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The South African Council for the Quantity Surveying Profession (SACQSP) has simplified the submission and assessment of Continuining Professional Development (CPD) requirements of registered persons. CPD submission now requires disclosure of the number of hours invested meaningfully in activities in two main categories. Category 1 activities are those arranged or presented by or to 'external' organisatins such as participation in conferences, congresses, workshops or seminars, presentation of lectures, external examination for academic programmes, publication of articles in journals or magazines, other similar activities. Category 2 activities are less formal 'internal' activities such as in-house training or seminars, small group discussions, self-study of journals, magazines, articles on web pages, etc.

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Royal Institution of Chartered Surveyors (RICS) supports *Acta Structilia*

Royal Institution of Chartered Surveyors (RICS) supports the aims and objectives of *Acta Structilia* and welcomes the efforts being made to improve our knowledge and understanding of the built environment, particularly in an African context.

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TRENDS IN APPLICATION OF GREEN STAR SA CREDITS IN SOUTH AFRICAN GREEN BUILDING

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ABSTRACT

The South African green building industry is growing towards maturity. Stakeholders need to observe, document, and be informed about trends and development of the industry. This article evaluates whether application trends have emerged of often achieved and seldom achieved Green Star SA credits by all new office buildings that received a Green Star SA rating between 2009 and 2015 in South Africa. Any observed trends are further described by aspects such as the categories of the Green Star SA tool and the Green Star SA rating achieved. The article considers the data of 95 office buildings, made available by the Green Building Council of South Africa (GBCSA). A quantatitive research approach is used to investigate the use frequency of every credit in the Green Star SA tool and to identify trends in credit use. The study finds that 21 of the 67 credits are achieved on average by >80% of the certified projects. Another 14 credits have an average achievement rate of <20%. The nine categories of the Green Star SA tool also varies from average achievements of 84% for Water to only 19% for Innovation. The Green Star SA rating level is also found to be positively correlated to often used credits and negatively correlated to seldom used credits. This article observes industry-wide trends with the potential to negatively affect the ability of green buildings to deliver the required sustainability outcomes expected of them. This finding and the potential outcome thereof need to be monitored and managed by stakeholders such as the GBCSA.

Keywords: Application trends, green building, South Africa, sustainability, trends

ABSTRAK

Die Suid-Afrikaanse groenbou-industrie groei tot volwassenheid. Dit is belangrik dat belangegroepe ingelig bly oor die verskillende fasette en ontwikkelings van die industrie. Hierdie artikel ondersoek die tendense in die toepassing van die Groenster-krediete van die verskillende nuwe Suid-Afrikaanse kantoorgeboue wat Groenster-gradering verwerf het tussen 2009 en 2015. Die studie soek na die bestaan van tendense in die nastreef van krediete wat verwerf is as deel van die groenbousertifiseringsproses. Enige geïdentifiseerde tendense word verder beskryf deur evaluering van aspekte soos die kategorieë van die Groenster-werksdokument en die Groenster-graderingvlak wat verwerf is. Die artikel oorweeg die data van 95 kantoorgeboue, beskibaar gestel deur die Groenbouraad van Suid-Afrika (GBRSA). ’n Kwantitatiewe navorsingsbenadering is gevolg om die gebruiksfrekwensie van elke krediet in the Groenster-werksdokument te ondersoek en om tendense in die gebruik van krediete te identifiseer. Die studie bevind dat 21 van die 67 krediete gemiddeld deur >80% van gesertifiseerde geboue verwerf is, terwyl 14 ander krediete deur <20% van gesertifiseerde geboue verwerf is. Die nege kategorieë van die Groenster-werksdokument wissel ook van 84% gemiddelde benutting vir Water tot 19% vir Innovasie. Die Groenster-gradering was ook positief gekorreleerd met dikwels benutte krediete en negatief gekorreleerd met selde verwerfde krediete. Die artikel identifiseer tendense met die potensiaal om die vermoë van groengeboue om hul verwagte volhoubare resultate te lewer, negatief te beïnvloed. Hierdie bevindinge en die potensiële effek daarvan behoort gemonitor en bestuur te word deur ’n belangegroep soos die GBRSA.

Sleutelwoorde: Groenbou, ontwerpstrategieë, Suid-Afrika, tendense, volhoubaarheid

1. INTRODUCTION

1.1 Background

The adverse effects of global warming, such as rising average temperature and even a possible ice-free winter by 2040 (UNEP, 2007: 1), and an ice-free Barents Sea between 2061-2088 (Onarheim & Arthun, 2017: 1) have been widely published. Birnie, Boyle and Redgewell (2009) stated that climate change might be the most significant environmental challenge of our time. The construction industry carries much of the blame for this situation, as the industry generates 50% of the world’s waste, much of the water pollution, and 40% of the world’s air pollution. Buildings account for 25% of world wood harvest, one-sixth of the world’s freshwater withdrawal, and two-fifths of its materials and energy flows. It is, therefore, important that buildings should become more natural-resources efficient (GBCSA, 2015; WGBC, 2010; Magoulès & Zhao, 2010: 13-15; Toller, Wadeskog, Finnveden, Malmqvist & Carlsson, 2011: 395).

The challenge created by global warming also creates the potential for the construction industry to significantly contribute to ensuring a greener and more sustainable environment (Pekka, 2009: 4,6; CIDB, 2009: 2). The challenge for the green building industry is to ensure that their green rating tools produce buildings that deliver on the promise of increased sustainability.

Energy consumption during the operation phase of the building may consume as much as 80% of total energy used (Junnila, 2004). A study by Jacobs and Ragheb (2010: 21) indicates that the building's operational demands over a 60-year lifespan represent 96% of the total life-cycle energy. Construction methodologies, including construction materials and fittings, must strive to minimize the environmental impact from the operational phase of buildings. Buyle, Braet and Audenaert (2013: 382) support a total life-cycle approach and argue that the choice of materials, construction methods, and end-of-life use deserve more attention from designers and specifiers. Green building rating tools should, therefore, sufficiently allow for concepts of whole life cycle and embodied carbon (Van der Heijden, 2016).

1.2 Importance of the study

With the growing maturity of the sustainability industry, the degree and volume of criticism and calls for introspection on green building issues have also increased. Over a decade ago, a study by Scofield (2009a: 775; 2009b: 1389) questioned data published by the New Buildings Institute (NBI) and the United States Green Building Council regarding energy savings produced by Leadership in Energy and Environmental Design- (LEED-) certified buildings. Scofield found that the data offers no evidence that LEED certification has collectively lowered either site or source energy demands of office buildings.

More recently, Cole and Valdebenito (2013) as well as Van der Heijden (2016) found that green building is often restricted to high-end office buildings in upmarket business districts. Not enough is done to extend green building to existing buildings and to address the behaviour of occupants. In a USA study, Boschmann and Gabriel (2013: 231) also warn against a superficial approach to the credits being pursued, in order to achieve green building certification. Martek and Hosseini (2018) proposed that the performance of green buildings should be independently audited.

In an article in *The Australian Financial Review*, the co-founders of the Green Building Council of Australia (GBCA), Maria Atkinson and Ché Wall, warned that the GBCA is risking watering down green building certification by extending the Green Star SA rating system to buildings that fall below the very top tier of sustainable practices and techniques (Bleby, 2014: 2). The above examples of challenges faced by green building and of criticism of the certification process put a high onus on the integrity of the design and the use of green building rating systems.

Green building is still relatively new in South Africa, with the Green Building Council of South Africa (GBCSA) only founded in 2007. In 2009, the GBCSA launched the Green Star SA rating tool, which is based on the Australian Green Star tool but customised to suit the South African context (GBCSA, 2020). The local industry has, however, developed relatively quickly. In 2016, the GBCSA certified the 200th Green Star SA certified building (GBCSA, 2016) and, in September 2018, the milestone of 400 certified buildings was reached within approximately ten years of its existence (GBCSA, 2018).

However, for the South African Green Building industry to keep growing, it is necessary to have a sound understanding of the roles and functions of all primary industry stakeholders. The Green Star SA rating tool plays a critical role in setting the scene of how developers and consultants respond to the challenge of securing green building certification status.

This article investigates whether there exist trends in the credits achieved by green building-certified projects, which is an important facet of the implementation of the Green Star SA tool. Trends in the credits achieved may indicate trends in the application of credits pursued by the consultant teams of the different certified green building projects. If such trends do exist and are significant in scope, the resultant contribution of green buildings towards a more sustainable environment may be skewed, as some aspects of sustainable construction will be over-applied, while other aspects may be lacking. Such development has the potential to negatively affect the ability of green buildings to deliver the required sustainability outcomes expected of them.

2. LITERATURE REVIEW

2.1 The global environmental sustainability scenario

The global construction industry had to respond to the challenge of environmental sustainability. Nine countries founded the World Green Building Council (WGBC) in 1998, namely Australia, Brazil, Canada, India, Japan, South Korea, Mexico, Spain, and the United States of America (GBCA, 2014). The WGBC expanded over the next two decades to now include 80 member countries (WGBC, 2020). The growing market demand for environmentally friendly buildings required changes to building design and operation. Measuring tools were needed for sustainability in the construction industry (Haapio & Viitaniemi, 2008: 469, 470). Although cost was an issue, Nixon (2009: 5) confirmed that people are much more attracted to resource-efficient products and services.

Various green building rating tools were developed and launched to regulate, evaluate, and certify buildings that qualify as green buildings, suited to their local conditions. Some of the most well-known green building rating systems are the Building Research Establishment Environmental Assessment Method (BREEAM) tool launched in the United Kingdom in 1990, and the Leadership in Energy and Environmental Design (LEED) launched in the United States in 2000 (WGBC, 2014). The GBCA (2014) launched the Green Star system in 2003.

According to the United States Environmental Protection Agency (EPA), green building can be defined as the practice of creating structures and using processes that are environmentally responsible and resource efficient throughout a building's life cycle (EPA, 2018: 1)

2.2 Green Building Council of South Africa

The GBCSA was established in 2007. South Africa is still the only established member of the WGBC on the African continent, with Ghana, Cameroon, Rwanda, Mauritius, Namibia, and Tanzania as prospective members and Kenya as an emerging member (WGBC, 2020). The GBCSA launched the South African Green Star SA rating tool in 2009. The tool is based on the Australian Green Star tool but customised for the local context (GBCSA, 2014).

The objectives of Green Star SA can be summarised as follows (GBCSA, 2020):

- Establishment of a common language and standard of measurement of green buildings;
- Promotion of integrated, whole-building designed buildings;
- Creating awareness about the benefits of green buildings;
- Reducing the impact that development has on the environment, and
- Recognition of environmental leadership.

Green Star SA provides a full array of rating tools for the different types of buildings as well as for interiors and existing buildings' performance:

- New Buildings and Major refurbishments v1 & v1.1 (Office, Multi-Unit Residential, Public and Educational, Retail);
- Existing Building Performance v1;
- Interiors v1;
- Sustainable Precincts;
- Green Star SA Custom (e.g. Hotel, Mixed Use, Hospital, Industrial);
- Net Zero Carbon, Water, Waste, Ecology;

- Socio-Economic Category PILOT;
- Energy and Water Performance (EWP), and
- EDGE Residential.

The Green Star SA rating tool is based on the GBCA's Green Star – Office v3 Tool. The Office rating tool version 1 was released in November 2008, and the amended version 1.1 was released in November 2014. The New Buildings and Major Refurbishment rating tools provide for both design and as built phases of new developments (GBCSA, 2020).

2.3 Rating categories and category weights

The Green Star SA rating tool consists of nine different categories that assess the environmental impact resulting from the project's site selection, design, and construction. The nine categories each include a number of credits that address different initiatives that improve a building's environmental impact. Each credit has been awarded a number of points. A project applying for Green Star SA certification may be awarded for each credit to the extent that the project has met the objectives (see Table 1) (GBCSA, 2020).

Table 1: Green Star SA Office v1.1 tool: Categories and weights

Description of categories and credits		*Weighting (score out of 100)*
Management (MAN)		9
Eight credits: MAN 1-MAN 8	Promotes environmental principles through the inception, design, and construction phases of a development and the commissioning, tuning, and operations of the development	
Indoor Environment Quality (IEQ)		15
Seventeen credits: IEQ 1-IEQ 17	Promotes the comfort and well-being of all the occupants of the building. Factors such as the HVAC system, lighting, indoor air pollutants, and some building attributes contribute to a good indoor environmental quality. Comfort factors including external views, individual climate control, and noise levels are also examined	
Energy (ENE)		25
Five credits: ENE 1-ENE 5	Aims to reduce energy consumption, which impacts on the greenhouse gas emissions and other harmful emissions that are related to energy production from fossil fuels	
Transport (TRA)		9
Five credits: TRA 1-TRA 5	Aims at similar principles laid out in the energy category by rewarding the reduction in automotive commuting as well as the use of alternative transportation methods	

Description of categories and credits		*Weighting (score out of 100)*
Water (WAT)		14
Five credits: WAT 1-WAT 5	Aims to reduce potable water through the efficient design of building systems, rainwater collection, and water reuse	
Materials (MAT)		13
Eleven credits: MAT 1-MAT 11	Promotes re-use of materials and efficient management practices; therefore, it considers the consumption of resources	
Ecology (ECO)		7
Four credits: ECO 1-ECO 4	Promotes the reduction of the impact of buildings on ecological systems and biodiversity and initiatives to improve ecological systems and biodiversity surrounding the project	
Emissions (EMI)		8
Nine credits: EMI 1-EMI 9	Targets the impacts of the building's emissions on the environment, including watercourse pollution, light pollution, ozone depletion, global warming, Legionella, and sewerage	
Total		100

Source: GBCSA, 2020: online

Once all the categories have been assessed, a total score is calculated for the project, using category weighting factors. Each category carries a different weighting depending on the importance of the category with regard to environmental performance. A maximum score out of 100 can be achieved (GBCSA, 2020).

The overall score is then compared with the rating scale, and a rating is then determined. The rating scale is shown in Table 2.

Table 2: Green Star SA rating tool scores

Overall Score	*Rating*	*Outcome*
10-19	One Star	Not eligible for formal certification
20-29	Two Star	Not eligible for formal certification
30-44	Three Star	Not eligible for formal certification
45-59	Four Star	Eligible for Four Star Certified Rating that was recognized/rewards 'Best Practice'
60-74	Five Star	Eligible for Five Star Certified Rating that recognizes/ rewards 'South Africa Excellence'
75+	Six Star	Eligible for Six Star Certified Rating that recognizes/ rewards 'World Leadership'

Source: GBCSA, 2020: online

2.4 Critical opinions on the green building industry

Section 1.2 refers to a growing volume of concerns and criticism being raised regarding issues relating to the green building industry. Much of this critical perusal centres around concerns regarding the efficiencies of green building rating tools, about the application of green rating tools, and if green buildings are delivering on their promise.

Recent studies (Cole & Valdebenito, 2013; Van der Heijden, 2016: 575, 584) found that green rating tools are struggling to access much deeper than market leading companies in the high-end commercial office property market. Van der Heijden also found that green building certifications are largely pursued by new buildings, while finding much lower application in existing buildings. Green building tools also focus on technology to reduce carbon load and energy consumption, but does little to change the behaviour of building users. Hayden (2014) speculated that the preference of a technological rather than a behavioural approach to address carbon footprint may be due to the ecological modernisation of many countries supporting green building.

A study by Boschmann and Gabriel (2013: 231) in Colorado, USA, critised LEED for only rewarding incremental solutions towards sustainability. The study proposed a more balanced approach to be pursued between rewarding the more superficial aspects of reduction of energy consumption and pollution through technology and green gadgetry versus a more in-depth approach involving local geographic conditions, natural climate systems, and informed design.

Martek and Hosseini (2018: 3), from Deakin University in Australia, also recently raised concerns regarding the actual performance of green buildings. They advised that sustainability rating tools should be independently audited. Most of the rating tools are predictive, while those few that take measurements use paid third parties. Governments should also be participating in the process.

2.5 Studies on green rating tools and application trends

Very few studies have focused on the difficulty of applying different credits included in green building rating tools. A recent study by Zuo, Xia, Chen, Pullen and Skitmore (2016) did a comprehensive analysis of all the office buildings certified by the GBCA at the time. The study focused on the Green Star SA rating tool to evaluate the challenges of achieving specific credits. The study found that credits relating to water efficiency, management of waste, and providing for alternative transport were relatively easy to achieve. Credits in the categories of Innovation, Ecology and Energy were relatively difficult to achieve.

Another study by Gou (2016: 627) considered the efficiency of green building for office interiors. The study found that very prominent and highly skilled architects and interior designers were often used in the projects considered. Most of the projects achieved high levels of interior sustainability, with low emitting materials and energy-efficient equipment. However, there was much evidence of easily achieved credits or 'low hanging fruit' being pursued. The study suggested that more significant green features need to be considered.

Work by Martek, Hosseini, Shresta, Zavadskas and Seaton (2018) places a specific perspective on the role and responsibility of green rating systems if the ideals of green building are to be achieved. Green rating tools were born from the conflict between economic growth, protecting the environment, and providing human well-being and comfort. Each rating tool proposes its own 'balance' between these conflicting interests. For green rating systems to work, they must be based on evidence of building performance. The embodied carbon of building products and processes over the full life cycle should also be integrated into green rating tools.

3. METHODOLOGY

3.1 Research method

The main aim of this article is to investigate whether there exist trends in the credits achieved by green building-certified projects. Such trends may indicate similarities in the green-building approach followed by the consultant teams of the different certified green building projects in the application of green building credits. The article considered the accreditation data of 95 Green Star SA-certified office buildings, made available by the GBCSA. The data is quantitative in nature and a quantatitive research approach was used to investigate the use frequency of every credit in the Green Star SA tool and to identify trends in credit use. The study was specifically looking to:

- identify credits achieved very often or achieved very seldom;
- compare the average achievement percentage of the different categories of the Green Star SA tool;
- describe the effect of 4 Star, 5 Star or 6 Star rating on the achievement percentage of credits, and
- analyse if time/the year of certification affected the average achievement percentage of the different credits.

3.2 Sampling

The study population is defined as all new office buildings that have been certified by the GBCSA with a 4, 5, or 6 Star Design or As Built rating, using the Office v1 and v1.1 rating tool from 2009 to 2015. A detailed credit score card also had to be available for each project. A total of 95 office buildings matched all of these requirements. The data of all of these projects was made available by the GBCSA to be included in the study. The fact that all qualifying buildings were included in the study addresses the aspect of validity and required that no further sampling was required.

3.3 Data collection

The data of the 95 buildings was captured on Excel in a matrix consisting of a Y-axis listing all the nine categories and the 67 credits of the Green Star SA tool and an X-axis listing all the 95 projects grouped according to their year of awarding of their green building certification from 2009 to 2015. Every credit achieved by each of the 95 buildings was then captured in the matrix for analysis. At the outset of the study, the GBCSA was contacted to secure their support. The GBCSA data was made available and the findings of the study will be shared with the GBCSA.

3.4 Data analysis

Most of the data analysis required descriptive statistics that were available in Microsoft Excel. The mean or average of data sets was calculated to describe the measures of central tendency of the often used credits (Table 3), the seldom used credits (Table 4), the average credit achievement per category (Table 5), the effect of 4 Star, 5 Star or 6 Star rating on the achievement percentage of credits (Table 6), and if time/the year of certification affected the average achievement percentage of the different credits (Figures 3-11). Descriptive statistics such as the variance, standard deviation and coefficient of variation were used to describe the measures of dispersion of the average credit achievement per category (Table 5) (Berenson & Levine, 2012).

Inferential statistics, more specifically the Pearson product moment correlation, was used to explore and describe the linear relationships between the average credit achievement percentage and the Green Star SA weighting factor per Green Star category (Table 5). The Pearson product moment correlation was also applied to describe the linear relationships between the Green Star SA certification level and the number of often or seldom achieved credits (Berenson & Levine, 2012; Puth, Neuhauser & Ruxton, 2014).

The number of credits achieved by all the projects per year was totalled and expressed as a percentage of the total number of projects for that year to calculate the average achievement percentage for a credit per year. For example, from the year 2012, a total of 15 projects were included in the study. In the category Management, the credit MAN-1 was achieved by eight of the 15 projects, giving MAN-1 an average achievement percentage for 2012 of 8/15 = 53%. After the data of all 95 projects were captured, a total number and an average achievement percentage for every credit for the total period of 2009-2015 were also calculated.

A deeper level of understanding of the credits targeted will be possible by analising the actual number of points of every credit that was targeted as well as the number of credits that was achieved. The data to enable this analysis was not available at the time of the study. A study to explore this aspect of application of Green Star SA credits similar to the study by Zuo *et al.* (2016) is planned for the near future.

Trends of credits achieved very often or achieved very seldom were identified according to the following parameters:

- Credits with an average achievement rate of >80% were defined as “Often achieved” credits that were favoured by the application approach followed.
- Credits with an average achievement rate of <20% were defined as “Seldom achieved” credits that were avoided by the application approach followed.

The effect of the Star rating level achieved on the achievement percentage of credits was calculated by sorting the buildings according to their 4, 5 or 6 Star rating achieved and repeating the sorting within the three groups of buildings to compare the findings with the overall findings to look for relationships. The same approach is used to study the effect of the date of certification on the achievement percentage of credits. The calculations will be done for buildings certified in every year for the period covered by the article: 2009-2015.

3.5 Limitations

Allthough every building that meets the requirements of the study was included and a total of 95 projects were analysed by the article, an even larger number may ensure higher levels of statistical confidence in the findings made. For this reason, the study should be repeated in future when the data of more certified green buildings will be available.

The article did not explore the achievements of Green Star SA credits to the depth of the total number of points available on each credit compared to the number of points targeted and the number of points achieved. This deeper level of analysis will be able to explore the reasons for the existence of trends identified and should, therefore, be considered as a follow-up study.

4. FINDINGS

4.1 Descriptive statistics

4.1.1 Often-used Green Star SA credits

The captured data was analysed to calculate the average achievement percentage for every credit for the period 2009-2015. The analysis revealed the following achievement percentage for the total number of 67 credits of the Green Star SA tool: six credits (0%-10%), eight credits (11%-20%), three credits (21%-30%), three credits (31%-40%), six credits (41%-50%), six credits (51%-60%), seven credits (61%-70%), seven credits (71%-80%), eight credits (81%-90%) and 13 credits (91%-100%). A total of 21 credits or 31.3% were achieved by more than 80% of the office buildings studied. These 21 credits are listed in Table 3 according to categories and are displayed in sequential order from lowest to highest achievement in Figure 1.

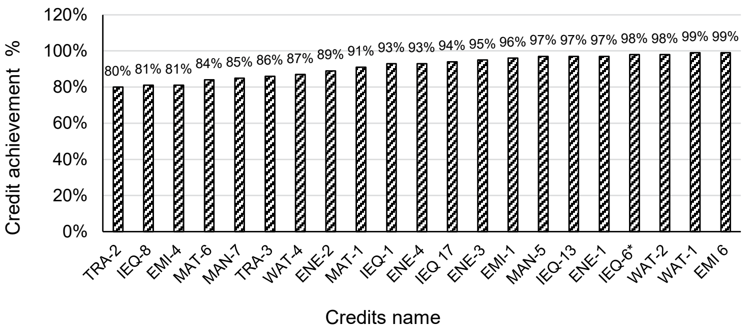

Figure 1: Green Star SA credits with > 80% achievement rate

4.1.2 Seldom used Green Star SA credits

The analysis also revealed that a total of 14 credits or 20.9% of the total number of credits had an average achievement rate of less than 20%. This trend may be due to technical, financial, or other constraints that hinder the frequent use of these credits. The credits are displayed in sequential order

Table 3: Green Star SA credits with >80% achievement rate

Description		*Average % achieved*
Management (MAN)		
MAN-5	Building users' guide	97
MAN-7	Waste management	85
Indoor Environment Quality (IEQ)		
IEQ-1	Ventilation rates	93
IEQ-6*	High-frequency ballasts*	98
IEQ-8	External views	81
IEQ-13	Volatile organic compounds	97
IEQ 17	Environmental tobacco smoke avoidance	94
Energy (ENE)		
ENE-1	Greenhouse gas emissions	97
ENE-2	Energy sub-metering	89
ENE-3	Lighting power sensity	95
ENE-4	Light zoning	93
Transport (TRA)		
TRA-2	Fuel-efficient transport	80
TRA-3	Cyclist facilities	86
Water (WAT)		
WAT-1	Occupant amenity water	99
WAT-2	Water meters	98
WAT-4	Heat rejection water	87
Materials (MAT)		
MAT-1	Recycling waste storage	91
MAT-6	Steel	84
Emissions (EMI)		
EMI-1	Refrigerant/Gaseous ODP	96
EMI-4	Insulant ODP	81
EMI-6	Discharge to sewer	99

* IEQ-6 High-frequency ballasts credit has been removed from the Green Star SA v1.1 tool, as this is regarded as code-compliant standard practice.

from the lowest to the highest percentage achievement in Figure 2 and listed in the category sequence in Table 4.

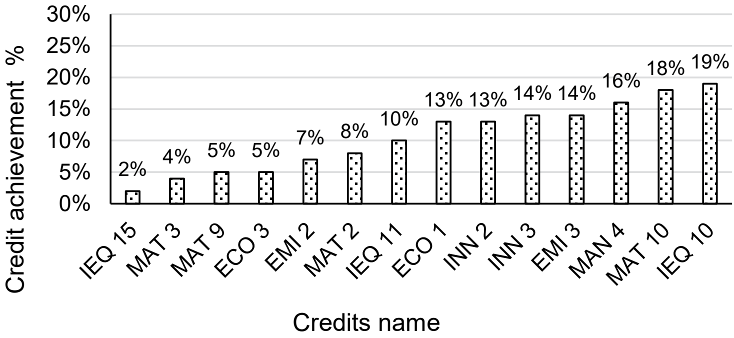

Figure 2: Green Star SA credits with <20% achievement rate

Table 4: Green Star SA credits with < 20% achievement rate

Description		*Average % achieved*
Management		
MAN-4	Independent commissioning agent	16
Indoor Environment Quality		
IEQ-10	Individual comfort control	19
IEQ-11	Hazardous materials	10
IEQ-15	Mould prevention	2
Materials		
MAT-2	Building reuse	8
MAT-3	Reused materials	4
MAT-9	Design disassembly	5
MAT-10	Dematerialisation	18
Land Use and Ecology		
ECO-1	Topsoil	13
ECO-3	Reclaimed contaminated land	5
Emissions		
EMI-2	Refrigerant GWP	7
EMI-3	Refrigerant Leaks	14
Innovation		
INN-2	Exceeding Green Star SA benchmarks	13
INN-3	Environmental design initiatives	14

4.2 Inferential statistics

4.2.1 Average achievement percentage of Green Star SA categories

The average achievement percentage of each credit was used to calculate an average achievement percentage for the credits within every Green Star SA percentage category. This analysis revealed a significant difference in the average achievement percentage of the nine categories. The three categories with the highest average achievement percentage are Water (84%), Transport (79%), and Energy (77%), respectively. The two categories whose credits had the lowest average achievement percentage are Ecology (37%) and Innovation (19%) (Table 5). The large degree of difference in the average achievement percentage of the nine categories is confirmed by the standard deviation (s = 19.8%) and the coefficient of variation (CV = 0.344).

Table 5: Green Star SA categories average credit achievement percentage

Green Star SA category	*Average credit achievement %*	*Green Star SA weighting factor*
Management	64	9
Indoor Environment Quality	56	15
Energy	77	25
Transport	79	9
Water	84	14
Materials	47	13
Land Use and Ecology	37	7
Emissions	57	8
Innovation	19	0
Total weighting factor		100
Average credit achievement %	Variance = s^2	0.039
	Standard deviation = s	0.198
	Coefficient of variation = CV	0.344
Achievement % versus weighting factor	Pearson's coefficient of correlation = r	0.665

The linear relationship between the average achievement percentage and the weighting factor was described by the Pearson product moment correlation (Puth *et al.*, 2014). The Green Star SA weighting factor allocated to the respective categories could only, to some extent, explain this variability in average achievement percentage (r = 0.665). Table 5 also indicates that a category such as Energy with a 77% average achievement also carries a weighted score of 25, which may explain in part why the Energy credits were often included in green building strategies. The category Transport, however, had an even higher achievement of 79%, although the category only carries a weighted score of 9. The category Indoor Environment Quality carries the second-highest weighted score of 15, but only had a 56% average achievement percentage.

The monetary implications or the cost per point scored are most probably a very real issue to consider when evaluating the application trend of Green Star SA credits. For example, credits in the WAT category may be more affordable than credits in the IEQ category.

Aspects such as technical challenges, financial constraints, credits that are not applicable to every project, and so on should also be considered when trying to explain this variability in average achievement percentage.

4.2.2 The effect of Green Star SA rating on the average achievement percentage of Green Star SA credits

The study also evaluated the extent to which the certification level targeted (4 Star, 5 Star, or 6 Star rating) affected the achievement percentage of credits. The findings detailed in Table 6 reveal that higher Green Star SA ratings targeted resulted in significantly higher number of credits being often achieved. A total of 20 credits were often achieved by the 4 Star buildings, but as many as 38 credits had to be often achieved by 6 Star buildings.

Table 6: Credit application versus Green Star SA certification level

Category	*Often achieved*	*Seldom achieved*
Total sample credits	21	14
4 Star rating	20	18
5 Star rating	31	9
6 Star rating	38	5

The linear relationship between the above sets of data was explored with the Pearson product moment correlation (Puth *et al.*, 2014). The weighted points score required for the different certification categories was compared against the credit achievement data (both often and seldom). Table 7 confirms a strong positive correlation between weighted points required and credits with an average achievement of >80% ($r = 0.992$) and also a strong negative correlation between weighted points required and credits with an average achievement of <20% ($r = -0.976$).

Table 7: Green Star SA rating versus average achievement percentage

Category	*Green Star SA rating*			*Pearson's coefficient of correlation*
	4 Star	*5 Star*	*6 Star*	
Weighted score required	45	60	75	
No of credits with achievement >80%	20	31	38	0.992
No of credits with achievement <20%	18	9	5	-0.976

The correlation between Green Star SA rating and the achievement percentage of credits confirms that a relatively large number of credits (18) are left unattended by buildings that apply for a 4 Star rating. This finding may indicate that most of the credits required by 4 Star buildings are sourced from 20 'often used' credits. By comparison, the 6 Star buildings applied 38 'often used' credits, while only five credits were left relatively unattended. When trends in Green Star SA credit use are considered, it is important to bear the certification rating of buildings in mind.

4.2.3 The effect of time/year of certification on the average achievement percentage of Green Star SA credits

The final analysis was to consider the relationship between time/the year of green building certification and the 35 credits that had already been identified as often used or seldom used. Figures 3 to 11 display these relationships graphically. In 2009, only a single green building was certified, and the analysis was, therefore, limited to only display data from 2010 to 2015.

Figure 3 details the Management category with MAN-5 Building users' guide and MAN-7 Waste management as often used credits and MAN-4 Independent commissioning agent as a seldom used credit. MAN-7 has trended lower since 2010, with a 2013 achievement below 80%. MAN-4 has trended higher since 2010, and in 2013 and 2015 exceeded 20% achievement. This trend is significant in light of the recent criticism of green building, suggesting that independent auditing of actual green building delivery should be considered.

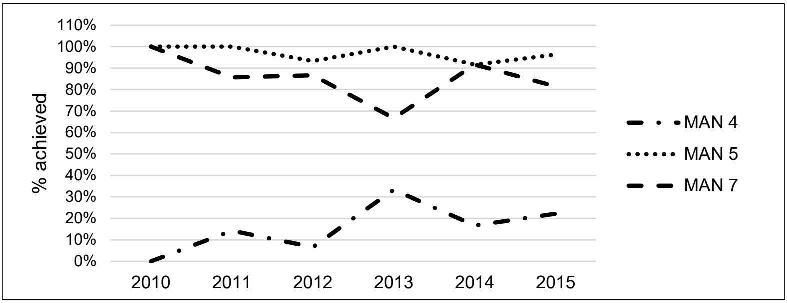

Figure 3: Management category – often used and seldom used credits

Figure 4 focuses on Indoor Environment Quality with IEQ-1 Ventilation rates, IEQ-6 High-frequency ballasts, IEQ-8 External views, IEQ-13 Volatile organic compounds, and IEQ-17 Environmental tobacco smoke avoidance as often used credits, and IEQ-10 Individual comfort control, IEQ-11 Hazardous materials, and IEQ-15 Mould prevention as seldom used credits. The often used credits had regular achievement rates of >80% other than IEQ-8 that in 2011 and 2014 dipped far below 80%. IEQ-10, IEQ-11, and IEQ-15, as seldom used credits, displayed three distinctly different trends. IEQ-15 seldom featured in green application strategies. IEQ-11 displayed an increasing use trend since 2010, and in 2014 and 2015 exceeded 20% achievement. IEQ-10 was constantly declining since 2010 as green building credit and in 2015 scored <10% for the first time.

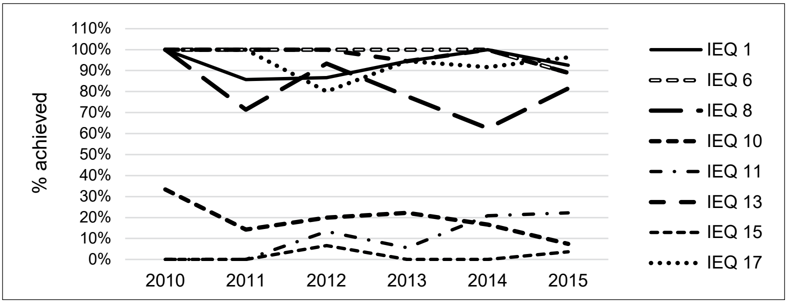

Figure 4: Indoor environment quality category – often used and seldom used credits

The Energy category was detailed in Figure 5 with ENE-1 Greenhouse gas emissions, ENE-2 Energy sub-metering, ENE-3 Lighting power density, and ENE-4 Light zoning as often used credits. In 2010 ENE-2 still had <70% achievement but since then has risen to >90% use. The other three credits had been used very frequently throughout the study period.

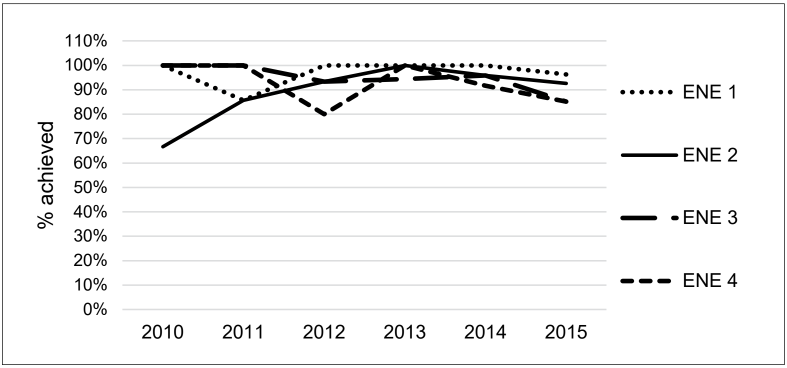

Figure 5: Energy category – often used and seldom used credits

The Transport category detailed in Figure 6 only had two often used credits, TRA-2 Fuel-efficient transport and TRA-3 Cyclist facilities. TRA-2 displayed use frequency varying about the 80% level. TRA-3 started in 2010-2012 as almost always used, but then declined, and in 2014 and 2015 was used by <80% f buildings.

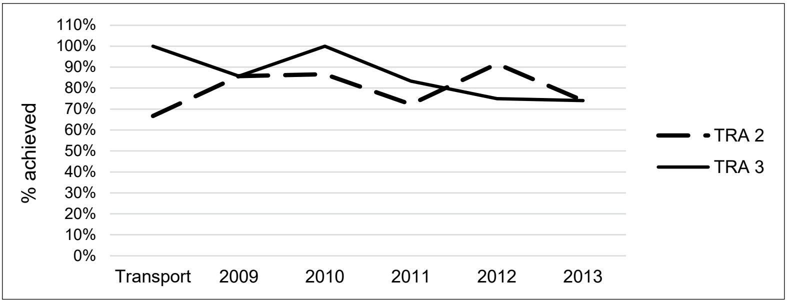

Figure 6: Transport category – often used and seldom used credits

Figure 7 details the Water category with WAT-1 Occupant amenity water, WAT-2 Water meters, and WAT 4 Heat rejection water as often used credits. All three credits were used at around 90% frequency or more, other than WAT-4 that, in 2010, was used <70%.

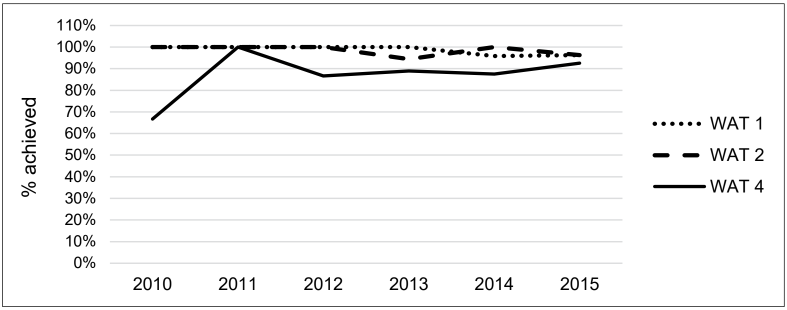

Figure 7: Water category – often used and seldom used credits

The Materials category is detailed in Figure 8, with MAT-1 Recycling waste storage and MAT-6 Steel, as often used credits and MAT-2 Building reuse, MAT-3 Reused materials, Mat-9 Design disassembly, and MAT-10 Dematerialisation, as seldom used credits. Both MAT-1 and MAN-6 were used around 90% of the time other than MAT-1, starting below 70% in 2010 and MAT-6 being used <60% in 2011. The four seldom used credits MAT-2, MAT-3, MAT-9, and MAT-10 were all used around 10% from 2012 to 2015. One point is available for each of MAT-3, MAT-9 and MAT-10, which may in part explain the low use rate. MAT-2 and MAT-9 are also primarily focused on existing buildings and since this study concerns new office buildings, the use factor of these credits can be expected to be low.

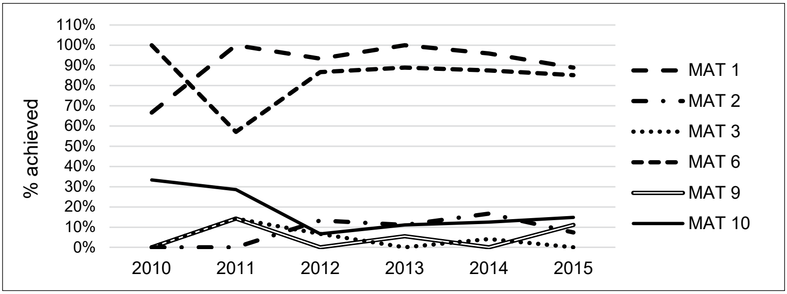

Figure 8: Materials category – often used and seldom used credits

However, any credits focused on reducing the extent of natural resources required by buildings or to extend the use life of resources that have been committed to construction should be regarded as important. This finding indicates that more focus or incentives may be considered to support the regular application of these credits. Studies such as Junnila (2004), Jacobs and Ragheb (2010) as well as Buyle *et al*. (2013) confirm that green building tools must support sustainability over the full use life of buildings.

The Land Use and Ecology category with two seldom used credits in ECO-1 Topsoil and ECO-3 Reclaimed contaminated land is detailed in Figure 9. However, the nature of these two credits that are only applicable to very specific circumstances explains why both credits were used very sparingly, with only ECO-1 used >30% in 2012.

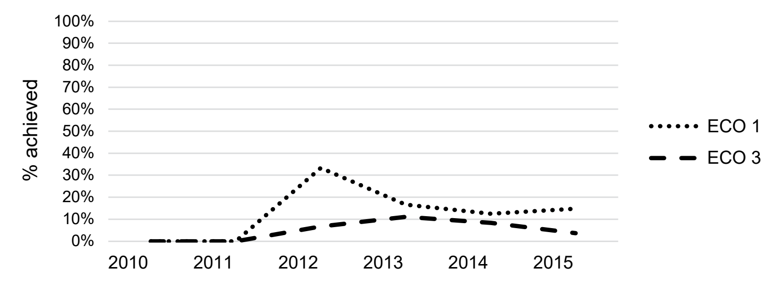

Figure 9: Land use ecology category – often used and seldom used credits

The Emissions category with five trending credits as detailed in Figure 10. EMI-1 Refrigerant/Gaseous ODP and EMI-6 Discharge to sewer were both used >95%, but EMI-4 Insulant ODP only stabilised at >80% use from 2013. EMI-2 Refrigerant GWP was constantly used by around 10% or less of buildings. EMI-3 Refrigerant leaks declined in use from >30% in 2010 to <10% from 2012.

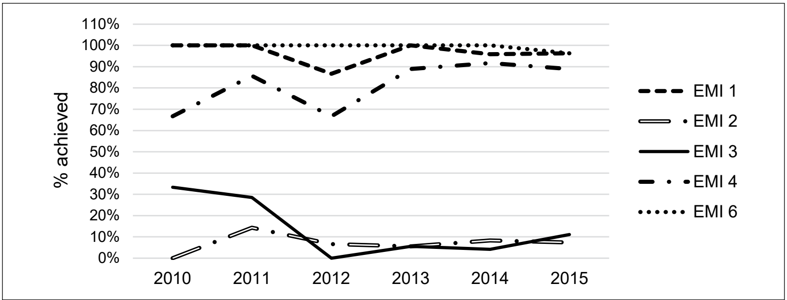

Figure 10: Emissions category – often used and seldom used credits

The last category of Innovation, with only two seldom used credits of INN-2 Exceeding Green Star SA SA Benchmarks and INN-3 Environmental design initiatives, is detailed in Figure 11. Both credits varied between the use of 0%-30%, but since 2013 has stabilised at <20%.

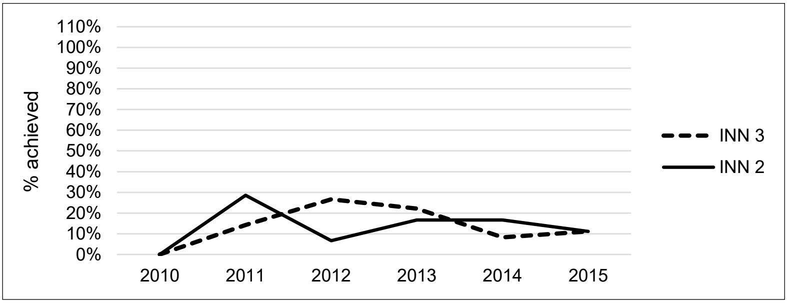

Figure 11: Innovation category – often used and seldom used credits

With the v1.1 version of the Office tool, the number of points in the Innovation category increased from 5 to 10. A wide range of items have been awarded as Innovation credits to date. Green building needs innovative ideas to grow and prosper. A new innovation item recognised by the GBCSA under the INN-3 credit is financial transparency which is worth two points and has no capital cost to the project. This credit should be included in every Green Star SA application. Follow-up studies will be able to confirm if credits in the innovation category will be more often achieved in the futore.

5. DISCUSSION

The study explored potential trends with regard to the application of green credit strategies followed by Green Star SA-rated office buildings in South Africa from 2009 to 2015. The findings revealed which credits are readily accessible and which credits very seldomly achieved Green Star SA. These insights were previously not available.

5.1 Often used Green Star SA credits

The first trend identified was that, out of the 67 credits of the Green Star SA Office v1.1 tool, a total of 21 credits (31.3%) were achieved by an average of more than 80% of the office buildings certified between 2009 and 2015. A total of 13 credits (19.4%) were achieved by more than 90% of these office buildings. This study, therefore, identified that there are specific green credits that are very accessible to the industry and that are included in the green building strategies of almost all South African green buildings.

A similar but much earlier study by Hoffman and Pienaar (2013) on green building strategies identified that, within the first three years of using the Green Star SA tool in South Africa, all but one of the above 21 often used credits were already identified as very often achieved by green buildings certified. This finding confirms that these credits had been favoured in the vast majority of South African green building strategies from the early days of South African green building certification.

A deeper and more detailed analysis of the credits and the actual points within these credits will add more value to, and insight into the use and application of Green Star SA credits in the South African green building industry. The ENE-01 credit may be of specific interest in this regard to reveal if the green building industry has made a real difference in the past decade.

If all the points of the above 21 often used credits are weighted and added, the sum of 50,78 weighted points, is 5,78 points (or 12.83%) more than is required for a 4 Star rating. In theory, an effective green building strategy that targets all the points of every one of these 21 credits can secure the majority of points to secure a 4 Star green building rating. However, if this process is repeated for 80% and more of buildings, the result may possibly be a less-than-ideal delivery outcome by certified green buildings from a sustainability point of view. The remaining 46 credits of the Green Star SA tool and their contribution to a more sustainable industry may then never be fully realised.

The Green Star SA tool is not designed to have most of the credits achieved by the vast majority of the projects, but to rather offer a wide menu of credits to projects to select from according to the circumstances of each project. However, the current status of a range of credits with very low application may warrant some attention from the GBCSA. It is, therefore, a potential outcome that has to be monitored and managed.

5.2 Seldom used Green Star SA credits

This study also found a second trend of 14 credits or 20.9% of all 67 credits that were achieved by less than 20% of the certified green buildings. A total of six credits (9.0%) were achieved by less than 10% of these buildings. This finding indicates that some credits are very inaccessible to the industry and may be a challenge to implement as part of green building strategies.

These 14 credits were all included in the Green Star SA tool with proper motivation and positive intent. These credits have the potential to make an important contribution to a more sustainable environment. The result of very seldom using these credits may again, as described in section 5.1, be a less-than-ideal outcome from a sustainability point of view. As proposed in section 5.1, this scenario will require monitoring and management.

5.3 Average achievement percentage of Green Star SA categories

The study also made a third finding with regard to the average achievement rate of each of the nine categories of the Green Star SA Office v1.1 tool. The average achievement rate per category varied between 84% for Water and 19% for Innovation. The three categories with the highest average achievement rates were Water (WAT-1 to WAT-5) with 84% (varying between 73%-89%), Transport (TRA-1 to TRA-5) with 79% (70%-83%) and Energy (ENE-1 to ENE-5) with 77% (75%-86%). The three categories with the lowest average achievement rates were Innovation (INN-1 to INN-3) with 19% (varying between 11%-24%), Land Use and Ecology (ECO-1 to ECO-4) with 37% (26%-46%) and Materials (MAT-1 to MAT-11) with 47% (44%-49%).

The weighted points allocated to the respective categories could only, in part, explain this variability in average achievement. Aspects such as technical challenges, financial constraints, credits not applicable to every project, and so on should be explored for a deeper insight to explain this variability in average achievement percentage.

5.4 The effect of Green Star SA rating on the average achievement percentage of Green Star SA credits

The fourth trend identified was a strong positive correlation coefficient of 0.992 found between the Green Star SA rating level of buildings achieved and the number of often used credits as well as a negative correlation coefficient of -0.976 between the Green Star SA rating level achieved and the number of seldom used credits.

Table 7 lends some support to the conclusion suggested in section 5.1 that the 21 credits with a >80% achievement can potentially secure a 4 Star rating. The finding also reveals that the additional credits required by a 5 Star rating needed more credits to be included in the green building strategies, resulting in 31 credits with a >80% achievement. A 6 Star rating requires even more credits targeted in the green building strategy, resulting in 38 credits with a >80% achievement.

Table 6 also details that 4 Star buildings have 18 credits with an average achievement of <20%, while 5 Star and 6 Star buildings only have nine credits and five credits, respectively, with an average achievement of <20%. The above finding supports the hypothesis that most of the credits required by 4 Star buildings are sourced from the ‘often used’ credits and that a relatively large number of credits can be left unattended.

5.5 The effect of time/year of certification on the average achievement percentage of Green Star SA credits

The vast majority of trends by credits that the study identified, either as often used or as seldom used, were apparent for most of the study period from 2010 to 2015. Time was, therefore, not found to have a significant impact on the majority of credit trends. Some of the often used credits such as EMI-4 had increased use, while MAN-7 seemed to be experiencing a decline in use. Among the seldom used credits, MAN-4 and IEQ-11 did experience an increase in use, while IEQ-10 and EMI-3 seemed to be declining even further.

6. CONCLUSIONS AND RECOMMENDATIONS

A young industry such as the green building industry that is starting to grow towards maturity lacks the well-defined descriptors of established industries benefiting from many years of development and analysis. This study explored facets of green building developments to look for possible industry trends in the application of green building credits. The findings revealed overall industry trends that may otherwise have remained hidden from view of individual stakeholders involved with a limited number of projects. The study did find and discussed a number of trends.

After completion of the analysis of the data and the findings made, the following recommendations are made:

- The study regarding green building application trends of green credits should be continued, in order to keep track of this dynamic aspect and to be aware of what is happening as the green building industry matures.
- The trends identified should be studied in more detail to explore the underlying causes of these trends.
- Aspects such as credits with technical challenges, financial constraints and the cost versus point ratio of credits, and credits only applicable to specific project types should be included in the above follow-up study.
- A study comprising the opinions of Green Star SA Accredited Professionals to explore and unpack the findings of this study will add insight into, and credibility to the findings and may be of value to the GBCSA when reviewing or updating the Green Star SA tool.
- Many of the Green Star SA credits are worth more than one point, and these credits should be explored in more detail to reveal the actual percentage of available points targeted and achieved.

One way of managing the trends identified is to, on a continued basis, peruse and consider the Green Star SA tool and, specifically, the points awarded and the weightings applied to the respective categories. New versions of the Green Star SA tool may be amended to move weighted points from often used credits with more modest sustainability contributions in favour of seldom used credits with highly desired sustainability outcomes. The result of such amendments to the Green Star SA tool may be future green building strategies amended to suit the new version of the tool and green buildings with a more substantial contribution towards environmental sustainability.

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ASSESSMENT OF TRANSPORTATION EFFICIENCY FOR THE DELIVERY OF CONSTRUCTION MATERIAL IN NORTH-CENTRAL NIGERIA

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ABSTRACT

In Nigeria, knowledge on the management of construction material logistics system, especially in transportation, is inadequate. This article assesses construction material manufacturers' transportation efficiency for the delivery of construction material, in order to improve manufacturers' transport operation in North-Central Nigeria. A total of 32 construction material manufacturers delivered their material to 42 distribution centres/warehouses and retailer stores, and 30 construction sites were purposely selected. The selected construction materials manufacturers produce six types of materials, namely cement, reinforcement bars (steel), ceramic tiles, crushed stones, masonry hollow sandcrete blocks, and sand (fine and coarse). A case study research design method was used, in which quantitative data were collected and analysed. An observation (quantitative) guide was used as the research instrument. The quantitative data collected were analysed, using descriptive statistical tools such as frequencies and percentiles. The results revealed that transportation efficiency levels are low in their vehicles' dwell time, loading and off-loading vehicles at the warehouses, retailer stores, and construction sites. It was also revealed that no technology was used in the transport system to integrate the manufacturers' warehouses with the other logistics partners in the supply chain. The article concludes that manufacturers should address transportation operations along the delivery nodes to help ensure that the construction material arrives at its final destination at optimal quality, time and cost.

Keywords: Construction material, efficiency, manufacturer logistics, technology, transportation

ABSTRAK

In Nigerië is kennis oor die bestuur van die logistieke stelsel vir konstruksiemateriaal, veral in vervoer, onvoldoende. Hierdie artikel evalueer die doeltreffendheid van die vervoer vir die aflewering van konstruksiemateriaal deur konstruksiemateriaalvervaardigers, ten einde die vervaardigingsvervoer in Noord-Sentraal Nigerië te verbeter. Altesaam 32 konstruksiemateriaalvervaardigers wat hul materiaal by 42 verspreidingsentrums/pakhuise en kleinhandelaarswinkels aflewer, asook 30 konstruksieterreine is doelbewus vir hierdie studie gekies. Die gekose konstruksiemateriaalvervaardigers vervaardig ses soorte materiaal, naamlik sement, wapeningstawe (staal), keramiekteëls, gebreekte klippe, messelwerk, hol sandbetonblokke en sand (fyn en grof). 'n Gevallestudie navorsingsontwerpmetode is gebruik, waarin kwantitatiewe data versamel en ontleed is. 'n Waarnemingsgids (kwantitatiewe) is as navorsingsinstrument gebruik. Die kwantitatiewe data wat versamel is, is geanaliseer met behulp van beskrywende statistiese instrumente soos frekwensies en persentiele. Die resultate het getoon dat die doeltreffendheid van vervoer laag is in terme van voertuigverblyftyd, asook tydens die op- en aflaai van voertuie by die pakhuise, kleinhandelaarswinkels en terreine. Resultate toon ook dat daar nie van tegnologie in die vervoerstelsel gebruik gemaak word om die vervaardigerspakhuis met die ander logistieke vennote in die verskaffingsketting te integreer nie. Die aanbeveling is dat vervaardigers vervoerbedrywighede langs die afleweringsnodusse moet aanspreek om te verseker dat konstruksiemateriaal by die finale bestemming teen optimale kwaliteit, tyd en koste kom.

Sleutelwoorde: Doeltreffendheid, konstruksiemateriaal, tegnologie, vervaardigerslogistiek, vervoer

1. INTRODUCTION

Construction material is a basic constituent in construction projects and can make an important contribution to the cost-effectiveness of projects (Kasim, Latiffi & Fathi, 2013: 7; Abhilin & Vishak, 2017: 911). Research has revealed that the usual cost of construction material is roughly 50%-60% of the total cost of a project (Kasim, Liwan, Shamsuddin, Zainal & Kamaruddin, 2012: 450; Duiyong, Shidong & Mingshan, 2014: 353). The logistics cost accounts for between 17% and 35% of the cost of material (Duiyong *et al.*, 2014: 353). Transportation costs account for between 39% and 58% of the total logistics costs (Ying, Tookey & Roberti, 2014: 262). Thus, transportation costs of construction material represents a greater percentage of the total cost in the construction industry.

The importance of transportation of construction material in the execution of a project cannot be overemphasised, because projects are made difficult by material inadequacies, delays in supply, increment in cost, material wastage and damage, and the absence of storage space (Kasim *et al.*, 2013: 7; Abhilin & Vishak, 2017: 911). The management of the storage and flow of construction materials and related information between the point of production (manufacture) and the point of utilisation is the essential element of logistics management (CSCMP, 2013: online). Therefore, a small percentage reduction in transportation costs could lead to a significant reduction in the price of materials (Ying *et al.*, 2014: 264).

Studies on construction material logistical systems in Nigeria focus mainly on Supply Chain Management (SCM), but with deprived knowledge on vital top subsections such as transportation (Shakantu & Emuze, 2012: 661). For example, construction material and transport providers/waste removal still operate as independent trades. In Nigeria, a few studies on the construction material-manufacturing industry focus on mode of transport, the inventory, and challenges in transportation condition in the cement-manufacturing firms (Adebumiti & Muhammed, 2014: 234; Adebumiti, Muhammed, Faniran & Yakubu, 2014: 242). Obiegue (2010: 8) appraised customer satisfaction and the challenges facing the transportation system of chemical and paint manufacturers. Similarly, Oludare & Oluseye (2015: 18) studied the influence of construction materials supply chain network structures and strategies on project delivery and the impact of logistics factors on material procurement for construction projects (Tunji-olayeni, Afolabi, Ojelabi & Ayim, 2017: 1142). Furthermore, Isah, Shakantu & Ibrahim (2020: 22) observed that the technological aspect of construction logistics, especially the forecasting, is ignored and barely understood in the Nigerian construction industry.

Hardly any study has been done on the Nigerian construction material manufacturers' transport system operational performance, showing that, currently, knowledge on the management of construction material logistics systems is inadequate. It is, therefore, important to assess construction material manufacturers' transport efficiency. The article assesses the load/offload period of vehicles at terminals, the number of vehicles loading at a time, the equipment/method used to load/offload vehicles, and the time and cost to load/offload vehicles, in order to improve the transport system of construction material manufacturers in North-Central Nigeria.

2. LITERATURE REVIEW

To understand transportation efficiency for the delivery of construction material in North-Central Nigeria, it is important to introduce the present theory on transportation included in this article. The current theory focuses on transportation systems, transportation efficiency, vehicle loading method/equipment, loading and offloading periods at the terminals, dwell time and idling, as well as the use of technology in transportation.

2.1 Transportation system

The transportation system is the spatial link that joins customers, raw material suppliers, distribution centres/warehouses and supply chain partners in the management of construction material logistics systems (Andrejić, Bojović & Kilibarda, 2016: 99). Normally, transportation is a key cost element of the logistics supply chain (Shakantu & Emuze, 2012: 664).

Contrary to the construction industry, the manufacturing industry can choose where they should conduct their productive operations. The companies are sited on fixed locations, hence the need to move their products to where their customers are. This brings transport into the core of the city and built-up areas (Pienaar, 2016: 386). The geographical region's network is the key component responsible for the performance of transportation within the logistics service (Kamali, 2018: 199). Using an efficient and effective transportation network, a firm can obtain more advantages in terms of service level and cost-effectiveness measurements (Chopra & Peter, 2007: 156). In addition, Chopra & Peter (2007: 156) defined the types of transportation networks as follows:

- The direct shipment system, where there is a direct transportation to one customer from a single merchant to a customer without a third party.
- The transportation method that a few manufacturers utilise to fulfil their customers' requests through intermediate stations in moving materials from one location to another. The strategy works by setting up distribution centres as an approach to attain the economies of scale in transportation.
- The indirect transportation technique is handled by a Third Party Logistics (3PL) company, in which their jobs are known as a helpful supply chain partner.

In contemporary business, various kinds of 3PLs service companies offer transportation services such as customised logistic solutions, joint logistic solutions, and in-house logistic solutions. Even though there are few benefits with 3PLs, a manufacturing firm can focus on its main business rather than on transportation services (Kamali, 2018: 199). Poor cost performance by manufacturers and suppliers can significantly increase the Total Acquisition Cost (TAC) of construction material which, through rising material purchase prices, results in higher construction costs (Vidalakis & Sommerville, 2013: 473). Transport efficiency is critical for timely delivery of construction material.

2.2 Transportation efficiency

According to Pienaar and Havenga (2016: 22), efficiency means realising an objective at the minimal cost. Andrejić *et al.* (2016: 99) recognised two factors in their evaluation of the efficiency of transport systems. The first factor is fleet efficiency, which is focused on senior level decision-making, and the second factor is vehicle efficiency at the operational level of decision-making. Understanding transportation economics and pricing is fundamental for efficient logistics management. The essential components of transportation costs are distance, volume, handling, liability, and market factors. These components control transportation prices, which are included in the budget as rates for performing specific services (Bowersox, Closs, Cooper & Bowersox, 2013: 203). Pienaar (2016: 388) identified the following key factors of road transport efficiency: cost level, the economies of fleet size, the economies of vehicle size, the economies of infrastructure extension, and the economies of distance.

Transportation cost efficiency and customer responsiveness have been identified as the two most prominent supply chain performance measures (Vanteddu, Chinnam, & Gushikin, 2011: 205; Vidalakis & Sommerville, 2013: 473). They further asserted that, in order to minimise transport-related costs, distance and weight, as transportation cost drivers, should be considered. Bowersox, Closs and Cooper (2007: 174) opined that the bigger the overall shipment and the longer the distance it is transported, the lower the transportation cost per unit. Delivery consolidation is crucial to increase distance and weight per shipment and, in this manner, reduce the number of vehicle movements, while increasing loading efficiency. But there is always a trade-off between loading efficiency and operational frequency (Geunes & Taaffe, 2008: 184). In fact, even though the former guarantees low unit transportation costs, the latter can reduce lead times by delivery in less truck load. This is also supported by Errasti, Beach, Oduoza & Apaolaza (2009: 261) who refer to it as the task of balancing efficiency and responsiveness. Construction material transport costs include capital and operating costs. The capital cost depends on the model and type of vehicle. Apart from capital or purchase price, vehicle owners also have operating costs, which can be classified as fixed (overhead) and variable costs (Pienaar, 2016: 386).

Another transportation performance metrics is responsiveness, meaning a supplier's aptitude to react to customer requests reliably and timely (Vanteddu *et al.*, 2011: 206). This holds especially right for construction logistics, since last-minute requests are likely to happen, due to the absence of an inventory control system and poor storage capacity on-site (Vidalakis, Tookey & Sommerville, 2011: 67).

For efficient delivery of material, transportation consolidation should be relied upon to bring about bigger total shipments and, hence, improved vehicle utilisation. Vidalakis and Sommerville (2013: 474) affirmed that, in order to give a total perspective on vehicle utilisation efficiency, three parameters must be considered, namely vehicle shipping efficiency (VSE), vehicle journey efficiency (VJE), and vehicle weighted efficiency (VWE). They established that vehicle loading efficiency levels were significantly lower for construction material than those assessed in other sectors. It also reveals the frequency of empty vehicle runs during backhauling (Vidalakis & Sommerville, 2013: 474).

Similarly, On Time Delivery (OTD) is vital for efficient delivery. OTD is defined as a measurement based on the percentage of customer orders delivered “On Time and In Full” (OTIF) (Kamali, 2018: 188). The OTD shows that manufacturers and suppliers could fulfil the delivery terms based on the agreed upon time, which is known as the delivery date (Kamali, 2018: 198). Thus, if they are unable to achieve the delivery on time, it will reduce the efficiency, considering that the OTD process could be realised if all variables involved in the process work out effectively (Kamali, 2018: 198). A study by Kamali (2018: 2004) recommended that, based on the findings, to be able to tackle the OTD issues, the following actions must be considered: full utilisation of the Enterprise Resource Planning (ERP) systems, improving management performance, and considering a 3PL partner as a strategic goal.

Ruamsook and Thomchick (2012: 130) noted that the commonly used transport performance metrics in terms of efficiency are ‘costs’ (transport costs, inventory carrying costs, material handling costs); ‘quality’ (on-time and damage-free delivery, complete order), and ‘time’ (order cycle time length and variability, response time). However, the sustainability of these metrics in terms of material transportation is not sufficiently addressed.

The absence of materials, when needed, is one of the main causes of loss of productivity at a job site. Inefficient transportation of materials can lead to an increase of 50% in work hours (Hasim, Fauzi, Yusof, Endut & Ridzuan, 2020: 020049-3). In addition, Ahmadian, Akbarnezhad, Rashidi and Waller (2014: 460) studied the significance of transportation in the procurement of construction materials. The results revealed that material-handling processes adopted in industry are highly disorganised and that transportation variables are ineffectively articulated. The results also established the need for methods to plan, monitor and control the transportation system as an independent activity in the material’s life cycle. In addition, the travelling distance, weight, dimension, mode of transportation, and terms of delivery were identified as the main factors affecting the transportation efficiency of the construction materials.

2.3 Vehicle loading method/equipment

Having efficient material-handling systems is crucial for maintaining and facilitating a continuous flow of materials through the workplace and guaranteeing that required materials are available when needed (Leung & Lau, 2018: 34). There is a need for efficient materials handling, with the purpose of control, productivity and cost in construction projects (Patel, Pitroda & Bhavsar, 2015: 3). However, there are monetary trade-offs between high capital costs of mechanised systems, and increased labour costs in manual systems and types of manual handling that occur in such places (Webster, Dalby, Fox & Pinder, 2014: 7).

The on-site materials handling, monitoring and locating are made difficult, due to the manual handling process that is labour intensive, inclined to mistakes, resulting in the delay in timely execution and increase in cost of construction projects (Kasim *et al.,* 2012: 448).

In order to achieve the maximum benefits of specialisation, handling tools at the nodes ought to offer fast loading and offloading of products to make best use of the quantity of full vehicle load kilometre per unit of time. Economies of density require the optimal use of big, strong equipment over as long a period as possible (Pienaar, 2016: 381). These include automatic loaders, high-level cranes, forklifts, manual, loader shovels, excavators, overhead gantries, and the utilisation of saddle carriers.

Furthermore, a wide range of attachments is accessible for fitting to forklift trucks so that they can handle materials that cannot be moved by forks. These truck attachments links can permit additional grades of movement for handling unit loads (Hannan, 2011: 32). Masonry hollow sandcrete block manufacturers usually utilise self-loading vehicles with cranes mounted on the edge or on a removable mounting. Big quarry trucks are usually loaded by loader shovels, while vehicles are often stacked by an excavator. Manual loading may utilise less effort by means of a low truck and body. Detachable bodies or containers can be left on the ground for loading and lifted onto the truck by a hydraulic or mechanical crane (Rushton, Oxley & Croucher, 2001: 370).

It is important to note Michael's (2015: 16) submission that each point of stockholding comprises handling of the material and, the more numerous handling of material, the more the total logistics expenses would be. The reason for this is that the process includes both equipment and human effort. This represents the cost of workforce in the warehouse and automation utilised to receive, put away, move, check, and count the inventory (Parvini, 2011: 32). It should be noted that efficiency of offloading processes could be enhanced by 61% with information system advances (Andrejić & Kilibarda, 2016: 145).

2.4 Period of loading and offloading at the terminals

Several customers receive products not only within working hours, but very early in the morning and later in the evening. The use of a vehicle that usually runs from 08h00 to 16h30, or for 8.5 hours, can be significantly improved if it can deliver goods between 07h00 and 08h00, thus avoiding peak traffic hours in the cities. The same would apply if deliveries can be made at night (Vogt, 2016: 342). Regardless of whether the delivery is optimised by a system or not, extended hours and flexible delivery times would significantly improve productivity. These times are bargained between the manufacturers, the distribution centres/warehouses, customers, suppliers, and facilities within the logistics chain. Again, the reduction of restrictions, in this case customer receiving times, improves the potential for increased efficiency (Vogt, 2016: 342). A few cities in the United States of America (USA) and the European Union (EU) have implemented day-time restrictions on truck deliveries in their downtown core areas (Ruamsook & Thomchick, 2012: 142). This has a negative impact on logistics efficiency, as it creates longer waiting times for vehicles at the terminals.

2.5 Dwell time and idling

Vehicles are not dispatched to their various locations, except when they are fully loaded or offloaded. The vehicle may wait at a plant, distribution centre/warehouse and a retailer store before it is sent to the next destination (Eskigun, Uzsoy, Preckel, Beaujon, Krishnan & Tew, 2005: 185). The whole of the load waiting time, the time wasted due to overcrowding, and other issues make up the total waiting time, or dwell time of the vehicle.

Idling differs by trip duration, season, geographic location, and trucking operation, making it difficult to quantify hours of truck idling for the truck population. Idling is classified as discretionary (non-essential, though desirable) or non-discretionary (*i.e.*, essential). Discretionary idling includes overnight idling and delivery idling, and mainly serves to maintain driver comfort levels; it could be eliminated using a fuel cell (Brodrick, Lipman, Farschchi, Lutsey, Dwyer, Sperling, Gouse, Harris & King, 2002: 307). Furthermore, there might be some idling time, due to managerial problems or ineffectiveness in the system. This may be unrelated to the volume of vehicles passing through these destinations (Eskigun *et al.,* 2005: 185; Gwynne, 2014: 73). Without proper scheduling of vehicle delivery, the workload in the facility will vary excessively. The burden on the operating staff increases during peak times and this reduces efficiency and the accuracy of the receipt (Vogt, 2016: 334).

There are also economic reasons to reduce idling. Previous studies by the US Environmental Protection Agency (EPA) (cited in Ruamsook &

Thomchick 2012: 131) revealed that an average long-haul trailer truck idles for approximately eight hours per day for at least 300 days per year, consuming roughly 0.8 gallons of fuel per hour or close to 1,900 gallons of fuel per year. In addition, there is some evidence that the average idling time for long-haul trucks may be even higher (Brodrick *et al.*, 2002). The study by Rahman, Masjuki, Kalam, Abedin, Sanjid & Sajjad (2013: 171) confirmed that long-distance trucks can remain idle for between six to 16 hours per day. Hence, to increase operation efficiencies, transporters are also concentrating on reducing idle time (Ruamsook & Thomchick, 2012: 131).

2.6 Technology in transportation

Andrejić, Bojović and Kilibarda (2013: 3927) identified five causes of transportation loss or inefficiency in the logistics system, namely driver breaks, excessive loading time, fill or cargo loss, speed loss, and quality delay. In order to address some of these transportation logistics problems, Ruamsook and Thomchick (2012: 130) highlighted the influence of utilising technology in transportation.

Software for Transport Management Systems (TMS) allows for effective and efficient management of the transportation fleet used in the outbound logistics system (Andrejić & Kilibarda, 2016:143). TMS makes it possible to assess driver performance and vehicle efficiency by remotely monitoring speed, braking, gear-shifting, idle time, and out-of-route miles (Ruamsook & Thomchick, 2012: 135). Intelligent Transportation System (ITS) incorporates Information Technology Communications- (wireless) and Geographic Information Systems (GIS)-based software into roads, trucks, traffic and transport management systems. Furthermore, the technology allows drivers to minimize the chances of getting lost, to keep track of pickup and delivery schedules, and to find out about adverse weather or traffic conditions. ITS guarantees more up-to-date transport managers, customers and prompt response services, thus improving safety, fairness, efficiency, and ecological protection (Kavran, Jolic & Cavar, 2009: 335).

In an investigation into load shipment organisations, Ndonye (2014: 2) advocated that they should utilise information technology to enhance the efficiency and effectiveness of their logistics performance in a bid to achieve a competitive advantage. Andrejić and Kilibarda (2016: 143) recommend that it is important to integrate TMS, Warehouse Management System (WMS) and other systems. A study where RFID is integrated with LEAN Production in both Central Distribution Centre (CDC) and Local Distribution Centre (LDC) revealed a significant improvement in the entire supply chain, thereby saving 89% and 70% on waiting and transportation times, as well as value-added time, respectively (Chen, Cheng & Huang, 2013: 3396). Similarly, Isah *et al.* (2020: 22) observed that the manufacturing industries (100%) adopted ERP technology for forecasting purposes (for material, demand, product, and production forecasts). Unexpectedly, ERP technology was not utilised for forecasting in the retailing and construction sectors.

3. RESEARCH METHOD

3.1 Research design

This study investigated the efficiency of the transportation system being practised and utilised in North-Central Nigeria by the construction material manufacturers to achieve customer satisfaction. Using a case study research design (Yin, 2014: 124), quantitative data were collected and analysed. Karim (2008: 3) considers a case study method as reality “out there” and something that can be examined objectively. In this study, a semi-structured observation template (Kamali, 2018: 192) was used to observe the dynamics of transportation efficiency in the 32 construction material manufacturing firms in aspects such as period of loading/offloading vehicles at the terminals; number of vehicles loading at a time; equipment/method of loading/offloading vehicles; loading/offloading time, and cost of loading/offloading vehicles. The quantitative data were recorded based on the observation in the case study to determine the transportation efficiency utilised by construction materials manufacturers.

3.2 Population, sampling methods and response rate

The study area is the North-Central geo-political zone of Nigeria, which comprises of six states and the Federal Capital Territory (FCT), Abuja. North-Central is one of the fastest developing regions, with a high concentration of construction activity, near FCT. From this wide zone, 32 construction material manufacturers were purposively selected. From these, 32 manufacturer firms, 42 distribution centres/warehouses, retailer stores and 30 construction sites were randomly selected, with at least two for a particular building material. In total, eight companies visited were identified as manufacturers of cement, reinforcement bars, ceramic tiles, and crushed stones, with two companies for each material. Their products were produced within and distributed across the six states of North-Central Nigeria and the FCT, Abuja. In addition, 12 companies producing masonry hollow sandcrete blocks and 12 companies producing sand were visited with two in each of the five state capitals and Abuja. Chosen construction sites were carefully and logistically selected, instead of statistically, significant in the population (Shakantu & Emuze, 2012: 668). The sample selected in each construction site gave adequate transportation operations and processes for analysis within a reasonable time. Table 1 shows the type of material, the number of deliveries per each state capital and FCT, distribution centres, and the warehouse and construction sites observed.

Table 1: Companies and construction sites observed

Materials	*Number of manufacturing companies*	*Transportation (number of deliveries)*	*Location Number of distribution centres/ warehouses and retailer stores*							*Construction sites*
			Abuja	*Minna*	*Lafia*	*Lokoja*	*Jos*	*Makurdi*	*Distribution centres/ Warehouses*	
Cement	2	12	2	2	2	2	2	2	12	
Reinforcement bars	2	12	2	2	2	2	2	2	12	
Ceramic tiles	2	12	2	2	2	2	2	2	12	
Crushed stone	2	12	2	2	2	2	2	2	6	6
Hollow sand-crete blocks	12	12	2	2	2	2	2	2	-	12
Sand	12	12	2	2	2	2	2	2	-	12
Total	32	72	12	12	12	12	12	12	42	30

Source: Researchers' Field Survey (2019)

3.3 Data collection

The researchers collected quantitative data using self-observations on material delivery operations from the construction sites in random order, time and day. The non-participant structured observations of logistics processes were conducted across the various sections of the companies, namely marketing/sales, packaging, warehouse, logistics/transport, and loading bays.

In this study, the Observation and Measurement Guide was used to record the time period (in hour time slots) for loading and offloading vehicles at the terminals as well as the vehicle dwell time on-site; the number (in frequency) of vehicles that could be loaded at a time; method and equipment (*e.g.* hand, crane, forklift) used for loading and offloading, and the average loading and offloading time for individual materials (per ton) at the terminals using a stop clock. The average loading and offloading cost for individual materials (per ton) at the terminals was recorded using the cost per company for equipment used, manual loading and offloading cost per vehicle per worker, and quantity of material transported per vehicle. The types of technology (*e.g.* wireless, GPS, speed limit) installed in vehicles used for delivery were recorded in frequency.

The observations were made until there was a minimum of six customer orders, one each from the five states and Abuja. All the deliveries were one drop and there was no multi-drop run that accounted for turnaround times at the various preceding delivery locations (see Table 1). A total of 72 deliveries by transport providers was observed. This number of observations is supported by Shakantu & Emueze (2012: 662), in that 30 is the lowest number of observations on any phenomenon, which is statistically significant and could lead to the generalisable explanation of a phenomenon.

The researchers improved the credibility of the observations by communicating directly with personnel involved in transportation operations. Furthermore, the field study took place in an environment (standard manufacturer warehouse processes and transportation operations) not designed by the researchers and had the advantage of a natural real-world view.

3.4 Method of analysis

The observation data were entered into Microsoft Excel (Bowen, Edwards & Cattel, 2012: 887) to calculate and report frequencies and percentiles using descriptive analytical tools (Loeb, Dynarski, McFarland, Morris, Reardon & Reber, 2017: 8). A percentage is calculated by dividing the number of times a value for a variable observed by the total number of observations in the population, then multiplying this number by 100. Using thematic analysis, the data were first tabulated into three sections. The first section comprised warehouse/loading bay processes at the manufacturers' firms; the second section consisted of processes that involved vehicles for delivery (arrival/departure time, quantity loaded, time taken to load/offload), and the final section consisted of offloading (cost/time) operations in the distribution centres/warehouses, retailer stores, and construction sites. Thereafter, the tabulated data were analysed and classified into conceptual themes, period of loading/offloading vehicles at the terminals, number of vehicles loading at a time, equipment/method of loading/offloading vehicles, loading/offloading time, and cost of loading/offloading vehicles. After tabulation of the data responses, a bar chart presentation was compiled to show the calculated frequencies and percentages of the observations.

3.5 Limitations

The researchers obtained management's approval for adequate access to observe logistics processes and operations. However, the researchers were denied access to some areas of operations and records of transactions, despite the assurance of anonymity and confidentiality. Managers explained that these actions were taken to safeguard the technology and business strategies from their competitors. In addition, the workers might not like the fact that they were being watched while working and could have assumed that the researchers were a management spy. Under such circumstances, the validity of the data may be compromised, as the workers would not behave 'naturally'.

4. RESULTS

4.1 Period for loading and offloading vehicles at the terminals

The study sought to know how much time a vehicle waited at the manufacturers' warehouse or the distribution centre/warehouse, retailer store and construction site before it was dispatched. Figure 1 indicates that 75% of the manufacturing companies load vehicles between 08:00 and 18:00 hours (10 hours), during working hours only.

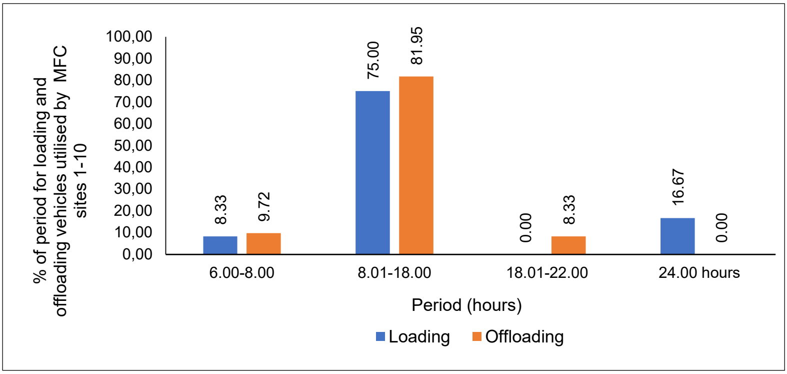

Figure 1: Period for loading and offloading vehicles at the terminals

The significant finding was that most of the company loading time was 10 hours out of the 24 hours per day. As a result, any vehicle that arrived at the plants/warehouses after 18:00 had to wait all night until the next morning before it could be loaded. The implication of this is that there is a longer vehicle dwell time between 18h00 and 08h00, a 14-hour difference. This reduced the vehicle utilisation, thereby increasing lead time. Roughly 8% of the blocks/sand companies loaded between 06h00 and 08h00, and 17% of the cement companies for 24 hours. It was observed that only cement companies loaded for 24 hours per day.

The findings confirmed that 81% of the distribution centres/warehouses and retailer stores had an offloading period between 08:00 and 18:00, which are normal business hours. As explained earlier, all vehicles that arrived after closing time had to wait until the next day to be offloaded. This also increased vehicle dwell time by 14 hours. In addition, 9% of the distribution centres/warehouses and retailer stores offloaded their materials between 06h00 and 08h00, and 8% between 18h00 and 22h00. These are basically hollow sandcrete block and sand companies, which sometimes work slightly beyond normal working hours, as their point of discharge is not constrained by law for offloading. This is unlike for other materials, which are normally offloaded in the market area. Most of the construction material markets have a fixed opening and closing time. This limits operations to working hours of between 08h00 and 18h00. The consequence is underutilisation of vehicles during operational hours, due to a longer dwell time of 14 hours per day at each or both terminals. However, most of the vehicle drivers would have preferred travelling during the night.

4.2 Number of vehicles loading at a time

There was a need to verify if there were queues, due to congestion at the dock or loading bay of the plants, as this may also create waiting time. Therefore, data were collected on the number of vehicles that could be loaded at a time.

Results in Figure 2 established that 37% of the company dock bays have a capacity for 1 to 3 vehicles loading at a set time. In addition, 21% of the dispatch bays have the capacity for 4 to 6 vehicles; 31% for 7 to 10 vehicles, and 6% for 11 to 15 vehicles loading at a time.

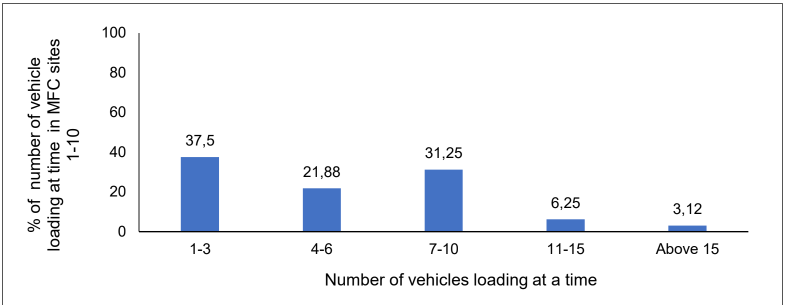

Figure 2: Number of vehicles loading at a time

This established that 58% of the manufacturer dock bays have the capacity for more than 4 vehicles at a time. No traffic congestion was observed at the company dispatch bays. This suggests that most of the time losses were not connected to congestion at the loading bay; they could have been caused by other factors such as administrative issues or inefficiency in the system. This inefficiency in the system may be as a result of paper-based communication, manual handling, and lack of use of technology, thus leading to longer order-processing period and poor efficiency.

4.3 Method of loading and offloading vehicles

The study sought to understand the type and level of automation adopted to increase efficiency in loading and offloading vehicles. Therefore, data on the method of loading vehicles at the manufacturers' warehouses and offloading of vehicles at the distribution centres/warehouses, retailer stores, and construction sites were analysed and are presented in Figure 3.

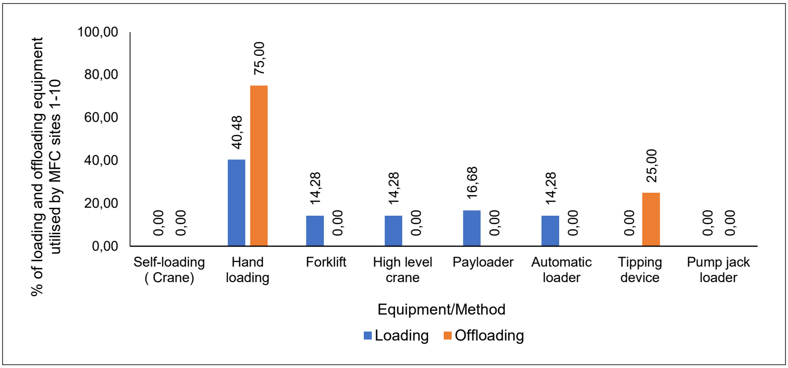

Figure 3: Method of loading and offloading of vehicles

The results indicated that 40% of the companies used manual methods of loading at the manufacturers' warehouses and construction sites. The other companies used pay loaders (16.67%), forklift trucks (14.29%), high-level cranes (14.29%), and automatic loaders (14.29%) to load material. The major finding was that more than 60% of the company warehouses were automated. This signifies operational efficiency, in terms of increase in speed, accuracy and productivity, while reducing repetitive or potentially unsafe manual labour.

In addition, the findings established that 75% of distribution centres/warehouses, retailer stores and construction sites used manual methods of offloading material. However, 25% used the tipping method, which was basically for sand and parts of crushed stones. It was also observed that trailers were also used to transport crushed stones. Since they cannot tip off, the material was manually offloaded. This signifies high operating time, cost, multiple handling, and low productivity.

4.4 Loading and offloading time

The economies of density are enhanced by using high-capacity technology to handle large bulk loads and minimise loading and offloading time and cost. Therefore, the time of loading and offloading individual materials at the terminals was evaluated. The results of the average time taken to load and offload material per ton are presented in Figure 4.

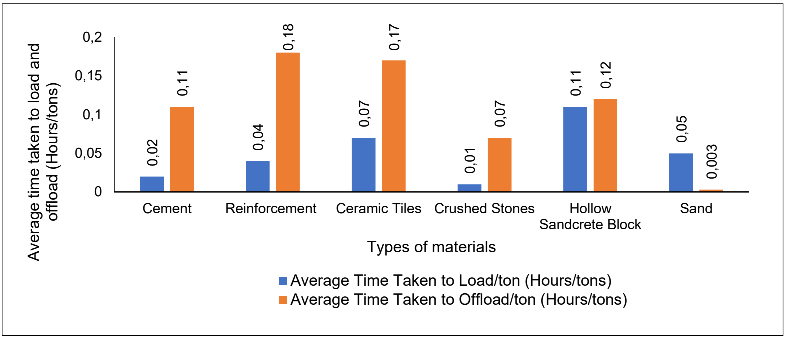

Figure 4: Average time taken to load and offload materials per ton

It was established that, for cement, the loading time was 0.02 hours/ton and offloading time was 0.11 hours/ton. Records confirmed the average loading and offloading time for reinforcement bars (0.04 and 0.18 hours/ton); ceramic tiles (0.07 and 0.17 hours/ton, and crushed stones (0.01 and 0.07 hours/ton). It is interesting to note that crushed stones offloading time is higher than its loading time. The reason for this is that trailer trucks were also used in the delivery of crushed stones. Since they do not tip off, the material had to be manually offloaded, thus resulting in increased offloading time and costs. The implication is that time and costs are non-value-added costs. This cannot be recovered when an invoice is made out for the offloading of material. On the other hand, it achieved load consolidation by transporting a larger quantity in a single trip.

4.5 Cost of loading and offloading material

The time taken for loading and offloading construction material was analysed. However, it also has cost implications. The cost of loading and offloading individual materials at the terminals was thus evaluated. Figure 5 shows the relationship of average cost to load and offload individual materials per ton.

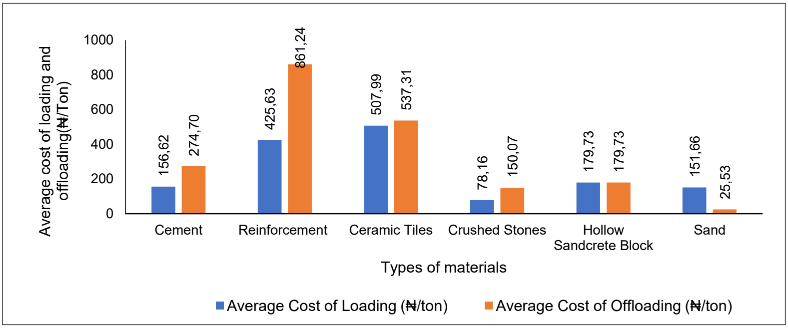

Figure 5: Average cost to load and offload materials per ton

The results confirmed that the average cost of loading per ton at the manufacturers' warehouses was as follows: cement (₦56.62/ton or R2.02/ton); reinforcement bars (₦425.63/ton or R15.20/ton); ceramic tiles (₦507.99/ton or R18.14/ton); crushed stones (₦78.16/ton or R2.79/ton); blocks (₦179.73/ton or R6.42/ton), and sand (₦151.66/ton or R5.42/ton).

Figure 5 also reveals that the average cost of offloading at distribution centres/warehouses, retailer stores and construction sites was as follows: cement (₦274.70/ton or R9.81/ton); reinforcement bars (₦861.24/ton or R30.76/ton); ceramic tiles (₦537.31/ton or R19.19/ton); crushed stones (₦150.07/ton or R5.36/ton); blocks (₦179.37/ton or R6.41/ton), and sand (₦25.53/ton or R0.91/ton). The average cost of offloading reinforcement bars per ton was the highest, probably because this involves offloading, bending and stacking them. However, it should be noted that ceramic tile companies used both forklift trucks and manual labour when loading at the manufacturers' warehouses.

The major finding was that the average cost of offloading materials/ ton was higher than the average cost of loading, except for blocks and sand. This may be explained by the fact that blocks are both loaded and offloaded manually. The cost of loading sand is higher, because most of the companies did this manually, but they offloaded mechanically by tipping off.

4.6 Technology used in vehicles

Technology in vehicles is required to integrate the transport subsystem with the warehousing subsystem and customers, in order to improve efficiency, and to monitor and track the load in transit. This forms the basis for which data were collected on the types of technology installed in the vehicles.

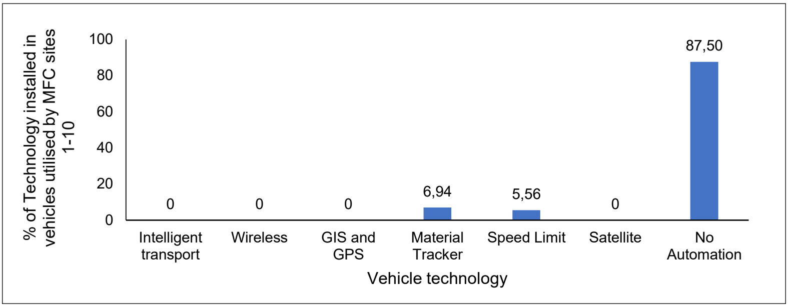

Figure 6: Types of technology installed in vehicles

Figure 6 indicates that 87% of the vehicles used for the shipment of construction material do not have any of the identified technology installed in them. About 7% of the vehicles had a material tracker, and 6% a speed limit tracker installed in them. This signifies that most of the vehicles do not have any of the technology installed in them. This further implies that the transport system is not linked to the manufacturers' plants, distribution centres/warehouses, retailer stores and construction sites. The vehicles cannot be tracked and monitored while in transit.

5. DISCUSSION OF RESULTS

5.1 Loading and offloading periods

Most of the company loading took place between 08h00 and 18h00, a time when vehicles were loaded and offloaded at the terminals. Similarly, most of the offloading times at the distribution centres/warehouses, retailer stores and construction sites occurred between 08h00 and 18h00. This means that vehicles are used only during operational hours, which leads to the longer dwell time of 14 hours per day in each terminal, or both. These results are in line with the findings of Rahman *et al.* (2013: 171). They confirmed that long-haul trucks were idle for between six and 16 hours per day. This is also supported by Andrejić *et al.* (2013: 3926) that inefficiency is measured in terms of the amount of time spent waiting on-site. The longer waiting time increases the inefficiency of vehicles' output in terms of time consumption. However, a shorter time increases the efficiency of the transportation processes (Drozd & Kisielewski, 2017: 32).

However, the findings are contrary to the fact that transport efficiency is achieved by full loads and utilising the transport for as long as possible each day (Vogt, 2016: 342). In addition, flexibility of loading and offloading times can significantly improve productivity and increase the vehicles' efficiency. Therefore, it can be deduced that underutilisation of vehicles during operational hours is due to the longer dwell time of 14 hours per day in each terminal, or both. This was due to restrictions and the inflexibility of loading and offloading periods.

5.2 Number of vehicles loading at a time

The study found that most of the manufacturer loading bays had the capacity to load four vehicles at a time. No traffic congestion was observed at the manufacturing companies' dispatch bays. This contradicts the submission that vehicles waste time, due to congestion at the docks of plants, or at the distribution centres/warehouses and retailer stores (Eskigun *et al.*, 2005: 181; Gwynne, 2014: 73). The waiting time could be due to administrative issues or inefficiencies in the system that are unrelated to the volume of vehicles passing through these locations (Eskigun *et al.*, 2005: 181). On this premise, it can be inferred that vehicle waiting time at the terminals was not related to the congestion at the loading bay. This long waiting time may be as a result of other adminstrative issues or inefficiencies in the system.

5.3 Loading and offloading equipment

The study revealed that two-thirds of the manufacturers' warehouses used equipment such as automatic loaders for loading cement, high-level cranes for loading reinforcement bars, pay loaders for loading crushed stones/sand, and forklift trucks for loading ceramic tiles. These findings are supported by Bouh & Riopel (2015: 468) that the operations should be mechanised and/or automated, where feasible, in order to improve operational efficiency, reduce operating costs, and eliminate repetitive manual handling of material. However, the remaining companies used manual labour in the loading of ceramic tiles (semi-mechanised), blocks, crushed stones, and sand.

Furthermore, the results revealed that offloading was done manually at the distribution centres/warehouses, retailer stores and construction sites. These findings contradict Pienaar's (2016: 381) assertions that to reap the optimum rewards of specialisation, handling equipment at terminals should be provided for rapid loading and offloading, in order to save time and cost. More so, it also contradicted the view that block manufacturers normally use self-loading vehicles with cranes mounted on the edge or on a removable mounting (Vidalakis & Sommerville, 2013: 478). This truck equipment allows for extra grades of movement for handling unit loads (Hannan, 2011: 36).

It can now be deduced that the use of loading equipment at the manufacturers' warehouses was minimal, while there was no offloading equipment at the distribution centres/warehouses, retailer stores, and construction sites. Hence, loading processes at the manufacturers' plant/warehouses, and offloading of vehicle processes at the distribution centres/warehouses, retailer stores and construction sites were inefficient.

5.4 Loading and offloading time

The study sought to confirm the average time taken per ton for loading and offloading each material. The results revealed much disparity in the average time taken per ton for loading and offloading each material. It took much less time per ton to load at the manufacturers' plants, where the loading was done mechanically. On the contrary, it took more time per ton to offload at the distribution centres/warehouses, retailer stores and construction sites, where most of the offloading was done manually. These processes combined used fewer machines, but more manual labour that involved multiple handling.

These findings contradict Pienaar's (2016: 380) assertion that using high-capacity technology to carry and handle large bulk loads can help minimise loading and offloading times. Therefore, the efficiency of loading and offloading time per ton is sub-optimal.

5.5 Loading and offloading costs

The study also revealed a great deal of disparity in average cost per ton for loading and offloading individual materials. It costs less per ton to load than to offload in companies where most of the loading is done mechanically at the manufacturers' warehouses, as against most offloading being done manually at the distribution centres/warehouses, retailer stores and construction sites. This finding supports the fact that the use of automation in material handling can increase efficiency, control costs, and optimise productivity (Bouh & Riopel, 2015: 468).

The findings corroborate Michael's (2015: 16) submission that the more the multiple handling of material, the more the overall logistics expense. The implication is that the touch time costs are non-value-added costs that will never be recovered when an invoice is made out for the load (Niggi, 2017: 52). Thus, for construction material handling, the efficiency of loading and offloading cost per ton was sub-optimal and inefficient.

5.6 Vehicle technology

The study sought to find the level of utilisation of technology to integrate the transport system with the other subsystems. The finding revealed that most of the vehicles used for the delivery of material do not have any transport system software installed in them. A few vehicles owned by the cement companies did have tracker and speed limits installed in them to enable their head office to monitor and track their vehicles. This did not link them to other subsystems and customers.

Andrejić and Kilibarda (2016: 143) found that it was necessary to integrate the transport management system, warehouse management system and other systems. Most importantly, the utilisation of TMS software can provide effective and efficient management of the transportation fleet used in the distribution network (Apte & Viswanathan, 2000: 291). This study found that there was minimal use of transport management system software in vehicles. It can thus be inferred that the transport management system was sub-optimal and inefficient.

6. CONCLUSION

This article assessed transport efficiency for the delivery of construction materials. Fundamentally, any inefficiency in the delivery of construction materials will result in higher material prices, thereby increasing construction costs. This assumption is well founded on the concept of TAC and strongly connected with the general perception that poor cost performance of construction material manufacturers can add significantly to the TAC of construction materials, which, by increasing material purchase price, results in higher construction costs.

Using the dynamics of transport operations as guidance for data collection, the evidence provided in the case study establishes significant inefficiency in construction material manufacturers' transport system. The main problems observed on-site were low efficiency in vehicle dwell time, loading and off-loading vehicles at the warehouses, retailer stores, and construction sites. The study also revealed that there was no utilisation of technology in the transport system to integrate the manufacturers' warehouses with the other logistics partners in the supply chain. The implication of the findings is high prices of materials and delay in delivery. Furthermore, transportation inefficiency became increasingly clearer.

This article concludes by providing the construction material manufacturers with areas that require addressing, in order to improve transportation operations along the nodes (terminals) to help ensure that the construction material arrives at its final destination at optimal quality, time and cost. Due to the small sample of participating companies, performance values estimated in this article are relevant to these companies and should not be considered as industry benchmarks. However, it is believed that the dynamics and capacity of the manufacturing company to provide a cost-effective service to the construction industry revealed by this research will be applicable to similar typical manufacturing firms. This study was conducted using observations, which is one of the limitations of this study. Another limitation of this study is the geographical aspect. Since this study covered only one out of the six geopolitical zones of the country, other zones should be studied and the results compared.

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HOUSING POVERTY IN DEVELOPING COUNTRIES: CHALLENGES AND IMPLICATIONS FOR DECENT ACCOMMODATION IN SWEDRU, GHANA

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ABSTRACT

Adequate supply of housing remains a challenge in developing countries. This article assesses the extent of housing poverty in developing countries and its implication for decent accommodation[1] in Swedru, Ghana. Using a cross-sectional survey design coupled with stratified and systematic sampling techniques, 1,161 household participants were selected. Questionnaires and interviews were used to collect raw data from 496 houses in 16 neighbourhoods in the Swedru Township, Ghana. Findings showed that the vast majority of houses in the Swedru Township share common housing facilities such as bathroom and lavatory. This has compelled some households to resort to bathing in open spaces, while practising free range especially in the morning where households have to queue

1 Decent home/housing is not about the moral conducts of the households, but rather about the extent to which households feel comfortable as occupants of a house to include adequate space, availability of facilities, and security.

for bathing and using the toilet facility. A room occupancy rate of 5.51 indicates that households are congested and a population of 4,603 accommodated in 496 housing units is evident. It was revealed that the high level of non-decent accommodation in the municipality is attributable to ill-enforcement of building laws that has allowed houseowners to supply housing without lavatories with impunity. Hence, effective implementation of the L.I.1630 was recommended.

Keywords: Decent accommodation, deficit, housing facility, housing supply

ABSTRAK

Voldoende aanbod van behuising bly ’n uitdaging in ontwikkelende lande. In hierdie artikel word die omvang van behuisingsarmoede in ontwikkelende lande en die implikasies daarvan vir ordentlike akkommodasie in Swedru, Ghana, beoordeel. Met behulp van ’n deursnee-opname-ontwerp tesame met gestratifiseerde en sistematiese monsternemingstegnieke, is 1 161 huishoudelike deelnemers gekies. Vraelyste en onderhoude is gebruik om rou-data van 496 huise in 16 woonbuurte in die Swedru Township, Ghana, te versamel. Bevindinge het getoon dat die oorgrote meerderheid huise in die Swedru Township gemeenskaplike huisvestingsgeriewe soos badkamer en toilet deel. Dit het sommige huishoudings genoop om te gaan bad in oop ruimtes, terwyl huishoudings moet wag om te bad en die toiletgeriewe te gebruik. ’n Kamerbesettingskoers van 5,51 dui aan dat huishoudings oorvol is en dat daar ’n bevolking van 4 603 in 496 wooneenhede is. Daar is aan die lig gebring dat die hoë vlak van nie-ordentlike akkommodasie in die munisipaliteit te wyte is aan die swak handhawing van die bouwette wat huiseienaars toegelaat het om straffeloos behuising sonder toilette te voorsien. Daarom word ’n effektiewe implementering van die L.I.1630 aanbeveel.

Sleutelwoorde: Behuisingsaanbod, behuisingsfasiliteit, ordentlike akkommodasie, tekort

1. INTRODUCTION

Housing has become a growing concern across the globe and, with the growing number of the urban poor, particularly in Africa, the situation has worsened to unprecedented levels and it seems that the trend is persisting (Chirisa & Matamanda, 2016: 41). Aribigbola (2011: 26) reiterated that housing is crucial to the welfare, survival, and health of individuals. Erguden (2001: 5) opined that housing, apart from being a treasured asset, has much broader economic, social, cultural, and personal connotations.

In accordance with UN-Habitat (2003: 31), although Africa is the least urbanised, it remains the continent urbanising the most, leading to a great challenge of providing decent housing for its urban population. A study by Kempe (1998: 4) reveals that, by 2025, Africa would have an average urban population growth of 3.05%, with West Africa alone estimated to have an average annual population growth of 3.16% (see Table 1).

Table 1: Average percentage annual growth rate of urban population in Africa by region, 1990-2025

	Year range						
Region	*1990-1995*	*1995-2000*	*2000-2005*	*2005-2010*	*2010-2015*	*2015-2020*	*2020-2025*
Africa	4.94	4.72	4.48	4.21	3.85	3.43	3.05
East Africa	6.41	5.94	5.44	5.12	4.72	4.24	3.74
Middle Africa	5.07	4.98	4.83	4.56	4.21	3.75	3.24
Northern Africa	3.92	3.66	3.40	3.08	2.71	2.36	2.18
Southern Africa	3.49	3.29	3.04	2.79	2.53	2.26	1.97
West Africa	5.32	5.15	4.90	4.59	4.12	3.62	3.16

Source: Adapted from UN, World Urbanization Prospects, 2012: 154-155

Unrestrained urban growth makes it difficult for cities to offer residents social facilities such as decent accommodation units for households, despite the recent urban partiality with respect to development disbursements and strategies (Rondinelli & Kasarda, 1993: 17). With the growing density of people in urban areas, land becomes scarce and very expensive where the demand for housing is increasing, making it a challenge for the poor to access decent housing (Jenkins & Scott, 2007: 12). Owing to the scarcity of land and the rising cost of housing, there is a paucity of affordable housing in Africa (Bashir, Julius & Rainer, 2017: 1).

Rapid urbanisation has led to overcrowding in most of the African countries and the rising urban population is not able, in most instances, to access decent housing, thus leading to slums and informal settlements that often do not meet formal benchmarks. According to UN-Habitat (2008: 13), at least 860 million people were living in slums in 2013, an increase of 725 million since the year 2000. The situation in Ghana is no different. According to the GSS (2005c: 24), the urban population has experienced a steady increase of 23.1% in 1960 and 43.8% in 2000. This situation has led to high levels of unsafe homes. Houses constructed in an open space without a lavatory, water, light and sometimes a bathroom are common in most of the rural areas in Ghana (Habitat for Humanity, 2009: 2).

Despite these conditions, the shortage of housing in urban areas has compelled many people to congest in small rooms in houses, where there are no acceptable housing facilities. These houses are mostly overcrowded and a room, which is meant to accommodate at most 3 persons, in accordance with the UN-Habitat (2016: 12) standard, is used by at least 6 persons. Tenants have to queue in the morning and in the evening to have access to a single bathroom or lavatory. This condition is referred to as housing poverty in the context of this article.

This article investigates the extent of housing poverty conditions in the Swedru Township, a conurbation of Accra, the capital city of Ghana, which provides accommodation for the overflow population of Accra and its nearby metropolis. Although some studies (Ansah, 2014: 1; Wuni, Boafo, Yeboah & Dinye, 2018: 2; Obeng-Odoom, 2014: 357) have been conducted on the extent of housing shortage in Ghana's urban cities, none focused on Swedru Township. Other similar studies (Boamah, 2010: 1; Appeaning, 2014; Gillespie, 2018: 64) did not consider how decent or non-decent households are being accommodated, as far as the provision of housing is concerned, in terms of room occupancy rate and housing facility per person. This article investigates the state of housing conditions relative to overcrowding and the availability of in-house facilities, and examines how decent households are accommodated in the Swedru municipality, as measured against the SDG11 and the UN-Habitat's housing standards.

2. LITERATURE REVIEW

2.1 Urbanisation and the extent of decent housing in developing nations

Africa is swiftly urbanising and will lead the world's urban growth in the coming decades (World Bank, 2015: 11). Presently, Africa is the least-urbanised continent, with 11.3% of the world's urban population. The sub-Saharan region is the continent's least-urbanised area. The region's cities are growing rapidly, and Africa's urban population is projected to reach 1.2 billion by 2050, with an urbanisation rate of 58% (UN-Habitat, 2014a: 23). With this growth rate, Africa will overtake Asia as the world's most rapidly urbanising region by 2025 (UN, 2014: 6). Although the nature and pace of urbanisation varies among countries, Africa, with over a quarter of the world's fastest growing cities, is undergoing a massive urban transition. The urbanisation progression in Africa is linked to an increasing demand for affordable housing and other subsidiary urban services, which most of the countries fail to provide (UN-Habitat, 2012: 5; Mugumbate, Maushe & Nyoni, 2013: 25a). As such, both academics and experts have acknowledged the need to reduce the rate of housing scarcity and poverty in developing cities (Riley, Fiori & Ramirez, 2001: 521-531; Sivam & Kuruppannan, 2002: 71). The key test for African cities, however, has been the moderately low growth in per-capita income, which limits the resources that households invest in housing. Recent studies have found that, in Africa, investment in formal housing (based on national current accounts data) lags behind urbanisation (Arvanitis, 2013: 2). Furthermore, the capital investment in infrastructure needed to handle rapid urbanisation typically happens after housing has already been built, often in informal settlements.

Relatively, Jelili (2012: 9) observes that sub-Saharan Africa now has the third highest total number of slum dwellers of all the regions of the developing world (after Southern Asia and Eastern Asia). According to Giddings (2007: 5), if this tendency continues, the slum population is expected to reach 400 million by 2020 in most of the sub-Saharan African countries, specifically Angola, Ethiopia, Mali, Sudan, and Tanzania. Unlike the other African regions, where slums are on the increase, northern Africa is experiencing negative slum development.

In terms of urbanisation, some African governments tend to play a proactive role in urban planning. This has resulted in a proliferation of slums in the vast majority of African cities where the poor reside. This has resulted in a situation where rental accommodation has been acknowledged as an alternative method to address the housing predicament in sub-Saharan countries, specifically Ghana (Ofori, 2019: 169). Generally, decent housing and accommodation is inadequately provided across the cities in Ghana. Several studies (Boamah, 2010: 4; Osumanu, Kosoe & Frederick, 2016: 12) reveal that the average occupancy per room is above 3, coupled with ill-quality housing as standardised by UN-habitat.

According to Chirisa & Matamanda (2016: 4), decent housing must be characterised by adequate living areas within the dwelling, access to improved water and sanitation, and security of tenure. A dwelling apartment should be located in a non-hazardous location and have the capability to effectively protect the occupants from adverse climatic conditions. The occupancy ratio in decent housing should be 3 or less persons per room. However, this article focuses on occupancy per room, access to sanitation and hygiene, in terms of access to facilities such as lavatory and bathroom as indicators for decent accommodation in the Swedru municipality of Ghana.

2.2 Causes of housing poverty (non-decent accommodation) among the urban communities of Ghana

2.2.1 High cost of land and substandard land tenure system

Land is a basic resource to every country's economic and social growth, since it is considered an economic good more than simply a social good (Barlowe, Adelaja & Babladelis, 2013: 8). A few years ago, a small amount of money (peppercorn rent) was paid as allegiance to hold the land for economic or social activities (Ariffian, Afrane, Hassan & Iddrisu, 2016: 138). At present, in urban property markets, uncertainty over the ownership of land, bureaucracy in the endorsements and the issue of titles, land racketeering, lack of compliance with planning requirements, tardy provision of infrastructure and other services, ill-disciplined land agents, and corruption in all aspects of the industry have led to distortions and inefficiencies in urban land markets (CDD, 2000: 14, cited in Ariffian *et al*., 2016: 141). The repercussion of this situation is that the cost of land to the purchasers is much higher than it should be. This notwithstanding, the traditional land administration system has been blamed for the ineffective land tenure system in Ghana, where ownership of land takes different forms, each with specific legal rights and incidents attached thereto (Appiah, 2007: 15).

2.2.2 Rural-urban migrations

Rural-urban drift has been one of the major contributing factors in making housing a challenge in the urban centre of Ghana. The search for greener pastures in the cities encouraged rural communities to join their families in the cities, placing the burden on urban housing (Business World Ghana, 2012: 26). Therefore, provision of housing has scarcely moved in tandem with demand, leading to pockets of slums and communities that seem to consist entirely of kiosks, containers and little by way of plumbing or drainage. For instance, in 2005, due to an acute shortage of housing and poor housing conditions, sub-Saharan Africa had 199 million slum dwellers, constituting 20% of the world's total slum population (Sean, 2014: 191). However, in the same year, Ghana had 5.4 million slum dwellers and is anticipated to reach 7.1 million by 2020. The worst hit cities are Accra, Kumasi and Sekondi-Takoradi (UN-Habitat, 2006). Swedru is a conurbation of Accra and the situation is not different.

2.2.3 Inadequate mortgage financing institution

Mortgage financing has become an increasing challenge in the commercial real-estate market in most of the developing countries, including Ghana (Buckley, 1989: 3; Tomlinson, 2007: 2). In the developed countries, the mortgage industry has proved to be the most proficient and largest financier of the housing needs of the population (Bank of Ghana, 2007: 9). Access to decent, affordable homes is a big challenge for a large part of the Ghanaian population, because the economy is narrowed by fewer savings and borrowing, and there is a trade-off between financing housing and the supply of other infrastructure (Okonkwo, 1998: 8). Moreover, the problem with housing finance among the banks in Ghana is that most of them are portfolio lenders and banks run a low-cost and low-risk business, where mortgage lending fits well in relation to other investment activities (Noah, 2002: 13).

2.2.4 Persistent change of government

Supply of housing is a long-term plan, mostly between five and fifteen years, and such plan needs a formidable policymaker to implement what has been put on paper. However, in Ghana, the persistent change of government has led to the breakdown of continuity of housing projects. This has also contributed to inadequate infrastructure and provision of utility services (Ariffian *et al.*, 2016: 144). For instance, in seeking to boost the housing supply, the Government of Ghana, in 2005, pursued various programmes such as the affordable housing programme to build over 100,000 units of housing through Private Public Partnerships (PPP) across the country (Bank of Ghana, 2007: 15). However, in 2009, after a change of government, all the projects were abandoned and left to squatters, with no intention to complete them. This housing project, when completed, could have accommodated hundreds of families (Ghana web, 2012: 3).

2.2.5 High cost of building materials

The provision of infrastructure and affordable housing for the citizens is constrained by the high cost of building materials (Danso & Manu, 2013: 14). Building materials account for 50% of the total cost of construction in Ghana (Asibuo, 1994: 13). In addition, the high cost of building materials in Ghana is attributed to the over-dependence on imported raw materials for buildings, for which local substitutes could be used if the necessary supports are given to the manufacturers (Yeboah, 2005: 10).

2.2.6 Rapid population growth and urbanisation

During 2000-2020, Ghana experienced a rapid population growth, coupled with sprouting urbanisation (Plecher, 2020: 1). It is projected that Ghana's urban population will be roughly 52% of the national total growth by 2050 and central to this rapid urban growth are housing shortages and poor sanitation (UN-Habitat, 2006: 12). Despite the increase in population growth and urbanisation, the increase in housing is slow, urban infrastructure scarce, social amenities and shelter conditions degraded, particularly in the Accra and Tema Metropolis, making adequate housing a big concern for the Ghana government at present (Modern Ghana, 2010: 4).

2.3 The extent of housing deficit

According to the World Bank (2002: 14), nearly 175,000 dwellings were supposed to be built in Algeria between 2002 and 2012 to alleviate the housing deficit in the country. The annual prerequisite for new dwellings in Ethiopia is projected to be between 73,000 and 151,000 housing units (UN-Habitat, 2006: 12). In the Greater Cairo Region (GCR), it is speculated that over two million housing units need to be built between 2010-2020 to meet the emergent urban population (UN-Habitat, 2010: 3). The situation is not different in Uganda. According to the National Population Council Secretariat (NPC Sec) of Uganda (2007: 10), the estimated 1.5 million housing bottleneck, 211,000 units, was in the urban areas, while the remainder was in the rural areas, resulting in non-decent housing accommodation in the township. The urban housing deficit in Zimbabwe rose from 670,000 to over 1 million between 1992 and 1999. The situation was aggravated by the mass expulsions and clearance of informal housing in 2005, resulting in an additional 92,460 buildings (Tibaijuka, 2005: 6). For the purpose of this article, housing units are separate living quarters, where the occupants live separately from other residents of the structure (Chen, 2020: online).

In spite of this annual increase in housing deficit across Africa, housing finance markets are discouraging, as the vast majority of governments do not invest a great deal in housing. The problem of delays in the housing construction sector is a major phenomenon in Ghana as in other emerging countries (Amoatey, Ameyaw, Adaku & Famiyeh, 2015: 198), with the exception of Morocco, Namibia, and South Africa (CAHF, 2018: 5). This situation is increasing with the result that many dwellers live under non-decent housing facilities, most of which are slums.Boamah (2010: 4) reveals that Ghana is challenged by a severe housing deficit, as only 25,000 units are supplied yearly and the annual demand is 108,000. According to Mahama and Antwi (2006: 3), the deficit in housing units in Ghana is 1,526,275. In 2000, the deficit in housing units in Kumasi was 164,219 (GSS, 2005d: 22) and in Tamale 18,690 (GSS, 2005c: 27). At least 52% of the houses in Ghana accommodate between two and four households (GSS, 2012b: 19).

According to the Ghana National Development Plan (GNDP, 2008: 4), the deficit of 2 million housing units is a major socio-economic challenge confronting Ghana presently (Daily Graphic online, 2014: 1; Ariffian *et al*., 2016: 139). Meeting the deficit implies providing 190,000 to 200,000 housing units annually for 10 years at a cost of US$3.4 billion (17.7 billion GH¢). This situation undermines Sustainable Development Goal 11. The major question is: To what extent has an increase in housing deficit in Ghana influenced non-decent accommodation in the urban cities? This study, therefore, explores the nature of housing accommodation and the characteristics of facilities within homes in terms of the L.I.1630 (CAHF, 1996: 4) and SDG11.

3. STUDY AREA

The study was conducted in Swedru, in the Central Region of Ghana. Swedru is the municipal capital of Agona West Municipal District, in the Central Region of South Ghana, with a population of roughly 68,216 (GSS, 2019: 1). It lies to the north of Winneba and is approximately 40 km off the main Accra-Takoradi Highway. It lies within latitudes 5 30' and 5 50N and longitudes 0 3.5 and 0 55W. It is bounded to the east and west by Effutu Municipal and Asikum/Odoben/Brakwa Districts respectively; to the northeast with West Akim; to the northwest with Birim Central, and to the South with Gomoa Central District (Figure 1).

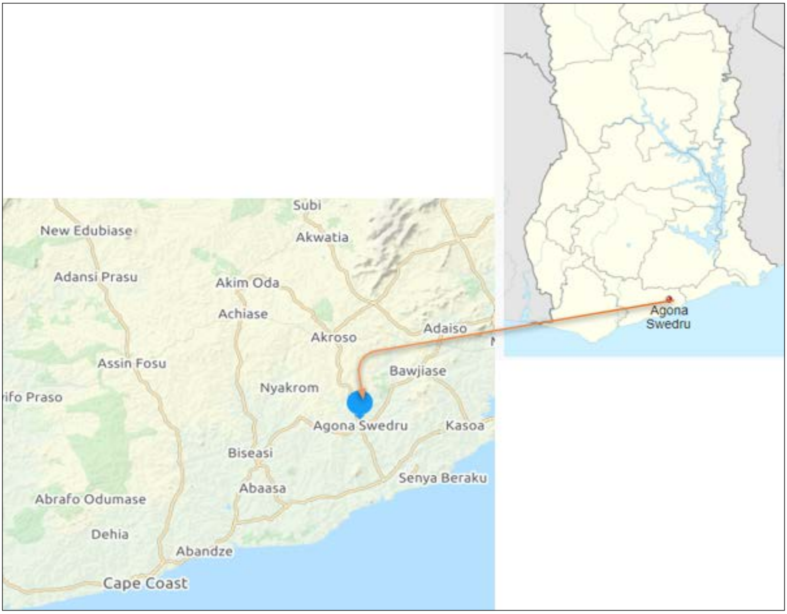

Figure 1: Map of Swedru, Ghana
Source: Maplandia, 2016: online

The township has 14,201 houses, with 53,964 households and accommodates 3.8 households on average per house (WPR, 2020: 1). Nearly seven out of ten (67.4%) of all housing in the municipality are compound houses; 19.3% are separate houses, and 4.2% are semi-detached houses (GSS, 2019: 1). Nearly half (43.4%) of the housing units in the municipality are owned by members of the household; 28.9% are privately owned; 24.7% are owned by relatives who are not members of the household, and only 1.4% are owned by the government. However, less than one per cent (0.6%) (GSS, 2019: 1; GSS, 2014: 13) of the housing units is owned through mortgage schemes.

3.1 Rationale for selecting study area

Ghana does not have any database at present that shows the number of housing units available in the country. In most of the major cities, no data are available on the number of housing units supplied within a year, showing the acceptable in-house facilities. The situation in Swedru is not exceptional. The selection of Swedru Township for the study was informed by the fact that it is one of the conurbations to the capital city of Ghana, Accra, and receives the overflow population of Accra. The reason being that most of the people who move from the various towns in Ghana in search of greener pastures in Accra get employment in Swedru, making the city overburdened with rural urban drift and its accompanied housing complexities.

Apart from the fact that it is one of the growing urbanised cities in Ghana, Swedru is sandwiched between three major cities (Accra, Winneba, and Cape Coast), where most of the people live and work in Accra. In spite of the fact that the housing situation in the town lacks academic recognition, particularly how the housing conditions meet the acceptable housing standards as defined by (UN-Habitat, 2014b: 4; UN-Habitat, 2007: 16) and the SDG11, a preliminary survey of the town shows that few households have in-house facilities such as lavatory and bathroom.

4. METHODOLOGY

4.1 Research design

This study examines the extent of non-decent housing in the Swedru municipality of Ghana and investigates the adequacy level of housing facilities supplied in the various houses across the municipality in terms of their availability and usage per household. This study uses a mixed methods approach, where both quantitative and qualitative data are collected simultaneously, analysed separately, and thereafter merged (Creswell & Plano-Clark, 2018: 8; Grbich, 2013: 27; Isah, Shakantu & Ibrahim 2020: 8). A quantitative semi-structured questionnaire survey was used to collect data from household respondents to enable the researchers to generalise their findings from a sample of a population (Bryman, 2012: 232).

Semi-structured face-to-face interviews were held to solicit qualitative information from some key informants on issues relating to the state of housing in the various residential areas (Isah *et al.*, 2020: 8). Data from the Ghana Statistical Service (GSS), Housing Policies of Ghana and Ghana

Living Standard Survey (GLSS) provided secondary information on issues relating to Ghana's current housing stock and housing deficit.

The reason for collecting both quantitative and qualitative data is to elaborate on specific findings from the breakdown of the interviews and government documents, and to cross-check this data against the questionnaire data set such as similarities in factors that influence non-decent accommodation in the Swedru municipality (Creswell & Plano-Clark, 2018: 27).

4.2 Population, sampling, and response rate

Using the housing stock of 14,201 and an estimated household population of 53,964 (WPR, 2020: 2) in approximately 48 observed neighbourhoods, the study employed purposive, stratified and systematic sampling techniques to select 496 houses and 893 households from 16 neighbourhoods (see Table 2). It must be acknowledged that 893 households were selected for the study, because, each house had more than one household. The purposive sampling technique was used to particularly select the houses based on types and specific characteristics (Rai & Thapa, 2015: 6), as explained in the subsequent paragraphs.

Owing to the heterogeneity of the housing types, the study employed maximum variation sampling, also known as heterogeneous sampling, as a purposive sampling technique to capture a wide range of perspectives relating to decent accommodation and housing poverty (Rai & Thapa, 2015: 6). In addition, due to the larger size of the community and, in order to fully replicate the selected neighbourhoods in the study area, stratified sampling was used to categorise the entire study area into units called stratum. Each stratum was treated separately, and participating households were drawn from each zone or stratum (Kusi, 2012: 61).

With the aid of quadrant stratification, the 16 neighbourhoods were categorised into four zones within the North-East, North-West, South-East, and South-West quadrants category, with four communities purposively selected based on their housing characteristics (inbuilt lavatory and bath, block or brick, types of roofing, location to the city centre, and age) of the neighbourhood under each zone (see Table 2). Out of the 893 households, the study selected two participants systematically from each household in each neighbourhood. A total of 1,786 participants were sampled to complete the questionnaires, with two key informants selected from within for face-to-face interviews.

The sampling for this study follows the recommended sample size table of Krejcie and Morgan (1970: 608). From the table, the recommended sample size for a population of 3,000 is 314, and for 3,500, 361. This recommendation validates the sample size of 1,786 as efficient for the population of 4,603 in Table 2. The trained questionnaire administration team retrieved 1,161 completed questionnaires, resulting in a 65.0% response rate. This response rate is good to support this empirical study, as built-environment survey response rates vary between 7% and 40%, in a broader perspective (see Moyo & Crafford, 2010: 68).

Table 2: Population, sample, and response rate

Zones	*Quadrant*	*Neighbourhood*	*Houses*	*Occupancy population*	*Sample*	*Response*	*Response rate (%)*
A	South-West	Mangoase	19	67	64		
	South-West	Pipetank	38	93	89		
	South-West	Dwenwoho	22	72	68		
	North-West	Yaabam	17	56	53		
Total			96	288	274	241	87.9
B	North-East	Botwe Estate	51	328	186		
	North-East	Manhodze	21	119	79		
	North-East	Tezako	19	97	72		
	South-East	Bypass	23	146	87		
Total			114	690	424	280	66.0
C	South-East	Odakwam	36	369	121		
	South-East	Ahmadya	28	297	173		
	South-East	Nine-Nine	44	428	124		
	North-West	Mandela	25	236	116		
Total			133	1330	534	294	55.1
D	North-East	Anwhease	31	493	114		
	North-East	Chapel Square	23	397	98		
	North-East	Asesim	47	691	124		
	South-West	Nsusoaso	52	714	218		
Total			153	2295	554	346	62.5
Overall			496	4603	1786	1161	65.0

4.3 Data collection

A breakdown of documents from the Ghana Statistical Service (GSS), Ghana Living Standard Survey (GLSS) and Housing Policies of Ghana were examined to determine the number of housing units that are supplied annually in each of the neighbourhoods, in order to measure housing poverty relative to housing supply. However, these documents had no data on the annual supply of housing in the entire Swedru municipality.

The semi-structured interview guide contains only one major question: "Do you have any knowledge on decent accommodation? This question was asked to determine the perceptual views of the participants on what decent housing means.

Using the structured questionnaire, data was collected from 1,161 available household respondents in the Swedru municipality of Ghana from December 2019 to the end of March 2020. The questionnaire consisted of five sections. The first section, on the respondents' demographic profile, obtained personal information on age and occupation. The second section set 20 tick-box options to measure the housing conditions in the Swedru municipality relative to housing supply in each of the various neighbourhoods in the selected study areas (where households were asked to tell how many new houses have been built or completed in their vicinity from the start of the year to date), household access to sanitary facilities and overcrowding. Section three and four contained 8 tick-box options, each to determine the types of housing in the Swedru municipality and the income status and extent of housing tenancy among households. Section five set one Likert-scale question with 13 items on the construct 'factors influencing non-decent accommodation'. Participants were requested to rate the level of influence on the statements regarding factors that influence non-decent accommodation.

The results from these measurements form the items used in the descriptive analysis, factor analysis, and inferential statistics (Naoum, 2013: 39). To reduce the respondents' bias, closed-ended questions were preferred for sections two to five (Akintoye & Main, 2007: 601).

4.4 Data analysis techniques and interpretation of the findings

The Statistical Package for the Social Sciences (SPSS), version 20 was used to analyse housing poverty, by means of descriptive and inferential statistics (Pallant, 2013: 134). The frequencies and/or percentages of responses were generated and reported, in order to analyse the number of housing units that are supplied annually, the respondents' profile, their perceptual views on decent housing, the types and non-decent housing conditions in the Swedru municipality, the income status, and the extent of housing tenancy in households.

A Pearson's correlation test with $p=0.05$ was employed to find any significant relationship between household income and housing ownership (Fenton & Neil, 2019: 18). SPSS was also used to determine the factor analysability of non-decent accommodation in the Swedru municipality, using inferential statistics (Pallant, 2013: 134). Thirteen factors were tested and, for the accurate selection of these factors, all were measured by ranking them, in terms of their mean scores, on the following scale measurement, where 1 = Not at all influential (≥1.00 and ≤1.49); 2 = Slightly influential (≥1.50 and ≤1.92); 3 = Moderately influential (≥1.93 and ≤2.11), and 4 = Most influential ((≥2.12 and ≤2.33). For the analysis of the internal reliability in the factors of the questions on non-decent accommodation, Cronbach's *alpha* values were tested (Kolbehdori & Sobhiyah, 2014: 347). Yount (2006: 15) argued that the standardised values of Cronbach's *alpha* would range between 0.70 and 0.95. For this study, a cut-off value of 0.80 was assumed. In addition, the optimal inter-item correlations mean (factor loadings) should vary between 0.2 and 0.4, in terms of factor reliability. For this study, a value of at least 0.3 was employed (Pallant, 2013: 134).

To confirm whether the data from the measurements was sufficient to test and validate the factor analysis, the Meyer-Olkin (KMO) test (Lorenzo-Seva, Timmerman & Kiers, 2011) and the Bartlett's sphericity test (Hair, Black, Babin, Andersen & Taham, 2006: 110) were used. In the KMO test, as the values of the test vary between 0 and 1, values above 0.7 are required for applying EFA (Hair *et al*., 2006). A statistically significant Bartlett test ($p < 0.05$) indicates that sufficient correlations exist between the variables to continue with the analysis (Hair *et al*., 2006: 110; Pallant, 2013: 190). For factor extraction, Principal Components Analysis (PCA) was adopted to analyse the information into a minimum number of factors, by concentrating the explanatory power on the first factor (find the principal components of data) (Rossoni, Engelbert & Bellegard, 2016: 102).

4.5 Limitations

The housing conditions in terms of housing space, availability of facilities, usage of facilities per person, room occupancy rate, and average household per room in the Swedru Township show some similarities when compared to housing conditions in the vast majority of urban areas in Ghana. However, these may differ in nature as the household's educational and affluence level changes with time. As a result, the conclusions drawn in this study could differ, if similar statistical analyses are done of multiple household characteristics and of the people's perceptual views on what decent housing is in another urban city in Ghana. The availability of housing database in the various statistical services at both the district and municipal levels of the study area (Swedru) limited the flow of information needed for the study.

5. RESULTS AND DISCUSSION

5.1 Participants' profile

Table 3 shows the participants' age and occupation profile. In all the zones, the vast majority of the participants (279) were aged 26-33 years, of which Zone D had the highest number (89) of household participants who fall within the age range 26-33 years and have the largest number (55) of student occupants. The number of 65+ in the municipality were very limited (74). Zone C recorded the highest number of 65+, namely 23. The Swedru Township shows ageing characteristics similar to developing or emerging cities with a growing population, where the number of youth or active population is always higher than that of the elderly.

The vast majority (64.1%) of the household respondents rent houses (paying rent for the spaces) and the remainder are owner occupiers (without rent payment). Table 3 shows that, in all the zones, the number of people who rent was more than that of owner occupiers. This study considers such situation critical to curbing the housing deficit in the Swedru municipality. An analysis of the respondents' occupations confirms the study by GSS (2015: 13) that approximately seven out of every ten non-farm enterprises (69.4%) are found in urban areas.

Of the non-farm enterprises, 40.4% are drivers (22.4%) or traders (18%), considering the economic base of the township. This indicates how urbanised and active the Swedru municipality is, as it is located closer to Winneba and Accra, the capital city of Ghana, all of which are trading zones.

5.2 Participants' perceptual views on decent housing

Table 4 shows the results of the respondents' perceptual views on whether the people in the Swedru municipality know what decent accommodation is.

Table 4: View on decent accommodation

Question to respondents	*Category*	*Frequency (N = 1161)*	*%*
Do you have any knowledge of what decent accommodation is?	Yes	89	7.7
	No	1072	92.3

The vast majority (92.3%) of the participants do not know what decent accommodation entails and do not support the recommendations of the SDG11 goals (Malcolm, 2018: online). This threatens housing development based on the fact that the knowledge on decent accommodation will help houseowners develop housing in a manner that is tenantable in terms of the provision of essential facilities that ensure comfortable living in a house. A key informant and a resident in one of the selected neighbourhoods stated:

Table 3: Age and occupation of participants

Characteristic	*Category*	*Zone A*		*Zone B*		*Zone C*		*Zone D*		*Total*	
		Frequency (N=241)	*%*	*Frequency (N=280)*	*%*	*Frequency (N=294)*	*%*	*Frequency (N=346)*	*%*	*Frequency (N=1161)*	*%*
Age	18-25	34	14.1	36	12.9	44	15.0	44	12.7	158	13.6
	26-33	66	27.4	71	25.4	53	18.0	89	25.7	279	24.0
	34-41	44	18.3	50	17.9	46	15.6	73	21.0	213	18.3
	42-49	29	12.0	38	13.6	49	16.7	49	14.1	165	14.2
	50-57	26	10.8	33	11.8	41	13.9	41	11.8	141	12.1
	58-65	25	10.8	32	11.4	38	12.9	36	10.4	131	11.2
	65+	16	14.1	20	7.1	23	7.8	15	4.3	74	6.3
Occupation	Teaching	27	11.2	31	11.1	36	12.2	42	12.1	136	11.7
	Driving	50	20.7	48	17.1	60	20.4	103	29.7	261	22.4
	Farming	59	24.5	56	20.0	73	24.8	86	24.8	273	23.5
	Trading	60	24.9	68	24.3	56	19.0	25	7.2	209	18.0
	Student	28	11.6	47	16.8	43	14.6	55	15.6	173	14.9
	Public Servant	17	11.2	30	10.7	26	8.8	36	10.4	109	9.3
Resident type	Owner occupied	82	34.0	98	35.0	108	36.7	129	37.3	417	35.9
	Tenant	159	65.9	182	65.0	186	63.3	217	62.7	744	64.1

> "Our aim is to get somewhere to lodge especially to escape from heavy rains and high sunshine and we have the belief that if you wish to have a comfortable room to stay in then you have to build your own house and decorate it the way you like."

A 48-year-old landlord reiterated:

> "My brother, I am aware that when you provide in-house bathhouse and lavatory it makes living very convenient but most of the tenants do not keep them neat and if you are not careful sometimes the stench from them may drive you away from your own house and that is why I decided not to add lavatory to the rented apartments."

5.3 Housing conditions in the Swedru municipality

5.3.1 Measuring sanitary facilities

There are a number of measures and indicators of non-decent accommodation (see Chirisa & Matamanda 2016: 12), but, in the context of this article, it is restricted to inadequate amenities (access to bathroom and lavatory in terms of the number available and how many people use them) and overcrowding (in terms of the number of persons per room). According to UN-Habitat, the standard is one facility for three persons. Table 5 shows the extent of the sanitary facilities in the housing units in the Swedru municipality.

Table 5: Sanitary facilities in the Swedru municipality

Sanitation	*Category*	*Frequency (N = 496)*	*%*
Available bathing facilities	Open space everywhere in the house	30	6.0
	Common bathroom in house	213	42.9
	Open partition attached to house	45	9.1
	Private bathroom for household	104	21.0
	Sharing bathroom with another house	59	11.9
	Individual bathroom attached to bedrooms	45	9.1
Types of lavatory services used by households	WC (in house)	27	5.4
	Common lavatory in homes	183	36.9
	Public toilet outside homes	33	6.7
	Pit latrine in house	130	26.2
	Free range on refuse dump sites	47	9.5
	Free range on any open space	31	6.3
	Public toilet with WC	19	3.8
	Households sharing lavatory with public schools	16	3.2
	Individual WC attached to bedrooms	10	2.0

Although 9.1% of the housing units have bathrooms attached to their bedrooms, 42.9% share one bathroom, and 11.9% share a bathroom with another house, causing a very uncomfortable situation. While 9.1% of the housing units use an open partition attached to the house as a bathing facility, 6% are without bathing facilities and households depend on open space everywhere in the compound when the need arises. The practical implication is that, if the average occupancy per household is 9.30 (see Table 6) and 213 houses have 213 bathrooms, then a single bathroom is used by at least nine persons and 30 housing units, without bathrooms having at least 279 persons bathing in open space. Nine persons using one bathroom poses a health risk to tenants in circumstances where physical distances are required to curb contagious, airborne and infectious diseases such as the coronavirus (COVID19). Two hundred and seventy-nine persons bathing in open space expose tenants to various degrees of insecurity and women and children to all forms of attack, including verbal assault and rape (Boamah, 2010: 5). This compromises the standards of decent accommodation proposed by Chirisa & Matamanda (2016: 31).

Table 5 also shows that 496 housing units use nine different types of lavatory services. Although the vast majority (36.9%) of housing units share one lavatory per household and 26.2% use pit latrines in their houses, 15.8% use free range as a lavatory facility. Free range, in the context of this article, is an indiscriminate means of defecating, where a person enters any bush nearby or any refuse dumpsite and defecates. Only 3.2% of the housing units share lavatory services with public schools, while 3.8% use public toilets with WC. Only 2% of the housing units have WC lavatories attached to their bedrooms.

Policy wise, the L.I.16030 (Tasantab, 2016: 152) compels every housing unit to have at least one lavatory facility that is spacious enough to accommodate all household members. The implication is that inadequate supply of housing compels people to live in any building and disregard the non-decent nature of the accommodation.

5.3.2 Measuring overcrowding

Table 6 indicates that the average number of housing units is 124 per zone in the Swedru municipality, accommodating 223.25 households. The results confirm the study by Smith-Asante (2018: 2) that Ghana has a housing glut of 130 to 140 housing units supplied every year for a decade. Comparatively, however, it shows a minimum average of 2 rooms (Zone A) and a maximum average of 5 rooms (Zone D) in each house in each neighbourhood in the Swedru municipality.

Table 6: Housing and household dynamics in Swedru municipality

Dynamic	*Category*	*Zone A*	*Zone B*	*Zone C*	*Zone D*	*Total*
Houses	Units	96	114	133	153	496
	Mean unit per zone					124
	Number of rooms in house units	192	345	532	765	1834
	Average room per house unit	2	3.03	4	5	3.70
Households	Size	182	216	224	271	893
	Mean number of households per zone					223.25
	Number of rooms in households	173	135	162	96	566
	Average room per household	1.05	1.60	1.38	2.82	1.57
	Average household size per unit	1.50	2	2.50	3	2.51
Occupancy	Per unit	288	690	1330	2295	4603
	Average occupancy per house	3	6.05	10	15	4603/496=9.30
	Mean occupancy per household	1.58	3.19	5.94	8.47	4603/893=5.20

The average household size of 2.51 implies that there are at least 2 households accommodated in one unit, with at least five people occupying one room. The overcrowded rooms do not meet the standard of two people per room, as stated by the L.I.1630 (CAHF, 1996: 4). The findings on average household size per unit (2.51) with 9.30 persons per house partially contradicts Boamah's study (2010: 10) that the average household size per house is 3.5 with 20.3 persons in every house in Kumasi neighbourhoods.

5.4 Types of housing in the Swedru Township

Table 7 shows eight different types of housing units in the selected study areas within the Swedru Township. Although 22.7% of the participants live in duplexes, the vast majority (33.2%) of them live in compound houses. In this article, a compound house is a house with at least two households sharing a bathroom and lavatory together. More than three persons using a single lavatory and bathroom in every house is contrary to the L.I.1630 recommendations (CAHF, 1996: 4) and compromises the SDG11 (see Tasantab, 2016: 151).

Table 7: Types of housing in the Swedru municipality

Housing type	*Frequency*	*%*
Compound house	165	33.3
Single room self-contained	61	12.3
Duplex	113	22.8
Three bedroom semi-detached	31	6.3
Three bedroom semi-detached	53	10.7
Two bedroom semi-detached	30	6.0
Three bedroom self-contained	20	4.0
Four bedroom self-contained	23	4.6
Total	496	100.0

5.5 Measuring housing poverty relative to housing supply

The report from the 2010 housing and population census indicates that Ghana has a housing deficit of 1.7 million. Hence, the country can meet the deficit only if 130 to 140 housing units are provided every year across the country for a decade. As such, using questionnaire responses, this study obtained the number of housing units that are built every year in each of the neighbourhoods selected in Swedru for the year 2020 (see Table 8).

Table 8: Annual (2020) housing supply in the Swedru neighbourhoods

Zones	*Quadrant*	*Neighbourhood*	*Annual housing supply*	*Total*
A	South-West	Mangoase	22	114
	South-Wes	Pipetank	31	
	South-West	Dwenwoho	36	
	North-Wes	Yaabam	25	
B	North-East	Botwe Estate	39	93
	North-East	Manhodze	19	
	North-East	Tezako	23	
	South-East	Bypass	12	
C	South-East	Odakwam	34	116
	South-East	Ahmadya	16	
	South-East	Nine-Nine	37	
	North-West	Mandela	29	
D	North-East	Anwhease	11	55
	North-East	Chapel Square	21	
	North-East	Asesim	9	
	South-West	Nsusoaso	14	
Overall				378
Average housing supply per neighbourhood				23.63

Source: Questionnaire survey, 2020

Table 8 indicates that, across the 16 neighbourhoods, a total of 378 housing units are supplied annually and, if that number is supplied for ten years, *ceteris paribus*, there will be 3,780 housing units. This is below the 5,200 minimum annual housing units required, according to GSS (2014: 27; Smith-Asante, 2018: 3). Moreover, if 496 housing units in 16 neighbourhoods are accommodating 4,603 occupants (both owner occupiers and renters), then there is a 27.31% shortage, thus a deficit of 142 housing units. This could make 2,885 people across the 16 neighbourhoods either homeless or sleeping in places such as kiosks and the frontage of shops. This situation characterises housing poverty, as it does not support the UN-Habitat's standards.

5.6 Income status and the extent of housing tenancy among households

Table 9 shows the income levels of participants who rent and own housing in the Swedru municipality. Overall, the vast majority of the participants rent housing. Most of them (245) earn a minimum income of GH¢200-800 per month and rent houses. In the GH¢3600+ income group, the majority (42) of them live in rented housing, and only 23 live in their own housing.

Table 9: Income status and the extent of housing tenancy

Housing tenancy (households)	*Income levels (per month-GH¢)*						*Total*
	200-800	*900-1500*	*1600-2200*	*2300-2900*	*3000-3600*	*3600+*	
Renting	245	74	50	52	53	42	516
Owner tenancy	209	50	29	31	35	23	377
Total	454	124	79	83	88	65	893

Table 10: The extent of housing tenancy among households vs income levels of participants (per month-GH¢)

Chi-square test	*Value*	*Df*	*Asymp. Sig. (2-sided)*	**Exact Sig. (2-sided)*	*Exact Sig. (1-sided)*	*Point probability*
Pearson *Chi*-square	6.144a	5	.292	.293		
Likelihood ratio	6.173	5	.290	.293		
Fisher's Exact Test	6.037			.302		
Linear-by-Linear Association	4.615b	1	.032	.033	.016	.002
Number of valid cases	893					

*significant at 0.05 (2 sided)

a. 0 cells (0.0%) have expected a count of less than 5. The minimum expected count is 27.44.

b. The standardised statistic is -2.148.

In Table 10, the Pearson's *Chi*-square test results show a very weak relationship between income and the extent of housing tenancy among households [χ^2 (5) = 6.144, n=893, p=.292 (>0.05)]. Though there is a relation between income and the ownership of housing, the situation in Swedru shows no strong statistical significance, because even higher income earners were living in rented apartments. Akuffo (2006: 18) reveals that commercial banks in Ghana are not interested in housing finance. They would rather concentrate on treasury bills and bonds.

5.7 Ranking of factors influencing non-decent accommodation

Table 11 shows the mean score and ranking of the 13 critical, non-decent accommodation factors that have an influence on housing poverty. The rank of each variable was determined by calculating the mean score (MS), which is the sum of scores of the respondents on the variable divided by the total number of respondents, and subsequently arranged in a rank order.

Table 11: Mean scores and ranking of factors influencing non-decent accommodation

Variables	*Factors influencing non-decent accommodation in the Swedru Municipality (N = 893)* *(1 = not at all influential … 4 = Most influential)*	*Bartlett's test of sphericity Value = .00*	*Kaiser-Meyer-Olkin Value = .870*	
		MS	*Cronbach's Alpha*	*Rank*
V3	Ignorance on the part of houseowners	2.33	.985	1
V12	Poor building plans	2.30	.984	2
V13	Low income	2.24	.982	3
V6	Overall housing deficit	2.22	.983	4
V4	High birth rate among household	2.21	.982	5
V11	Outmoded cultural practices	2.21	.982	5
V8	Lack of national policy for sustainable housing	2.17	.982	6
V9	Land tenure problems	2.17	.982	6
V10	Inadequate building supervision in Ghana	2.16	.981	7
V7	Higher rural urban migration	2.15	.981	8
V5	Higher demand for housing over supply	2.11	.983	9
V1	Poor implementation of the L.I.1630	1.91	.984	10
V2	Lack of affordable housing	1.72	.986	11
Average MS		2.15	984	

The average MS of 2.15 in Table 11 indicates that household participants perceived all critical factors identified as most influential on non-decent accommodation, particularly, with MS above 2.23, ‘Ignorance on the part of houseowners’ (MS=2.33), ‘Poor building plans’ (MS=2.30) and ‘Low income’ (MS=2.24) were rated the top three factors influencing non-decent accommodation. Interestingly, ‘Poor implementation of the L.I.1630’ (MS=1.91) and ‘Lack of affordable housing’ (MS=1.72) were perceived to have a slight influence on non-decent accommodation.

The Cronbach’s *alpha* was greater than 0.80 at .985, showing approvable internal reliability, as suggested by Hair, Tomas, Ringle and Sarstedt (2014: 102). The Kaiser-Meyer-Olkin (KMO) of .870 with Bartlett’s test of sphericity of $p < 0.000$, implies consistency with the recommended KMO cut-off value of 0.80 and Bartlett’s test of sphericity of $p < 0.05$, as suggested by Pallant (2013: 190). These results imply that factor analysis could be conducted with the data.

5.8 Principal component analysis for factors influencing non-decent accommodation in the Swedru municipality

The 13 variables or factors influencing non-decent accommodation in the Swedru municipality were subjected to PCA to study the trend of inter-correlations between variables and to group variables with similar characteristics into a set of reduced factors according to the hidden components in the collected data. The results present the factor extraction, Eigenvalues, correlation, and interpretation.

In Figure 2, the scree plot consists of the Eigenvalues and the data points above the break (point of inflexion), which are the components that are meaningful to retain for rotation. Using a cut-off value of initial Eigenvalues greater than one (>1.0), three components explain a cumulative variance of 65.402%, indicating that the other factors are below the point of influence as far as non-decent accommodation is concerned. These factors are V3, V12 and V13, respectively.

The scree plot confirms the finding of retaining three components. Hence, components 4 to 13 are not significant and thus not included for rotation.

Table 12 shows that the three components that are meaningful to retain had a cumulative variance of 65.40, where factor one explains 46.445% of the total variance, factor two 10.782%, and factor three 8.174%. This indicates that all three factors had total initial Eigenvalues greater than 1, thus component 1 (6.038), component 2 (1.402) and component 3 (1.063).

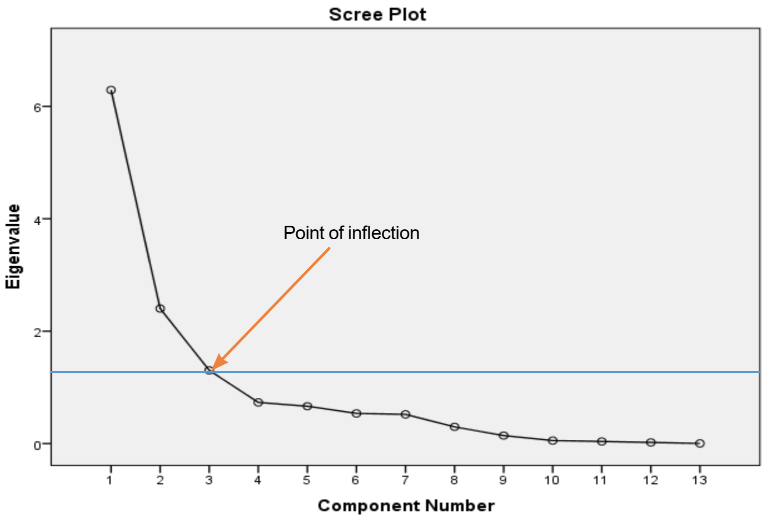

Figure 2: Scree plot for the most influential factors on non-decent accommodation

Table 12: Total variance explained, extraction method, principal component analysis

Component	*Initial Eigenvalues*			*Extraction sums of squared loadings*			*Rotation sums of squared loadings*
	Total	*% of variance*	*Cumulative %*	*Total*	*% of variance*	*Cumulative %*	*Total*
1	6.038	46.445	46.445	6.038	46.445	46.445	5.636
2	1.402	10.782	57.227	1.402	10.782	57.227	2.994
3	1.063	8.174	65.402	1.063	8.174	65.402	1.432
4	.877	6.749	72.151				
5	.827	6.360	78.511				
6	.611	4.697	83.208				
7	.581	4.469	87.677				
8	.438	3.370	91.048				
9	.408	3.141	94.188				
10	.255	1.958	96.147				
11	.252	1.940	98.087				
12	.155	1.192	99.279				
13	.094	.721	100.000				

The grouping of variables was based on their factor loadings. A factor loading indicates the degree of association of a variable with the component and the percentage variance of the component that is explained by the variable (Oladimeji, 2019: 157). Using Principal Component Analysis and Varimax with Kaiser Normalization rotation method and with a significant factor of .04, Table 13 shows the correlation between components and variables after rotation. Correlation exists between variables 1, 4, 6, 7, 8, 10 and 13, as they are loaded onto Component 1, denoted as "Ignorance on the part of houseowners". Correlations were also identified between variables 2, 9, 11 and 12, which are loaded onto Component 2, denoted as "Poor implementation of the L.I.1630". Variables 1, 3 and 7 show correlation as they are loaded onto Component 3, denoted as "Low income".

Table 13: Rotated component matrix for factors influencing non-decent accommodation

Variables		*Components*			*Communalities*
		1	*2*	*3*	
		Ignorance on the part of houseowners	*Poor implementation of the L.I.1630*	*Low income*	
V1	Ignorance on the part of houseowners	.983		.674	.617
V2	Poor building plans		.861		.544
V3	Low income			.864	.871
V4	Overall housing deficit	.983			.410
V5	High birth rate among household				.894
V6	Outmoded cultural practices	.889			.926
V7	Lack of national policy for sustainable housing	.926		.582	.948
V8	Land tenure problems	.907			.945
V9	Inadequate building supervision in Ghana		.859		.893
V10	Higher rural urban migration	.856			.959
V11	Higher demand for housing over supply		.837		.713
V12	Poor implementation of the L.I.1630		.896		.544
V13	Lack of affordable housing	.904			.731

For **Factor 1: Ignorance on the part of houseowners (Component 1)**, variables with high loadings above .90 are Overall housing deficit (.983); Ignorance on the part of houseowners (.983); Lack of national policy to sustainable housing (.926); Land tenure problems (.907), and Lack of affordable housing (.904). Ghana had a housing deficit of over 2 million units in the year 2010 and approximately 5.7 million as of 2020 (GSS, 2012a: 8; Ansah, 2014: 1; Willows Property Management, 2020: 1). This implies that the overall housing deficit in the country is compelling people to live in housing simply for the sake of being safe from the vagaries of the weather and not for comfortable living. Land tenure problems occur, because the acquisition of land for housing purposes in Ghana abounds in bureaucracy and land racketeering (see Appiah, 2007: 15), leading to housing shortage. The lack of affordable housing has made many homeless in Ghana and, although housing is acknowledged as a human right, government involvements have not met the housing needs of the poor (Yirenkyi, 2014: 1). The lack of a national policy for sustainable housing has been a long-term policy problem in Ghana (Oleg & Badyina, 2012: 1). However, since 1980, national housing policies have tended to focus on conferring ownership rights and largely omit rental housing, although it is a viable livelihood strategy for tenants (WSUP, 2013: 2).

For **Factor 2: Poor implementation of the L.I.1630 (Component 2)**, variables with high scores are Poor implementation of the L.I.1630 (.896); Poor building plans (.861); Inadequate building supervision in Ghana (.859), and Higher demand of housing over supply (.837). Since the L.I.1630 is the sole legislative body in Ghana to regulate the construction industry, poor implementation of the L.I.1630 implicates that building plans are not properly approved, and that ongoing building constructions are poorly supervised (Thong, 2014: 18). This has led to poor building quality and layout in the Swedru Township, with the resultant effect of poor road networks, while drains are blocked and poor quality housing structures put tenants in danger, due to fire outbreak and building collapse, aside the fact that buildings do not follow the accommodation standards for decent living (Claude, Omer & Mempouo, 2017: 1).

For Factor 3: Low income (Component 3), Low income (.864), Ignorance on the part of the houseowners (.674) and Lack of national policy for sustainable housing (.582). Low income leads to poor housing in terms of construction materials, furnishes, building services and facilities that bring comfort to the tenants and, hence, decent homes or housing. Housing completion, development and improvement are limited to financing, and in Ghana, most of the house- and landowners are ignorant about how to get loans in the form of a mortgage to complete and improve their housing. A study by Ofori and Ameyaw (2020: 252) reveals that most of the mortgage loans applied for are used for the supply of commercial office spaces, because many residential space owners are concerned about the mortgage rates and perceive that the payment of mortgage loans is perpetual in nature. This has even compelled some landowners to live in uncompleted buildings that lack salient building facilities that bring comfort.

Although there is a considerable lack of national policy for sustainable housing in Ghana, in this study, such factor is considered not critical, as indicated by lower loadings. Boamah (2010: 1) revealed that several housing policies have been instigated in Ghana since independence in 1957. However, housing in Ghana is branded by insufficient housing stock, congestion, neighbourhood disfigurement, jamming, and housing obsolescence. This study is of the view that in the Swedru municipality of Ghana, the income status of houseowners does not influence the supply of decent accommodation, but rather ineffective enforcement of building laws and regulations. Such findings contradict those of Mitlin (2010: 517), which revealed that the urban poor live in houses with unacceptable standards. The implication is that people feel discomfort in their housing and the policies to redress their challenges are futilely implemented.

6. CONCLUSION

The article investigated the extent of non-decent accommodation in the Swedru municipality of Ghana. It examined the types of housing available and found that, although most of the residents are accommodated in compound houses and duplexes, the annual housing supply of 378 houses in 16 communities shows a housing shortage in the Swedru municipality. The study concluded that 16 communities with total housing units of 496 accommodating 4603 people, with an average occupancy per house of 9.30 persons, and 5.51 persons occupying a single room implies that most of the households in the Swedru Township are overcrowded. This is against the SDG11.

The percentage of houses (42.9%) sharing a single bathroom implies that over nine persons using one bathroom pose a health risk in circumstances where physical distancing is a key measure to mitigating contagious diseases such as the coronavirus (COVID19) and is against the sustainable development goal 11 that focuses on sustainable city development. An urban area with 15.8% of the households practising free range owing to inadequate provision of lavatories is a threat to the SDG6 that focuses on clean water and sanitation. A municipality with the vast majority of the population aged between 26 and 33 years implies that the birth rate would be high in the near future and, if housing stock is not increased to match up with demand of the growing population, the municipality would have most of its households become homeless. The provision of affordable housing units by the state to increase the housing stock in the municipality is recommended. In general, there must be effective implementation and enforcement of building regulations in Ghana

(L.I.1630) to ensure the provision of adequate housing facilities needed to complement decent accommodation.

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MACROECONOMIC LEADING INDICATORS OF LISTED PROPERTY PRICE MOVEMENTS IN NIGERIA AND SOUTH AFRICA

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ABSTRACT

This article aims to identify macroeconomic leading indicators that influence changes in the listed property price movements in South Africa and Nigeria. This serves to improve the quantitative approaches to investment appraisal in emerging markets of sub-Saharan Africa. The data relating to macroeconomic leading indicators, including Johannesburg Stock Exchange (JSE) Listed Property (J253) quarterly price data, Nigerian listed real-estate data, and Macroeconomic indicator series for Nigeria and South Africa, were collected from Iress Expert Database, Stats SA, the Central Bank of Nigeria (CBN), the National Bureau of Statistics (Nigeria), and the World Bank. The article identifies that coincident indicators and the exchange rate have a positive and significant relationship with the JSE-listed real estate in the South African market. While the bank lending rate, the consumer price index, and the Treasury bill rate (TBR) are identified as reliable indicators in the Nigerian listed real-estate market. The results show that investors must pay attention to these indices in their choice of the market(s) within the sub-Saharan African context, as this will guarantee capital appreciation or growth.

Keywords: Indicators, investment, listed property, macroeconomic, price

ABSTRAK

Hierdie artikel het ten doel om makro-ekonomiese leidende aanwysers te identifiseer wat die veranderinge in die genoteerde eiendomsprysbewegings in Suid-Afrika en Nigerië beïnvloed. Dit help om die kwantitatiewe benaderings tot beleggingsbeoordeling in opkomende markte in Afrika suid van die Sahara te verbeter. Die gegewens rakende makro-ekonomiese leidende aanwysers, insluitend die kwartaallikse prysdata van die Johannesburgse Effektebeurs (J253), die Nigeriese vaste eiendomsdata en die makro-ekonomiese aanwyserreeks vir Nigerië en Suid-Afrika is versamel van Iress Expert Database, Stats SA, die Central Bank of Nigeria (CBN), die National Bureau of Statistics (Nigeria) en die Wêreldbank. In die artikel word aangedui dat samevallende aanwysers en die wisselkoers ’n positiewe en beduidende verband het met die JSE-genoteerde vaste eiendom in die Suid-Afrikaanse mark. Terwyl die bankleningsyfer, die verbruikersprysindeks en die skatkis (TBR) as betroubare aanwysers in die Nigeriese genoteerde eiendomsmark geïdentifiseer word. Die resultate toon dat beleggers aandag moet skenk aan hierdie indekse in hul keuse van die mark(te) binne Afrika suid van die Sahara, aangesien dit kapitaalappresiasie of groei sal waarborg.

Sleutelwoorde: Aanwysers, belegging, genoteerde eiendom, makro-ekonomies, prys

1. INTRODUCTION

The real-estate sector significantly contributes to the gross domestic product (GDP) of countries worldwide. Therefore, several countries pay special attention to making this sector attractive to both local and international investors. According to the Organisation for Economic Co-operation and Development (OECD) (2018), real estate contributes a total of 2.3 trillion US Dollars to GDP in the United States of America (USA); 404.9 billion US Dollars in the United Kingdom (UK); 151.3 billion US Dollars in Australia, and 191.4 billion US Dollars in Canada. However, in comparison to these major economies, the contribution of real estate to GDP in sub-Saharan Africa’s emerging markets is marginal (Bodunrin, 2019). In particular, real estate contributed 0.8%, representing roughly 40 billion Rands (2.8 billion US Dollars), to South Africa’s GDP in 2018 (SA Commercial Prop News, 2019), while the real-estate sector contributes 6.85%, representing approximately 9.4 trillion Naira (25.9 billion US Dollars), to the Nigerian GDP (BudgIT, 2018).

Although there is a marginal growth in the contribution of the real-estate sector to GDP in South Africa and Nigeria, this is attributable more to additional stream from development finance institutions (DFI), sovereign wealth funds (SWF), and foreign direct investment (FDI) (PwC, 2015: 85). However, since the safety of investor(s) capital or income is foremost in decision-making, real-estate market participants are particularly interested in knowing the future trajectory of rent or price relative to their choices.

There are a considerable number of studies on finding the future direction of rent or price (Karakozova, 2004: 51; Tsolacos, Brooks & Nneji, 2014: 541; Michael & Almeida, 2016; Harrami & Paulsson, 2017). However, most of these studies were carried out in mature or more developed real-estate markets, where there is relative economic stability and historical real-estate transaction data are readily available. Consequently, due to differential contextual settings and market behaviour of real-estate markets, findings from these studies could not be used to make significant inferences about other markets, especially the emerging markets.

Accordingly, the different contextual market settings in the two sub-Saharan African countries, Nigeria and South Africa, necessitate an investigation into the real-estate market behaviours. In Nigeria, particularly in Abuja, the nation's capital city, a high vacancy rate for real estates is reported in several locations (Namnso, Ighalo & Sanusi, 2015: 64). In addition, the recent security situation in some parts of Nigeria is a negative strain on investors' confidence in the real-estate market. In South Africa, the recent spate of xenophobic occurrences in some parts of the country is cause for concern to foreign investors in the real-estate market. It, therefore, becomes important to evaluate the responses of the real-estate market to recent changes in the overall economies. On the surface, the challenges might seem to scare investors from committing their funds into the markets; however, these could not be substantiated without a careful analysis of the leading economic indicators across the two countries.

The motivation in this study is to use the indicators to unravel perceived economic consequences of the changes on real-estate investment returns. In addition, to comparatively identify the leading market indicators across these two top economies is *sine qua non* for real-estate investment decisions. Consequently, the place of these countries in the African continent serves as an avenue for useful information on market indicators to be marginally applied across the rest of sub-Saharan Africa. It is, therefore, important to identify the key market determinant variables that forecast timeous recognition of turning points in commercial real-estate rents in Nigeria and South Africa. In order to analyse the turning points, Tsolacos *et al.* (2014: 541) review related studies on reliable real-estate market indicators. The identification of market indicators is used to understand advance market behaviour of different periods of positive or negative growth in rents.

2. LITERATURE REVIEW

This study was premised on the possibility that macroeconomic factors could drive real-estate prices and thus provide insight for better investment decision-making. Leading indicators signal the fluctuations in markets that manifest as expansions or contractions. Accordingly, several technique(s) have been used to test the leading indicators, in order to reflect market performance or to predict business variations. This is achieved by means of repetitive patterns that reveal a state of growth or reduced economic activity (Krystalogianni, Matysiak & Tsolacos, 2004).

Clark and Daniel (2006) listed eleven leading economic and financial indicators for forecasting South African house prices: all share index, prime interest rate, gross domestic product, building plans, business confidence, motor vehicle sales, household debt/disposable income, Rand/Dollar exchange rate, gold prices, oil prices, and transfer costs. Akinsomi, Mkhabela and Taderera (2018) as well as Sibanda (2013) considered the macroeconomic drivers of direct real-estate returns, and found that GDP, interest rate, and unemployment are statistically significant drivers of direct real-estate returns in South Africa.

The opportunity to deliver greater insight into these relationships promises better understanding of real-estate investment risks and enhances investment confidence (Ntuli & Akinsomi, 2017; Emerole, 2018). According to Boshoff and Binge (2019), investment confidence indicators possess analytical signals for economic growth and are frequently accurate leading indicators and useful for detecting early warning signals for economic turning points (Krystalogianni *et al.*, 2004). Boshoff (2013) opines that the information provided by indirect real-estate investment shows that analysts can rely on these data for evaluating markets, because real estate at this level is like any other asset class and could be influenced by various economic and financial drivers.

The leading nature of some macroeconomic indicators has been found to serve as early warning signals of imminent significant changes in the direction of the real-estate market. Accordingly, D'Arcy, McGough and Tsolacos (1999) carried out a study of the Dublin office rental market and found that changes in real gross domestic product (GDP) and service sector employment (SSE) are significant determinants of the demand and pricing for office space. Similarly, MacFarlane, Murray, Parker and Peng (2002) identified employment as the primary driver of demand for office space in Sydney, Australia.

Krystalogianni *et al.* (2004) examined the future trajectory of real-estate prices in the United Kingdom's (UK) industrial, office and retail properties, and found gilt yield and broad money supply (M4) as key market indicators for the direction of the real-estate markets. Karakozova (2004) undertook a study in Finland to identify the drivers and the best methods for modelling and forecasting property returns and concluded that the leading indicators for predicting commercial rents are growth in service-sector employment, GDP, and output from financial and business services. Ng and Higgins

(2007) in the United States of America (USA) investigated the critical determinants of the commercial real-estate market performance. They found the GDP, the unemployment rate, as well as office finance, insurance and real-estate services (FIRE) employment as leading indicators.

In a related study in the USA, Baba and Kisinbay (2011) found labour market, housing, yield spreads, and consumption to be determinants that lead to changes in the market. Similarly, Harrami and Paulsson (2017) investigated rent modelling for the Swedish office market and found that the GDP was useful in predicting the direction of the real-estate market. Similar studies in the UK and the USA (Füss, Stein & Zietz, 2012; Tsolacos, 2006; Frankel & Saravelos, 2012; Buehler & Almeida, 2016) report that, in order to create predictive models, identifying the “right” set of variables that combine to trigger changes in the market was the first step. In particular, Buehler and Almeida (2016), noted that the risk of downturns in the commercial real-estate prices in USA cities was attributable to several macroeconomic indicators, including inflation rates, bond yields, consumer confidence, and employment.

These studies attempt to provide models for forecasting real-estate price movement in highly developed and well-structured markets. The importance of this study is underscored in Tsolacos and Brooks (2010), who suggested that research on early warning signals for real-estate markets should be predicated, using the leading macroeconomic indicators. Leading indicators are used to capture changes in direction and turning points. Thus, as noted earlier, security challenges witnessed in Nigeria and South Africa, though difficult to directly capitalise, could be modelled on the leading market indicators.

Consequently, there is a paucity of literature on identifying the leading macroeconomic indicators in the Nigerian and South African real-estate markets. Namnso *et al.* (2015) undertook a study of the drivers of office rent in three districts in Abuja, Nigeria, and found that real GDP growth and the vacancy rate were significant determinants of rental growth. In the real-estate market, Mourouzi-Sivitanidou (2020) undertook a study to identify leading macroeconomic drivers of the market direction and found employment, retail sales/wholesale trade sales, GDP (by sector), manufacturing production/factory utilisation, consumer price index (CPI), and producer price index (PPI) inflation as determinants. Clark and Daniel (2006) also attempted to develop an econometric model for forecasting South African house prices for 2005/2006. The study found a positive relationship between lagged stock market returns, GDP, transfer costs, and house price growth rates, while a negative relationship exists between interest rates, exchange rate movements, and house-price growth rates.

Monde (2008) reports that the first mark of an imminent turning point in the business cycle is typically when the composite leading business cycle indicator changes course for at least six months. The study suggests that interest rates play a significant role in the South African real-estate sector, but that it is challenging to carry out a sector-specific analysis of macroeconomic interactions. Akinsomi, Mkhabela and Taderera (2018) considered the macroeconomic drivers of direct real-estate returns in South Africa and found the GDP, interest rate, and unemployment as significant drivers of real-estate returns. Despite macroeconomic variables playing a substantial role in understanding the growth and performance of real estate, modelling this relationship still poses a considerable challenge.

Clear identification of leading economic indicators and modelling of turning points should provide insight into the changes and direction in the commercial real-estate markets. It thus seeks to investigate how much forecasting accuracy can be achieved by modelling the relationships between listed real estate and macroeconomic time series. Tsolacos *et al*. (2014) observed that the choice of modelling tools was particularly crucial in achieving accuracy, and thus suggested the use of a probit model and a Markov switching model. Therefore, in addition to the comparative analysis of the commercial real-estate macroeconomic indicators that this study undertook between the two leading economies in Africa, the logit techniques employed add to its uniqueness from a pan-African perspective.

3. METHODOLOGY

In identifying reliable indicators for modelling the probability of turning points, this study employed a quantitative content analysis and the use of inferential statistics, as noted in Frankel and Saravelos (2012). Through content analysis, macroeconomic indicators and commercial real-estate market information were identified and then tested. The study investigated the relationship between the identified macroeconomic (independent) variables and the listed real-estate (dependent) variable, using the correlation and logistic regression statistical measures. Similar studies that informed the use of these methodologies included Krystalogianni *et al.* (2004), Tsolacos (2012), Tsolacos and Brooks (2010); Buehler and Almeida (2016), and Moolman and Jordaan (2005).

3.1 Data collection

The indicators and sources identified in the literature review were examined for preliminary selection of the independent variables. The dependent variable was extracted from the listed real-estate indices found in this investigation. The major sources of relevant data in South Africa and

Nigeria included the South African Reserve Bank; Statistics South Africa; IRESS Expert, and the Central Bank of Nigeria (CBN) statistic database.

Other data sources such as the Amalgamated Bank of South Africa (ABSA) real-estate data, the data from the JSE website and others were inaccessible or insufficient, sometimes only providing 1 to 5 years of time-series data. FTSE/JSE SA Listed Property (J253) quarterly price data were, however, extracted from the Iress Expert database. The Nigerian REIT time-series data used were sourced from the Union Homes, Skye Shelter, and UACN Properties. The historical data available covered ten years as compared to fifteen years' data that were collected for South Africa. With respect to the Nigerian data, the analysis examines the Nigerian Stock Exchange (NSE) instruments for the availability of a commercial real-estate data series. The NSE listed RE index developed is a proxy for the listed real-estate indicator that was not provided in the NSE index database.

There was a limitation on the selection of time series for dependent and independent variables, in that the longest series available for some South African macroeconomic indicators was from Quarter 1 of 2003 to Quarter 4 of 2018. Jadevicius, Sloan and Brown's (2013) study suggests that the FTSE/JSE SA Listed Property (J253) is the only available real-estate data that spans to the required 15 years. The availability of data spanning the required period served as a basis for selecting the real-estate time series adopted as the dependent variable. The FTSE/JSE Property Loan Stock (J256) and FTSE/JSE Real Estate Investment Trusts (J867) were thus excluded from the analysis. This implied that other series not meeting this range were invalid for consideration. Missing data for quarters not exceeding 1-5 quarters were replaced with the closest available data. Olanrele, Adegunle, Fateye and Ajayi (2019) noted the limitation of using other Nigerian REIT (N-REIT) data such as Smart Products Nigeria Plc (SMURFIT) and UPDC REIT because of their recent establishment. Thus, the weighted average of Sky Shelter REIT (SKY REIT) and the UACN property development company data served as a proxy for the listed real-estate sector. Accordingly, the available data for the Nigerian listed real-estate market were collected for the period 2008: Q1 to 2018: Q4.

3.2 Data analysis and interpretation of data

Descriptive statistic measures employed included the Minimum, Maximum, Median and Standard Deviation. All monthly data were converted into quarterly data before analyses to ensure uniformity with the exogenous data. These indicators were set as the variables tested in the two models (South Africa and Nigeria). In this study, several statistical tests and indicators were used to analyse and evaluate the accuracy, applicability, and statistical significance of the logistics model(s).

3.2.1 The chi-square and significance level

The model's *chi*-square statistic and its significance level present the first test of model performance. A significant p-value is compared to a critical value, perhaps .05 or .01, to determine whether the overall model is statistically significant. The value given in the Sig. column is the probability of obtaining the *chi*-square statistic, given that the null hypothesis is true (NCSS, 2020). This test was used to indicate whether there is a significant association between the dependent listed real-estate variable and the other independent variables.

3.2.2 The omnibus test of model significance

This is a test for the performance of the independent variables over the null model with only the intercept. This test evaluates how much of the variance in the dependent variable is explained by changes in the independent variables (NCSS, 2020). This test was used to evaluate how much of the change that occurs in the dependent listed real-estate variable is accounted for by the independent variables in the model.

3.2.3 Cox & Snell R-square and Nagelkerke R-square

These are pseudo R-squares. These R-squared values test the model's goodness of fit. The Cox & Snell R 2 can be interpreted like the R-squared in a multiple regression, but cannot reach a maximum value of 1. The Nagelkerke R-squared can reach a maximum of 1 (NCSS, 2020). This test measured how well the model derived fits the data and classifies the outcomes of the predictive model.

3.2.4 Hosmer-Lemeshow test

A second test for the model's goodness of fit is the Hosmer-Lemeshow test. This tests the null hypothesis that predictions made by the model will fit perfectly with observed group memberships. The higher the value of this test, the better the goodness of fit (NCSS, 2020). The test helps identify the relative performance of the models in predicting the future direction (rise or fall) of the listed real-estate market.

3.3 Model description

3.3.1 Dependent variable used in the model(s)

The Nigerian REIT and JSE time-series data are used to create dummy binary outcomes for the purpose of logistic regression. The time-series data difference of Yt-Yt-1 was classified based on a rise or fall. A growth in the time series represented a 0., while a fall represented a 1. This provided the data for the binary variable in both data sets. The South African dummy variable is denoted as South Africa Listed Real Estate (SALRE), while the Nigerian dummy variable is denoted as Nigeria Listed Real Estate (NLRE). The Iress Expert Database provided the three top real-estate instruments, including FTSE/JSE Property Loan Stock (J256), FTSE/JSE Real Estate Investment Trusts (J867), and FTSE/JSE SA Listed Property (J253). The FTSE/JSE SA Listed Property (J253) proved to be the only real-estate variable spanning to the required 15 years, as suggested in Jadevicius *et al.* (2013).

3.3.2 Independent variables used in the model(s)

The South African macroeconomic variables that were evaluated, included the GDP at market prices (R million), Percentage CPI Consumer prices: CPI, excluding food and non-alcoholic beverages and fuel (all urban areas), manufacturing (2015=100), leading indicator (2015=100), coincident indicator (2015=100), lagging indicator (2015=100), M0, M1A, M1, M2, total monetary (M3) deposits, exchange, interest rates, and the gold price.

The leading indicator (2015=100), coincident indicator (2015=100), and lagging indicator (2015=100) are further explained in Van Der Walt and Pretorius (2004: 29-35) as follows:

3.3.2.i The leading indicator series

This is composed of: Opinion survey of volume of orders in manufacturing; opinion survey of stocks in relation to demand (manufacturing and trade); opinion survey of business confidence (manufacturing, construction, and trade composite); leading business cycle indicator of major trading-partner countries (percentage change over twelve months); commodity prices in US Dollars for a basket of South Africa's export commodities (six-month smoothed growth rate); real M1 money supply (deflated with the CPI): six-month smoothed growth rate; prices of all classes of shares (six-month smoothed growth rate); number of residential building plans passed for flats, townhouses, and houses larger than $80m^2$; interest rate spread (10-year bonds less 91-day treasury bills); gross operating surplus as a percentage of gross domestic product; labour productivity in manufacturing: (six-month smoothed growth rate); job advertisements in the *Sunday Times* newspaper (six-month smoothed growth rate), and opinion survey of the average hours worked per factory worker in the manufacturing sector

3.3.2.ii The coincident indicator series

This is composed of: Gross value added at constant prices, excluding agriculture, forestry and fishing; value of wholesale, retail and new vehicle sales at constant prices; utilisation of production capacity in manufacturing; total formal non-agricultural employment, and industrial production index.

3.3.2. iii The lagging indicator series

This is composed of: Employment in non-agriculture sector; total number of hours worked by production workers in the construction sector; physical volume of mining production of building materials; value of unfilled orders as percentage of sales in manufacturing; value of fixed investment in machinery and equipment; value of non-residential buildings completed; value of commercial and industrial inventories at constant prices, and labour cost per unit of the physical volume of manufacturing production.

Nigerian macroeconomic variables included the total GDP, prime lending/ interest rate (%), the Treasury bill rate (%), the total money asset, money supply (M1), currency in circulation, and money supply (M2).

3.4 Logit modelling

The logit model provides the best fitted combination of macroeconomic variables that improves on the null/naïve model. The probabilities are summed up or down between 0 and 1 to provide the forecast based on thresholds such as 0.5, 0.7, 0.9.

T; being the state of the independent variable is estimated to be 1 or 0, based on the logit regression rule:

T = 1 for the period that capital values decline
T = 0 otherwise

Therefore, the objective of using a logit approach is to estimate a response probability:

$$Pr\ (T = 1|x) = Pr\ (T = 1|\ x1, x2, ..., xk)$$
$$Pr\ (T = 1|x) = \log(p/1-p) = \beta 0 + \beta 1x1 + \ldots + \beta kxk$$

In Equation 1, the coincident indicator β = 0.479, while the exchange rate was β = 0.083. The constant or intercept value was -74.738.

The South African logit model is expressed as:

$$Y = Pr\ (T = 1|x) = \log(p/1-p) = -74.738. + 0.479CI + 0.083ER \qquad \text{Equation 1}$$

Where:

Y = Binary variable outcome
Pr = Probability
β0 = Model intercept
βx= Regression coefficient
CI = Coincident indicator
ER = Exchange rate

For Nigeria, the coefficient for variables in the equation is summarised in the logit regression equation as:

Y = Pr (T = 1|x) = log(p/1-p) or *ln* (ODDS)
log(p/1-p) or *ln* (ODDS) = -21.938 + 0.143(IR) - 0.037 (TBR) - 0.034 (CPI
Equation 2

Where:

Y = Binary variable outcome
Pr = Probability
IR = Lending/interest rate
TBR = Treasury bill rate
CPI = Consumer price index

4. RESULTS AND DISCUSSION

4.1 South African model

Dependent variable: South Africa Listed Real Estate (SALRE)

Independent variables: GDP at market prices (R million), Percentage CPI Consumer prices: CPI, excluding food and non-alcoholic beverages and fuel (all urban areas), manufacturing (2015=100), leading indicator (2015=100), coincident indicator (2015=100), lagging indicator (2015=100), M0, M1A, M1, M2, total monetary (M3) deposits, exchange, interest rates, and the gold price.

Descriptive statistics for the South African regression model are presented in Table 1. The prime lending rate and Treasury bill data are presented as percentages, while other indicators present as actual figures. Table 1 provides information about the nature of the data used for the logistic regression.

The South African FTSE/JSE SA Listed Property (J253) is the annual capitalization of listed real estate on the JSE. The indicator shows a minimum and maximum value of R24,905,288,373 (USD1,451,472,927.71) and R585,250,954,031 (USD34,108,254,558.04, respectively with a mean of R196,738,877,374 (USD11,450,422,969.30). Its standard deviation of R161,566,289,587 (USD9,416,036,138.72) represents a large dispersion of the values from the mean.

The percentage CPI consumer prices has a standard deviation of 3.09, a mean of 4.33, and a range of -11.20 and 9.20. These values represent the possibilities for the investment to generate higher real-estate returns.

The mean of the SALRE at 0.70 and a 0.460 standard deviation suggests that a growth is more frequently recorded in the time series with the maximum (1) than the fall as recorded by the minimum (0). Interest rates show a standard deviation from the mean of 6.31% with a maximum of 51% and a 25.5% minimum and a 32.56% mean value. Meanwhile, the GDP maximum stands at 1,236,403 (R millions). GDP also has a minimum

Table 1: Descriptive statistics of South African data employed in logit analysis

	Minimum	*Maximum*	*Mean*	*Std. deviation*
FTSE/JSE SA Listed Property (J253)	24905288373	585250954031	196738877374	161566289587
Binary variable (SALRE)	0	1	.70	.460
GDP @ market prices (R million)	317548.00	1236403.00	743515.90	283143.52
Percentage CPI consumer prices	-11.20[1]	9.20	4.33	3.09
Manufacturing (2015=100)	87.77	108.40	98.22	4.32
Leading indicator (2015=100)	86.87	108.40	102.10	4.49
Coincident indicator (2015=100)	69.43	103.67	90.68	10.28
Lagging indicator (2015=100)	94.53	124.37	101.37	6.46
M0	59579.67	250307.67	144681.46	60638.57
M1A	220759.67	848555.67	501334.74	202849.47
M1	395897.00	1726139.67	947969.44	413235.46
M2	746724.33	2830701.67	1704159.54	640799.34
Total monetary (M3) deposits	833366.00	3508983.00	2090677.05	818284.46
Interest rates	25.50	51.00	32.56	6.31
Price of gold per ounce (Rand)	7664.75	56662.66	30071.49	16290.20
Exchange rates	212.05	312.30	267.04	24.21

1 Negative inflation/deflation is not uncommon situation and has been reported in the South African economy in time past. However, this study reports year on year CPI Consumer prices/inflation which could be a growth or a fall. A negative annual CPI (year on year) implies that the government's effort to control inflation led to a major fall in money supply and a deflationary trend. According to the Research Department and Information Division (2007), when setting monetary policy, the Bank decides on the level of short-term interest rates necessary to meet the inflation target. This can be increased and decreased to respond to the inflation levels at a certain time. Inflation in 1995, as reported by Department of Finance, Republic of South Africa (RSA) (n.d.), declined to levels last seen in the early 1970s. The annual rate of increase in consumer prices has been below 10 percent for three years prior to it.

of 317,548 (R millions), a mean and standard deviation of 743,515.90 (R millions), 283,143.52 (R millions), respectively. The high standard deviations indicate the growth or change over the time period include values that are significantly dispersed from the mean values. These values capture peaks and troughs in the time series and should as such demonstrate significant deviations from a mean value.

A logistic regression model with all 14 selected South African leading indicators was compared to the effect of selectivity, excluding variables with insignificant p-values from the model (Tables 2 and 3). Multivariate logit regression is performed to evaluate the perfect combination of independent variables for predicting the probability of a decline or rise (Table 4).

Table 2: Spearman correlation of South African economic (money supply) indicators with the dependent listed real-estate variable

			M0	*M1A*	*M1*	*M2*	*Total monetary (M3) deposits*	*Interest rates*	*Price of gold per ounce (Rand)*	*Exchange rates*
Spearman's rho	FTSE/JSE SA listed property (J253)	Correlation coefficient	.986**	.986**	.987**	.984**	.985**	.591**	-.974**	.580**
		Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000
		N	64	64	64	64	64	64	64	64

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

A Spearman's correlation was run to assess the relationship between South African economic (money supply) indicators and FTSE/JSE SA Listed Property (J253), using a sample of 64 indicators. In Table 2, from the South African data analysed, all money supply variables show a strong positive correlation with the listed real estate indicator, where M0 [rs=.986, p<.001], M1A [rs=.986, p<.001], M1 [rs=.987, p<.001], M2 [rs=.984, p<.001] M3 [rs=.985, p=.000] was statistically significant. There was a moderate correlation between interest [rs=.591, p<.001] and exchange [rs=.580, p=.000] rates and FTSE/JSE SA Listed Property (J253). Although the price of gold per ounce showed significant value as an indicator [rs=-.974, p=.000], there is a strong negative correlation with FTSE/JSE SA Listed Property (J253).

Table 3: Spearman correlation of South African economic indicators with the dependent listed real-estate variable

			FTSE/JSE SA listed property (J253)	*GDP at market prices (R million)*	*% CPI*	*Manufacturing (2015=100)*	*Leading indicator (2015 = 100)*	*Coincident indicator (2015=100)*	*Lagging indicator (2015=100)*
Spearman's rho	FTSE/JSE SA listed property (J253)	Correlation coefficient	1.000	.984**	.342**	.450**	.230	.948**	-.471**
		Sig. (2-tailed)	.	.000	.006	.000	.067	.000	.000
		N	64	64	64	64	64	64	64

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

In Table 3, GDP at the market price indicated a strong correlation with the dependent FTSE/JSE SA Listed Property (J253) indicator, which was statistically significant, rs=984, p=000. The CPI indicator was not significant and showed a relatively low correlation [rs=.342, p=.006] with FTSE/JSE SA Listed Property (J253), indicating almost no relationship between product prices or inflation and the listed real-estate market. Although manufacturing showed significant value as an indicator [rs=.450, p<.001], there is a weak correlation with FTSE/JSE SA Listed property (J253).

With rs=.230, p=.067, the leading indicator failed to show any level of significance and no existence of any linear relationship with the listed property data. There was a strong positive correlation between the coincident indicator and FTSE/JSE SA Listed Property (J253), which was statistically significant, rs=.948, p<.001. Although the lagging indicator was a significant indicator, [rs=-.471, p<.001], it shows a weak negative correlation with the listed property data.

There was some degree of collinearity between the money supply variables M0, M1, M1A, M2, M3, the coincident indicator, and GDP. However, they all indicate a level of significance p<0.05, except for the leading indicator which had no significant relationship with most of the other independent variables. Most of the variables with collinearity have a significant impact on the output J253 listed real-estate pricing variable, hence they could not be excluded randomly. The binary logistic modelling process solves the problems of collinearity, by excluding variables that do not contribute significantly to the model derived. In Table 4, the logit model provides the best fitted combination of macroeconomic variables that improves on the null/naïve model. The probabilities are summed up or down between 0 and 1 to provide the forecast based on thresholds such as 0.5, 0.7, 0.9. These thresholds are arbitrary and thus require the analyst understanding of the market's sensitivity to changes in these economic variables.

Table 4: Significant indicators accepted in the South African logistic regression

Indicator	*B (beta)*	*S.E. (standard error)*	*Wald*	*Df*	*Sig.*
GDP at market prices (R million)	.000	.000	.215	1	.643
Coincident indicator (2015=100)	.479	.156	9.467	1	*.002
M0	.000	.000	1.509	1	.219
M1A	.000	.000	.403	1	.526
M1	.000	.000	1.135	1	.287
M2	.000	.000	.523	1	.469
Total monetary (M3) deposits	.000	.000	.169	1	.681
Price of gold per ounce (Rand)	.000	.000	3.409	1	.065
Exchange rates	.083	.032	6.598	1	*.010
Constant	-74.738	28.311	6.969	1	.008

* significant at the 0.05 level

In Table 4, the Wald Z-test shows the values are not zero, which confirms that the selected indicators are significant and should be included in the model. The β (beta coefficient) allows comparison of **the relative importance** of indicators in a regression model. GDP (β=0.000, p=.643), M0 (β=0.000, p=.219), M1A (β=0.000, p=.526), M1 (β=0.000, p=.287), M2 (β=0.000, p=.469), M3 (β=0.000, p=.681), and price of gold (β=0.000, p=.065) have zero influence on, and do not predict the listed real-estate market. The β values for South African data sets show that coincident indicators (β = 0.479, p=.002) and exchange rates (β=0.083, p=.010) are significant indicators and predict the listed real-estate market trends in South Africa. This signifies that an increase in these two economic indicators will impact positively towards growth in the listed real-estate market.

The tests for significance of the South African model are shown in Tables 5 to 8.

Table 5: Omnibus test of Logit Regression Model for indicators with a strong negative or positive correlation with the FTSE/JSE J253 indicator (r≤0.05)

	Chi-square	*df*	*Sig.*
Step	18.928	9	.026
Block	18.928	9	.026
Model	18.928	9	.026

Table 6: Pseudo-R values of Logit Regression Model for indicators with a strong negative or positive correlation with the FTSE/JSE J253 indicator (r≤0.05)

-2 Log likelihood	*Cox & Snell R Square*	*Nagelkerke R Square*
58.920a	.256	.364

Table 7: Hosmer and Lemeshow goodness of fit test of Logit Regression Model for indicators with a strong negative or positive correlation with the FTSE/JSE J253 indicator (r≤0.05)

Chi-square	*Df*	*Sig.*
5.010	8	.757

Table 8: Classification table of Logit Regression Model for indicators with a strong negative or positive correlation with the FTSE/JSE J253 indicator (r≤0.05)

Observed		*Predicted null model*			*Predicted new model*		
		SALRE		*Percentage correct*	SALRE		Percentage correct
		0	1		0	1	
SALRE	0	0	19	0	9	10	47.4
	1	0	45	100	3	42	93.3
Overall percentage				70.3			79.7

The South African model in Tables 4 to 8 is significantly a better (p<.05) fit than the null model (does not include explanatory indicators), as the omnibus test shows (chi-square=18.928*,* df=9, p=026). The Cox and Snell and Nagelkerke R-squared were 0.256 and 0.364, respectively, which implies that the model explains approximately 25.6% or 36.4% of the variation (changes) in the listed real-estate market. The Hosmer and Lemeshow test of the goodness of fit show that the model is a good fit to the data with p=0.757 (>.05) *(*p-values close to 1 indicate a good logistic regression model fit). The model has a 93.3% accuracy in predicting growth (Y=1), while it has a 47.4% accuracy in predicting a decline (Y=0). This model correctly predicts, with a 79.7% accuracy, changes in the listed real-estate market, compared to 70.3% on the null model, thus 9.4% improvement.

4.2 Nigerian model

Dependent variable: Nigeria Listed Real Estate (NLRE)

Independent variables: total GDP, prime lending/interest rate (%), the Treasury bill rate (%), the total money asset, money supply (M1), currency in circulation, and money supply (M2).

Descriptive statistics for the Nigerian logistic regression model variables are presented in Table 9.

Table 9: Descriptive statistics of Nigerian data employed in logit analysis

	Minimum	*Maximum*	*Mean*	*Std. deviation*
NSE listed property index	4145.10	4921.11	4548.48	227.73
Binary variable (NLRE)	0	1	.50	.506
Total GDP (N millions)	12583478.33	35230607.63	22098650.22	5959960.915
Prime lending/interest rate (%)	44.65	58.27	50.72	3.11
T-bill %	5.12	44.10	27.94	10.65
Total money asset	21542374.30	97307716.20	54437047.19	22378043.23
Money supply (M1)	11801598.20	33680739.24	21257092.87	6650841.91
Currency in circulation	2624429.50	6385845.91	4455189.75	1015721.20
Money supply (M2)	21542374.30	78588158.53	47817724.05	16402868.45

In Table 9, the NSE listed property indicator shows a minimum and maximum value of ₦ 4145.10 and ₦ 4921.11, respectively, with a mean of ₦ 4548.48. Its standard deviation of ₦ 227.73 represents a significantly high variation of the values from the mean. The mean of the NLRE at 0.50 and a 0.506 standard deviation show that there are almost equal number of values closer to the maximum (1) as those close to the minimum (0). Interest rates show a standard deviation from the mean of 3.11% with a maximum of 58.27% and a 44.65% minimum and a 50.72% mean value. The interest rate maintained a more stable high value compared to the South African interest rate data, which can be explained by the riskier investment market requiring higher interest rates. Meanwhile, the GDP maximum stands at 35,230,607.63 (₦ millions). GDP also has a minimum of 12,583,478.33 (₦ millions), a mean and standard deviation of 22,098,650.22 (₦ millions), and 5,959,960.91 (₦ millions), respectively. The high standard deviations indicate that the growth or change over the time period includes values that are significantly dispersed from the mean values. These values capture peaks and troughs in the time-series data and should as such demonstrate significant variations from a mean value.

Table 10: Correlation coefficient of Nigerian variables relative to NSE-listed RE Index

		NSE Listed RE Index	*Total GDP*	*Prime lending /Interest rate (%)*	*T-bill %*	*Total money asset*	*Money supply (M1)*	*Currency in circulation*	*Money supply (M2)*
NSE Listed RE Index	Pearson correlation	1	.372*	-.281	.429**	.385**	.385**	.356*	.375*
	Sig. (2-tailed)		.025	.064	.004	.010	.010	.018	.012

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

A Pearson correlation was run to assess the relationship between Nigerian economic indicators and N-REIT. In Table 10, all selected money supply variables were significant, but show low positive correlation with the listed real-estate market, total money asset [r=.385, p<.010], M1 [r=.385, p<.010], and currency in circulation [r=.356, p<.018], M2 [r=.375, p<.012]. Although the total GDP is a significant indicator [r=0.025, p=.025], it shows a very low positive correlation with the listed N-REIT index. Unlike in South Africa, the prime lending/interest rate is not a significant indicator [r=-.281, p<.064] and shows a low negative correlation with the listed real-estate market in Nigeria. Although the Treasury bill (T-bill) rate is significant, it shows a moderate correlation [r=.429, p<.004] with the listed real-estate sector.

The high multicollinearity noticed between the GDP and money supply (MI), currency in circulation, total money asset, and money supply (M2), confirms the observation that South Africa's selected economic variables also applies to Nigeria. This collinearity implies that not all economic variables contribute significantly to modelling the listed real-estate market. The logit regression model resolves the multicollinearity, by eliminating economic variables that do not explain much of the variation in the listed real estate data series.

For the Nigerian data sets, in Table 4, the Wald Z-test shows the values are not zero, which confirms that the selected indicators are significant and should be included in the model. The β (beta coefficient) allows comparison of **the relative importance** of indicators in a regression model. GDP (β=0.000, p=.036), total money asset (β=0.000, p=.043), M1 (β=0.000, p=.656), M1 (β=0.000, p=.287), currency in circulation (β=0.000, p=.129), and M2 (β=0.000, p=.012) have zero influence on, and do not predict the listed real-estate market in Nigeria. Although not significant (β=0.143, p=.666), the β value shows that the lending/interest rate predicts the listed real-estate market in Nigeria. CPI (β=-0.034, p=.695), and T-bill % (β=-0.037, p=.560), have a negative influence on, and do not predict the listed real-estate market trends in Nigeria. This signifies that a decrease in these two economic indicators will impact negatively towards growth in the listed real-estate market.

Table 11: Significant indicators accepted in the Nigeria Logistic regression

Indicator	*B (beta)*	*S.E. (standard error)*	*Wald*	*Df*	*Sig.*
Total GDP	.000	.000	4.419	1	.036
Composite Consumer Price Index (%)	-.034	.086	.153	1	.695
Prime lending/interest rate (%)	.143	.331	.187	1	.666
T-bill %	-.037	.064	.339	1	.560
Total money asset	.000	.000	4.087	1	.043
Money supply (M1)	.000	.000	.198	1	.656
Currency in circulation	.000	.000	2.307	1	.129
Money supply (M2)	.000	.000	6.249	1	.012
Constant	-21.938	21.429	1.048	1	.306

* significant at the 0.05 level

The tests for significance of the Nigerian model are shown in Tables 12 to 15.

Table 12: Omnibus test of Logit Regression Model for Nigerian indicators ($r \leq 0.05$)

	Chi-square	*Df*	*Sig.*
Step	20.875	8	.007
Block	20.875	8	.007
Model	20.875	8	.007

Table 13: Pseudo-R values for the full model including all Nigerian indicators ($r \leq 0.05$)

-2 Log likelihood	*Cox & Snell R-square*	*NagelkerkeR-square*
28.920	.440	.587

Table 14: Hosmer and Lemeshow's goodness of fit test for the full model, including all Nigerian indicators

Chi-square	*Df*	*Sig.*
3.599	7	.825

Table 15: Classification table for the null and full model including all Nigerian indicators

Observed		*Predicted null model*			*Predicted new model*		
		SALRE		*Percentage correct*	*SALRE*		*Percentage correct*
		0	*1*		0	*1*	
NLRE	0	0	17	0	12	5	70.6
	1	0	19	100	4	15	78.9
Overall percentage				52.8			75.0

The Nigerian model in Tables 12 to 15 is significantly a better (p<.05) fit than the null model (does not include explanatory indicators), as the omnibus test shows (chi-square=20.875, df=8, p=007). The Cox and Snell and Nagelkerke R-squared were 0.440 and 0.587, respectively, which implies that the model explains approximately 44.0% or 58.7% of the variation (changes) in the listed real-estate market. The Hosmer and Lemeshow test of goodness of fit shows that the model is a good fit to the data with p=0.825 (>.05) (p-values close to 1 indicate a good logistic regression model fit). The model has a 78.9% accuracy in predicting growth (Y=1), while it has a 70.6% accuracy in predicting a decline (Y=0). This model correctly predicts the outcome for 75% of the changes in the market, which is a 22.2% increase from 52.8% recorded in the null model.

5. DISCUSSION

5.1 South African model

The supply of money and cash in circulation, as well as increasing money deposits indicate the availability of liquidity within the South African economy for long-term investments in commercial real estate and similar alternatives. The data shows that monetary supply variables are significant contributors to commercial real-estate pricing models. Money supply variables were found to be significant predictors of the South African listed real-estate market. This was to be expected, given that real estate is a capital-intensive venture. The listed real-estate instruments, being a significant source of financing for actual real-estate supply, are affected significantly by the money supply. Simo-Kengne, Balcilar, Gupta, Reid & Aye (2012) also agreed that monetary policy is not neutral, as house prices decrease substantially as a result of a contractionary monetary policy.

Business indicators: leading, lagging and coincident, within the South African context are relied on for confirming the direction of the overall economy. However, the business leading indicators have been criticised regarding their accuracy and reliability, as noted in Boshoff and Binge (2019). The study found only the coincident indicator (gross value added at constant prices – see 3.3.2.ii) contributed significantly to explaining variations in the South African listed real-estate market. The leading indicator series also indicates relatively high collinearity with other independent variables, which implies that the variance it adds to the dependent variable (SALRE) is not significant.

The GDP has a strong correlation coefficient, which presents it as a strong economic indicator for price discovery and forecasting the South African listed real-estate market. As production increases, economies tend to experience growth in employment and subsequent demand for commercial office space. The GDP, as a major economic indicator, is bound to affect the spending capacity and general sentiments regarding long-term investment in commercial real estate. A growing GDP would signify growing interests in commercial properties, offices, warehouses, shopping centres, and serviced apartments. A strong positive correlation with the exchange rate indicates that strong growth in FDI and demand for local currency or other expansionary foreign policies would stimulate growth in the South African listed real-estate market.

The cost of capital has a moderately strong positive relationship with the listed real-estate market in South Africa. The higher cost of capital implies an increased risk for direct real-estate investment, which makes indirect real estate an attractive alternative. Indirect or listed real-estate instruments would appreciate, as the increasing costs of capital implies that developers would require other sources of capital than bank loans.

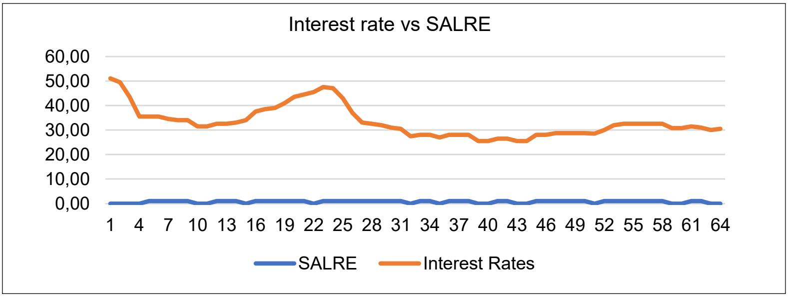

Figure 1: Time series of the South African interest rate compared to the South African Listed Real Estate Index

Figure 1 shows that the South African bank lending rate also indicates similar growth and fall patterns with the corresponding SALRE index from 1 January 2003 to 31 December 2018. This does not suggest causality, but is still a good indicator for investment.

5.2 Nigerian model

The test for correlation was also conducted on Nigerian data. All the independent variables proved statistically significant at the 0.05 level, except the lending or interest rate, which had a P-value of .064. The interest rate also had a low negative correlation of p=-.281 with the dependent variable. This implies that the regime of the lending rate over the years had a negative correlation and an insignificant impact on the listed real-estate market. This result aligns with the findings of Olanrele, Said, Daud and Ab (2015) that REITs are sensitive to interest rates, but with insignificant effect.

The prime lending rate or interest rate has a low negative correlation of p=-0.281, but, unlike the case in South Africa, it proves insignificant to the dependent variable.

As in South Africa, money supply variables including total money asset, money supply (M1), currency in circulation, and money supply (M2) all have a positive significant correlation with the listed real-estate market.

GDP shows a low positive correlation with the listed N-REIT index, which indicates that a large increase in GDP would lead to growth in the listed real-estate pricing. The Treasury bill rates would cause increases in listed real-estate or N-REIT share prices. This indicates that an increasing Treasury bill rate would have growth value for the real estate market in Nigeria.

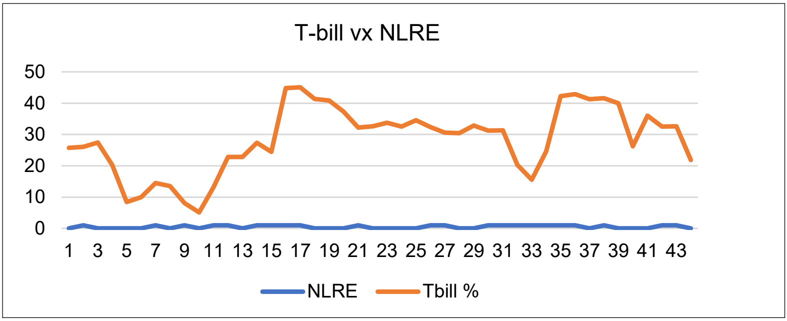

Figure 2: Time series of the Nigerian T-bill rate compared to the NSE Listed Property Index.

The Nigerian T-bill rate indicates the government's monetary policies. In Figure 2, the growth and fall pattern of the two series (for the period 1 January 2008 to 31 December 2018, except for 2013 and 2015) align to indicate similar patterns. Nigeria's listed real and the T-bill rate share a common historical growth pattern. This similarity implies that general inferences can be made about the growth of the NLRE based on the policy decisions on the T-bill rate.

The study concluded that not all economic indicators lead to changes in price movements in the listed real-estate market in South Africa and Nigeria. However, a combination of some of these significant variables help explain variations in the listed real-estate indicator. The best-fitted models in South Africa and Nigeria also perform well in classifying the in-sample data. Therefore, in relation to real-estate investment within the two leading economies, the market indicators do not altogether reveal negativity. Hence, local and international real-estate investors can still undertake investments in the two countries, but careful feasibility and viability analyses must precede the decision.

6. CONCLUSION

This study used the logit regression modelling framework to identify the leading economic variables for predicting changes in the rental values of commercial real estate in Nigeria and South Africa. The goal was to use these macroeconomic indicators to understand the real-estate market behaviour of these two economies, so that real-estate investors could from their performance plan possible investments. Thus, related and contrasting variables that are common to these markets were used to explain future trajectory and early warning signals.

After a careful assessment of these macroeconomic market indicators, their performance reveals a positive outlook for the Nigerian and South African real-estate market, although at a varying level of acceptability, despite the recent negative image of the two markets. This potentially reduces the risk and uncertainty associated with participation in the real-estate markets of emerging African economies such as Nigeria and South Africa.

Further study could be done towards understanding predictive probabilistic models, as there is a need to evaluate the accuracy they add to real-estate market analysis and reporting. Further research could also be conducted on how econometric models should fit into business reporting for residential and commercial real-estate companies. This would make it possible to evaluate data on real-estate performance, based on consistent data sources such as listed real-estate data.

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IDENTIFYING FACTORS OF COLLABORATION CRITICAL FOR IMPROVING HEALTH AND SAFETY PERFORMANCE IN CONSTRUCTION PROJECTS: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Collaboration is key to the success of construction project delivery. Several researchers have realised the importance of collaboration for health and safety (H&S) performance. The construction industry (CI) is affected by poor H&S performance exacerbated by lack of collaboration. The purpose of the article is to conduct a systematic literature review to identify factors of collaboration that will improve H&S performance in CI. A literature review method was adopted; identification test method was used to identify collaboration factors. Using Scopus and Google Scholar, a total of 758 papers were identified. 57 papers were found to be relevant for review through content analysis and were analysed in terms of source and year of publication, research method, country of origin, and research focus. The review identified 11 critical success factors of collaboration: trust, culture, commitment, communication, clear roles and responsibilities, resource/information sharing, mutual goals, conflict resolution, early involvement of key participants, competence, and continual improvement. These factors can influence H&S performance in construction projects. Focusing on these factors can facilitate collaboration, thus improving H&S performance. The limitation of this article is that the literature review covered a period between 2010 to 2019. Searches in other search engines might have provided additional information on collaboration. The findings of this study make way for future research into the impact of collaboration on H&S performance and provide an understanding that H&S performance can be improved by adopting collaboration. The review concludes that CI should adopt collaboration to influence H&S performance.

Keywords: Construction industry, factors of collaboration, health and safety performance, literature review

ABSTRAK

Samewerking is die sleutel tot suksesvolle konstruksieprojekte. Verskeie navorsers besef die belangrikheid van samewerking vir gesondheids- en veiligheidsprestasies (G&V). Die konstruksiebedryf word geraak deur swak G&V-prestasies wat vererger word deur gebrek aan samewerking. Die doel van die artikel is om ’n sistematiese literatuuroorsig te doen om faktore van samewerking te identifiseer wat die prestasie van G&V in die konstruksiebedryf sal verbeter. ’n Literatuurbeoordelingsmetode is gebruik; die identifikasietoetsmetode is gebruik om samewerkingsfaktore te identifiseer. Met behulp van Scopus en Google Scholar is altesaam 758 artikels geïdentifiseer. Daar is bevind dat 57 artikels relevant is vir hersiening deur middel van inhoudsanalise en is geanaliseer in terme van bron en jaar van publikasie, navorsingsmetode, land van herkoms en navorsingsfokus. Die oorsig het 11 kritieke suksesfaktore van samewerking geïdentifiseer: vertroue, kultuur, toewyding, kommunikasie, duidelike rolle en verantwoordelikhede, die deel van hulpbronne/inligting, onderlinge doelwitte, konflikoplossing, vroeë betrokkenheid van sleuteldeelnemers, bekwaamheid en voortdurende verbetering. Hierdie faktore kan H&S-prestasie in bouprojekte beïnvloed. Deur op hierdie faktore te konsentreer, kan dit samewerking vergemaklik en sodoende die prestasie van G&V verbeter. Die beperking van hierdie artikel is dat die literatuuroorsig ’n tydperk tussen 2010 en 2019 beslaan. Soektogte in ander soekenjins kon moontlik aanvullende inligting oor samewerking verskaf. Die bevindinge van hierdie studie maak plek vir toekomstige navorsing oor die impak van samewerking op G&V-prestasies en bied ’n begrip dat G&V-prestasies verbeter kan word deur samewerking. Die oorsig kom tot die gevolgtrekking dat die konstruksiebedryf samewerking moet aanneem om G&V-prestasies te beïnvloed.

Sleutelwoorde: Konstruksiebedryf, faktore van samewerking, gesondheids- en veiligheidsprestasies, literatuuroorsig

1. INTRODUCTION

The construction industry (CI) is important for the development of any country (Idrus, Sodangi & Haq Husin, 2011: 1142; Ofor, 2012: 5; Umeokafor, 2018: 473;). The CI is significant for the development of infrastructure and physical structures (Ofori, 2012: 5; Kayumba, 2013: 34; Kumar & Bansal, 2013: 34) and is the driver for social and economic developments in a country (Idrus *et al*., 2011: 1142; Windapo & Cattell, 2013: 65; Kayumba, 2013: 510; Pillay & Haupt, 2016: 374). The CI is deemed critical for the economic advancements of South Africa through infrastructure delivery such as roads, buildings and stadiums and, hence, the creation of employment (Pillay & Haupt, 2016: 374; Windapo & Cattell, 2012: 65). Conversely, a poorly performing CI can affect other industries.

Internationally, the CI ranks high in terms of dangerous and risky workplaces (Atkinson & Westall, 2010: 1007; Pillay, 2014: 75; ILO, 2014: 8; Okorie, 2014: 2). Poor health and safety (H&S) performance is reported as a serious problem in the CI and results in loss of lives, skills, resources, time, and money (Mroszczyk, 2015: 67; Okorie, 2014: 12; Saifullah & Ismail, 2012: 604; Benjaoran & Bhokha, 2010: 395).

Poor collaboration between project participants has been identified as a serious impediment to achieving project objectives (Sebastian, 2011: 179; Akintan & Morledge, 2013: 2; Faris, Gaterell & Hutchinson, 2019: 2), including H&S objectives. Scholars have criticised the CI for, specifically, relationships between clients, designers and contractors, where poor collaboration is identified as one of the shortcomings (Sebastian, 2011: 179; Akintan & Morledge, 2013: 2; Faris *et al.*, 2019: 2). Professionals such as project managers, designers, engineers, construction managers, and H&S professionals contribute to H&S in construction projects. Despite, these contributions, the CI continues to experience accidents, injuries, and ill health at an unacceptable rate (Mroszczyk, 2015: 67; Okorie, 2014: 12). This poor H&S performance is exacerbated by lack of collaboration (Deacon, 2016: 154; Mroszcyk, 2015: 67; Olsen, 2012: 2625). The purpose of this article is to conduct a systematic literature review to identify factors of collaboration that will improve H&S performance in the CI.

2. LITERATURE REVIEW

2.1 Collaboration

There is no one universally accepted definition for collaboration. The vast majority of researchers agree that collaboration is about jointly working towards achieving common goals (Dietrich, Eskerod, Dalcher & Sandhawalia, 2010: 60; Patel, Pettitt & Wilson, 2012: 1; Ozturk, Arditi, Yitmen & Yalcinkaya, 2016: 798). In this article, collaboration refers to a process in which information, activities, responsibilities, and resources are shared to jointly plan, implement, and evaluate a programme of activities in order to achieve a common goal and a joint generation of value (Camarinha-Matos, Afsarmanesh, Galeano & Molina, 2009: 47-48). The concepts of collaboration in the CI are complex and are influenced by different factors during the execution of projects (Patel *et al.*, 2012: 21). Although there is evidence that collaboration as a management strategy (Bidabadi, Hosseinalipour, Hamidizadeh & Mohebifar, 2016: 1438) improves project performance, there is a paucity of empirical studies on the concept of collaboration in the CI (Skinnarland & Yndesdal, 2010: 356).

Dietrich *et al*. (2010: 60) and Faris *et al.* (2019: 1) stress the need for collaboration during construction projects worldwide, including South Africa, that face problems such as poor collaboration between participants, frequent disputes, high stress levels (Masemeni, Aigbavboa & Thwala, 2015: 8), poor quality workmanship, project delay, time and cost overrun (Greenwood & Wu, 2012: 299; Pal, Wang & Liang, 2017: 1226), and poor H&S performance (Saifullah & Ismail, 2012: 604; Mroszcyk, 2015: 67).

Mutual objectives, sharing of information, trust, commitment, culture, gain/pain sharing, as well as clear roles and responsibilities typify the collaboration process (Hughes, Williams & Ren, 2012: 365; Meng, 2013: 4260; Faris *et al*., 2019: 4).

The project-based nature of the CI justifies the need to focus on the collaboration process, in order to solve problems and exploit opportunities (Cao & Zhang, 2011: 174; Ozturk *et al*., 2016: 798). Through collaboration, simple construction processes are created; better quality service is provided (Emuze & Smallwood, 2014: 302); better relationships between main and subcontractors are created (Schottle, Haghsheno & Gehbauer, 2014: 1278); H&S performance is influenced (Deacon, 2016: 218; Tau & Seoke, 2013: 58), and performance in the construction supply chain improves (Bidabadi *et al*., 2016: 1437; Cao & Zhang, 2011: 174).

Factors critical for collaboration include top management support, selection of an appropriate partner, and commitment to a win-win attitude (Hasanzadeh, Hosseinalipourb & Hafezi, 2014: 816), no-blame culture, communication, fair distribution of responsibility, and proactive problem-solving (Msomba, Matiko & Mlinga, 2018: 152), mutual goals, gain-pain sharing, early involvement of key participants, and trust (Faris *et al*., 2019: 4). Other factors such as continuous improvement (Meng, 2012: 191), mutual goals (Hosseini, Wondimu, Bellini, Tune, Haugseth, Andersen & Laedre, 2016: 250; Meng, 2012: 190) and trust between actors (Dietrich *et al*., 2010: 70; Hosseini *et al*., (2016: 244), communication, conflict resolution, and understanding roles (Rahman, Induta, Faisol & Paydard, 2014a: 417; Dietrich *et al*., 2010: 70; Mensah, 2016: 16) have been mentioned as critical for collaboration. In South Africa, findings indicate that the CI does not have enough partners with appropriate collaborative skills (Emuze & Smallwood, 2014: 302).

2.2 Collaboration and health and safety management

H&S on construction projects is managed by project managers, designers, engineers, construction managers, and H&S professionals who have diverse work experiences, resources, and skill sets. These professionals contribute to H&S (Tymvios, Gambatese & Sillars, 2012: 342; Antonio, Isabel, Gabriel & Angel, 2013: 92). Dietrich *et al*. (2010: 70) argued that collaboration may lead to the creation of new or emergent knowledge or skills not possessed previously by every professional on the project. Collaboration between designers and construction professionals could be effective in reducing construction worker injuries and fatalities (Qi, 2011: 32). Based on this, Tymvios *et al*. (2012: 353) concluded that increased collaboration between professionals should be encouraged, in order to increase understanding of issues relating to H&S. Since each professional provides resources and a set of skills to the team, collaboration and communication become critical (Sebastian, 2011: 177), because collaboration is important for knowledge integration within projects (Dietrich *et al*., 2010: 68).

Although, the South African Construction Regulations 2014 and the United Kingdom (UK) Construction Design and Management (CDM) regulations 2015 (HSE, 2015: 17-18; Deacon, 2016: 83) require that all those involved in projects should collaborate and address H&S, the CI continues to experience accidents, injuries, and ill health, because of an apparent lack of collaboration among these professionals (Deacon, 2016: 223).

2.3 Benefits of collaboration

Benefits of collaboration may include improvement in construction quality, risk sharing, and innovation (Hasanzadeha *et al*., 2014: 816), creativity and working relationship (Smith & Thomasson, 2018 192), information sharing, and better communication (Rahman *et al*., 2014a: 419). It may also include project efficiency improvements and the development of shared vision or objective (Fulford & Standing, 2014: 324; Bidabadi *et al*., 2016: 1439), productive conflict-resolution strategy, mutual trust (Mensah, 2016: 44), and reduction of supply-chain costs (Bidadabi *et al*., 2015: 554). Collaboration facilitates a combination of resources and expertise to increase project performance (Faris *et al*., 2019: 2). Collaboration leads to high levels of productivity among project participants and reduced reworks (Torneman, 2015: 23). Past studies have provided several benefits of collaboration to H&S management. Collaboration between project stakeholders can lead to success in H&S management (Lingard, Blismas, Cooke & Cooper, 2009: 132). Examples of collaboration benefits to H&S performance include better buildability and integration of H&S in projects (Lingard, Pirzadeh, Blismas, Wakefield & Kleiner, 2014: 920). Collaboration can facilitate trust, improve communication and better working relationships (Jitwasinkul & Hadikusumo, 2011: 524; Deacon, 2016: 183), and can help share H&S information and resources (Vinodkumar & Bhasi, 2020: 2091).

2.4 Barriers to collaboration

Barriers to collaboration include lack of commitment, communication, and breach of trust (Deep, Gajendran & Jefferies, 2019: 1); lack of trust, unfair risk sharing (Faris *et al*., 2019: 1); ineffective communication (Nursin, Latief & Ibrahim, 2018: 1); consultant managerial incompetence (Akintan & Morledge, 2013: 7); conflicting personalities, bullying, and lack of understanding (Ey, Zuo & Han, 2014: 154), as well as lack of consistent production standards, and absence of formal training systems (Kalantari, Shepley, Rybkowski & Bryant, 2017: 569). It also includes lack of top management support and unrealistic deadlines (Masemeni *et al*., 2015: 8), as well as fear of micromanagement, lack of trust, and lack of common goals (Mensah, 2016: 40). Barriers such as lack of commitment, resources and expertise, trust and confidence undermine effective collaboration (Patel *et al*., 2012: 7; Umeokafor, 2017: 481). Barriers of collaboration on H&S performance are not limited to a lack of H&S legislation that specifies the H&S roles and responsibilities of all involved (Dewlaney & Hallowell, 2012: 169; Umeokafor, 2017: 481). Not being familiar with H&S principles, design and the construction process; lack of management commitment to H&S (Mwanaumo, 2013: 208), and a poor safety culture (Sunindijo, 2015: 111) are also barriers to collaboration in H&S.

3. RESEARCH METHODOLOGY

3.1 Search strategy

A systematic literature search was performed to identify critical success factors of collaboration. This search consisted of literature published between 1 January 2010 and 31 December 2019. First, the Identification Test from Wu, Greenwood & Steel (2008) and Faris *et al*. (2019), which reviewed 35 articles/papers on factors of collaboration for influencing project performance in the CI from 2000 to 2018, was used to identify related keywords based on their frequency rate (Wu *et al*., 2008: 5). The Identification Test resulted in 11 most prevalent factors of collaboration (Table 1).

Table 1: Critical success factors of collaboration and their frequency of occurrence

Rank	*Factors of collaboration*	*Frequency*
1	Trust	31
2	Communication	26
3	Conflict resolution	21
4	Mutual goals	20
5	Top management support	20
6	Commitment	19
7	Gain-pain sharing	18
8	Culture	16
9	Resource sharing	14
10	Early involvement of key participants	14
11	Clear roles	13

Source: Faris *et al*. (2019)

The search was performed between 1 August 2019 and 25 February 2020. Thereafter, a systematic search of the literature was performed on 1 April 2020 on Google Scholar and Scopus (Li, Burnham, Lemley & Britton, 2010: 205-206). Free search phrases with Boolean search operators (AND, OR, NOT), including titles, abstracts and keywords, were used. In the main database search (Scopus and Google Scholar), two sets of entry terms were applied (Figure 1). The first set of entry terms describes studies on collaboration that influence project performance in the CI. The second set of entry terms describes factors of collaboration in the CI to be considered for H&S performance.

3.2 Inclusion and exclusion criteria

Inclusion criteria:

- Papers published between 2010 to 2019.
- Papers with more than four factors of collaboration.
- Factors of collaboration in the CI, factors of collaboration between H&S professionals and project participants, factors of collaboration in the CI, impact of collaboration on project performance, success factors of collaboration, and impact of collaboration on H&S performance in the CI.

Exclusion criteria:

- Papers without the name of the author or the date of publication.
- Papers published prior to 2010 and post-2019.
- Papers investigating H&S performance mentioned nothing about factors of collaboration.

3.3 Identification of studies

The reference lists of the included literature were scanned, and relevant literature included. Only full text research papers on collaboration and the CI written in English were considered. Papers published in management science journals on the factors of collaboration were also considered, because some construction-related papers are published in management and social sciences journals. Papers that addressed collaboration, H&S performance and the CI, but did not include any factors of collaboration, were consequently removed. Another criterion was to target the majority of papers published by construction management journals such as *International Journal of Construction Management* (*IJCM*), *International Journal of Engineering and Management* (*IJEM*), *Journal of Construction Management and Economics* (*JCME*), *International Journal of Project Management* (*IJPM*), *Journal of Built Environment Project and Asset Management* (*JBEPAM*), *Journal of Construction Engineering* (*JCE*), and other peer-reviewed publications. Ibrahim and Belayutham (2019: 3), Oraee, Hosseini, Namini & Merschbrock (2017: 124) and Wu *et al*. (2008: 6) recommended some of these construction journals. Similarly, Bemelmans, Voordijk & Vos (2012: 344) as well as Ibrahim and Belayutham (2019: 3) supported the idea of using construction-related publications that publish peer-reviewed papers, as these journals also include reference to other publications such as conference papers, masters or doctoral dissertations.

3.4 Search findings

A total of 769 results from each individual database search (Google Scholar, 426 results, and Scopus, 343 results) were sent to Endnote X5 and Microsoft Excel and the papers' abstract and content were subsequently analysed (Rokni, Ahmad & Rokni, 2010: 230; Deep *et al*., 2019: 2; Jessica, 2011: 23-37). After removing duplicates, the number of results was 520. The second search returned 220 paper results (Figure 1). Papers screened based on titles and abstracts produced 68 construction management papers and the use of references of the identified articles produced 10 non-construction management papers, some of which included dissertations. Seventy-eight papers were subjected to content analysis, in order to identify critical success factors of collaboration. Some of these factors of collaboration that influence project performance can be considered for H&S performance, but some of these factors are not limited to communication, trust, commitment, clear roles and responsibilities, culture, continual improvement, competence, early involvement of key participants, and top management. Full text analysis resulted in 58 relevant papers, to be used in the final analysis (see Figure 1).

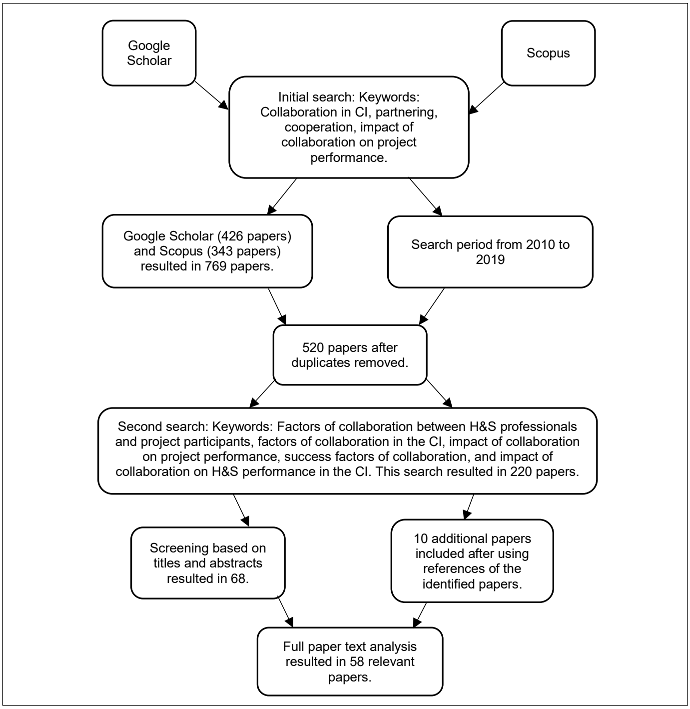

Figure 1: Procedure of systematic literature review
Source: Author's own construction

3.5 Analysis of identified literature

One author scanned the titles and abstracts of the identified literature. Literature that did not comply with the inclusion criteria was excluded. The full text was obtained for articles, and inclusion was subject to consensus among all three of the authors. First, data analysis was performed on the 58 relevant studies to identify articles on collaboration that influence project performance in the CI. They were classified according to the author(s), year of publication, type of study/research methods used, country where the study was conducted, journal/source of publication, and the research purpose/focus of the study. The results were reported by arranging the year of publication in ascending order (see Table 2). Thereafter, results from the Identification Test (Table 1) were used as criteria to do data extraction by classifying the factors of collaboration in the CI. Based on Table 1, collaboration is demonstrated by 11 common factors. For this analysis, two factors were added, thus the criteria classified the data into

Table 2: Articles on collaboration that influence project performance in the CI (2010 to 2019)

No.	*Author(s) and year of publication*	*Type of study*	*Country*	*Journal/Source of publication*	*Research purpose/focus of study*
1	Dietrich *et al.* (2010)	Literature review	Denmark	International Journal of Project Management	Collaboration elements and their dependencies in multi-partner projects
2	Eriksson (2010)	Case study	Sweden	Supply Chain Management: An International Journal	Supply chain in construction; factors affecting collaboration
3	Skinnarland & Yndesdal (2010)	Case study	Norway	People Culture and Change	Collaboration indicators to describe the collaborative development process
4	Löfgren & Eriksson (2010)	Survey	Sweden	Lulea University of Technology	Collaboration effects on project performance
5	Eriksson & Westerberg (2011)	Literature review	Sweden	International Journal of Project Management	How procurement-related factors affect performance criteria
6	Phong-arjarn & Jeenanunat (2011)	Survey	Thailand	Neresuan University Journal	Factors that have influence supply chain collaboration
7	Patel *et al.* (2012)	Literature review	UK	Applied Ergonomics	Factors for the Cospaces collaborative model
8	Meng (2012)	Survey	UK	International Journal of Project Management	Specific factors of supply chain relationships
9	Hughes *et al.* (2012)	Mixed method	UK	Journal of Construction Innovation	Producing a clear definition for collaboration within the UK CI
10	Bemelmans *et al.* (2012)	Literature review	The Netherlands	Engineering, Construction and Architectural Management	Supplier-contractor collaboration
11	Akintan & Morledge (2013)	Mixed method	UK	Journal of Construction Engineering	Collaboration in the traditional construction procurement supply chain
12	Meng (2013)	Survey	UK	Journal of Civil Engineering Management	Supply chain collaboration and its role in construction
13	Groenewegen (2013)	Case study	The Netherlands	Delft University of Technology	Individuals' views on factors influencing collaboration
14	Hasanzadeha *et al.* (2014)	Case study	Iran	Social and Behavioral Sciences	Project partnering as applied in CI
15	Fulford & Standing (2014)	Case study	UK	International Journal of Project Management	Identifying factors inhibiting collaboration

Table 2:

Table 2 continued ...

No.	*Author(s) and year of publication*	*Type of study*	*Country*	*Journal/Source of publication*	*Research purpose/focus of study*
16	Rahman *et al.* (2014a)	Mixed method	Malaysia	Innovation, Management and Technology Research	Importance of collaboration from contractors' perspectives
17	Hudnurkar *et al.* (2014)	Literature review	India	Social and Behavioural Sciences	Factors affecting supply chain collaboration
18	Ey *et al.* (2014)	Case study	Australia	International Journal of Construction Management	Current practices of collaborative procurement
19	Rahman *et al.* (2014b)	Survey	Malaysia	Business, Engineering and Industrial Applications Colloquium	Readiness of main contractor for collaboration in CI
20	Jefferies *et al.* (2014)	Case study	Australia	Engineering, Construction and Architectural Management	Factors that influence the successful implementation of project alliance
21	Kumar & Banerjee (2014)	Survey	India	Benchmarking: An International Journal	Supply chain collaboration index
22	Emuze & Smallwood (2014)	Survey	South Africa	Journal of Engineering, Design and Technology	A level of collaborative working among partners in South African construction
23	Donato *et al.* (2015)	Literature review	Australia	International Journal of Procurement Management	Conceptual model for construction supply chain actors
24	Bidabadi *et al.* (2015)	Case study	Iran	International Journal of Innovative Science, Engineering & Technology	Importance of collaborating in construction supply chain
25	Torneman (2015)	Case study	Sweden	Chalmers University of Technology	Technical consultant engagement in a collaborative project
26	Suprapto *et al.* (2015)	Case study	The Netherlands	International Journal of Project Management	Effects of collaboration antecedents on project performance
27	Lavikka *et al.* (2015)	Case study	Finland	Supply Chain Management: An International Journal	Coordination of supply chain networks
28	Masemeni *et al.* (2015)	Survey	South Africa	SACQSP	Barriers in the execution of collaborative models
29	Iyer (2015)	Literature review	USA	Texas A&M University	Framework to assess construction collaboration
30	Hosseini *et al.* (2016)	Case study	Norway	Energy Procedia	Partnering practices
31	Ozturk *et al.* (2016)	Literature review	Turkey	Procedia Engineering	Factors affecting collaboration in the design

Table 2 continued ...

No.	*Author(s) and year of publication*	*Type of study*	*Country*	*Journal/Source of publication*	*Research purpose/focus of study*
32	Bidabadi *et al.* (2016)	Survey	Iran	Organisation, Technology and Management in Construction: International Journal	Collaboration to improve supply chain construction
33	Roberts *et al.* (2016)	Literature review	South Africa	Southern African Institute of Management	Development of a model of collaboration
34	Kozuch & Sienkiewicz-Malyjurek (2016)	Literature review	Poland	Transylvanian Review of Administrative Sciences	Factors driving effective inter-organisational collaboration
35	Mensah (2016)	Survey	Ghana	Khame Nkruma University of Science and Technology	Barriers and benefits of collaboration
36	Liu *et al.* (2017)	Literature review	China	International Journal of Project Management	Critical effects on building information modelling (BIM) collaborative design
37	Pal *et al.* (2017)	Survey	China	International Journal of Project Management	Supplier and contractor relationships
38	Boton & Forgues (2017)	Literature review	Canada	International Journal of Project Management	Complexity of collaboration in CI
39	Kapogiannis & Sherrat (2017)	Survey	UK	Built Environment Project and Asset Management	Integrated collaborative technologies
40	Kalantari *et al.* (2017)	Mixed method	Middle East	Facilities	Obstacles to collaboration
41	Ayegba *et al.* (2017)	Literature review	South Africa	University of the Witwatersrand	Collaboration and long-term relationships in CI
42	Bond-Barnard *et al.* (2018)	Survey	South Africa	International Journal of Managing Projects in Business	Trust and collaboration for increasing project success
43	Nursin *et al.* (2018)	Mixed method	Indonesia	MATEC web of conferences	Critical success factors of collaboration
44	Msomba *et al.* (2018)	Literature review	Tanzania	International Journal of Engineering Research and Technology	Enabling factors of collaboration in risk
45	Smith & Thomasson (2018)	Case study	Sweden	Public OrganizReve	Public-private partner collaboration
46	Andreas & Ida (2018)	Case study	Sweden	Jonkoping University	Collaboration aspects during tender process
47	Hughes (2018)	Mixed method	UK	University of South Wales	Aspects of collaboration
48	Deep *et al.* (2019)	Literature review	Australia	International Journal of Construction Management	Enablers governing factors of collaboration
49	Faris *et al.* (2019)	Survey	Iraq	International Journal of Construction Management	Underlying factors of collaboration

Table 2 continued ...

No.	*Author(s) and year of publication*	*Type of study*	*Country*	*Journal/Source of publication*	*Research purpose/focus of study*
50	Aghania *et al.* (2019)	Survey	Indonesia	International Journal of Civil Engineering and Technology	Collaboration in building projects
51	Hamzeh *et al.* (2019)	Survey	Middle East (Qatar, Lebanon)	Built Environment Project and Asset Management	Extent of forms of contract addressing collaboration
52	Nader (2019)	Case study	The Netherlands	Delft University of Technology	Client and contractor collaboration
53	Ozturk (2019)	Survey	Turkey	Journal of Materials Science and Engineering	Individual level collaboration and BIM
54	Bygballe & Sward (2019)	Case study	Norway	International Journal of Project Management	Model of how partnering is institutionalised
55	Oraee *et al.* (2019)	Literature review	Australia	International Journal of Project Management	Barriers to collaboration in BIM
56	Marinelli & Salopek (2019)	Mixed method	UK	Journal of Engineering, Design and Technology	Dimensions of the collaborative ethos
57	Liu *et al.* (2019)	Survey	Malaysia	MATEC Web of Conferences	Collaboration critical factors
58	Ibrahim & Belayutham (2019)	Literature review	Malaysia	MATEC Web of Conferences	Social collaboration in BIM-based construction projects

Research themes total and %
Collaborative procurement 2 (13.7%)
Factors of collaboration in construction management 10 (17.2%)
Supply chain in construction and factors affecting collaboration 11 (18.9%)
Collaboration in the design building environment 8 (13.7%)
Contractor and subcontractor collaboration 4 (6.8%)
Client and contractor 4 (6.8%)
Collaboration models 5 (8.6)
Barriers and benefits of collaboration 4 (6.8%)
Other 10 (17.2%)

Source: Author's own construction

13 factors, namely trust, communication, resource/information sharing, mutual goals/vision, culture, commitment, clear roles and responsibilities, top management support, conflict resolution, early involvement of key participants, competence/experience, gain and pain sharing, and continuous improvement. Content analysis was used to rank each factor of collaboration by reporting the number of articles that mentioned the factor. The ranking results show the factors of collaboration critical for improving H&S performance in construction projects (see Table 3). One author performed data extraction, and a second author checked the results

4. FINDINGS AND DISCUSSION

4.1 Collaboration in the CI

The classification of articles on collaboration that influence project performance in the CI can be considered for H&S performance. Table 2 ranks the articles based on the year in which they were published.

4.1.1 Publication year and sources of publication

The construction journals delivered 46 of the 58 articles, the largest contribution came from the IJPM (11), the IJCM (6), the IJEC (4), other construction-related journals, and some papers from university masters and doctorate studies. Social and management sciences studies delivered 11 of the 58 articles. The inclusion of other articles besides construction management-related journals was an attempt to bring a balanced view on factors of collaboration. Publication sources included 51 journal articles and 7 papers from university masters and doctorate studies. The IJPM (11) has been the most used journal for publishing papers on collaboration factors in the CI. From the non-construction journals, Journal of Social and Behavioral Sciences provided 3 articles, which is the highest contribution. From 2010 to 2013, there was less focus on collaboration in the number of articles per year, but more articles focus on collaboration since 2014. This finding is consistent with a recent finding by Deep *et al*. (2019: 4), indicating that construction organisations and professionals are realising the benefits of collaboration in the CI.

4.1.2 Research methods used

Analysis based on the research methods used shows that most of the authors used surveys 18 (31%), literature reviews/conceptual 17 (31%), and case studies 16 (29%), while only a few 7 (13%) employed mixed method design in researching collaboration. Existing empirical studies investigating collaboration, for example by Suprapto, Bakker and Mooi (2015) and Ey *et* *al*. (2014), used case study method. The lack of studies on collaboration using the mixed method strategy points to a gap in knowledge.

4.1.3 Country of origin

Studies on collaboration were undertaken in over 25 countries. Researchers from Europe published 27 (49%) articles; UK 9 (16%); Asia 8 (14%); Sweden 6 (11%); Africa 6 (11%) (5 from South Africa); Middle East 6 (11%) (3 from Iran); Australia 5 (9%); North America 2 (4%), and India 2 (4%). Based on the analysis, Europe published almost half (49%) of the articles and Africa only 12%. This suggests that collaboration in the CI is more researched in Europe, with 9 articles in the UK and 6 in Sweden, while Africa only published 6 articles with 5 from South Africa. This could mean that, in Africa, there is less focus on collaboration in the CI and that research on collaboration is still at an early stage in Africa and South Africa. Only one paper from Africa (Tanzania) investigated the factors of collaboration. The study used a literature review to identify factors of collaboration in construction risk management.

4.1.4 Research purpose/focus of the study

Analysis on the research purpose/focus of the studies shows that researchers have investigated collaboration from many perspectives such as collaborative procurement 2 (13.7%); factors of collaboration in construction management 10 (17.2%); supply chain in construction and factors affecting collaboration 11 (18.9%); collaboration in the design building environment 8 (13.7%); contractor and subcontractor collaboration 4 (6.8%); client and contractor 4 (6.8%); collaboration models 5 (8.6%); barriers and benefits of collaboration 4 (6.8%), and other 10 (17.2%).

Only 4 (6.8%) studies investigated barriers to collaboration that are consistent with a study by Bemelmans *et al*. (2012: 355); only one study discussed the barriers or obstacles to partnering. Only 8 (13.6%) articles investigated interpersonal collaboration (client, contractor, subcontractor). This suggests that most of the studies are focused on interorganisational collaboration and a few studies focused on interpersonal collaboration.

From the 58 identified articles, only 10 (17.2%), of which one is from Africa, investigated factors of collaboration. None focused on factors of collaboration that improve H&S performance in the CI. It is reasonable to conclude that, while collaboration is slowly gaining the attention it deserves from researchers and practitioners, studies focusing on factors of collaboration for improving H&S performance are limited or not available. This suggests that identifying factors of collaboration critical for improving H&S performance is an important aspect to consider.

4.2 Factors of collaboration in the CI to be considered for H&S performance

Table 3 shows the ranking of each factor of collaboration by reporting the number of included articles that mentioned or discussed the factor. Mentioned 43 or more times, results show that the top three factors of collaboration critical for improving H&S performance in construction projects are trust (48), communication (47), resource/information sharing (43), as well as mutual goals and commitment (43). Factors such as continuous improvement, gain and pain sharing, early involvement of key participants, top management support, and culture have been overlooked, with only a

Table 3: Factors of collaboration critical for improving H&S in the CI

Rank	*Factor of collaboration*	*Frequency*	*Article number from Table 2 that mentioned the factor*
1	Trust	48	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,17,18,19,20,21,22,23,25,26,28,29,31,32,33,34,35,36, 38,40,41, 42,43,44,46,47,48,49,50,51,52,53,55,56
2	Communication	47	1,2,3,5,6,7,8,9,10,12,13,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,35,36,39,40,41, 42,43,44,45,46,48,49,50,51,53,54,55,56
3	Resource/ information sharing	43	1,2,3,4,6,7,9,10,11,14,16,17,18,19,20,21,23,24,25,26,27,28,30,31,32,33,35,36,39,40,42,43,44,45, 46,48,49,50,52,53,54,55,56,57
4	Mutual goals/ vision	43	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,20,21,22,23,24,25,26,27,30,33,34,36,37,38,39,40,42,43,45,46, 47,48,50,51,52,53,55,56
5	Commitment	36	1,2,3,4,5,6,7,9,11,14,16,17,19,20,21,22,24,25,27,28,29,32,33,35,38,40,41,42,43,44,47,48,51,53,55,57
6	Clear roles and responsibilities	30	1,2,3,7,9,11,12,13,14,16,20,21,24,26,27,31,32,33,38,40,44,46,48,49,50,51,54,55,56,57
7	Competence	29	1,2,3,7,10,18,20,21,23,24,25,26,30,34,35,39,40,42,43,46,47,49,51,52,53,54,55,56,57
8	Conflict/problem resolution	27	1,2,3,4,6,7,9,10,12,20,21,24,25,27,28,32,36,37,38,41,43,44,46,47,48,53,65
9	Culture	26	1,3,6,7,10,11,14,19,21,22,24,25,28,31,32,33,38,39,42,43,44,46,48,53,54,57
10	Top management support	20	3,6,7,9,14,16,17,18,23,24,25,27,28,30,31,33,40,42,46,48
11	Early involvement of key participants	19	1,2,7,9,10,11,23,22, 24,28,39,46,47,48,50,53,54,55,56
12	Gain and pain sharing	16	3,8,9,10,12,13,16,20,46,47,48,50,53,54,55,56
13	Continual Improvement	12	5,10,21,22,24,25,32,36,40,45,46,57

Source: Author’s own construction

few studies mentioning or discussing them. This indicates that the present literature focuses on certain factors, while others are disregarded.

As the top-rated factor of collaboration critical for improving H&S performance in construction projects, **trust** is an important collaboration factor in project success (Phong-arjarn & Jeenanunat, 2011: 10; Meng, 2013: 423; Bond-Barnard, Fletcher & Steyn, 2018: 434). For project success, knowledge exchange on time, cost, quality and H&S objectives creates expectations between project participants and is more likely to determine the level of trust between project members (Hosseini *et al*., 2016: 244). A situation where project participants trust each other plays a critical role in ensuring collaboration (Msomba, Matiko & Mlinga, 2018: 152). A more recent study by Bond-Barnard *et al*. (2018: 466) confirmed that the degree of collaboration did indeed increase as the level of trust in the project increased. The level of trust between H&S professionals and line managers (Provan, Dekker & Rae, 2017: 27) is a key factor in influencing decision-making processes, as trust between team members influences the level at which the team performs (Patel *et al*., 2012: 5).

Rated as the top-two factor of collaboration critical for improving H&S performance in construction projects, **communication** is a key for minimising project conflicts where diverse professionals with varying levels of knowledge and skills are involved (Aghania, Ramzani & Raju, 2019: 125). Previous studies identified lack of communication as the reason for project participants failing to collaborate, due to distrust and poor relationships (Meng, 2012: 190; Pal *et al*., 2017: 1227). Information exchange among participants on achieving H&S goals (Lingard *et al*., 2014: 920) to improve project performance in the CI include formal and informal or verbal and written means of communication (HSE, 2008: 29; Jitwasinkul & Hadikusumo, 2011: 524). The importance of effectively communicating safety hazards and control measures among participants limits the probability of accidents (Pandit, Albert, Patil & Al-Bayati, 2018: 2). To demonstrate its significance, the International Organisation for Standardisation (ISO) (2018: 17) and the South African Council for Project and Construction Management Professions (SACPCMP) (2013: 7) identified communication management as a key knowledge area within H&S management practice.

Resource/information sharing was rated one of the top-three factors of collaboration critical for improving H&S performance in construction projects. Free information exchange between clients, designers and contractors (Jefferies, Brewer & Gajendran, 2014; Akintan & Morledge 2013; Ey *et al*., 2014) is critical for improving collaboration, overall project performance (Pal *et al*., 2017: 1227), and successful project completion (Rahman *et al*., 2014a: 419). Sharing of information and resources is important not only for ensuring successful contractual relationships (Bemelmans & Voordijik, 2012: 355; Banerjee & Kumar, 2014: 188; Rahman *et al*., 2014a: 414), but also for effective supply chain collaboration, because sharing of information ensures that activities are executed efficiently and effectively (Banerjee & Kumar, 2014: 189).

As one of the top-three factors of collaboration critical for improving H&S performance in construction projects, **mutual goals and commitment** is key to improve collaboration between project participants (Pal *et al*., 2017: 1227) and establishing mutual objectives among project stakeholders (Faris *et al*., 2019: 5). In general, project managers, designers, construction managers, and H&S professionals have conflicting objectives (Meng, 2013: 427), but mutual goals between project participants promote collaboration and better project performance (Hosseini *et al*., 2016: 250). H&S performance improvement through mutual goals and commitment is key when setting H&S objectives in the CI (ISO, 2018: 14).

Commitment was rated the top-four factor of collaboration critical for improving H&S performance in construction projects and is important for interpersonal and interorganisational collaboration in the CI (Bond-Barnard *et al*., 2018: 439). Commitment from top management (Deep *et al*., 2019: 8) and individual project participants plays a vital role in achieving project H&S goals (Msomba *et al*., 2018: 155). Top management commitment for improving H&S performance is demonstrated by providing resources for H&S activities (ISO, 2018: 9; El-nagar, Hosny & Askar, 2015: 185), while individual commitment is reflected through attending H&S meetings and other H&S-related activities. For instance, commitment to H&S can be shown through monitoring leading indicators of H&S performance (Hinze, Thurman & Wehle, 2013: 26). Conversely, findings of Okori (2014: 208) revealed that inadequate site management commitment contributes to poor H&S performance.

Rated as the top-five factor of collaboration critical for improving H&S performance in construction projects, defining **clear roles and responsibilities** is important for successful collaborative relationships in the CI (Meng, 2013: 426; Kapogiannis & Sherratt, 2017). Clearly defined roles and responsibilities limit uncertainty and provide a fair distribution of the roles and responsibilities of project participants in H&S management (Aghania *et al*., 2019: 125). Unclear roles and responsibilities may lead to conflict that affects project team members psychologically and leads to poor performance (Patel *et al*., 2012: 10).

Conflict/problem resolution, as a factor of collaboration critical for improving H&S performance in construction projects, refers to resolving or dealing with issues such as technical problems and disagreements between partners (Banerjee & Kumar, 2014: 189) that may affect procurement, design, construction, and H&S processes. In the CI, setting proactive strategies for resolving conflict or problems is vital within a collaboration process, in order to save time, cost and improve H&S processes (Msomba *et al*., 2018: 156).

According to Patel *et al*. (2012: 4), **culture** exists at national, organisational and professional levels, showing that each organisation, nation and professional has its own way of doing things. A culture of blaming each other is prevalent in construction projects (Akintan & Morledge, 2013: 3) and influences performance, people/employee behaviour and their level of optimism (Meng, 2013: 190). A "no blame" culture enabling collaboration in risk management (Msomba *et al*., 2018: 156). Managing risks in high-risk industries such as the CI includes setting H&S objectives and establishing a good H&S culture in the CI. This becomes necessary for the safe improvement of H&S performance (Lingard *et al*., 2009: 134; Nielsen, 2014: 7).

Competence/experience, as a factor of collaboration critical for improving H&S performance in construction projects, refers to knowledge, skills and experience among project team members that contribute to the success of the project (Msomba *et al*., 2018). Working in collaboration integrates relevant knowledge and skills from past work experience of project participants (Torneman, 2015: 23), increasing the project teams' competence and knowledge of construction H&S processes and enhancing their capability for delivering a successful project (Liu *et al*., 2017: 692). Developing competence in H&S management through training and adequate supervision (HSE, 2008: 31-32) gives project participants experience. Applying skills and knowledge helps them identify hazards on construction sites.

The **support of top management**, as a factor of collaboration critical for improving H&S performance in construction projects, is important for implementing a safety culture and safety standards (Charehzehi & Ahankoob, 2012: 306) and for establishing H&S policies and objectives in the CI (ISO, 2018: 9). This support is necessary to create a culture for collaborating between project participants (Faris *et al*., 2019: 5), in order to ensure that workers are safe (Charehzehi & Ahankoob, 2012: 304). Top management also provides resources or funds for creating a safe workplace (Mohammandi, Tavakolan & Khosravi, 2018).

As a factor of collaboration critical for improving H&S performance in construction projects, **early involvement of key participants** such as project managers, designers, contractors, subcontractors and other consultants had the greatest impact on project innovation and improvement of project efficiency (Hosseini *et al*., 2016: 248). Early involvement of key project team members in H&S management who have specialised knowledge in project decision-making is linked to the adoption of higher work H&S risk controls (Emuze & Smallwood, 2014: 302).

Gain and pain sharing, as a factor of collaboration critical for improving H&S performance in construction projects, refers to shared profits or cost savings and shared losses, due to errors (for example, H&S) or cost increases between the parties in a construction project (Meng, 2012: 190). According to Faris *et al*. (2019: 2), in collaboration, risks and rewards are shared between all parties, but parties must find an effective way as to how to share risks and rewards between those involved, with a view to improving collaboration. One of the recommendations was to allocate risks and rewards fairly prior to tender. This will help improve project and H&S performance (Hasanzadeh *et al*., 2014: 816).

Although **continuous improvement** was rated the lowest factor of collaboration critical for improving H&S performance in construction projects, it is a key element in H&S management practice (Andreas & Ida, 2018), because it is characterised by non-ending improvements in products, services and processes (Pal *et al*., 2017: 1227). In H&S management, leading indicators such as audits, training, incident recalls (Hinze, Thurman & Wehle, 2013: 25; ISO, 2018: 23), percentage of accidents, frequency of H&S meetings, and the number of trained workers on H&S are used to ascertain if H&S performance is improving. Organisations with a “zero harm” policy will adopt the most effective leading indicators; that is, those that drive H&S management systems to continual improvement (Sinelnikov, Inouye & Kerper, 2015: 241).

5. CONCLUSION AND RECOMMENDATIONS

The review contributes to literature about collaboration in construction H&S and the factors that can be used to influence H&S performance. Findings show that there are 11 critical success factors of collaboration that can influence construction H&S performance: trust, communication, commitment, resource/information sharing, mutual goals, clear roles and responsibilities, culture, early involvement of key participants, competence, conflict resolution, and continual improvement. Based on reporting the number of included articles that mentioned or discussed the factor, the top three factors of collaboration critical for improving H&S performance in construction projects are trust (48); communication (47); resource/information sharing, (43) and mutual goals and commitment (43).

During 2014-2019, studies investigating collaboration have increased, but studies on collaboration in the CI were limited in developing countries such as Africa. Limited studies used a mixed method research design and most of the studies were based on surveys, literature reviews, and case studies. The literature review revealed that few studies investigated factors of collaboration and barriers inhibiting collaboration in CI.

The limitation of this study is that the literature review and findings are based on studies done between 2010 and 2019 and that the unit of analysis was limited to studies obtained on Google scholar and Scopus databases. Searches in other search engines might have provided additional information on collaboration. The findings make way for future research into the impact of collaboration on H&S performance and provide an understanding that H&S performance can be improved by adopting collaboration.

The study presented in this article is based on work in progress and intermittent findings of an ongoing PhD research on a framework to improve H&S professionals' collaboration and value addition to H&S performance.

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THE BUILDING EMISSION REDUCTION POTENTIAL OF SOUTH AFRICAN RESIDENTIAL BUILDING EFFICIENCY TOOLS – A REVIEW

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ABSTRACT

The building sector's levels of greenhouse gas emissions and energy consumption are a significant contributor to South Africa's overall carbon emissions. This influences the country's ability to meet its commitments to the Paris Agreement, which aims to limit the effects of global climate change. This review article focuses on the climate change mitigation strategies that are employed by the building sector, specifically the potential impact of mandatory and voluntary building energy efficiency regulations, standards, initiatives, and certifications common to South Africa's residential market. International research on the impact of green building tools tends to focus on the commercial rather than the residential sector, due to limited energy data availability. Within this context and given the exploratory and evaluative nature of the present research endeavour, substantial reliance has had to be made on grey literature for this research. A review of the South African building efficiency tools shows that there is potential for a 16% reduction in the energy intensity of the residential sector by 2030. This will, however, be offset by the projected increased building floor area and is as such insufficient to meet South Africa's commitments to the Paris Agreement. Thus, more ambitious targets are required. Given the growth of the residential sector and the potential impact of the various tools, a focus on improved and timeous mandatory regulations for new builds is crucial, in order to meet our climate commitments.

Keywords: Building energy efficiency tools, climate change mitigation, green buildings, residential sector

ABSTRAK

Die energieverbruik en kweekhuisgasvrystellings deur die boubedryf lewer 'n beduidende bydrae tot Suid-Afrika se algehele koolstofvrystelling en beïnvloed ons vermoë om ons verbintenisse tot die Parys-ooreenkoms na te kom, wat daarop gemik is om klimaatverandering te beperk. Hierdie oorsigartikel ondersoek die versagtingsmaatreëls wat in die boubedryf gebruik word om klimaatverandering te bekamp, en spesifiek die potensiële energie-besparende impak van verpligte en vrywillige energie-doeltreffendheid of groenbou-instrumente wat in die Suid-Afrikaanse residensiële mark gebruik word. Internasionale navorsing is tipies toegespits op die impak van groenbou-instrumente op die kommersiële eerder as op die residensiële sektor, as gevolg van beperkte beskikbaarheid van energiedata in die residensiële sektor wêreldwyd. Gegewe hierdie konteks, en die verkennende en evaluerende aard van die navorsing, moes daar aansienlike vertroue op 'n aantal grysliteratuur vir hierdie navorsing gemaak word. Na 'n hersiening van die Suid-Afrikaanse residensiële groenbou-instrumente, is daar 'n potensiaal vir 'n afname van 16% in die energie-intensiteit van die residensiële sektor teen 2030. Hierdie afname word egter teengewerk deur die geprojekteerde toename in algehele residensiële vloeroppervlakte en is sodanig onvoldoende om aan ons verbintenisse van die Parys-ooreenkoms te voldoen. Meer ambisieuse teikens word dus benodig. Gegewe die groei in die residensiële sektor en die potensiële impak van die verskillende groenbou-instrumente, is tydige en verbeterde verpligte regulasies vir nuwe geboue uiters belangrik om aan ons klimaatverbintenisse te voldoen.

Sleutelwoorde: Energiebesparings, groenbou-instrumente, groen geboue, klimaatverandering, residensiële sektor, versagtingsmaatreëls

1. INTRODUCTION

The World Health Organization (WHO, 2015: online) views climate change as "the greatest threat to global health in the 21st century". This may necessitate a global response to the climate change crisis, akin to that required of the COVID-19 pandemic (Bir, 2020).

According to the special report of the Intergovernmental Panel on Climate Change (IPCC), disadvantaged and vulnerable populations, especially the poor in Africa and Asia, will be hardest hit by climate change, with an increased risk to their "health, livelihoods, food security, water supply, human security, and economic growth" (IPCC, 2019: 11). Globally, cities are responsible for more intensive resource use, and 70% of carbon dioxide emissions (UN-Habitat, 2016: 1). This, coupled with continuous urbanisation, will lead to a "deadly collision between urbanization and climate change" (UN-Habitat, 2011: 183). Cities can thus be viewed as major environmental culprits. However, they can also dramatically contribute to mitigating the effects of climate change (UN-Habitat, 2016: 17).

This, of course, has many ramifications, but the focus, in this instance, is on the building sector in cities, since this sector presents the most significant opportunity for low-cost emissions and energy-use reductions (WRI, 2016: 17). Given that buildings last for generations and have long renovation cycles, there is a "need for early and rapid investment to prevent locking in carbon intensive investments" (CBI, 2017: 12).

Since the International Energy Agency (CBI, 2017: 10) has projected that residential floor area would increase by 75% between 2015 and 2050, this article focuses specifically on the residential building sector in South Africa. Part of South Africa's attempt to meet its climate change commitments is to employ building efficiency tools, which include several mandatory and voluntary regulations, standards, initiatives, and certifications. This article thus aims to describe and especially evaluate the potential impact on emissions reduction of such tools, specifically in the formal residential sector.

2. METHODS AND REVIEW APPROACH

The review provides both an international and a South African background to the impacts of, and responses to climate change. First, the climate change mitigation commitments made under the Paris Agreement are summarised, and the scope and impact of these commitments clarified. Secondly, the carbon emissions impacts of the building and residential sectors are discussed, creating the impetus to focus on this area. Thirdly, the climate change mitigation tools used in the building sector and their impact on the mitigation of climate change are reviewed.

Qualitative research methods were employed for this article, primarily through the application of desktop research and secondary data analysis. Relevant materials used in this review consisted of articles, theses, reports, and other documents obtained from the University of the Witwatersrand's Library database and the internet. As an initial search, relevant documents were identified through the application of a database keyword search for terms associated with the climate change mitigation potential of green building tools. Search terms included climate change, Paris Agreement, building sector, residential sector, green building tools, and building efficiency. The primary search was performed between 15 October 2019 and 30 November 2019, with supplementary supporting information sourced between 24 February 2020 and 19 April 2020. Preference was given to more recent literature so as to reflect current research on, and approaches to the topic. To expand the relevant literature for review, several of the references used in the initial texts were additionally evaluated for their relevancy to this topic.

It was evident from the initial search for relevant academic material that international research on the impact of green building tools tends to focus on the commercial rather than the residential sector. This may be because residential energy consumption data are limited across the world (CBI, 2017: 8). This worldwide trend of limited energy data availability, and subsequently research output, is also evident in South Africa. The paucity of relevant literature, and the exploratory and evaluative nature of the present research endeavour, required a heavy reliance on grey literature for its review. This documentation primarily consists of reports and policy documents from both governmental and non-governmental agencies, which were identified and sourced either through internet search terms, or because they were referenced or referred to in the sourced journal articles.

It is important to note that this review utilises sources with varying degrees of credibility, and this may influence the final accuracy and validity of the results obtained. For example, statistics and assessment reports by the IPCC are considered highly credible, as the IPCC assesses and summarises published climate change research that has been undertaken worldwide. This could be contrasted with statistics provided by state-owned entities regarding residential energy and electricity consumption, which are inconsistent (UNEP-SBCI, 2009: 25, 31). Thus, educated assumptions need to be made regarding which data to use. Data obtained from Statistics South Africa and the Quantum database, which were used in this study, are accurate, although they may contain some unknown biases.

In the discussion section, the building efficiency tools utilised or proposed in South Africa are evaluated, within the context of the carbon footprint of our national energy supplier, and the residential sector's energy demand, composition, and growth projections. This is done by considering the tools' areas of impact (energy efficiency, carbon footprint of energy supply, carbon footprint of building materials), and ultimately their potential reduction in the energy intensity of the residential building.

3. KEY ISSUES

3.1 The Paris Agreement and nationally determined contributions

The impacts of global warming on natural and human systems have already been observed (Scholes, Scholes & Lucas, 2015: 51-52), and some of the projected impacts may be long-lasting or even irreversible. Disadvantaged and vulnerable populations will be hardest hit by climate change (IPCC, 2019: 20), and countries in Africa would need to devote 5% to 10% of their Gross Domestic Product (GDP) simply to adapt to these negative impacts (DPW, 2018: 63).

These global warming (and climate change) risks and impacts can be addressed through increased, accelerated, and far-reaching climate mitigation action (IPCC, 2019: 7). The Paris Agreement (Climate Focus, 2015: 1; UN, 2015: 1) was adopted by parties at the UN Framework Convention on Climate Change (UNFCCC) on 12 December 2015, with 195 countries having ratified the Paris Agreement by October 2019 (United Nations Treaty Collection, [n.d.]). This Agreement aims to hold "global average temperature to well below 2°C above pre-industrial levels" and to pursue "efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (UN, 2015: 3). In addition, greenhouse gas emissions are intended to peak as soon as possible, with a rapid reduction afterwards (UN, 2015: 4).

All parties to the Paris Agreement were to develop their own country-specific climate mitigation plans and commitments and provide progressively more ambitious nationally determined contributions (NDCs) every five years (Climate Focus, 2015: 1). Intended NDCs (INDCs) were submitted by 97% of the parties to the UNFCCC by 18 April 2016, which represented 94.6% of carbon dioxide (CO_2) emissions worldwide (UNFCCC, 2019).

South Africa ratified the Paris Agreement on 1 November 2016, having already provided its INDC by 25 September 2015. The main targets of the INDC (Government of South Africa, 2015: 6) are that:

- emissions will range within 398 and 614 Mt CO_2-eq[1] between 2025 and 2030;
- the emission profile will peak between 2020 and 2025, plateau for a decade and then decline in absolute terms from there onwards, and
- targets apply to all sectors of the economy.

In 2018, South Africa released the draft Climate Change Bill for comment (DEA, 2018: 4), which seeks to establish a legal framework to determine a national emissions reduction trajectory and to set carbon budgets and sectoral emissions targets (DEA, 2019: 75). While South Africa is one of the few countries to provide absolute targets in its INDC, the commitment is nevertheless insufficient to place the country on a pathway that will limit warming to +2 °C or less (Climate Action Tracker, 2019).

This is consistent with the findings in the report by the United Nations Framework Convention on Climate Change (UNFCCC), which states that the aggregate effect of all the INDCs by countries worldwide is insufficient to meet the target warming level limit (UNFCCC, 2016: 13). Similarly, another study (Fawcett, Iyer, Clarke, Edmonds, Hultman *et al.*, 2015:

1 Mt CO_2-eq denotes 'metric tons of carbon dioxide equivalent', which is used to quantify the global warming impact of emissions from different greenhouse gases, standardised to that of one unit mass of carbon dioxide.

1169) concludes that a continuation of current weak policies that target a 2% annual improvement in CO_2 emissions per unit of GDP provides zero chance of limiting warming to +2°C. Whilst current NDCs pledge stabilising the total yearly global CO_2 emissions, they provide only an 8% probability of limiting warming to +2°C. If the NDC pledges are "progressively tightened" from 2030 onwards, as per the intent of the Paris Agreement, the probability increases to 30%.

No sector-specific targets or plans are provided in South Africa's INDC, beyond the recognition of the large impact of the energy sector and the need for a lower-carbon supply. A United Nations Environment Program (UNEP) report (2018b: 15) notes that South Africa's current 2030 upper emissions target would be reached only if the country's future energy mix decarbonises, as per the 2019 Integrated Resource Plan (DMRE, 2019: 42), which came into effect in October 2019. South Africa's INDC refers specifically to the significant impact of our energy sector on our current Greenhouse Gas (GHG) emission levels, and that substantial investment in transforming the sector away from coal is required (Government of South Africa, 2015: 9).

3.2 The climate change impact of the building sector

Global levels of urbanisation have increased rapidly from approximately 29% to 49% in the past half century, and South Africa was already 66% urbanised by 2018 (Statista, 2020). Global emissions from fossil-fuel burning have increased by almost 500% in the same period, with 2016 being the hottest year in recorded history, exceeding 2019's level by 0.04°C. Cities are essential in the conversation about global emissions, as they account for between 60% and 80% of the world's energy consumption and generate 70% of the human-induced greenhouse gas emissions (UN-Habitat, 2016: 1).

The construction and operation of buildings is a leading contributor to these emissions, accounting for 36% of the world's energy use and 39% of the carbon dioxide emissions in 2017, as illustrated in Figure 1 (IEA & UNEP, 2018: 11). The residential sector accounts for 22% of worldwide energy consumption and roughly 17% of global emissions.

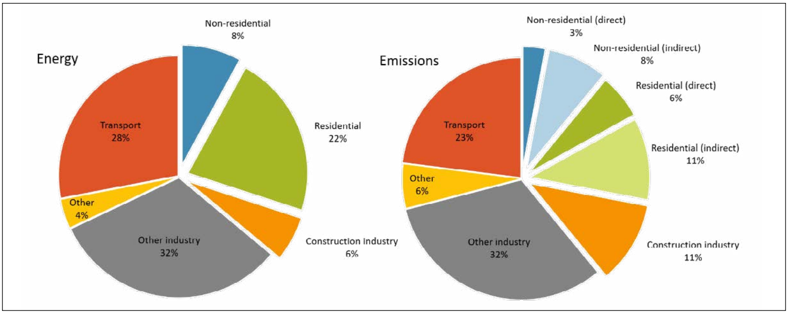


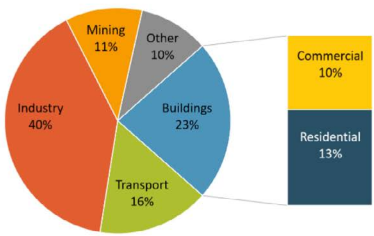
Figure 1: Global share of buildings and construction final energy and emissions in 2017.

Source: Adapted from IEA & UNEP, 2018: 11

The picture in South Africa is similar, with the residential sector responsible for 20% of the electricity consumption (Deloitte, 2017: 20) and 13% of the country's total greenhouse gas emissions (UNEP-SBCI, 2009: 33), as per Table 1.

Table 1: The building sector and the residential market's carbon emissions in 2006

South African CO_2 emissions per sector in 2006	%
Commercial	10%
Residential	13%
Building sector subtotal	**23%**
Transport	16%
Industry	40%
Mining	11%
Other	10%
Total	**100%**



Source: Adapted from UNEP-SBCI, 2009: 33

The International Energy Agency (CBI, 2017: 10) has projected that residential floor area will increase by 75% between 2015 and 2050, with similar growth levels projected for non-residential buildings. Africa, Asia and India are expected to show particularly rapid building growth, with floor area in Africa expected to more than triple by 2060.

The South African housing market is becoming more formalised at a rate that is higher than the average population growth rate, with the number of formal dwellings increasing by an average of 3.1% per year (Quantec, 2018). Despite improved energy efficiency of buildings globally, the energy needs of the building sector as a whole continue to increase, due to the floor area growth outpacing the reduced energy use per square metre that has been achieved (CBI, 2017: 10; UNEP & IEA, 2017: 7). With the massive increase in floor area projected in non-OECD countries, in part due to the significant housing deficit currently experienced, a focus on high-performing new builds should be prioritised in these regions (UNEP, 2011: 344).

The built environment can be viewed as high-inertia infrastructure, where investment and construction decisions made currently can lead to a detrimental lock-in of carbon-intensive investments for decades to come (Akerman & Hojer, 2006: 1953; UNEP & IEA, 2017: 13). The reason for this is that buildings tend to last decades, sometimes generations, with the thermal envelope[2] and roofs being very infrequently renovated during the usable life of buildings (CBI, 2017: 12).

3.3 Mitigating the climate change impact of the building sector

As urbanisation brings about fundamental changes in cities' production and consumption patterns, cities can be both part of the problem of, and the solution to climate change. They offer many opportunities to develop mitigation and adaptation strategies, with the economies of scale making it less expensive and easier to take action, in order to minimise both emissions and climate-related hazards (UN-Habitat, 2016: 17). As illustrated in Figure 2 (WRI, 2016: 17), bottom-up studies have shown that, compared to other sectors, the building sector presents the most substantial opportunity for cost-effective energy and emission reduction by 2030.

In the WRI's (2016: 56) report titled "Accelerating building efficiency: Eight actions for urban leaders", the first four of the eight actions identified as ways to deliver accelerated building efficiencies are Building Efficiency Codes and Standards; Efficiency Improvement Targets; Performance Information and Certifications, and Incentives and Finance. These speak directly to the building efficiency tools that are the focus of this article and are elaborated on in the ensuing subsections. These priorities broadly align with the key strategies identified by other institutes, including the roadmap provided by the Global Alliance for Buildings and Construction (UNEP & IEA, 2017: 13).

3.3.1 Building Efficiency Codes and Standards

Voluntary and mandatory energy codes or certification schemes for the building sector have been in use in over 80 countries worldwide for the

2 In countries where there is a large temperature difference between the inside and the outside of buildings, thermal insulation of the envelope elements such as walls, roofs and windows, becomes a key means of passively reducing the energy required to maintain comfortable temperatures inside (Szokolay, 2014).

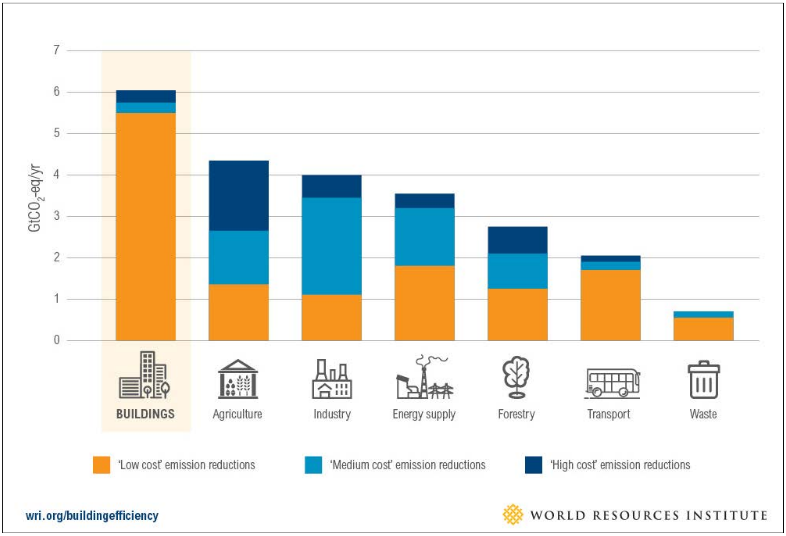


Figure 2: Estimated economic mitigation potential by sector in 2030
Source: WRI, 2016: 17

past 30 years (Wong & Kruger, 2017: 310; IEA & UNEP, 2018: 20), with this rise being correlated to the oil crisis of the 1970s (Caceres, 2018: 1). A precursor to building certification and energy rating schemes was the implementation of household appliance efficiency ratings, which provide accurate energy consumption information of appliances (Wong & Kruger, 2017: 310).

As of 2018, 69 countries worldwide have mandatory or voluntary building energy codes or standards, but this still leaves two-thirds of countries without either of these (IEA & UNEP, 2018: 20). Over half of the new buildings expected to be constructed between 2020 and 2060 are projected for so-called 'developing countries' that do not have *any* mandatory building codes requiring minimum energy efficiency levels in place (UNEP & IEA, 2017: 8).

In September 2011, the South African National Building Regulations (NBRs) were updated to include a section on energy efficiency, designated 'Part XA – Energy Usage in Buildings'. This section requires that all new buildings or major refurbishments be designed and built so that their passive design (orientation, shading, services, and the building envelope) ensures efficient use of energy, and that at least 50% of hot water generation (by volume) takes place without the use of electric resistance heating.[3] The intent is that this standard is updated every five years to become gradually more stringent (Ecolution Consulting, 2019: 30), although there are suggestions that even the best-practice norm of 3 to 5 years between updates is not optimal (Gray & Covary, 2015: 16).

The update of the NBRs is currently overdue, as eight years have passed since the promulgation of the previous version, with the Department of Public Works (DPW) stating that an update is "urgently needed" (DPW, 2018: 15). In January 2020, a draft version of the updated standard was released for public comment, with the window for comments closing on 24 March 2020. While the maximum annual energy consumption of commercial buildings is set to be reduced significantly if the standard is implemented in its current form, it is yet unclear to what extent the proposed update will influence the energy intensity of residential buildings (SANS, 2020).

3.3.2 Energy Efficiency Improvement Targets

Of the 194 NDCs submitted as part of the Paris Agreement, only 70% referenced the building or construction sectors (Figure 3), despite these sectors contributing to nearly 40% of the global greenhouse gas (GHG) emissions (UNEP, 2018a: 13). No sector-specific targets or plans are provided in South Africa's NDC.

Over 50% of NDCs referenced building energy efficiency, while 26% mentioned low carbon energy supplies (IEA & UNEP, 2018: 18), and only 5 NDCs (2.5%) mentioned low carbon construction, despite this providing a third of the carbon reduction potential (CBI, 2017: 7). Most of these NDCs do not provide specific targets or policy actions on reducing the impact of buildings, even for those countries that have such policies in place (UNEP & IEA, 2017: 18). The lack of targets was identified as a critical gap to be addressed as part of the support provided by the Global ABC to countries in the update to their NDCs (IEA & UNEP, 2018: 9).

3.3.3 Building Efficiency Performance Information and Certifications

Quality building performance information can provide stakeholders with the ability to make informed decisions on actions to improve their buildings' efficiency. Certifications, which are often voluntary, can provide public recognition and increased value to highly efficient buildings (WRI, 2016:

3 The conventional approach to water heating for domestic use uses an electrical element inside a geyser to heat water ('electric resistance heating'). SANS 10400–XA Regulations require that all new buildings utilise other means of heating at least 50% of the water, such as solar water heaters, heat pumps and gas geysers.

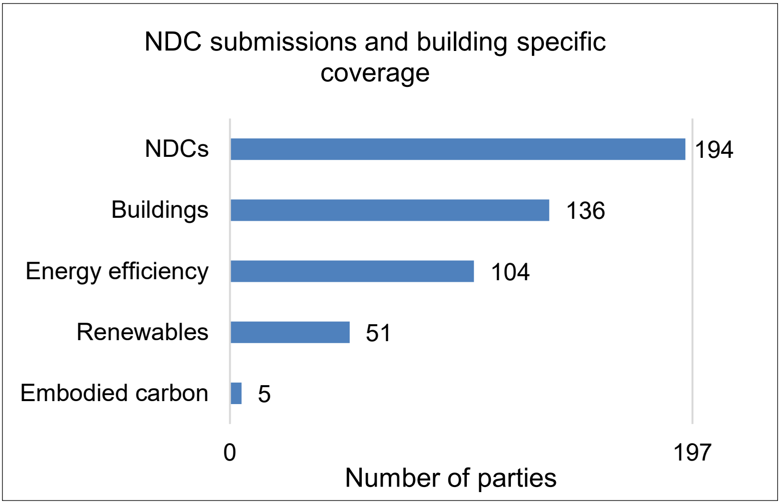


Figure 3: NDC and buildings policy coverage for 2017-2018
Source: Adapted from IEA & UNEP, 2018: 18

74). Green building rating tools or certifications are used in 85 countries and focus on evaluating the design (expected) or operational (measured) energy use of buildings. They are broadly voluntary outside of the European Union (EU), but the uptake is growing among the high-end building sector (IEA & UNEP, 2018: 23). Where building codes typically provide the minimum (often mandatory) building standard, several voluntary rating tools offer certification against best-practice standards (DPW, 2018: 12).

Energy Performance Certificates (EPCs) provide performance information as well as certification and have been used across the world to improve building energy efficiency and inform stakeholder decisions since the 1990s (Pasichnyia, Wallinb, Levihnc, Shahroknia & Kordasa, 2019: 486). EPCs serve to benchmark buildings against regulatory standards or industry benchmarks and to establish a database of building energy performance. EPCs provide either estimated ratings based on building features, or measured ratings determined through energy meter readings. The intent is to provide accurate and valuable information with regard to building energy performance (Caceres, 2018: 2), and a true reflection of this can only be obtained through energy consumption data. Studies have shown that design ratings are rarely an accurate reflection of energy performance, although more accurate estimates are possible based on the estimation methodology used (Wong & Kruger, 2017: 321).

Mandatory EPCs have been implemented in all 28 EU member states (BPIE, 2014: 6), and are used worldwide, including in the United States of America, Australia, Singapore, Japan, Brazil, Turkey, and India. In the EU, EPCs are required when buildings are newly constructed or advertised for rent or sale, and must be placed in a visible location in public buildings (Wong & Kruger, 2017: 320). South Africa's Department of Energy published draft EPC regulations for public comment in 2018 (Parliamentary Monitoring Group, 2018). The proposed mandatory EPCs (SANS, 2014: 3) are not required in the residential sector and are for existing commercial buildings used for entertainment, public assembly, theatres, indoor sports arenas, places of instruction, and offices only.

EPCs have been shown to not only improve the energy efficiency of buildings, but highly efficient buildings also attract a sales premium of up to 10%, thus acting as economic incentives for developers to innovate further (Wong & Kruger, 2017: 316). An EPC's effectiveness in reducing energy intensity can be increased through the provision of cost-effective recommendations on how to improve the building's energy efficiency (Wong & Kruger, 2017: 321; Caceres, 2018: 3), something that is not required in the current South African scheme.

Globally, green building certifications are typically voluntary, and they intend to promote and reward environmental sustainability in buildings (Yigit & Acarkan, 2016: 4840). The World Green Building Council (WorldGBC) has approximately 70 member Councils worldwide, which together administer 54 different green building rating tools (WorldGBC, 2019b). Internationally, several additional tools are used that are not managed by WorldGBC member Councils.

In the South African residential market, the EDGE ('Excellence in Design for Greater Efficiencies') Residential tool has had the largest uptake of the residential green building certifications available. The EDGE certification and other 'design' ratings derive their rating levels from estimated or modelled energy performance based on building features, which is poorly correlated to actual operational performance or emission intensity and has been criticised on this basis (CBI, 2017: 38; Wong & Kruger, 2017: 321; Khosla & Janda, 2019: 4). Given consistent energy modelling assumptions, 'design ratings' do, however, allow for the comparison of the relative potential energy efficiency of different building designs (Mey, 2020: 19).

'Operational' or 'measured' green building ratings such as Net Zero Carbon, which validate their energy performance or emission intensity through actual energy meter readings, are considered preferable to design ratings (CBI, 2017: 26; Wong & Kruger, 2017: 321). Net Zero certifications carry additional support in that they are compatible with the rapid decarbonisation of the building sector to meet the targets of the Paris Agreement (CICERO, 2015; CBI, 2017: 17; WorldGBC, 2017).

The WorldGBC launched a 'Net Zero Carbon Buildings Commitment' in September 2018, intending to achieve a 40% reduction in embodied carbon emissions by 2030 and 100% net zero carbon emissions by 2050. As of September 2019, the commitment has been signed by 63 organisations, including 31 businesses, 6 states and regions, and 26 cities (WorldGBC, 2019a), representing over 130 million people globally (IEA & UNEP, 2018: 10). Regions include Catalonia in Spain and Yucatan in Mexico, with Johannesburg, Tshwane, eThekwini and Cape Town in South Africa having also committed to actions that target improved energy efficiency in both commercial and municipal buildings (WorldGBC, 2019a).

3.3.4 Building Efficiency Incentives and Finance

Incentives and financing promote the uptake of green new builds and the energy-efficient retrofitting of existing buildings, by alleviating the burden of the additional upfront costs, whose benefits tend to only accrue over time (WRI, 2016: 7).

Financial incentives can take the form of grants (such as the German 'Kfw Energy-Efficient Renovation' programme), rebates (Singapore's 'Design for Efficiency Scheme'), tax incentives (Brazil's 'Qualiverde Program'), and green mortgages (pilot by 37 European banks) (Climate Action, 2018).

The EU's building stock is dominated by existing buildings, and improving the energy efficiency of existing residential homes is considered essential to achieving their carbon emission targets (UK, 2019). As part of this, green mortgages are being piloted to encourage residential retrofits and improve their energy efficiency.

The minimum performance threshold for new builds is 'nearly net zero' buildings, or a 20% improvement over national standards, or a 30% energy demand reduction for renovations (WorldGBC, 2018b).

In South Africa, no national incentives exist, although two banks are offering 'green loans'. Nedbank is offering an extension to their home loan product, where renewable and energy-saving products from a specific supplier can be rolled into homeowners' home loans (Nedbank Limited, 2019). Most recently, ABSA and Balwin Properties have announced the 'Absa Eco Home Loan', which provides preferential interest rates on the 16,000 EDGE-certified homes under development by Balwin Properties (Engineering News, 2020).

Green bonds are financial instruments that allow the raising of debt to finance eligible green projects or activities. Of the $46 billion capital that has been raised on the green bond market, 28% has been allocated to the building sector. In South Africa, three bonds have been issued under the Johannesburg Stock Exchange's green bond requirements since its launch in late 2017, of which one was for a certified green building portfolio (CSS, 2019: 6). Green bonds benefit the issuer in that they are often oversubscribed, allow a company to market its 'green credentials', and can often be sold at a premium. In return, the proceeds are ringfenced for socially responsible activities, as per the bond mandate (Bagnoli & Watts, 2020: 1). Non-financial incentives are often aimed at developers of new builds in high-density cities, where green features or energy efficiency measures are encouraged. The incentive can take the form of allowing extra height or floor area, such as Delhi's 'Sustainable Buildings Incentive Scheme', which can award a bonus 1% to 4% coverage (WRI, 2016: 80-82).

Internationally, 2017 saw a slowdown in the rate of energy efficiency investments, with a 4.1% increase (2.5% adjusted for inflation), compared to the 6%-11% annual growth rates from 2014 to 2016. Overall energy efficiency accounts for only roughly 8% of total spending on buildings, with residential buildings receiving only half of the total investments, despite contributing to three-quarters of the global building energy use (IEA & UNEP, 2018: 26).

4. DISCUSSION

In order to decarbonise the building sector and stay within the +2°C limit,[4] the CBI advocates a focus on 'total building emissions', not simply on improved energy efficiency. The IEA states that only approximately a third of the required carbon reduction can be achieved through building efficiency alone (net zero buildings and deep renovations). The remaining two-thirds reduction requires a low carbon energy supply and the use of low carbon building materials (CBI, 2017: 7).

The mandatory and voluntary building efficiency tools are discussed individually in the ensuing sections, first, to see with which of the three 'total building emission' reduction areas they align; secondly, to discuss their reach, and finally the targeted energy intensity reduction and calculated achievable impact.

4.1 Impact of individual mandatory tools from the National Energy Efficiency Strategy

The post-2015 National Energy Efficiency Strategy (NEES) was developed to respond to the dual scenario of increased energy demand and a

4 The Paris Agreement aims to hold "global average temperature to well below 2°C above pre-industrial levels" and to pursue "efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (Paris Agreement, 2015: 29).

commitment to a reduced environmental footprint, as per South Africa's National Development Plan 2030 and its Paris Agreement commitments. The post-2015 NEES aims to "encourage continued growth by 'reducing energy inefficiency as a barrier' to future progress" (emphasis in original), through the promotion of energy efficiency as a 'first fuel'[5] (DEA, 2016: 3). The post-2015 NEES document addresses several sectors and, for the residential sector, provides a targeted overall energy intensity reduction of 33% by 2030, using 2015 as the baseline.

The overall target of 33% comprises a targeted 20% improvement of the average energy performance of the residential stock overall, and a 33% improvement in the energy efficiency of new household appliances. Measures to improve the energy performance of the residential stock include the progressive tightening of the building efficiency standards; the issuance of energy performance certificates; financial incentives for improving the thermal performance, and educational programmes. The measures related to household appliances include mandatory labelling; the successive tightening of minimum energy performance standards; energy endorsement labels, and a scrappage scheme for old, inefficient appliances. Table 2 provides an overview of the potential impact of the NEES.

4.1.1 The impact of mandatory national building regulations and standards

Successive tightening of the building efficiency regulations and standards constitutes a large portion of the NEES' targeted 20% improvement in the average energy performance of the residential sector, as it is based on a 38% tightening of the South African National Building Regulations (NBRs) energy efficiency standards by 2030. This is discussed in terms of focus area, reach, target, and achievable impact.

Focus area – The National Building Regulations and Standards' primary focus is 'energy efficiency', as the 'Environmental Sustainability' portion (part X) of the national standards currently pertains only to 'Energy usage in buildings' (part XA), specifically the efficient use of energy. The embodied energy of the material used in construction is not addressed, and the

5 The 'first fuel' concept is one that evolved from considering energy efficiency as a 'hidden fuel source', as the ability to use energy more efficiently allows the unused portion to be applied to other needs. As the energy use avoided by IEA member countries in 2010 was larger than any one fuel source, including coal, energy efficiency can be considered as the 'first' or largest fuel (IEA, 2014: 29).

Table 2: Potential energy intensity reduction by mandatory building efficiency tools, as per the NEES

	Tool	*Focus area: Energy efficiency*	*Focus area: Low carbon energy source*	*Focus area: Embodied energy*	*Achievable impact based on the reach of the tool*	*Potential energy intensity reduction*
Mandatory tools: National Efficiency Strategy (post-2015 NEES)	National building regulations	Yes	Limited to water heating	No	7.6% reduction in the energy intensity of the 2030 residential building stock, if ambitious targets are met	7.6%
	Thermal retrofits incentives	Yes	No	No	12% improvement of the energy intensity of the 2030 residential building stock, if ambitious targets are met. 1% reduction in the energy intensity is considered a more achievable target	1%
	Energy performance certificates	Yes	Promotes low carbon energy sources such as PV solar as its use lowers overall energy consumption and improves certificated rating	No	Most of the properties could have EPC by 2030, although energy intensity improvements will only be noticed later. A national database of residential energy intensity, track the impact of building policies, and implementation of minimum energy efficiency requirements	~
	Appliance minimum energy performance standards	Yes	No	No	15% MEPS tightening by 2021 would result in a 4% to 6% reduction in residential energy intensity by 2030	4% to 6%
	Educational programmes	Yes	Yes	No	Not quantified	~

carbon intensity of the energy used is only viewed as part of the hot water heating requirement.

Reach – The NBR requires that all new buildings or major refurbishments be designed and built so that their passive design (orientation, shading, services, and building envelope) ensure efficient use of energy, and that at least 50% of hot water generation (by volume) takes place without the use of electric resistance heating.[6]

Target – To achieve its targets, the NEES (DEA, 2016: 22) states that it requires a 38% reduction in household energy consumption in new builds, by tightening the current National Building Regulations (NBRs) energy efficiency standards by 2030, assuming that at least 20% of all buildings in 2030 will be built after 2015 or the introduction of the new standard.

Achievable impact – To achieve an overall reduction of 38%, a significant tightening of the NBR is required, as it currently mandates only efficiency requirements for hot water systems and the passive design (orientation, shading, services, and building envelope insulation). As water and space heating accounts for only 53% of the energy consumed in urban medium- and high-income households (UNEP-SBCI, 2009: 29), it would require an average efficiency improvement of 72% for these two systems to meet the 38% target.

The NBR is applicable only to formal dwellings. An evaluation of South African housing data (Quantec, 2018) indicates that 33% of formal households projected to have been built by 2030, will be built post-2015. With medium- and high-income households responsible for 89% of total electricity consumption (UNEP-SBCI, 2009: 29), the homes built from 2016 will constitute 29% of the total household electricity consumption. Thus, in order to achieve the requisite minimum 20% of formal new housing for the target, the NBR standards must be tightened by the proposed 38%, by 2021 at the latest. If the target is met, it could result in a total impact of 7.6% reduction of energy consumption per square metre of 2030 residential building stock (excluding plug loads) (Mey, 2020: 55). It is important to note that raising the minimum standards of the NBR by the proposed 38% would not guarantee an equivalent energy consumption reduction in the new homes implementing the improved standard. The reason for this is that implementing the requirements of the standard would only ensure that the notional energy use of buildings is improved, but no measurements are required to confirm or prove expected savings.

6 The conventional approach to water heating for domestic use uses an electrical element inside a geyser to heat water ('electric resistance heating'). SANS 10400–XA Regulations require that all new buildings utilise other means of heating for at least 50% of the water, such as solar water heaters, heat pumps, and gas geysers.

4.1.2 The impact of thermal retrofits incentives

As of 2014, low-cost state-subsidised housing has been required to meet NBR standards as well, after the release of the improved norms and standards for stand-alone residential dwellings built by the government (DHS, 2014: 1). For the past 20 years, these houses were constructed without insulated ceilings and weather-proofing, thus providing inferior thermal insulation to the homes. The updated standard requires the installation of ceilings and insulation, plastering or rendering of walls, and smaller windows with energy efficiency safety glass panes (SEA, 2017: 79).

Focus area – As an interim measure for existing buildings or built before the proposed NBR update, financial incentives are proposed to encourage the undertaking of thermal retrofits.

Reach and target – The NEES targets a 15% improvement for existing homes, which would amount to roughly 80% of the residential building stock in 2030.

Achievable impact – Globally, the typical renovation rates are approximately 1% to 2% of the building stock per year, with an overall energy intensity improvement of 10% to 15% from multiple improvement measures (GlobalABC & UNEP, 2016: 16; IEA & UNEP, 2018: 37). It is thus unlikely that the 15% improvement of the total existing stock would be achieved by 2030. If met, it would result in an overall impact of 12% reduction of energy consumption, which conflicts with a report, cited in the NEES, stating that the potential for energy intensity improvements from passive thermal design is limited to 5% (DEA, 2016: 12). In order to achieve the target of 15% improvement, it would require a 65% reduction in the electricity expended on space heating, as space heating accounts for only 23% of households' average electricity consumption (UNEP-SBCI, 2009: 29).

Assuming an optimistic average renovation rate of 2% per year, with a 10% energy intensity improvement starting in 2020, a more realistic, if bullish, target for South Africa is a 1% improvement in the residential stock's energy intensity, due to thermal retrofits (Mey, 2020: 57).

4.1.3 The impact of energy performance certificates

South Africa's Department of Energy published draft Energy Performance Certificates (EPCs) regulations for public comment in 2018 (Parliamentary Monitoring Group, 2018). EPCs would allow landlords to systemically analyse their building's stock energy performance, while populating a country-wide energy intensity database of the building sector and supporting the government's national energy efficiency strategy.

The proposed mandatory EPCs (SANS, 2014) are not required in the residential sector and are for existing commercial buildings used only for entertainment, public assembly, theatres, indoor sports arenas, places of instruction, and offices. EPCs are, however, used extensively in the residential sector in several countries, and they may also be extended to the residential sector in South Africa in the future, as per the measures to be assessed for feasibility under the post-2015 NEES.

Focus area – Energy performance certificates (EPCs) report on the energy intensity of a property and serve as an informative tool for both owners and occupiers, in terms of the energy efficiency of a building. Because EPCs have been shown to improve the sales and rental price of properties, they drive improvement in energy efficiency and alternative energy sources (Wong & Kruger, 2017: 316; Caceres, 2018: 3).

Reach and target – The NEES envisions the use of EPCs for both newly constructed and existing residential stock, with different strategies for owners and renters. As per the 2017 Household Survey (Stats SA, 2017), 56% of households own the dwellings they occupy, while 30% rent and 14% occupy rent-free. For owners, the NEES may explore the use of incentives such as rebates on transfer duty, if made voluntary, or making EPCs mandatory upon transfer of a property. If it is assumed that South African tenure trends are similar to those of other countries (Moon & Miller, 2018; GBCSA, 2018), it takes between 10 and 20 years for properties to change hands, the point at which a mandatory EPC on transfer would be required. The majority of properties could thus feasibly have an EPC by 2030, although the energy intensity impact may only be felt later as the market matures its response to EPC ratings (DEA, 2016: 20). EPCs may have to be made mandatory for rentals (up to 44% of the market), due to the split incentive that exists, as the tenant receives the benefits from lower utility bills, instead of the owner (Mey, 2020: 58).

Achievable impact – International studies show a broad band of possible impacts of implementing EPCs, with the most conservative in the range of 2% to 3% energy consumption reduction (Wong & Kruger, 2017: 316). The NEES provides no targeted energy intensity improvement as a result of EPC implementation. This may be due to the difficulty in separating the impact, due to policies and standards, or wholly due to the market incentive created by the EPCs. As EPCs serve as a national source of information on the energy intensity of properties, they can also be a tool used to track the impact of building policies and the implementation of minimum energy efficiency requirements (BPIE, 2014: 8).

4.1.4 The impact of appliance minimum energy performance standards

The NEES intends to transform the market for household appliances to more energy-efficient models, through the application of both push-and-pull strategies. The four specific strategies are minimum energy performance standards (MEPS) that are successively tightened; a scrappage scheme for old inefficient appliances (the 'push' strategies); mandatory labelling, and energy endorsement labels (the 'pull' strategies).

Focus area – Energy efficiency only, with this measure not seeking to address any of the other focus areas.

Reach and target – Minimum Energy Performance Standards (MEPS), combined with energy labels, have been shown to be an effective method to encourage appliance energy efficiency (Götz, Tholen, Adisorn & Covary, 2016: 8). Up to 77% of electricity is consumed by lighting and appliances used for water heating, cooking, cold storage, and laundry in urban high-medium income households in South Africa (UNEP-SBCI, 2009: 29). The MEPS and energy labels target this large segment, with the NEES targeting an overall 33% reduction in average specific energy consumption of new household appliances purchased by 2030 (with a 2015 baseline) (DEA, 2016: 22).

Achievable impact – As appliances typically have a lifespan of between 7 and 20 years (CBI, 2017: 12), the shorter lived appliances have only one or two upgrade cycles between 2020 and 2030. Recently purchased appliances with long lifespans may not be replaced by 2030 at all. To reach the 33% NEES target, it is proposed that two successive tightenings of the MEPS take place before 2030. Assuming a uniform distribution of appliance lifespans and purchase dates, 75% of the current appliances will be replaced at least once by 2030.

A study by Götz *et al*. (2016: 8) on the impact of the South African MEPS that came into effect in 2015, showed that the vast majority of appliances had already met the minimum standard by 2014, indicating that no further efficiency gains can be expected, unless the current standard (2015 MEPS) is raised. On the assumption that a 15% tightening of the MEPS takes place by 2021, 54% of equipment in households by 2030 will be based on the new MEPS, resulting in an average specific energy consumption reduction for appliances of 8%. Given that 77% of total household energy consumption is from appliances in urban high-medium income homes, the improved MEPS could result in a 6% reduction in residential energy intensity by 2030. With 30% of energy consumption in these homes due to water heating (UNEP-SBCI, 2009: 29), there may be an overlap and double counting of the savings targeted under the improved MEPS and the improved NBR discussed in section 4.1.1. Discounting any improvements in the water-heating category to account for possible overlap in savings would then provide a potential 4% reduction in residential energy intensity by 2030, due to improved MEPS.

4.1.5 The impact of educational programmes

According to the NEES, campaigns to provide energy conservation and sustainable energy information should continue, so that consumers can positively respond to market signals such as the labelling of energy-efficient appliances. It does, however, recognise that these programmes are often aimed at middle- and upper-income groups, and suggest that municipalities develop programmes specifically aimed at low-income groups. These groups often spend a disproportionate amount of household income on energy and suffer from the health consequences associated with using biomass for cooking and heating (DEA, 2016: 21; SEA, 2017: 1).

However, it is often impossible to separate the energy improvement, due to behavioural changes from equipment replacement (Lopes, Antunes & Martins, 2012: 4095), and the NEES does not set an energy intensity reduction target based on this proposed measure.

4.2 The impact of voluntary, market-driven energy efficiency strategies and tools

Table 3 summarises the findings regarding the potential impact of voluntary, market-driven Energy Efficiency strategies and tools, before providing a review of this information.

4.2.1 The impact of small-scale embedded generation (PV solar)

The pace of newly installed small- and medium-scale private generation of solar electricity in South Africa is increasing, with 150 to 200 MW_p capacity[7] estimated to have been installed in 2018, from an overall installed capacity of roughly 430 MW_p in 2017. This is due to two key factors, namely the above-inflation increases of electricity prices of over 300% in the past decade, and the fall in the international price for solar PV installations to approximately a quarter of what they were seven years ago. Locally, the cost of PV for both residential and commercial (sub-utility) is projected to drop below the cost of an ESKOM supply by 2020 (GreenCape, 2019: 10).

7 MW_p, which denotes megawatt peak, is a typical measure of a solar PV plant generating capabilities under standard test conditions.

Table 3: Potential energy intensity reduction by voluntary and market-driven building efficiency tools

	Tool	*Focus area: Energy efficiency*	*Focus area: Low carbon energy source*	*Focus area: Embodied energy*	*Achievable impact based on the reach of the tool*	*Potential energy intensity reduction*
Voluntary tools: Market-driven energy efficiency strategies commonly utilised in South Africa	Solar PV	Not a focus area, but typically encouraged as energy efficiency reduce costs of PV installs	Yes	No	Up to 1% reduction in residential energy intensity by 2030.	1%
	Green building certification - EDGE	Yes	Not required, but encourage to achieve EDGE Advanced or EDGE Zero	Yes Refurbishes get recognised for material re-use	Up to 0.5% reduction in the energy intensity of the sector by 2030.	0.5%
	Green building certification - Net Zero	Yes	Yes	Not current certification focus, but will be included in future versions	Up to 0.25% reduction in the energy intensity of the sector by 2030.	0.25%
	Green home loans	Yes	Yes	No	Facilitates the investment into technologies that reduce the sector's energy intensity, impact not quantified	~
	Green bonds	Yes	Yes	Yes	Facilitates the investment into technologies that reduce the sector's energy intensity, impact not quantified	~

Focus area – While the installation of solar PV or other alternative energy sources does not equate to improved energy efficiency, energy-efficiency improvements are often promoted as the first step before progressing to solar energy. Lower energy consumption, due to energy efficiency improvements, reduces the size and cost of the alternative energy system required (Vieira, 2006: 2; Matt Power for Green Builder Media, 2016; SEA, 2017: 4; GBCSA, 2019: 48; D'Agostino & Mazzarella, 2019: 2470).

Reach – Solar PV has a much better business case in commercial applications than in residential applications, due to a mismatch between residential peak electricity demand and peak solar power generation, with some local suppliers advising against a solar system if it is not grid-tied (Green Energy Solutions, 2019). Solar PV is also more common with owner-occupied properties than with rental properties, as the benefit primarily accrues to the occupant. Some commercial property developers and managers in both the residential and non-residential sector do, however, install PV solar on their properties for on-selling the solar energy to the tenant, and to improve the 'green' characteristics and marketability of the property.

Achievable impact – Depending on the system size and tariff structure, residential solar PV projects can have a typical payback period of between 12 and 20 years. Commercial projects typically have a payback period of 10 years or less, making PV solar projects in this sector a more reasonable business case. Due to these factors, residential Small-Scale Embedded Generation (SSEG) market penetration tends to be low, with world leader Australia having achieved a penetration rate of 15% by 2015, while Belgium has a rate of 7% (SEA, 2017: 223).

While Section 12B of the Income Tax Act allows companies to accelerate capital depreciation of renewable energy assets, there are currently no tax incentives aimed at the homeowner in the residential market. A potential residential SSEG consumer can either be incentivised or discouraged through the SSEG tariff structure that municipalities develop, but a cost-reflective SSEG does not pose a significant threat to a municipality's financial sustainability, even at penetration rates as high as 20% (SEA, 2017: 226).

The IRP 2019 currently places a cap of 500 MW additional SSEG capacity per year (DMRE, 2019: 42), and the market is expected to grow to this saturation point from the current rate of approximately 200 MW of new systems per year (GreenCape, 2019: 21). If this point is reached in the next five years, the overall installed SSEG capacity will be roughly 5 GW in 2030, equating to 6% of the total installed generating capacity in the country. Assuming the residential sector remains at 15% of the installed systems (GreenCape, 2019: 22), it would represent a 1% reduction in the energy intensity of the residential sector by 2030.

4.2.2 The impact of EDGE certification

EDGE certification, developed by the International Finance Corporation to stimulate the uptake of energy-efficient buildings in developing countries, is used in 140 countries worldwide. EDGE positions itself as both a free online assessment tool and a certification system, so that architects and engineers can quickly identify low-cost, high-return design alternatives before (or instead of) committing to perusing certification. EDGE can thus help determine, at a concept level, the financial viability of a project's green building initiatives early in the design stage (GBCSA, 2017).

The online assessment tool has been localised for South Africa concerning the local climate, utility costs, standard construction and system specifications, in addition to building regulations, thus allowing it to accurately calculate a building's inputs and consumption (IFC, 2018b: 2). The EDGE assessment tool presents the building's potential utility savings and reduced carbon footprint against a base case (IFC, 2018a).

Focus area – To pursue certification, the EDGE standard of 20% less energy use, 20% less water use, and 20% less embodied energy in materials compared to a base case building[8] must be achieved, which is then independently verified and certified. This makes EDGE one of the only green building certification schemes that explicitly address the embodied energy or 'upfront carbon' of constructing buildings. In 2019, additional levels of certification became available in the form of EDGE Advanced and EDGE Zero Carbon, which require 40% less energy use and 100% carbon neutral, respectively. Low carbon energy sources are not required for the standard EDGE certification, although achieving EDGE Zero Carbon would involve either renewable energy sources or carbon offsets.

Reach and achievable impact – Many local residential EDGE certifications are being pursued by developers in the affordable or gap housing market, primarily due to the social co-benefits that have attracted funding by development finance institutions, but also for market differentiation. The International Housing Solutions Fund II has enabled the development of 5 000 EDGE certified residential units, of the nearly 10 000 certified units between 2017 and 2019 (CSS, 2019: 11). With between 40 000 and 50 000 residential buildings being completed annually, EDGE certified units could represent up to 10% of all new homes being constructed annually.

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8 EDGE models its saving projections as a function of exceeding the consumption of a base case building with the same overall dimensions, which in South Africa would be a building that meets the National Building Regulation requirements.

By 2030, 32% of the formal housing would have been built after 2030 (Quantec, 2018), meaning that up to 3% of the total housing stock could be EDGE certified. As EDGE certification requires buildings to be at least 20% more efficient than the local building codes, it could equate to a 0.5% reduction in the energy intensity of the sector by 2030.

4.2.3 The impact of Net Zero certification

Net Zero Carbon buildings have net zero emissions, typically by being a highly energy-efficient building with very low energy demand, the remainder of which is met through zero carbon energy sources such as PV solar. While there are a variety of definitions for Zero Energy or Zero Carbon buildings (D'Agostino & Mazzarella, 2019: 2471), they typically all require that a building produces at least as much emissions-free energy as it uses from emission-production sources (CBI, 2017: 34; GBCSA, 2019: 13; WorldGBC, 2019c). The South African National Development Plan Vision 2030 (NDP 2030) set the objective of creating a national zero emission building standard by 2030, through the progressive strengthening of energy efficiency standards of the National Building Regulations (Government of South Africa, 2012: 288). The GBCSA's Zero/Net Positive certification programme launched in 2017 aims to accelerate the transformation of the market towards this goal. Projects in South Africa can pursue Net Zero certification as part of other certifications offered by the GBCSA, such as Green Star or EDGE, or as a stand-alone submission.

Focus area – Energy efficiency and low carbon energy are generally required for Net Zero certifications, which will typically set a minimum level of energy efficiency. Only once this level is reached can the remainder of the energy needs be produced from low carbon energy sources, such as PV solar, or by purchasing carbon offsets. Embodied energy is not currently included as a focus area in most of the Net Zero certifications, although it may be included in future versions (WorldGBC, 2019d).

Reach and achievable impact – To meet the 2-degree goals[9] provided by the IPCCC, net zero emissions for all sectors must be reached by 2050 or earlier. In support of this, several organisations are calling for net zero buildings, with typical targets set as 2030 for all new builds and 2050 for existing buildings (GlobalABC & UNEP, 2016: 18; WorldGBC, 2018a). Currently, net zero new builds make up less than 5% in most of the markets (IEA & UNEP, 2018: 37). While the South African National Development Plan Vision 2030 set the objective of creating a zero-emission building

9 The Paris Agreement (2015: 29) aims to hold "global average temperature to well below 2°C above pre-industrial levels" and to pursue "efforts to limit the temperature increase to 1.5°C above pre-industrial levels".

standard by 2030, the post-2015 NEES targets only a 38% energy consumption reduction, due to improved NBR requirements.

In the absence of specific government-mandated net zero requirements for the residential market, it is assumed that South African new builds will not exceed the typical 5% penetration rate. As PV solar is typically key to generating the energy in net zero building, it is assumed that the residential versus non-residential split in net zero buildings will be similar to that of the PV spread in South Africa, where only 15% is due to the residential market.

Thus, a residential penetration of net zero is assumed as reaching a maximum of 0.75% of the market. An evaluation of South Africa's housing data (Quantec, 2018) indicates that 33% of formal households, projected to have been built by 2030, will be built after 2015, meaning up to 0.25% of all formal houses could be net zero in 2030. As Net Zero certification requires a building to produce as much emission-free energy as it consumes, it could equate to a 0.25% reduction in the energy intensity of the sector by 2030.

4.2.4 The impact of green financing

Internationally, there is a robust appetite for green bonds, which is evident in the scale of oversubscription and other benefits when they are issued (CBI, 2017: 13; CSS, 2019: 3; Walker, 2019). These bonds are accessed by aggregators, including residential property investors and home loan providers such as banks and home loan companies (CSS, 2019: 34). Green home loans and green bonds facilitate the investment into technologies that reduce energy intensity, whether through energy efficiency, renewable energy, or thermal envelope upgrades. Some have argued that, in the absence of a global carbon pricing scheme, green bonds are key to financial climate change mitigation projects (Blanding, 2019). Still, questions have been raised as to whether those projects would not have taken place, despite the availability of green bonds (Walker, 2019). The impact of green financing is thus poorly defined, and no energy intensity reduction is quantified based on this measure.

Figure 4 summarises the key findings of the preceding review of the common residential building efficiency tools used in South Africa and an interpretation of their impact within this context.

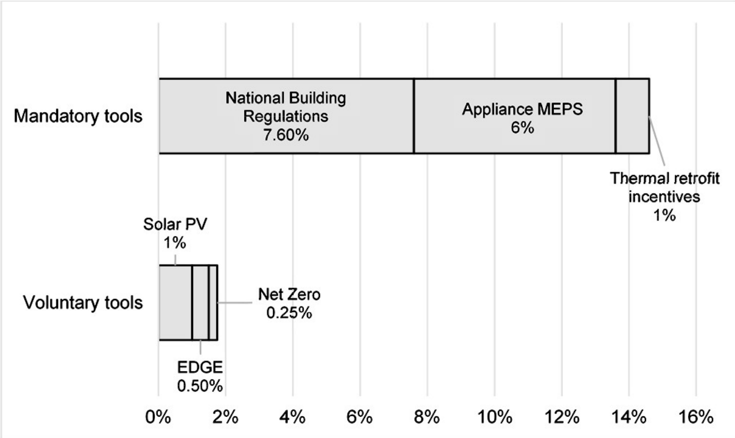

Figure 4: Energy intensity reduction potential of different building efficiency tools commonly used in South Africa

Source: Author's own

Given the review of the current proposed energy efficiency improvements as per the post-2015 NEES and commonly used voluntary tools in the residential market, it is possible that, by 2030, there could be up to a 16% reduction in the energy intensity of the residential sector (see Figure 4).

If the South African residential market continues to grow at its current pace of roughly 2% per year (Quantec, 2018), the housing market will be nearly 40% larger in 2030 than it was in 2015. This means that the projected potential of a 16% reduction in the energy intensity (measured as energy consumed per square metre) will be more than offset by the increased building floor area. This shows that the current targets are insufficient to meet the peak, plateau and decline trajectory of our INDC as they relate to building emissions specifically, and that more ambitious targets must be set and implemented within a reasonable time frame.

The projected massive growth in the South African housing market over the next decade and beyond shows that tools focused on the new residential market are critical. Over 80% of the total potential for energy intensity reduction can be derived from the mandatory tools that focus on the new build sector, namely the National Building Regulations and minimum performance standards for appliances.

5. CONCLUSION

What then is the building emission reduction potential of South African residential building efficiency tools? The dominance of the potential impact of mandatory tools seems to confirm what others have stated, namely that voluntary green building certifications do not directly contribute to a significant change in the residential sector's emissions, although they are becoming more common and demonstrate the tangible feasibility of low or zero carbon buildings (IEA & UNEP, 2018: 36). Mandatory regulations must thus continue to be updated timeously, with standards (based on scientifically obtained targets) being tightened, and enforcement strengthened. These areas are often sorely lacking in South Africa, where draft documents can linger in limbo, and they are no longer able to provide the desired positive impact.

While the projected energy reduction (due to small-scale embedded solar) is relatively small in the medium term, the impact of a decarbonised electricity grid is significant. If the IRP 2019 is followed, coal-generated electricity will contribute 60% of the energy mix in 2030, down from the current level of 90%. This could result in a 35% reduction in the carbon emissions of the residential sector, due to fuel switching alone (Mey, 2020: 73).

Finally, despite providing a third of the potential carbon reduction potential, the embodied energy of materials remains a poorly understood and a largely ignored improvement area, featuring in only two of the voluntary tools and not in any of the mandatory tools. Accordingly, in late 2019, the World Green Building Council launched a "Bringing Embodied Carbon Upfront" campaign to create a conversation around embodied energy and to further stimulate embodied carbon reductions. This is an area that deserves additional focus by all, given its large untapped potential.

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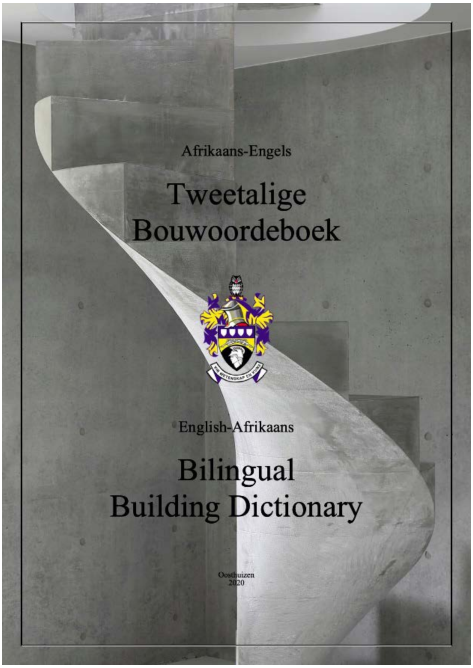
ENGLISH-AFRIKAANS BILINGUAL BUILDING DICTIONARY



Title: English-Afrikaans Bilingual Building Dictionary/ Afrikaans-Engels Tweetalige Bouwoordeboek

Author: Die Suid-Afrikaanse Akademie vir Wetenskap en Kuns

Publisher: Sunbonani Media
Ninth print: 2020

With originating roots scattered across the globe, this playful language derived its name from Africa. What is more unique to South Africa than Afrikaans? A communication medium amalgamated, adapted and applied by mothers from different cultures and continents who not only chose South Africa as their *domicilium citandi et executandi*, but also to raise their children through a unique South African mother tongue. By accommodating variety, this language tends to be inclusive against the norm, which might explain why Afrikaans is the preferred *lingua franca* in many parts of the country. Since the tower of Babel, building sites are recognised as a gathering of miscellaneous cultures and languages in dire need for a bridging communication medium. Phenomenally, evolved through time, building terms were and still are being born. The pregnancy period for the first bilingual building dictionary took longer than expected and was only delivered in 1960 by the "Vaktaalburo", a division of the South African Academy of Science and Art. Thirty years and eight prints later saw the last issue of this document. This year, the year of the COVID-19 world pandemic, marks sixty years after the first publication and thirty years since the previous print. This 2020 edition contains over 1,480 additional Afrikaans and English building terms, mainly obtained from a collection of building documents. Where else will you find Afrikaans and English built environment abbreviations and metric units than in a building dictionary? The appearance of this document has been renewed, revised, and attuned with page letter tags and affluent guided headers to quickly allocate terms. A surprisingly valuable educational addition to this dictionary is the 360 colourful illustrations and explanations weaved through the pages. In conclusion, this 2020 English-Afrikaans Bilingual Building Dictionary is a long overdue, well-crafted revision, now available to fill that reserved space on the bookshelves of professionals, practitioners, academics and students in the built environment. With a concrete spiral staircase on a gloss cover, the dictionary will be effortlessly distinguishable from other books in all good bookstores throughout South Africa. Alternatively, contact the publisher, Sunbonani Media (liezel@sunbonani.co.za or (051) 444 2552), for printed and electronic copies.

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2. Voornemende outeurs moet 'n elektroniese kopie van 'n artikel in MS Word formaat (oorspronklike word deur die outeur bewaar) voorlê deur dit per e-pos aan te stuur (sien e-pos adres by punt 28.).

3. Enige toepaslike artikel, in 'n verstaanbare skryfstyl, duidelik uiteengesit en reeds taalversorg, word verwelkom, vergesel van 'n verklaring dat dit die oorspronklike werk van die outeur(s) is en dat die artikel slegs aan *Acta Structilia* aangebied is.

4. Tabelle en figure: Daar moenie meer as 10 figure en tabelle in totaal per artikel wees nie. Alle onderskrifte moet in die teks verskaf word. Afkortings/akronieme wat in figure en tabelle gebruik word, moet in die opskrif/sleutel of voetnoot verduidelik word. Figure moet gestuur word in hoë resolusie TIFF formaat (vermy gekomprimeerde formate soos GIF en JPEG). Maak seker dat die figure duidelik en leesbaar sal wees wanneer dit verminder word. Tabelle moet in 'n geredigeerde formaat in Word of Excel ingedien word en nie as foto's nie. Excel lêers moet opgelaai word as individuele spreivelle, nie die hele werkboek nie.

5. Die hoofredakteur behou die reg voor om die artikel(s) te verander waar nodig met betrekking tot die styl en aanbieding van die publikasie. As uitgebreide wysigings deur die beoordelaars aanbeveel word, sal die artikel(s) aan die outeur teruggestuur word.

6. Kopiereg word aan die outeur(s) by aanvaarding van die artikel oorgedra.

7. Teksgedeeltes van artikels moet in Microsoft Word, Ariel skrif, font grootte 12, enkel spasiëring gedoen word.

8. Die titel van die artikel moet kort en bondig wees en in beide Afrikaans en Engels aangebied word. Voorsien gepaste opskrifte en subopskrifte waar nodig.

9. 'n Kort opsomming (tussen 200-250 woorde), in beide Afrikaans en Engels, moet aan die begin van die teks aangebring word.

10. Toepaslike sleutelwoorde in Afrikaans en Engels moet onder die opsomming aangebring word.

11. Die opsomming moet begin met 2-3 sinne wat 'n inleiding tot die studieveld gee en die spesifieke probleem wat ondersoek word, gevolg deur 'n enkelsin oor die hoofbevindings (of gevolgtrekkings, in die geval van 'n oorsigartikel), en 'n verdere 2-3 sinne wat hierdie bevindinge/gevolgtrekkings in konteks plaas sodat lesers bewus gemaak word van die implikasies van die bevindings. Gewoonlik word bronverwysings nie in opsomming gegee nie.

12. Literatuuroorsigte moet internasionale navorsing oor soortgelyke onderwerpe identifiseer en 'n duidelike gaping in navorsingsartikels met betrekking tot internasionale voorpuntnavorsing aandui. Skrywers moet duidelik demonstreer hoe hul navorsing verband hou met dié van ander geleerdes oor soortgelyke onderwerpe.

13. Die belangrikheid van die hoofbevindinge of gevolgtrekkings behoort nie 'n opsomming van die resultate te wees nie, maar moet die bydrae wat die resultate tot die veld lewer, weerspieël en ook hoe die resultate in hulle onderskeie velde en op ander terreine van toepassing is. Die bevindinge moet begin met algemene bydraes en voortgaan met meer spesifieke bydraes. Die belangrikheid van die bevindings sal gepubliseer word met die doel om groter belangstelling te bevorder, nie net onder lesers in die veld nie, maar ook vir ander lesers. Die belangrike bevindinge moet dus vir 'n nie-spesialis geskryf word.

14. Opskrifte en onderskrifte word in Arabiese syfers genommer, geskei deur 'n punt en hoogstens tot drie vlakke, waarna 'n letter in hakies gebruik word, bv. 1. en 1.1 gevolg deur 1.1.1 en daarna a) ens.

15. Bronverwysings in die teks geskied volgens die Harvardstyl van verwysing: (Outeur, datum: bladsynommer[s]): bv. (Schleien, 2014: 20-23).

16. Net egte voet- en eindnote met die tersaaklike inligting moet gebruik word. Die Harvardstyl van verwysing is hier van toepassing.

17. Die verwysingslys volgens die Harvardstyl van verwysing moet volledig in alfabetiese volgorde aangebied word. Bv. Sun, M. & Howard, R. 2014. *Understanding I.T. in construction*. London: Spon Press.

18. 'n Kopie van alle internet dokumente wat in die teks verwys en gelys is in die bibliografie, moet die artikel vergesel.

19. Aanhalings word nie kursief gedruk nie, en word in dubbelaanhalingstekens aangedui. Invoegings binne aanhalings word in blokhakies aangedui. Aanhalings wat langer as drie reëls is, word geïndenteer en het nie aanhalingstekens nie.

20. Slegs standaard-afkortings word aanbeveel. Afkortings vir instellings kan gebruik word nadat dit vir die eerste keer volledig uitgeskryf is, met die afkorting daarna in hakies, vir terugverwysing.

21. Kursief moet nie oormatig gebruik word nie, indien wel, slegs vir konvensionele Latynse uitdrukkings bv. *per se* en vir woorde in ander tale.

22. Beklemtonings kry enkelaanhalingstekens.

23. Besonderhede van die oorsprong van 'n artikel moet aangedui word, soos in die geval van 'n kongresreferaat. Artikels word net vir keuring oorweeg indien vergesel van 'n verklaring dat dit in geheel of gedeeltelik nie elders vir publikasie voorgelê is, of reeds gepubliseer is nie.

24. Artikels word anoniem gerefereer. Die outeur(s) kan die name en adresse van tot drie vakkundiges (nie aan outeur[s] se eie instansie van werk verbonde nie) voorstel wat as referente sou kon optree.

25. Die outeur(s) van artikels wat geplaas word, sal elk twee komplimentêre kopieë van die betrokke uitgawe van *Acta Structilia* ontvang.

26. 'n Artikel moet vergesel word van die volledige titel, kwalifikasie en affiliasie, adres, telefoon- en faksimiliee-nommers en indien moontlik 'n e-posadres van die betrokke outeur(s).

27. Neem kennis dat 'n publikasieheffing van R50 per bladsy op die artikels wat gepubliseer word, betaalbaar is. 'n Faktuur sal aan die hoofouteur gestuur word.

28. Rig u bydrae(s) aan:

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