to address the sustainability concerns [48].

Solutions to implementing green walls

Governmental incentives and regulations strengthened by discounts and fines is one of the most effective stimuli to promote and help pay for sustainable living walls [49]. To increase the awareness of green infrastructures, however, educational programs could improve residents' willingness to support urban greening. Policy makers could also consider subsidies for example rent assistance or electricity subsidies [50].

The standardization of the metrics used to quantify living wall performance to compare data between systems will influence living wall optimization. Koehler cited in [28] begun to establish the criteria that includes appropriate units of measure and methodologies.

Although the National Building Regulations of South Africa does not encourage greenery and sustainability, the cities have influence through the building plan approval process, building inspectorate and regulatory functions. In South Africa, the local authorities introduce their own by-laws regarding greenery and sustainability. Four of South Africa's metros (Johannesburg, eThekwini, Cape Town and Tshwane) are working towards the implementation of innovative programmes and ambitious policies that aim for net zero carbon emissions from newly-built buildings by 2050 [51]. In South Africa, the Green Building Council of South Africa (GBCSA) is the main driver of green building principles [52] and should take the lead in the encouragement of developing green systems like green walls.

Ismail and Rogerson investigated ten hotels in South Africa that participated in environmental retrofitting. They found that the hotels that introduced environmentally friendly measures, were motivated by the reduction of the hotel's carbon footprint, reduced costs and to enhance brand image [53]. South Africa's local governments are currently facing the concept of local economic development (LED). LED is seen as a tool in order to achieve developments that are sustainable. Local governments are thus faced with the challenge of developing sustainable settlements [54]. A solution suggested by Holliday, Schmidheiny and Watts is to mobilize markets to favour sustainability, leveraging the power of global markets and innovation for the benefits of everyone – not just the developed world [55].

RESEARCH DESIGN

This study aims to answer the following research question: What are the barriers for implementing green walls in developing countries? The research design followed in order to answer the research question is a systematic literature review. The databases used for this research includes Google Scholar as well as the Wits University library e-journal database that consists of various journal databases. The following key words were used consistently in all databases: Green walls, advantages of green walls, disadvantages of green walls, sustainable buildings, green walls South Africa, and barriers of implementing green walls. The criteria for the Articles to be included in this study is the following: it must be relevant to the topic; it must be scientific and peer reviewed journals, conference papers, books, master and/or doctoral theses; most of the articles must not be older than five years; data must have been collected ethically, i.e. lawfully, accurately and protecting the identity of people/organisations that participated.

ANALYSIS AND DISCUSSION

The articles in the literature review is used to categorise green wall systems and the extent of the applicable advantages and barriers that goes with each type of green wall. Table 1 summarises the analysis of the advantages and barriers of each type of green wall system. The exact quantities and units of measure for each advantage and barrier is difficult to pin down, hence the extent of the advantages or barriers are represented by '*' and is relative to the other types of green wall systems. Green walls can be divided into six categories. Green facades and living walls have the same advantages and the same barriers. The extent of the advantages and barriers however, differ. Living walls provide a more effective insulation layer, has greater energy savings, is more effective with sound

absorption and reduction of storm water run-off and provides greater biodiversity. Although the extent of the advantages are greater for the living walls, the barriers are also greater. Living walls are more expensive, requires more maintenance and water usage, as well as expertise. Even though the exact quantities and measures of units are not available, from the table it is clear which type of green wall system has greater advantages and/or barriers, what these advantages and barriers are and what type of green wall system could be suitable for a particular situation. A cost-benefit analysis would however be a helpful decision making tool with regards to the implementation of a certain green wall system.

Table 1: Advantages and barriers of green wall systems

	Direct green facades	Indirect green facades	Indirect green façade with planter box	Indirect green façade as double skin	Continuous living walls	Modular living walls
Advantages						
Increased albedo	*	*	*	*	**	**
Insulating layer	*	*	*	*	**	**
Shading	*	*	*	*	*	*
Evapotranspiration	*	*	*	*	*	*
Energy savings	*	*	*	*	**	**
Carbon Sequestration	*	*	*	*	*	*
Removal of pollutants	*	*	*	*	*	*
Sound absorption	*	*	*	*	**	**
Biodiversity	*	*	*	*	**	**
xerothermophilous	Cliff	Cliff	Cliff	Cliff	Vegetated waterfall	Vegetated waterfall
Biophilic design	*	*	*	*	*	*
Reduction of stormwater runoff	*	*	*	*	**	**
Barriers						
Installation cost	*	**	***	***	****	****
Published costs for guidelines	-	-	-	-	-	-
Maintenance	*	**	**	**	****	****
Water usage	*	*	*	*	****	****
Climate	*	*	*	*	*	*
Light	*	*	*	*	*	*
Expertise	*	**	**	**	***	***

Developing countries, however, have additional barriers when it comes to the implementation of greenery systems. The lack of awareness of sustainable options and not knowing the benefits that comes with it makes the implementation of systems slow or non-existent. Uneven distribution of green spaces in cities creates extra challenges and strain. Lower socio-economic areas are less inclined to the development of green systems. Building regulations and policies have not yet been put into place and does not support or guide greenery developments. There is often lack of incentives as it cannot be afforded. Africa as a whole lacks behind sustainable development in its entirety and guidance for the development thereof is often insufficient.

Solutions to increase green wall implementation in developing countries includes the following: The correct national regulations and policies in place and motivated by discounts and fines; create awareness through education; educate professional members in the construction industry; publish costs of green wall systems and a standard way of quantification; use entities like the GBCSA to drive greenery projects; understand the benefits and reduction in energy costs; promote the branding of green; use LED as a tool in order to achieve developments that are sustainable, green and desirable living conditions; mobilize markets to favour sustainability, leveraging the power of global markets and innovation for the benefits of everyone – not just the developed world; understand the various options when it comes to green walls and the advantages and barriers that comes with it and initiate green wall projects that are within reach of the developers.

CONCLUSIONS

The built environment contributes significantly to the energy consumption and greenhouse gas emissions. Cities are taunted by pollution, the heat island effect and lack of vegetation. This is less than desirable living conditions. Greenery systems such as green walls provides sustainable solutions and mitigate the negative impacts that the building environment has on the surrounding environment. In South Africa, however, greenery systems are still a relatively new concept and the professionals in the construction industry lack knowledge thereof. Developing countries has additional barriers to overcome when it comes to the implementation of green wall systems, there are solutions to overcome these barriers in order to promote and accelerate the implementation thereof. It seems that knowledge of the different types of green walls is imperative in order to promote the installation thereof as there are options that would better suit developing countries with lack of expertise. The direct green façade requires the least installation costs, expertise, maintenance and water usage and is the ideal starting point for developing countries.

Research on green walls in developing countries is limited and limits the comprehensiveness of this study. Indigenous vegetation and climate differs from location to location, which could lead to different behaviours of green walls. This study is thus limited by the parameters of various locations. The behaviour of green walls have been generalised with regards to all climates. However, behaviour and the extent of advantages and barriers could slightly differ for each location. It is recommended that research should be done regarding the behaviour of green walls for each desired location in order to get the most accurate results and true

behaviour. The following research is recommended: standardising of metrics of quantification of green walls; expected costs of the various types of green walls; detailed comparative studies on the various benefits and barriers of the different types of green walls; sustainable water usage for living walls in drought sensitive countries; the level of knowledge of professionals in the construction industry regarding green walls; level of awareness of green walls in developing countries; and cost-benefit analysis for the various types of green wall systems.

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