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THE LIMITS OF GREEN INFRASTRUCTURE DEVELOPMENT IN URBAN SOUTH AFRICA: THE CASE OF GREEN ROOFS

Jayne M. ROGERSON*
School of Tourism & Hospitality, University of Johannesburg
Bunting Road, Auckland Park, 2006, Johannesburg, South Africa, e-mail: jayner@uj.ac.za

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Abstract: With the advance of urbanisation many cities are confronted with environmental problems including air pollution, the absence of green spaces and urban heat island effects. The expansion of green infrastructure is viewed as an important aspect of urban sustainability agendas. One dimension of green infrastructure is green roofs. The objective in this article is to examine the development and challenges of green roofs in South Africa, presenting the results of a survey of the suppliers of green roofs. The findings show for South Africa the relative underdevelopment of green roof systems, the geographical unevenness of such developments and the challenges that confront the emergence of green roof systems in the South African context. Key issues relate to current high costs associated with green roof construction, absence of government support in the form of financial incentives, and lack of awareness of the sustainability benefits of green roof systems.

Key words: Green roofs, green infrastructure, urban, South Africa

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INTRODUCTION

By 2050 projections made by the United Nations suggest that approximately one-third of the world's population will live in cities (United Nations, 2018). Many growing urban areas are struggling with environmental problems, such as local climate change linked to global warming, air pollution, energy shortages as well as a range of natural hazards (Zhang & He, 2021). Shao and Kim (2022) pinpoint that rapid urbanisation is triggering land-use change, replacing green spaces and vacant land with built urban infrastructure. Furthermore, the march of global warming and climate change has exacerbated, according to Shao and Kim (2022, p. 1), "the frequency of extreme climate events and the intensity of heatwaves, which has strongly impacted the urban thermal environment, resulting in higher land surface temperatures and higher thermal absorption of solar radiation". Currently, therefore, city ecosystems are experiencing urban heat island effects, air and water pollution as well as flooding in part due the absence of green spaces. Accordingly, a critical challenge for urban sustainable development is to significantly transform the manner in which urban spaces are built and managed (Joshi & Teller, 2021). As pointed out by Manso et al. (2021) greening

* Corresponding Author

the urban environment can be a significant strategy to address the challenges of urban densification and to strive towards the United Nations Sustainable Development Goals. Indeed, as is observed by Joshi and Teller (2021, p. 1) unprecedented rates of global urbanization have precipitated "enormous challenges with energy consumption, social inequality, air and water pollution, and resource depletion resulting in a massive strain on urban systems".

Policy-makers in several countries are placing green infrastructure on the agenda as part of urban planning and design. Among others Liberalesso et al. (2020, p. 1) observe a global trend that "green infrastructure is increasingly used to mitigate the impacts of dense urban areas, contributing towards the naturalization of the built environment". Green roofs – also referred to as eco-roofs or living roofs - are defined as living vegetation planted on the roofs of buildings (Berardi, Ghaffarian Hoseini, & Ghaffarian Hoseini, 2014; Shafique, Kim, & Rafiq, 2018; Zhang & He, 2021; Ávila-Hernández, Simá, & Ché-Pan, 2023). As building roofs are abundant within urban ecosystems and may occupy as much as 20-25 percent of urban surfaces nature-based solutions such as green roofs "are increasingly gaining popularity due to their positive effect on urban ecosystems" (Joshi & Teller, 2021, p. 1). Against this backcloth it is the aim of this paper to draw together the existing evidence concerning the development and challenges of green roofs in South Africa, including insights from the supplier survey results of green roofs.

GREEN ROOFS – INTERNATIONAL DEBATES

The phenomenon of green roofs has a long ancestry. For some observers its application can be traced back to the Gardens of Babylon and the Roman Empire when planting vegetation on rooftops was undertaken (Jim, 2017a; Jim, 2017b). The archaeological studies by Jim (Jim, 2017a; Jim, 2017b) track the historical origins and development of green roofs as a human invention. The contemporary practice of developing green roofs is differentiated into a number of different types in respect of being fully or partially planted and in terms of the planting medium that is utilised (Claus & Rousseau, 2012; Zhang & He, 2021). The first category of 'extensive green roofs' are known for the simplest structure and requiring the least maintenance during its lifespan. This system though has only limited options in terms of plants that can be grown due to the thinness of the soil. Benefits in order to undertake an extensive green roof are its lower initial cost and the need for only limited additional support. Often extensive green roofs are recommended for building retrofits because of their lighter weight as compared to other options. In addition, they are also often recommended for projects with only a limited budget. 'Extensive' green roofs have a shallow substrate and low-growing plants (Oberndorfer, et al., 2007; Jaffal, Ouldboukhitine, & Berlarbi, 2012). By contrast 'intensive green roofs' are costlier, require additional structural support but as roof gardens have a wider variety of plants and can provide recreational spaces for the public (Claus & Rousseau, 2012; Mahdiyar, Mohandes, Durdyev, Tabatabaee, & Ismail, 2020). A third category of 'semi-intensive' green rooftop system is also recognised with its defining characteristics being a growing medium of 15-25 cm, vegetation consisting of small shrubs and the requirement of some maintenance (Labuschagne & Zulch, 2016).

According to Berardi et al. (2014, p. 411) the core benefits of green roofs relate "to the reduction of building energy consumption, mitigation of urban heat island effect, improvement of air pollution, water management, increase of sound insulation, and ecological preservation". Further, Berardi et al. (2014, p. 411) maintain that "green roofs have been proposed for sustainable buildings in many countries with different climatic conditions". This said, it is acknowledged that "the performance of green roofs in attenuating temperate extremes is dependent on local climatic conditions" (Fitchett, Govender, & Vallabh, 2020, p. 5025). For Joshi and Teller (2021, p. 1), green roofs can improve the energy performance of buildings and assist in combating the urban heat island effect both by reducing the atmospheric temperature as well as enhancing human thermal comfort. Arguably, however, the effectiveness of green roofs in delivering ecosystem services is "largely dependent on context-specific parameters such as weather conditions and existing construction or

design-related parameters" (Joshi & Teller, 2021, p. 1). Green roofs have been demonstrated as effective at reducing urban stormwater development pressures, reducing energy consumption, improving air quality, and above all mitigating the urban heat island effect (Liu, et al., 2021). It is observed that green roofs provide several ecosystem services and support urban transitions "toward circularity and resilience" (Calheiros & Stefanakis, 2021, p. 395). Arguably, green roofs are known for the benefits they contribute to the triple bottom line of the sustainability of urban environments (Teotónio, Silva, & Cruz, 2018). According to Chen et al. (2019, p. 1) it is accepted from the international experience that "green roofs have a variety of environmental, economic and social benefits". Mahdiyar et al. (2020) point to such environmental benefits as addressing the urban heat island, reduction of air pollution and improved air quality, economic benefits are seen in terms of increases in property values and energy savings whilst social benefits are defined in terms of beautifying spaces for human interaction and a quality indoor environment (Williams, et al., 2019) argue that research investigating the psychological benefits of green roofs highlights aesthetic enjoyment and improved concentration and that such outcomes are becoming significant objectives in green roof design.

For Liu et al. (2021, p. 1) green roofs represent "an effective nature-based solution to eco-environmental problems arising from climate change and rapid urbanisation because they provide multiple ecosystem services and can have a significant positive impact on human well-being". Calheiros and Stefanakis (2021, p. 395) stress that green roofs are garnering interest as nature-based solutions "to counteract with several environmental and socio-economic problems associated to urban sprawl and climate change". The direct ramifications of green roofs on carbon sequestration are identified by Shafique et al. (2020, p. 1) as involving "vegetation and soil media which can capture and store air pollutants on a building scale". Indirect impacts encompass the so-termed 'long-run green roof effect' which can reduce building energy consumption and in turn lead to a reduction in the consumption of fossil fuels (Shafique, Xue, & Luo, 2020, p. 1). Overall, the strengths of green roof adoption can play a vital role "in making cities safe, sustainable and resilient to climate change" (Shafique, Kim, & Rafiq, 2018, p. 757). According to Zhang and He (2021) important drivers for the implementation of green roofs therefore are policy pressure for energy efficiency, urban heat island mitigation, urban infrastructure improvement as well as innovation and technology advancement.

A critical global research issue is to understand the root causes and barriers to the implementation of green roofs (Chen, Shuai, Chen, & Zhang, 2019). It is observed that most extant studies on the barriers to implementation of green roofs in cities have been conducted in developed urban areas of countries in the Global North. Among others Bianchini and Hewage (2012) pinpoint that the cost of green roofs has been one of the biggest challenges for the development of the green roof industry. Likewise, according to Liberalesso et al. (2020) there are major challenges in promoting green infrastructure as private investors point to the need for substantial upfront costs for installation and in many cases also of significant maintenance costs. The review undertaken by Shafique et al. (2018) highlighted issues of initial high construction costs, high maintenance costs and roof leakage challenges as the main barriers associated with the application of green roofs in many countries. In addition, Teotónio et al. (2018) attribute their limited implementation to the absence of a clear understanding of the economic value of green roofs. Zhang and He (2021) stress that green roof implementation programmes can be inhibited by a complex of multiple barriers in economic, technical and political dimensions. These encompass lack of government policy, unsound technological level, poor economic benefit assessment methodologies and individual unwillingness to innovate.

Across the Global South there is acknowledgement of the environmental problems of large urban areas and that "one of the methods of mitigating electricity consumption and reducing the temperature in buildings is green infrastructure" (Ávila-Hernández, Simá, & Ché-Pan, 2023, p. 1). For example, the importance of green roofs in terms of reducing energy consumption in buildings

and the urban heat island effect is well-recognised in Mexico (Ávila-Hernández, Simá, & Ché-Pan, 2023). In sub-Saharan Africa, a region of the world which is experiencing rapid rates of urbanisation, obviously there is great potential for securing benefits from green roof systems. Overall, however, as noted by Chen et al. (2019) there is a paucity of research about the challenges in developing countries or the Global South where "implementation of green roofs is still at the initial stage" (Chen, Shuai, Chen, & Zhang, 2019, p. 742). In a developing country context Durdyev et al. (2022, p. 1) observe that the implementation of green roofs "is yet to hit a sufficient level" to make a significant contribution to sustainable urban environments. As is stressed in the case of Malaysia by Mahdiyar et al. (2020) the adoption of green roofs has been inhibited by a series of barriers. The research in Malaysia reveals that critical constraints relate to 'high initial costs' and 'lack of awareness and knowledge'. Barriers hindering the adoption of green roofs in Malaysia included lack of standard or industry guidelines, albeit such barriers were acknowledged as different between extensive and intensive forms of green roofs (Mahdiyar, Mohandes, Durdyev, Tabatabaee, & Ismail, 2020). In China the major explanations offered for the laggard progress of green roofs on new buildings in urban areas surround increase of maintenance cost, increase of design and construction, poor arrangement of the use of green roofs and lack of incentives from government for the development of green roofs (Chen, Shuai, Chen, & Zhang, 2019). The study by Durdyev et al. (Durdyev, Koc, Karaca, & Gurgun, 2022, p. 1) recommends in the context of developing countries that the essential strategies needed to speed the progress of green roofs are financial incentives, low-cost government loans and the offer of tax rebates. International reviews confirm that incentive policies in terms of financial subsidies are mainly concentrated in the Global North, especially Europe and North America, for the promotion of green infrastructure including green roofs.

Overall, a decade ago, Blank et al. (2013, p. 23) could state that "green roof research is a multidisciplinary and new research area". Indeed, Blank et al. (2013) noted that green roof research is a comparatively new area of science. Since 1981 Liu et al. (2021, p. 1) identify that "the amount of research on green roofs has steadily increased". Research on green roofs experienced a take-off with a burst of publications beginning in the 1990s (Blank, et al., 2013). An early influential review of evidence for the benefits of green roofs and the provision of ecosystem systems was produced by Oberndorfer et al. (2007). Ten years on the work of Shafique et al. (2018, p. 757) reflected that research concerning "the green roof has been raised expeditiously over the past decade". Of note is also a sharp increase in the number of different countries where green roof research is conducted (Blank, et al., 2013). Berardi et al. (2014, p. 411) present a state of the art synthesis of green roofs literature emphasizing current implementation, technologies and benefits. Similarly, Shafique et al. (2018) review the history of the green roof, green roof components and its multiple benefits as a significant sustainable practice to mitigate the effects of urbanization. According to Joshi and Teller (2021, p. 1) whilst a significant amount of international research already has been undertaken on green roofs "research covering more geographical locations and contexts is needed". This analysis turns to the case of South Africa, a country where published scholarship on green roofs is relatively small (Labuschagne & Zulch, 2016; Fitchett, Govender, & Vallabh, 2020; Sucheran & Sucheran, 2021).

GREEN INFRASTRUCTURE AND GREEN ROOFS IN SOUTH AFRICA

The need to plan for green infrastructure is acknowledged as a critical issue for South Africa's growing cities (South African Cities Network, 2016). The vital importance of green assets and greening urban infrastructure and the built environment has been identified in several academic studies about the urban landscape, property development (Rogerson, Green commercial property developments in urban South Africa: emerging trends, emerging geographies, 2014; Burton & Rogerson, 2017; Fitchett, Govender, & Vallabh, 2020; Van der Walt, 2018; Sucheran & Sucheran, 2021) and especially for the hotel sector (Rogerson & Sims, The greening of urban hotels in South Africa: Evidence from Gauteng, 2012; Rogerson, Green commercial property developments in

urban South Africa: emerging trends, emerging geographies, 2014; Ismail & Rogerson, 2016). With evidence of the advance of the impacts of climate change there is an acceleration in policy interest in South Africa about the greening of the country's cities. For example, the role of the South African Cities Network is to promote shared-learning partnerships between different spheres of government in support of the management of the country's cities. One report issued by this organization points to the critical need to further embed sustainability thinking into city planning in South Africa (South African Cities Network, 2016).

One facet of sustainability thinking is to consider the role that green roofs might assume in improving the urban built environment. In one recent study conducted in South Africa a technical analysis by Fitchett et al. (2020) reported that green roofs have been shown to enhance the comfort levels of rooms directly below them since they function as insulators. The green building concept is not a new phenomenon in South Africa. Organisations such as the South African Property Owners' Association (SAPOA) and the Council for Scientific Industrial Research (CSIR) have been promoting the adoption of green building practices since the Green Buildings For Africa (GBFA) programme in 1997 (Rogerson & Sims, 2012). The aim of the Green Building Council of South Africa (GBCSA) is to ensure that all buildings in South Africa are designed and built in an environmentally responsible way (Rogerson, 2014). GBCSA's objectives are to promote green buildings, to enable the measurement of green practices in buildings (rating system) and to improve skills and knowledge in the green building industry (Rogerson, 2014). In one recent investigation Sucheran and Sucheran (2021) assert that green infrastructure within the South African context mainly focuses on issues of preservation of biodiversity. Indeed, these authors go so far as to argue that the implementation of "green roofs in South Africa has not been seen as a priority, with the only motivation for the implementation being the additional points allocated by the Green Building Council of South Africa when a building is being assessed" for its green rating (Sucheran & Sucheran, 2021, p. 177).

Although the concept of green building in South Africa can be traced back to the 1990s the phenomenon of green roofs seemingly is of more recent origin. The pioneer developments in South African buildings include two municipal projects namely a roof top vegetable garden in Johannesburg, part of an initiative for improving food security, and a green roof pilot project in Durban which was part of a municipal climate protection programme focused on addressing the effects of climate change (South African Cities Network, 2016; Allen, 2019). Early private sector initiatives include the establishment of green rooftop systems at two of Johannesburg's leading upmarket hotels in order to offer recreational space and relaxing space as well as at the showpiece Sandton Convention Centre which has vegetation on the side of the building for aesthetic reasons (Rogerson, 2014; Labuschagne & Zulch, 2016). Beyond such commercial developments there has been a small number of green roof developments as part of upmarket eco-residential complexes which have been established in Gauteng, South Africa's economic heartland around the cities of Pretoria and Johannesburg. One such development is the mixed-use mega development of Waterfall City which is located midway between Johannesburg and Pretoria. Murray (2015) describes this as 'privatized urbanism in extremis', a master-planned holistically designed urban enclave which was built on vacant land. Waterfall City, according to Murray (2015, p. 503) is an expansive city building project which "combines a hyper-modernist stress on 'smart' growth, cutting-edge technologies, and state of the art infrastructure" which includes a human-scale built environment that incorporates an element of green roofing.

The minimal footprint of green roof developments prompted the observation made in 2016 that "green rooftop systems are a new concept in South Africa" (Labuschagne & Zulch, 2016, p. 710). Nevertheless, evidence exists of a latent demand for green roof development which is driven by its potential benefits. The most important factors relate to contributions towards improved air quality, aesthetic satisfaction, provision of recreation space, habitats and its potential for job creation in a country with one of the highest unemployment rates in the world. Set against this potential

demand the small extent of green roof developments occurring in South Africa requires further interrogation. The research conducted by Labuschagne & Zulch (2016, p. 710) disclosed that in South Africa "there is a lack of knowledge amongst the professional team members in the construction industry regarding the construction of green rooftop systems". Accordingly, "professional members of the construction industry do not recommend the development" of green roof constructions (Labuschagne & Zulch, 2016, p. 710). Indeed, the lack of an established green roof industry has the consequence of making more problematic and costly the retrofitting of existing buildings than in other countries (Van der Walt, 2018). Overall, it was suggested that of the three different types of green roofs the findings of Labuschagne & Zulch (2016, p. 714) were that "the semi-intensive green rooftop system is the most feasible for South African circumstances and the intensive green rooftop systems to be not feasible at all". The preference for the semi-intensive green roof system was explained as follows: "due to the structural changes to existing buildings being minimal, affordable and possible to accommodate the system".

METHODS

Supplementing these investigations are the results presented here of recently completed work undertaken in South Africa's major metropolitan areas. The study methods involved a national audit of green roofs and relevant legislation which was followed up by 44 semi-structured interviews (conducted in 2016-2017) with a range of companies engaged in the supply chain for green roof systems. These enterprises included architects, green building consultants, landscape architects, landscapers, green roof specialists, waterproofing specialists as well as representatives of the Green Building Council of South Africa (GBCSA). The interviews targeted information concerning details of the implementation of green roofs, the amount of green roofs completed, and perceptions of the challenges of green roof development in South Africa.

RESULTS

An initial finding was the revelation that no current specific legislation exists in South Africa concerning guidelines for the implementation of green roofs systems, albeit there is certain legislation which indirectly supports the use of green roofs (Cuthbertson, 2017). One example is that of eThekwini Municipality (Durban) which has specific bylaws relating to buildings and water supply regulating storm-water management, wasting of water, roof coverage and the prevention of the pollution of water all which can be applicable to green roofs (Sucheran & Sucheran, 2021).

The results concerning the supply of green roofs point to the fact that nationally there are only five companies that specialise in and are dedicated to the supply of green roofs in South Africa. This said, a range of other suppliers are engaged with rooftop developments as part of a broader portfolio of construction projects. In terms of South Africa's leading metropolitan centres there is observed a geographical unevenness in the numbers of green roofs that have been supplied. The results from Cuthbertson (2017) suggest that companies in Johannesburg have supplied approximately 100 green roofs, Cape Town 65 green roofs, Pretoria 60 green roofs, Durban 29 green roofs and Gqeberha (former Port Elizabeth) only three green roofs. It should be appreciated that these totals include commercial properties as well as residential developments, mostly eco-residential estates located in the surrounds of Johannesburg and Pretoria. Further, it must be added that the majority of these constructed 'green roofs' are not always placed on the roof itself but rather on terraces. The leading role of Johannesburg and Pretoria links to their function in the South African urban system as respectively commercial hub and administrative capital of South Africa. Johannesburg and Pretoria are in Gauteng province, South Africa's richest province and economic heartland. The city of Cape Town is a secondary business/commercial centre but a major focus for international tourists as well as foreign investment in new property developments. The coastal centre of Gqeberha (former Port Elizabeth) with minimal green roof developments is the major city of Eastern Cape, the poorest of the South Africa's nine provinces.

According to the suppliers the main reason for clients choosing green roofs was for the aesthetic value that green roofs can provide. The results are shown on Figure 1. It was apparent that the South African market for green roofs is therefore driven by image and aesthetics rather than environmentally considerations. Suppliers found clients wanting a recreational space which can be used as an entertainment area. Green star grading points from the GBCSA was a widely expressed reason as green star rated properties have a market premium. This said, certain international companies have certain standards that the South African branch was expected to follow. A building being viewed as 'sustainable' can be seen as marketable to the environmentally conscientious market and could attract more clients. Creating a natural space or an entertainment area on the top of a building, creates a comfortable environment that employees can enjoy thus supporting employee well-being and potential staff recruitment. The core market for green roof suppliers is commercial rather than residential property developments. Of the sampled enterprises 96 percent targeted commercial buildings. The small market for residential green roofs was accounted for by high costs and lack of incentives which has restricted residential green roofs mainly to upmarket eco-estates and high-end residential developments which have terraces with green roofs. It was evidenced that in the commercial building sector initiatives were ongoing to incorporate green roofs into new designs. The embrace of green roofs in commercial buildings was primarily driven by the desire of developers and tenants for natural space as opposed to a commitment to the environmental benefits from green roof systems. In the commercial property developments therefore the driver is 'natural space' for tenants and securing green star points in certification processes of the GBCSA.

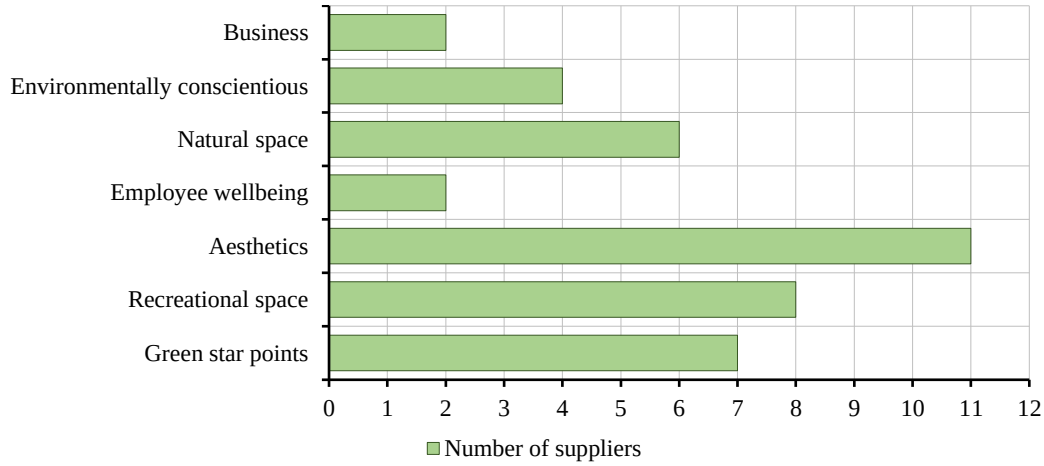

Figure 1. The reasons for supply of green roofs in South Africa
(Source: adapted from Cuthbertson, 2017)

Variations were disclosed in terms of types of green roofs that were available. The majority (44%) of the companies that supply green roofs offer all three types of green roofs, 30% offer only intensive green roofs, 19% offer extensive green roofs and the least type of green roof offered in the semi-intensive (7%). The purpose of the green roof is important in deciding the type of green roof. For example, most of the green roofs in Johannesburg, Cape Town and Pretoria are rooftop gardens (intensive), which are used to create a space in which the occupants can enjoy and often used as entertainment spaces for the commercial and residential buildings. This space which can be on various levels, which means that the occupants do not have to leave the building to experience green space. Of note is that the five companies that are dedicated to green roofs prefer to supply only extensive green roofs due to the perceived benefits these might offer as compared to intensive green roofs. Respondents gave several reasons for choosing the particular type of green roofs utilised in

South Africa. The type of green roof depends on the building, its location, height and what the client expects from the green roof. In addition, the weight of the green roof plays an important factor in deciding which type of green roof should be supplied as the building needs to be designed to carry potential extra weight. Further, the availability of space on the terrace as well as the availability of the materials such as the drainage system or the plants that will be used impacts the selection of the green roof type.

The interviews with 44 suppliers in green roof systems disclosed an array of challenges surrounding the implementation of green roofs and associated building projects. The most significant cluster of challenges that were profiled related to cost considerations, logistics and waterproofing. In addition, a constant issue highlighted by green roof specialist and landscape architects is a lack of client awareness of the benefits of green roofs. Respondents confirmed that green roof systems are costly endeavours and vary in cost per square metre dependent on type of installed green roof, plants used, the materials such as the filters or drainage systems, amount of soil, and the size of the green roof. It was stressed that in commercial projects a high cost item is the use of high reach machinery which is deemed a necessity as it assists in creating green roofs in such commercial buildings. Maintenance of green roofs is another cost issue that suppliers have to deal with clients; indeed, the imperative for maintenance was signalled as the leading negative factor surrounding green roof systems. Waterproofing of the roof for the green roof was highlighted by 25 percent of respondent suppliers. Leakages from damaged or incomplete waterproofing have been central problems. The supplier companies expressed the view that clients often queried waterproofing and its complex of issues but the companies that specialised in green roofs inform clients that green roofs protect the waterproofing layer from exposure to sunlight.

Another critical challenge is the logistics attached to green roof system construction – flagged by one-quarter of respondents – as many of the roofs have limited access thus necessitating the use of expensive heavy machinery (such as cranes) to move materials and soil. A further challenge of building logistics surrounded access to the roof as buildings without lifts to transport the materials results in time-consuming manual transfer of materials to roof sites. Beyond logistical issues surrounding access to roofs for many suppliers the weight of the green roof is critical as weight is a determining factor as to whether buildings can support a green roof. If the building cannot, reinforcement is needed which once again can be a high cost consideration. In the absence of reinforcement, the green roof design needs to be specifically undertaken to handle the roof's weight and especially of the soil cover. Other matters highlighted by respondents surrounded project timing and of client's often unrealistic expectations about project completion schedules. The positioning of plants was an issue for landscape architects as too much or too little sunlight can cause the plants to die. The choice of materials is also seen as a challenge as type of drainage system or filter used needs to be considered to prevent blockage as well as the combination of different growing mediums as some products are expensive or are too heavy to use solely.

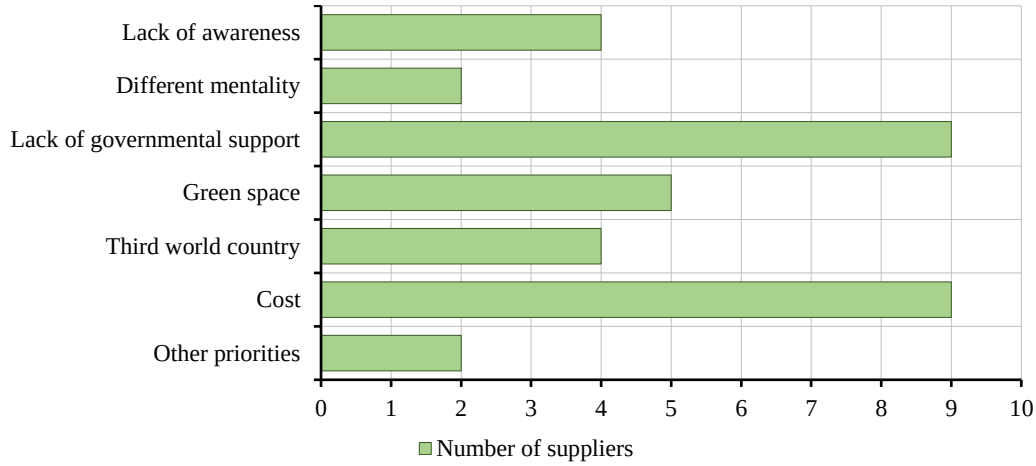

Figure 2. Reasons for lack of uptake of green roofs in South Africa
(Source: Adapted from Cuthbertson, 2017).

Finally, the 44 respondents were probed as to their perceptions for the lack of uptake and limited progress of green roof initiatives in South Africa. The results from the Cuthbertson (2017) study are captured on Figure 2. As is evidenced the two most significant issues which account for the underdevelopment of green roof systems in urban South Africa relate to cost considerations and lack of any government financial support for green roofs. The absence of any government incentives in South Africa contrasts with the availability of green roof incentives or subsidies available in several countries in the Global North (Liberalesso, Cruz, Silva, & Manso, 2020). Other explanatory factors that were raised concerned the greater broader availability of green space in South Africa as compared to other countries, its status as a developing economy and an overarching lack of awareness of the potential benefits that might accrue for urban sustainability from the growth of green roof systems. Lastly, there was clear acknowledgement among respondents that the lack of government support might be understood (and partially excused) on the grounds of massive urban challenges faced in South Africa around basic service and infrastructural provision.

CONCLUSION

Green infrastructural developments are an integral part of planning for urban sustainability and dealing with the multiple problems surrounding climate change (Zhang & He, 2021). In light of the projected concentration of rapid urbanisation in cities of the Global South there is a particular imperative in these areas for advancing sustainable urban development agendas (Ávila-Hernández, Simá, & Ché-Pan, 2023). One critical aspect of this agenda is the development of green roofs. Arguably, there is an accumulating body of research which is confirming that green roofs have significant potential for addressing a part of the environmental challenges that are facing cities (Jim & Hui, 2022; Scolaro & Ghisi, 2022; Wooster, Fleck, Torpy, Ramp, & Irga, 2022; Tafazzoli, 2023).

This study has investigated the limits of green infrastructure in a Global South context. In the South African case the findings in respect of green roofs show the relative underdevelopment of green roof systems, the geographical unevenness of such developments and the challenges that confront the emergence of green roof systems in the South African context. Key local issues relate to current high costs associated with green roof construction, absence of government support in the form of financial incentives, and lack of awareness of the sustainability benefits that attach to the roll out of green roof systems. These findings underline the urgency for further research investigations to be conducted into the green infrastructural challenges that face urban development in the Global South and most especially in the challenging environment of contemporary urban South Africa.

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