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The Impact of Climate Change on the Built Environment: Built Environment Professionals' Perceptions and Practices

The built environment contributes to GHG emissions, the increase in the earth's surface temperature has resulted in forced climate change, and climate change has been linked to the increase, severity, and frequency of natural disasters. The study investigated the effects of climate change on the built environment. A self-administered questionnaire was completed by 39 built environment professionals (BEPs). Findings include: respondents understand the extent to which activities/ processes contribute to GHG emissions, the extent to which manifestations are caused by climate change, and the extent to which climate change impacts on the built environment. Conclusions include: increasing urbanisation contributes to the built environment's contribution to GHG emissions; climate change has impacted on the built environment in several ways, and South African designers' climate change knowledge is inadequate. Recommendations include: green transition strategies must be accelerated; new investments must focus on decarbonisation; new construction projects should be energy efficient; the use of renewable energy must be incorporated into new structures; existing buildings must be retrofitted to reduce energy usage; climate change information should be easily accessible, and tertiary education should include sustainable design and construction processes.

Keywords: *built environment, climate change, impact*

Introduction

According to Wentz (2015), climate change and its effects on temperature, precipitation, storm patterns, sea level, and other environmental processes have important implications for the construction, maintenance, and operation of buildings and infrastructure. The US Global Change Research Program (2018) in turn states that vulnerabilities within the built environment have been revealed by extreme weather conditions, which affects the population who spend most of their time in these urban areas.

The aim of the study reported on is to investigate the effects of climate change on the built environment, and to evolve a framework of built environment interventions to mitigate climate change. The objectives are to determine the:

- sources and level of knowledge of South African designers relative to climate change and climate change mitigation strategies;
- extent to which climate change manifestations negatively affect the built environment;
- extent of the impact of climate change on the built environment;
- extent to which eight interventions seek to reduce GHG emissions, and
- importance of nine climate change mitigation interventions to respondents' practices.

Literature Review

Greenhouse Gas Emissions

GHG emissions from the construction industry have more than doubled since 1970, reaching 9.18 Gt CO_2eq in 2010 (Lucon, et al., 2014). During 2019, building sector emissions increased by 0.9%, reversing a large departure from the long-term trend (+0.1%) in 2018, when emissions soared by 3.2%. In the G20, building-related CO_2 emissions account for 24.4% of total energy-related CO_2 emissions. However, since 2005, emissions in the building sector have grown at a slower rate than those in the manufacturing and transportation sectors.

Buildings account for 22% of South Africa's CO_2 emissions due to direct and indirect energy use (Climate Transparency, 2020). This in turn has an impact on the country's capacity to achieve its Paris Agreement obligations, which aim to mitigate the consequences of global climate change (Bosshoff, *et al.*, 2020).

To reduce emissions, cost-effective solutions and best practices must be implemented, particularly in developing nations where millions of people are receiving homes, power, and improved cooking facilities (Climate Transparency, 2020).

Manifestations that Negatively Affect the Built Environment

Recent climate-related extremes, such as heatwaves, droughts, floods, cyclones, and wildfires, reveal that some ecosystems, and many human systems, are vulnerable and exposed to current climatic variability. Ecosystem disruption, disruption of food production and water supply, damage to infrastructure and communities, sickness and mortality, and ramifications for mental health and human well-being are all outcomes of such climate-related extremes. These effects are consistent with a considerable lack of readiness for current climatic variability in some industries for countries at all levels of development (Field, *et al.*, 2014).

Impact of Climate Change on the Built Environment

Many structures are vulnerable to climate change and harsh weather occurrences. Increased precipitation, thawing permafrost, more frequent wildfires, severe storms, and floods are some of the consequences. This vulnerability is going to worsen until more investment is in improving resilience. The vulnerability of developed assets is determined by their location, and the construction industry is directly impacted. Extreme precipitation may cause building delays and increased costs. Climate change has the potential to impact the duration of 'building seasons'. More rebuilding and repair work is required as extreme weather patterns change (Chalmers, 2014).

The rising frequency and intensity of heatwaves also have ramifications for building design; possibly signalling a need to shift away from current architectural designs and toward new ones for new construction. Climate-related energy demand will shift as temperatures rise. Increased prosperity will be the main driver of increasing energy demand in low-income countries, which frequently have warmer climates. This will primarily be for air-cooling and transportation. Without additional mitigating initiatives, worldwide air-conditioning energy demand is expected to rise from roughly 300 TWh in 2000 to approximately 4000 TWh in 2050 (Chalmers, 2014).

Furthermore, increases in precipitation frequency, intensity, and duration, as well as peak wind loads and the frequency with which high winds occur. As a result, intense wind-driven rain events are projected to become more common in the future. As a result, the exterior of the building will be exposed to more intense climate loads for longer periods, increasing the risk of premature degradation of building elements such as the roof, wall, and fenestration systems, as well as the risk of water entry, resulting in moisture-related problems (Lacasse, *et al.*, 2020).

For decades, scientists have recognised the broad climate characteristics linked with climate change as they relate to effects on buildings. The number of relevant methods, techniques, and recommendations for strengthening the climate resilience of new and retrofit buildings demonstrates the need for climate resilience in buildings (Lacasse, *et al.*, 2020).

Interventions to Reduce GHG Emissions

According to Gallego-Schmid *et al.* (2020) material reuse stands as the most promising circular economy solution for reducing GHG emissions.

To effectively reduce GHG emissions and handle other climate-related challenges, international cooperation is essential. In addition, mitigation-related research and development generate knowledge spillovers. International cooperation in turn can help to produce, disseminate, and positively transfer knowledge (Edenhofer, *et al.*, 2014).

Climate Change Mitigation Interventions

Climate change mitigation requires not only the creation of a sustainable environment but also the development of a sustainable economy based on renewable energy resources. As people become more aware of the severity and breadth of future climate change, the term 'sustainability' has become a household term (Lackner, *et al.*, 2015).

Methodology

The sample stratum included built environment professionals (BEPs) - architects, construction managers, electrical and mechanical engineers, and project managers.

102 Self-administered questionnaires were distributed to participants and 39 completed questionnaires were returned, which equates to an overall response rate of 38.2%. The questionnaire consisted of 20 questions - 11 closed ended Likert scale type questions, 3 open-ended, and 6 close ended demographic questions.

The analysis of the data captured in MS Excel included the computation of descriptive statistics in the form of frequencies and mean scores (MSs), a measure of central tendency.

Results

Table 1 indicates the occupation of respondents. Architectural Technologist (35.8%) predominates, followed by architect (28.2%), and Project Manager (15.3%). The other four occupations were represented by 7.6% and less of respondents.

Table 1. *Occupation of Respondents*

Occupation	No.	%
Architectural Technologist	14	35.8
Architect	11	28.2
Project Manager	6	15.3
Mechanical Engineer	3	7.6
Electrical Engineer	3	7.6
Architectural Administration	1	2.5
Interior Design	1	2.5

25 Respondents reside in Durban, 8 in Cape Town and 3 each in Johannesburg, and Port Elizabeth, a total of 39 No.

Table 2 indicates the frequency at which respondents attend three activities to enhance their knowledge of climate change in terms of a MS with a minimum value of 1.00 and a maximum value of 5.00, based on percentage responses to a range of never to monthly. It is notable that no MSs are > 3.00, which indicates that respondents attended these activities infrequently, as opposed to frequently, as in the case of MSs ≥ 3.00.

Climate change courses and programmes (online courses included), climate change seminars hosted by your practice, and climate change seminars hosted by your local municipal council all have MSs ≥ 1.00 ≤ 1.80 indicating that respondents attended the climate change activities between never to annually.

Table 2. *Frequency at which Respondents Attend Three Climate Change Activities*

Activity	**MS**	**Rank**
Climate change courses and programmes (online courses included)	1.22	1
Climate change seminars hosted by your practice	1.16	2
Climate change seminars hosted by your local municipal council	1.11	3

Table 3 indicates the extent to which respondents obtain climate change information from eleven sources in terms of a MS with a minimum value of 1.00 and a maximum value of 5.00, based on percentage responses to a range of 1 (minor) to 5 (major). It is notable that only 2 / 11 (18.2%) MSs are > 3.00, which indicates that respondents obtain climate change information through these sources to a major as opposed to a minor extent, as in the case of MSs ≤ 3.00 (81.8%).

The MS of the internet is > 3.40 ≤ 4.20, which indicates that respondents use this source as the preferred method to obtain climate change information between some extent to a near major / near major extent. Furthermore, the MS of television is > 2.60 ≤ 3.40, which indicates that respondents use this source as a method to obtain climate change information between a near minor extent to some / some extent. 6 / 11 (54.4%) MSs are > 1.80 ≤ 2.60, indicating that respondents use specialist publications / academic journals, friends and colleagues, environmental groups, college / university, newspaper, and government agencies as a method to obtain climate change information between a minor to near minor / near minor extent. Furthermore, 3 / 11 (27.7%) MSs are ≥ 1.00 ≤ 1.80, indicating that respondents use the radio, local council, and public libraries between a minor to near minor extent.

Table 3. *Extent to which Respondents Obtain Climate Change Information from Eleven Sources*

Source	MS	Rank
Internet	3.92	1
Television	3.05	2
Specialist publications / academic journals	2.53	3
Friends and colleagues	2.50	4
Environmental groups	2.30	5
College / University	2.18	6
Newspaper	2.17	7
Government Agencies	1.89	8
Radio	1.79	9
Local council	1.45	10
Public libraries	1.28	11

Table 4 indicates the respondents' rating of their knowledge relative to seven aspects in terms of a MS with a minimum value of 1.00 and a maximum value of 5.00, based upon percentage responses to a range of 1 (limited) to 5 (extensive). It is notable that only 1/7 (14.2%) MSs is > 3.00, which indicates that the respondents' knowledge relative to the one aspect is extensive as opposed to limited, as in the case of MSs ≤ 3.00 (85.8%).

However, all the MSs are > 2.60 ≤ 3.40, which indicates that the respondents' knowledge relative to GHGs from the built environment, greenhouse effect, climate change mitigation strategies, climate change future predictions, the effects of climate change on the built environment, and climate change history are below average to average/average.

Table 4. *Respondents' Rating of their Knowledge Relative to Seven Aspects*

Aspect	MS	Rank
Climate change	3.28	1
Greenhouse gas emissions from the built environment	2.94	2
Greenhouse effect	2.92	3
Climate change mitigation strategies	2.82	4
Climate change future predictions	2.79	5
The effects of climate change on the built environment	2.74	6
Climate change history	2.64	7

Table 5 indicates the extent to which eleven climate change manifestations negatively affect the built environment in terms of a MS with a minimum value of 1.00 and a maximum value of 5.00, based upon percentage responses to a range of 1 (minor) to 5 (major). It is notable that 11/11 (100%) MSs are > 3.00, which indicates that respondents can be deemed to perceive that the eleven manifestations negatively affect the built environment to a major as opposed to a minor extent, as in the case of MSs ≤ 3.00.

8/11 (72.7%) Manifestations' MS are > 3.40 ≤ 4.20, namely increasing intensity and frequency of extreme weather events, flooding, precipitation changes, heat waves, rise in sea level, drought, carbon emissions and wildfires, which indicates that respondents can be deemed to perceive that these manifestations negatively affect the built environment between some extent to a near major / near major extent. The manifestations ranked 9th to 11th have MSs > 2.60 ≤ 3.40, namely environmental pollution, ozone depletion, and air pollution, which indicates that respondents can be deemed to perceive that these manifestations negatively affect the built environment between a near minor extent to some extent/some extent.

Table 5. *Extent to which Eleven Climate Change Manifestations Negatively Affect the Built Environment*

Manifestation	**MS**	**Rank**
Increasing intensity and frequency of extreme weather events	4.19	1
Flooding	4.16	2
Precipitation changes	3.55	3
Heat waves	3.55	4
Rise in sea level	3.47	5
Drought	3.41	6
Carbon emissions	3.41	7
Wildfires	3.41	8
Environmental pollution	3.39	9
Ozone depletion	3.33	10
Air pollution	3.28	11

Table 6 indicates the extent to which climate change impacts on the built environment according to respondents in terms of a MS with a minimum value of 1.00 and a maximum value of 5.00, based upon percentage responses to a range of 1 (minor) to 5 (major). It is notable that 6 / 8 (75%) MSs are > 3.00, which indicates that respondents can be deemed to perceive that climate change has a major impact on the built environment in these six cases, as opposed to a minor impact, in the case of MSs ≤ 3.00.

The MS for increased energy usage for heating and cooling is > 4.20 ≤ 5.00, which indicates that respondents can be deemed to perceive that the impact of climate change in this case is between a near major impact to a major / major impact. The activities ranked 2nd to 4th have MSs 3.40 ≤ 4.20, which indicates that respondents can be deemed to perceive that climate change has between an impact to a near major / near major impact, in these cases. The last four ranked activities, namely reduced building lifetime, significant loss of value of buildings due to damage, increased building deterioration and building collapse, have MSs 2.60 ≤ 3.40, which indicates that respondents can be deemed to perceive that climate change has between a near minor impact to an impact / impact, in these cases.

Table 6. *Extent of the Impact of Climate Change on the Built Environment*

Impact	**MS**	**Rank**
Increased energy usage for heating and cooling	4.36	1
Increased design and building cost to address changing climate conditions	4.05	2
Increased design and building cost to comply with regulations	4.00	3
Increased cost of building maintenance	3.72	4
Reduced building lifetime	3.16	5
Significant loss of value of buildings due to damage	3.08	6
Increased building deterioration	2.88	7
Building collapse	2.84	8

Table 7 indicates the perceived extent to which the eight interventions seek to reduce GHG emissions according to respondents in terms of a MS with a minimum value of 1.00 and a maximum value of 5.00, based upon percentage responses to a range of 1 (minor) to 5 (major). It is notable that 8 / 8 (100%) MSs are > 3.00, which indicates that respondents can be deemed to perceive the eight interventions seek to reduce GHG emissions to a major as opposed to a minor extent, as in the case of MSs ≤ 3.00.

The use of renewable energy has a MS > 4.20 ≤ 5.00, which indicates that respondents can be deemed to perceive that this intervention seeks to reduce GHG emissions between a near major extent to major / major extent. The remaining 7 / 8 (87.5%) MSs are 3.40 ≤ 4.20, which indicates that respondents can be deemed to perceive that these seven interventions seek to reduce GHG emissions between some extent to a near major / near major extent.

Table 7. *Perceived Extent to which Eight Interventions Seek to Reduce GHG Emissions*

Intervention	**MS**	**Rank**
Use of renewable energy	4.28	1
Incorporating the most efficient cooling and heating	4.20	2
Appropriate orientation and location of buildings	4.15	3
Evaluate and measure a building's design carbon footprint as early in the design process as possible	4.05	4
Continuous insulation	3.97	5
Specify recycled materials for building and interior construction	3.94	6
Use of recycled water	3.92	7
Use of state-of-the-art lighting and optimisation of daylighting	3.84	8

Table 8 indicates the importance of nine climate change mitigating interventions to respondents' practices in terms of a MS with a minimum value of 1.00 and a maximum value of 5.00, based upon percentage responses to a range of 1 (not) to 5 (very). It is notable that 5/9 (55.5%) MSs are > 3.00, which indicates that respondents can be deemed to perceive that these five climate change mitigating interventions are more than important as opposed to less than important to their practices, as in the case of ≤ 3.00.

Design to optimised massing and orientation, and understanding how buildings perform in use have MSs > 3.40 ≤ 4.20, which indicates that respondents can be deemed to perceive that these two interventions are between important to more than important / more than important. The interventions ranked 3rd to 7th have MSs > 2.60 ≤ 3.40, which indicates that respondents can be deemed to perceive that these four interventions are between less than important to important/important. The remaining 2 / 8 (25.0%) MSs are > 1.80 ≤ 2.60, which indicates that respondents can be deemed to perceive that these two interventions are between not important to less than important / less than important.

Table 8. *Importance of Nine Climate Change Mitigation Interventions to Respondents' Practices*

Intervention	MS	Rank
Design to optimised massing and orientation	3.78	1
Understand how buildings perform in use	3.52	2
Continuous insulation	3.40	3
Use of renewable energy	3.24	4
Advising clients on mitigating climate change	3.03	5
Adapt and retrofit existing buildings	2.76	6
Use of recycled water	2.74	7
Reduce the use of concrete	2.30	8
Use of carbon smart material	2.25	9

Conclusions

The vast majority of GHG emissions released into the earth's atmosphere can be attributed to the built environment, and GHG emissions mostly originate from urbanisation.

The increase in the earth's surface temperature has resulted in forced climate change, and the latter has been linked to the increase, severity, and frequency of natural disasters.

The impact of climate change on the built environment manifests itself in several ways. The increase in natural disasters negatively affects the built environment in terms of causing building collapses, accelerating building deterioration, loss of value due to damage, and reduced building lifetimes. Furthermore, climate change has increased the cost of building maintenance, is responsible for the increase in energy usage for heating and cooling, and is responsible for an increase in design and building costs.

In terms of South African designers' climate change knowledge, it can be concluded that they: are largely uninformed with respect to global initiatives to combat climate change; rarely attend climate change-related seminars, courses, or programmes; have no real sources for updated climate change information, and are reasonably knowledgeable with respect to climate change, but make no additional contribution to implementing mitigating strategies.

The perceived extent of the impact of climate change on the built environment, and the perceived extent to which eight interventions seek to reduce GHG emissions leads to the conclusion that the respondents are knowledgeable with respect to the impact of climate change on the built environment, and the potential impact of the interventions.

Given the importance of nine climate change mitigation interventions to respondents' practices, it can be concluded that in general, they are not committed to mitigating climate change through built environment interventions.

Recommendations

Green transition strategies must be accelerated, and new investments must focus on the decarbonisation of all sectors of the economy.

New construction projects should be designed to minimise artificial heating and cooling and promote passive heating and cooling. Furthermore, the use of renewable energy must be incorporated into new structures and existing buildings must adapt and be retrofitted to reduce energy usage.

In terms of knowledge: strategies are required to better communicate climate change strategies to BEPs; climate change information should be easily accessible e.g., social media platforms to raise awareness, and tertiary education should educate BEPs in terms of sustainable design and construction processes.

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