Green Retrofitting of Existing Buildings in South Africa

Lerato Aghimien[1], Douglas Aghimien[2], Olugbenga Oladinrin[3], Clinton Aigbavboa[4], and Lerato Mokwena[5]

[1] Department of Construction Management and Quantity Surveying, University of Johannesburg, South Africa
[2] School of Art, Design and Architecture, De Montfort University, Leicester, United Kingdom
[3] Built Environment Department, School of Art, Design and Architecture, University of Plymouth, United Kingdom
[4&5] cidb Centre of Excellence, Faculty of Engineering and the Built Environment, University of Johannesburg, South Africa
douglas.aghimien@dmu.ac.uk

Abstract
Existing buildings account for a large consumption of energy and greenhouse gas emissions. However, studies have noted that the conversion of existing buildings into green buildings has great potential to conserve energy and reduce these greenhouse gas emissions. Based on this knowledge, this study assessed the green retrofitting features employed in existing buildings and the drivers of the use of these features in South Africa. The study was conducted among participants with expertise in green construction through a questionnaire survey. The data gathered were analysed using a mean score, Kendall's coefficient of concordance, chi-square, and exploratory factor analysis. The study found that the use of movement sensors to control electricity usage is a common feature in the country. Furthermore, the use of green retrofitting is driven by five major group of factors, vis; (1) economic growth, (2) occupants' expectations and satisfaction, (3) environmental sustainability, (4) return on investment, and (5) government support. The findings also offer a theoretical contribution to the existing green construction discourse from the perspective of existing buildings in South Africa.

Keywords Green building, Green retrofit, Sustainable construction, Sustainability

1. Introduction
The building sector plays a vital role in developing countries economic growth and job creation (Fenske, 2019). However, despite its significance, the building sector has been heavily associated with greenhouse gas emissions, environmental degradation, global warming and energy consumption (Doan *et al.*, 2017; Okorafor *et al.*, 2020). Approximately 10% of all global energy supply occurs during building materials manufacturing (Burdett *et al.*, 2011). The United Nations environmental programme reports that the built environment contributes approximately 40% to global energy consumption and 36% to greenhouse emissions (Terblanche, 2019). Also, rapid urbanisation has been seen to cause pressure on energy, resources and the environment (Baldwin *et al.*, 2018), and recently, developing countries have become known for their rapid urbanisation (Aghimien *et al.*, 2022; Terblanche, 2019). To this end, the International Energy Agency (2008) has predicted an increase in the share of urban energy demand to 70% and CO_2 emissions to 76%.

Green retrofitting has been proposed as a viable option to address this issue of the unsustainable nature of the built environment. The term retrofitting, according to Ismail and Rogerson (2016:3), "is an attempt at rectifying environmental degradation and improving upon the existence of resource-intensive and efficient systems which inevitably exert negative environmental consequences". Aigbavboa *et al.* (2019:2) define building retrofit as "the addition and utilisation of new technologies and features to enhance their effectiveness and efficiency". Therefore, green retrofitting can be described as a sustainable approach to enhancing the energy resource efficiency of existing buildings (Li *et al.*, 2020). The conversion of existing buildings to green buildings can assist in conserving energy and reducing the global emission of carbon gas (Lueng, 2018).

Like other developing countries, South Africa is experiencing rapid urbanisation, with more than 60% of the country's population moving into cities (United Nations, 2020). Expectedly, this influx of people into cities has put significant stress on the available infrastructure and has also resulted in intense pressure on energy resources and the environment (Baldwin *et al.*, 2018). Thus, it has become a challenge for the government to meet the energy demand of the large population (Aigbavboa *et al.*, 2019). According to McClintock *et al.* (2017), existing buildings consume the highest amount of energy within the building sector. Therefore, green retrofitting of the existing structure has been proposed as an effective tool to mitigate the deteriorating environment, attain sustainability, and improve energy resource efficiency (Deng *et al.*, 2019; Li *et al.*, 2020). However, in South Africa, not much attention has been paid to greening existing buildings (Aghimien *et al.*, 2018). Only a few studies have explored the green retrofitting of existing buildings in the country. Thus, the need for empirical evidence that will encourage the transformation of existing buildings into more sustainable dwellings and reduce the negative impact of these buildings on the environment is important. To this end, this study assessed the green retrofitting features employed in existing buildings and the drivers of the use of these features in South Africa. Subsequent parts of the paper include a review of extant literature, methodology, findings and conclusions drawn from the study's results.

2. Green Retrofitting of Existing Buildings

It is accepted that 21st-century urban areas must be greener and more intelligent; thus, advancing maintainable urban areas has become a central point of contention for some diverse countries worldwide. The idea of sustainability is a broad worldwide issue, including different interrelated examinations of individuals, the climate and society (Berardi *et al.*, 2013). To this end, the Green Building Council of South Africa (GBCSA) was formed in 2007. The GBCSA is aimed at developing green building solutions to drive the revolution of the South African construction industry towards sustainability. The council advocates for solutions and tools that enable the design, construction and operation of all buildings in an environmentally sustainable manner. It provides certification of buildings using diverse rating tools such as Green Star, Net Zero, EDGE among others. The council further encourages a new approach to designing and building by rewarding best practices and excellence.

Unfortunately, many existing structures have been noted to be energy and water-wasteful (Alam *et al.*, 2019). By adhering to new codes, by 2050, the world structure warming and cooling energy use could be decreased by about 46% when contrasted with 2005 (Ürge-Vorsatz and Herrero, 2012). Also, by consolidating the presently accepted procedures in building plans, developments, and activities, through cutting-edge retrofits, energy and water wastage can decrease by up to 40%. Hence, retrofitting existing structures is the way into a supportable future since the current structures, which seem to be unstainable at the moment, will be with us as long as possible (Alam *et al.*, 2019).

Several drivers can play a significant role in achieving the effective implementation of green retrofitting. For instance, the attitude towards energy savings, awareness of sustainable measures, income, age, and education have been noted as some factors (Dunkelberg and Steib 2013). According to Organ *et al.* (2013), internal and external factors motivate green building retrofit. The external factors can be financial rewards, while the internal factors are based on individual needs, expectations, and satisfaction. Studies have also noted the role of government policies and legislation in driving green retrofitting of existing buildings (Ampratwum *et al.*, 2019). Policy guidance and government can motivate building owners to implement green retrofit (Li *et al.*, 2020). In December 2015, South Africa's National Treasury released a draft carbon tax bill. The carbon tax aims to influence change in how firms operate, providing incentives to those moving towards cleaner technologies (Aigbavboa *et al.*, 2017; Bohlmann *et al.*, 2016). Also, enforcing these policies and legislations is crucial to successfully implementing these green concepts (Powmya and Abidin, 2014). The availability of administrative and authoritative structures puts focus on all significant development partners to either embrace the new concept or face the consequences of non-adoption. Administrative and authoritative prerequisites are powerful and compelling in both driving change and bringing issues to light (Ampratwum *et al.*, 2019). Also, Cheng *et al.* (2019) noted that government provision of economic subsidies, tax preferences, discounts on loans' interest rates, technical support for green retrofitting initiatives and direct rewards could be a positive driver of green retrofitting. Lueng (2018) also emphasised the significance of the government's financial support in influencing green building.

The expectations of occupants of an existing building can also be a crucial driver to the green retrofitting of such a building. According to Liang *et al.* (2016), the owners and occupants are key players in establishing green retrofit. Occupants have a direct impact on the energy use of the building through expectations of indoor air quality and visual and acoustic comfort, which determine their satisfaction with the building (Leng, 2018). Clearly, the satisfaction of these occupants is important. Ampratwum *et al.* (2019) noted that when existing buildings are green-retrofitted, they become energy-effective and less contaminating, giving a more advantageous climate to their occupants. More so, green structures save energy and water and add to the occupant's wellbeing.

Buildings are considered an investment for many owners, and the main concern is risk and rate of return. Greening existing buildings gives building owners the possibility of impressive future returns on their structures. According to Windapo (2014), investors seek assurance that buildings are green star rated to avoid being unable to sell or lease their building in the future. Green structures have a serious market advantage as designers and investors have noted that green structures command more noteworthy market interest in readiness to pay than conventional structures (Aliagha *et al.*, 2018). Retrofitting a structure is frequently more affordable than destroying and rebuilding new ones. Furthermore, since no destruction is done or as the development time frame is decreased, the financing cost is diminished (Jagarajan *et al.*, 2017). Other significant drivers are the conservation of energy and the natural environment (Jagarajan *et al.*, 2017), the need to combat global warming (Lueng, 2018), enhancing the sustainability of existing buildings (Jagarajan *et al.*, 2017; Li *et al.*, 2020) and potential growth on the economy (Saladin and Turok 2013).

3. Research Method

The study is quantitative and employs a structured questionnaire to explore the green retrofitting of existing buildings in South Africa. The use of questionnaires was premised on the ability of the instrument to reach a larger group of respondents within a short time (Tan, 2011). The study employed a purposive and snowball sampling approach to gather data from green building experts. Purposive sampling was first used to identify some professionals that have worked on green buildings. However, because it was difficult to determine the total number of green building experts at the time of conducting the research, a snowball approach was then employed to reach out to more experts through a referral from those initially identified. Based on the approach adopted, 123 usable samples were derived and considered fit for data analysis in the study. The questionnaire was designed in sections, where the first section sought answers to specific demographic questions. The second section assessed some of the green retrofitting features adopted on a 5-point Likert scale, with one being very low usage and five being very high. The third section of the questionnaire explored the drivers of implementing green retrofitting in existing buildings using a 5-point agreement scale, with 1 being strongly disagree and 5 being strongly agree.

The analysis of the data gathered on the respondents' background information was done using frequency (*f*) and percentage (%). The reliability of the questions in sections two and three was tested using the Cronbach alpha (α) test with a cut-off of 0.7. To rank the factors in both sections, the mean score ($\bar{X}$) was employed. Furthermore, Kendall's coefficient of concordance (*W*) and chi-square (χ^2) were adopted to affirm the level of agreement between respondents in the ranking of the variables in the two sections. The choice of employing χ^2 is premised on its suitability in assessing variables higher than seven (Siegel and Castellan, 1988). The data from section three was further explored using exploratory factor analysis (EFA). EFA is suitable for regrouping many variables into more describable subscales using the latent similarity between variables (Field, 2000). To conduct EFA, studies have encouraged a large sample (Norris and Lecavalier, 2010; Tabachnick and Fidell, 2013), a good Kaiser–Meyer–Olkin (KMO), and a significant *p*-value for the Bartlett test of sphericity (BTS) (Field, 2000; Preacher and MacCallum, 2002). The sample size, KMO and BTS derived in the study were considered adequate for EFA to be conducted.

4. Findings and Discussion

4.1 Background information

The analysis of the background information of the respondents revealed a spread of respondents from consulting (f = 60), contracting (f = 15), property investment (f = 26) and public sector (f = 22). These respondents possess bachelor's degrees (f = 66), master's degrees (f = 20) and diplomas (f = 24). They comprise green-star engineers (f = 15), green consultants (f = 36), facilities managers (f = 17), property developers (f = 18), and construction project managers (f = 37). Also, many of these respondents (f = 41) have between one to five years of working experience, while the remaining 82 respondents have above five years of experience within the South African built environment. The findings from this background information show that the respondents for the study are well equipped both academically and in experience to give logical answers to the questions of the research.

4.2 Green retrofitting features used in existing buildings in South Africa

The reliability test revealed an α-value of 0.782 for the green retrofitting features assessed in the study area. This implies that the instrument used for this section is reliable as the derived α is higher than the 0.7 cut-off. The result in Table 1 shows that the respondents for the study noted that the use of movement sensors ($\bar{X}$ = 4.49) and the installation of water tanks for water preservation ($\bar{X}$ = 4.37) are the two most commonly used features of green retrofitting in the study area. The use of cool roofs ($\bar{X}$ = 4.34), grey water recycling ($\bar{X}$ = 4.34) and replacing electrical fixtures ($\bar{X}$ = 4.32) are also gaining prominence in the study area. On the other hand, using materials that are less volatile appeared as the least features ($\bar{X}$ = 3.18) and requires further attention in the quest for a green environment.

The standard deviation (SD) of all the assessed variables is below 1.0, thus implying that there is no deviation in the $\bar{X}$-values of these variables as rated by the respondents. Further analysis using Kendall's *W* gave a value of 0.45, below the average of 0.5. However, the calculated χ^2 (340.48) is greater than the critical χ^2 (26.76) derived from the statistical table, thus implying that the respondents' ranking of the green retrofitting features is related to each other within the groups, and no disparity exists.

Table 1: Green retrofitting features of existing buildings

Green retrofitting features	$\bar{X}$	SD	Rank
The use of movement sensors	4.49	0.502	1
Installation tanks collecting rainwater for water preservation	4.37	0.760	2
The use of a cool roof for minimising the roof surface temperature	4.34	0.675	3

Grey water recycling systems	4.34	0.756	4
Replacing electrical fixture	4.32	0.577	5
The use of daylight control measures	4.20	0.746	6
Installation of louvers to minimise heat gain	4.20	0.757	7
Installing mechanical ventilation of systems	4.11	0.749	8
Insulation of internal and external wall cavities	4.08	0.609	9
Modifying existing windows	3.86	0.793	10
Replacing fan coils with heat pumps	3.45	0.898	11
The use of painting, carpets, sealants, glues, and adhesives with low volatility	3.18	0.869	12
Kendall's *W*	0.452		
χ^2	340.48		
χ^2 – Critical values from the statistical table (p = 0.05)	26.76		
Df	11		
Sig.	0.000		

4.3 Drivers of green retrofitting of existing buildings in South Africa

The reliability test conducted revealed an α-value of 0.812 for the drivers of green retrofitting in the study area. This implies that the instrument used for this section is reliable as the derived α is higher than the 0.7 cut-off. The result in Table 2 shows that the most significant drivers, according to the rating of the respondents, are the need to combat global warming ($\bar{X}$ = 4.54), government financial support ($\bar{X}$ = 4.39), conservation of the natural environment ($\bar{X}$ = 4.38), future competitiveness for investors ($\bar{X}$ = 4.37), and expectations of occupants ($\bar{X}$ = 4.31). The idea that retrofitting cost lesser than demolishing and rebuilding was rated as the least driver with a $\bar{X}$ of 3.02. The SD of all the assessed variables is below 1.0, thus implying that there is no deviation in the $\bar{X}$-values of these variables as rated by the respondents. Further analysis using Kendall's *W* gave a value of 0.58, which is above the cut-off of 0.5 set for a disparity to exist in the rating of the variables. Also, the calculated χ^2 of 659.13 is greater than the critical χ^2 (32.80) derived from the statistical table. This result shows that the ranking of the drivers of green retrofitting by the respondents is related to each other within the groups, and no disparity exists.

Table 2: Drivers of green retrofitting of existing buildings

Drivers	$\bar{X}$	SD	Rank
Need to combat global warming	4.54	0.617	1
Government financial support	4.39	0.661	2
Conservation of the natural environment	4.38	0.594	3
Future competitiveness for investors	4.37	0.812	4
Expectations of occupants	4.31	0.703	5
Satisfaction of occupants	4.24	0.682	6
Government policies and regulations	4.04	0.814	7
Conservation of energy	4.01	0.659	8
Attractive return on investment	4.00	0.810	9
Protecting investment	3.99	0.773	10
Enhancing the sustainability of existing buildings	3.97	0.557	11
Government enforcing existing legislation and policies	3.95	0.700	12
Potential growth on the economy	3.72	0.890	13
Pressure on construction stakeholders	3.44	0.925	14
Retrofitting cost lesser than demolishing and rebuilding	3.02	0.730	15
Kendall's *W*	0.557		
χ^2	659.13		
χ^2 – Critical values from the statistical table (p = 0.05)	32.80		
Df	14		
Sig.	0.000		

Considering the large number of drivers assessed (15), EFA was conducted to further reduced these drivers into a more manageable subscale, as suggested by Pallant (2011). In conducting EFA, the factorability of the data was tested using the KMO and BTS analysis. KMO revealed a value of 0.623, which is above the threshold of 0.6 for factorable data. Also, BTS was significant at a p-value of 0.000 which is in line with past submissions that the BTS value must be < 0.05 for data to be considered factorable (Tabachnick and Fidell, 2013). Following these results, the EFA was conducted on the 15 drivers using principal component analysis (PCA) with Varimax rotation. Five principal components with an eigenvalue of above one and a cumulative variance of 85.17% were derived. This implies that the 15 assessed variables account for 85.2% of the drivers of green retrofitting in the study area. The other 14.8% can be found in other variables not assessed in this current study. The result from the scree plot in Figure 1 further confirms the retaining of these five components as a clear change is visible from the fifth variable.

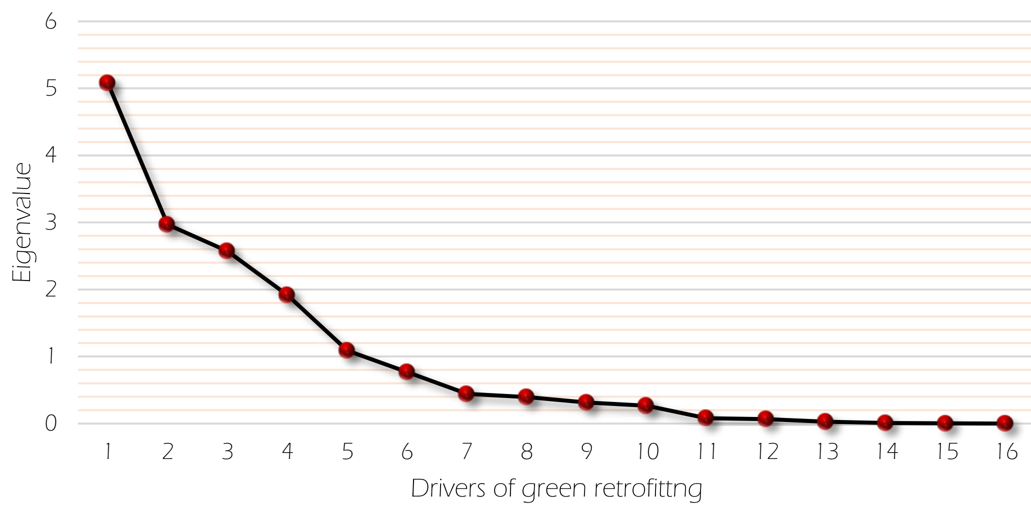

Figure 1: Scree plot

Table 3 shows the five extracted components. These components are:

Economic growth - The first principal components account for 31.7% of the total extraction and have two variables; retrofitting cost lesser than demolishing and rebuilding and the potential economic growth. This component was named economic growth drivers based on the latent similarity between these two variables.

Occupants' expectations and satisfaction - The second principal component account for 18.6% of the total extraction and has three variables. These variables are the satisfaction of occupants, expectations of occupants and pressure on construction stakeholders. This component was subsequently named occupants expectations and satisfaction based on the relatedness of the variable.

Environmental sustainability - Component three, which accounts for 16% of the total extraction, has four variables. These variables are the conservation of energy, conservation of the natural environment and enhancing the sustainability of existing buildings. The variables' similarity led to the naming of the group as environmental sustainability.

Return on investment - The fourth principal component has three variables and accounts for 12% of the total extraction. The variables in the component are future competitiveness for investors, attractive return on investment, and protecting investment and were subsequently named return on investment drivers.

Government support - The last principal components account for 6.8% of the total extraction and have three variables, vis, government policies and regulations, government enforcing existing legislation and policies, and government financial support. Since these variables are all government related, the component was subsequently named government support.

Table 3: Rotated component matric of the drivers of green retrofitting of existing buildings

	Extracted components					Communalities
Drivers	**1**	**2**	**3**	**4**	**5**	**Extraction**
Retrofitting cost lesser than demolishing and rebuilding	0.936					0.923
Potential growth in the economy	0.918					0.889
Satisfaction of occupants		0.961				0.945
Expectations of occupants		0.837				0.917
Pressure on construction stakeholders		0.692				0.724
Conservation of energy			0.907			0.901
Conservation of the natural environment			0.900			0.949
Enhancing the sustainability of existing buildings			0.698			0.837
Need to combat global warming			0.530			0.780

Future competitiveness for investors	0.911		0.923
Attractive return on investment	0.870		0.860
Protecting investment	0.661		0.802
Government policies and regulations		0.865	0.834
Government enforcing existing legislation and policies		0.803	0.893
Government financial support		0.688	0.772

4.4 Discussion of findings

The findings of the study revealed that while green retrofitting is not as common as the traditional approach in the study area, some green retrofitting features are evident. The use of movement sensors born out of the rapid technological advancement that is also influencing South Africa (Dall'Omo, 2017) was observed from the result of the study. Also, the installation of water tanks for water preservation, use of cool roofs, grey water recycling and replacing electrical fixtures with energy-efficient ones are commonly used in green retrofitting in the country. Evidently, while the perseveration of water is heavily considered, the perseveration of energy through the use of appropriate fittings is necessary. This is in support of Camhbel *et al.*'s (2014) submission that the replacement of electrical fixtures with energy-efficient light controls and green power promotes sustainable buildings. As such, Fansa and Gunatilake (2018) have suggested that movement sensors and dimmers are to be utilised to meet lighting requirements in buildings at all times.

The use of green retrofitting is driven by several factors that can be grouped into five major clusters, vis; (1) economic growth, (2) occupants' expectations and satisfaction, (3) environmental sustainability, (4) return on investment (5) government support. Studies have noted that green retrofitting can offer better value for money. Since it is easier to green retrofit than to demolish and reconstruct, some savings are made in cost and time (Jagarajan *et al.*, 2017). This can be a significant driver of the adoption and implementation of green retrofitting in some existing buildings, as indicated by the findings of this current study. Also, Liang *et al.* (2016) have earlier noted that owners and occupants are key players in establishing green retrofit. The findings of this current study support this submission as it was discovered that drivers relating to the satisfaction and expectations of the occupants and other stakeholders could significantly shape the adoption of green retrofit. Thus, building owners seeking to ensure that their occupants gain satisfaction with their buildings might have to consider using green features to retrofit their structures. This is because studies have noted that green retrofitted buildings give a better atmosphere and improve occupants' wellbeing (Ampratwum *et al.*, 2019).

Past studies have noted that the built environment is one of the biggest contributors to greenhouse emissions (Burdett *et al.*, 2011). However, it has also been noted that green retrofitting has the potential to reduce carbon emissions (Lueng, 2018). As such, it is not surprising to see experts within the study area indicating that the need to conserve energy and the natural environment and ensure the sustainability of existing buildings are essential drivers of the use of green retrofitting. All these are pointers to the fact that as the sustainability discussion grows, more green concepts will be introduced to existing buildings to make them reach the required standards. Also, it has been noted that green retrofitting of buildings offers a better return on investment for clients and a competitive market advantage (Aliagha *et al.*, 2018). The finding of this study affirms this submission as the envisaged return on investment is a key driver of green retrofit in the study area. Investors and owners of existing buildings can, therefore, take the opportunity of improving the future worth of the property by investing in green features that will yield better investment returns.

Finally, the government's role in attaining a green environment has been emphasised in past studies (Ampratwum *et al.*, 2019). This support can be in the form of financial assistance for clients seeking to implement green concepts (Cheng *et al.*, 2019), enacting of laws that support green concepts (Li *et al.*, 2020) and ensuring that measures are put in place to enforce the laws enacted (Powmya and Abidin, 2014). The findings of this current study support these past submissions as it was noted that government support is a significant driver of green retrofitting of existing buildings in South Africa.

5. Conclusion

The study set out to assess the green retrofitting features employed in existing buildings and the drivers of using these features in South Africa. Through a quantitative survey, the study concludes that while green retrofitting is just gaining recognition in the country, green retrofitting features such as the use of movement sensors, water tanks installations for water preservation, cool roofs, grey water recycling and replacement of existing electrical fixtures with energy-efficient ones are evident in the country. The drivers of green retrofit in the country can be grouped into economic growth, occupants' expectations and satisfaction, environmental sustainability, return on investment and government support. Thus, the study recommends that for green retrofit to be pervasive in South Africa, it is essential for building owners and investors to be sensitised on the economic benefits and possible return on investment they can get from employing this approach. Also, the government must be ready to push the green transformation agenda rigorously through support, policies, and legislation favouring green concepts.

The study's findings offer guidance on the use and drivers of green retrofitting to encourage the transformation of existing buildings into more sustainable dwellings. The findings also offer a theoretical contribution to the existing green construction discourse from the perspective of existing buildings in South Africa. Despite these contributions, the study's methodology limits the results. The current study adopted only a quantitative approach. Future works can employ a qualitative or mixed-method approach to get a different perspective.

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