Examining the impact of indoor environmental quality on individual productivity of knowledge workers in green certified buildings

Received 4 November 2022
Revised 1 March 2023
22 May 2023
Accepted 22 August 2023

Saul Nurick
Urban Real Estate Research Unit (URERU), Department of Construction Economics and Management, University of Cape Town, Cape Town, South Africa, and

Andrew Thatcher
Department of Psychology, School of Human and Community Development, University of the Witwatersrand Johannesburg, Johannesburg, South Africa

Abstract

Purpose – This paper aims to investigate green buildings and individual productivity, specifically within the context of indoor environmental quality (IEQ) within green certified office buildings. The purpose of the research was to determine how self-assessed productivity levels were influenced by the indoor environment of the office building.

Design/methodology/approach – Qualitative data analysis was conducted via semi-structured interviews in two financial services companies (FSCs), both based in green certified office buildings in South Africa. Thematic analysis was conducted to extract common themes from the data. Furthermore, the data were compared to previous research to identify new potential pathways or provide support for existing pathways.

Findings – The main findings were that physical components, such as temperature, lighting, ventilation and noise, contribute depending on the respondent to individual productivity, engagement, organisational commitment and psychological wellbeing. Safety, underpinned by location and amenities, was a new component not previously considered that subtly contributed to individual productivity.

Originality/value – The research provides valuable insight into the contributing factors that impact individual productivity within a green certified office building, as previous researchers have yet to reach a consensus on the relationship between individual productivity and IEQ in green certified office buildings.

Keywords Indoor environmental quality (IEQ), Financial services companies (FSCs), Productivity, Engagement, Comfort, Well-being

Paper type Case study

Urban Real Estate Research Unit (URERU), Department of Construction Economics and Management, University of Cape Town. University Staff Doctoral Programme (USDP) based at the University of Cape Town for the research funding to conduct the field work.

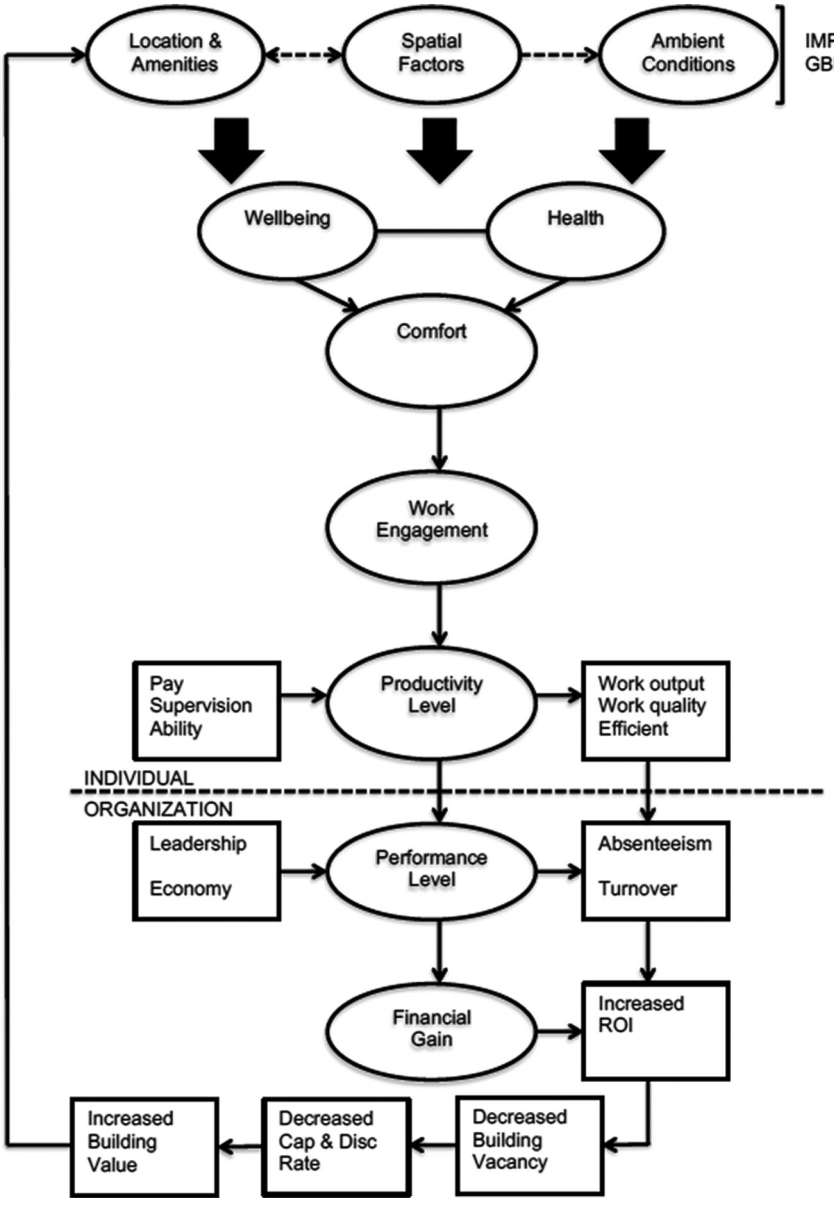
Journal of Corporate Real Estate
Vol. 25 No. 4, 2023
pp. 307-324
Emerald Publishing Limited
1463-001X
DOI 10.1108/JCRE-11-2022-0036

1. Introduction

The emergence of green building since the 1990s in developed real estate markets has mostly focused on the financial benefits (Milne, 2012), specifically building materials during construction and utility costs (water and electricity) during occupation. Indoor environmental quality (IEQ) is a category that is found in most mainstream green building tools (Green Building Council Australia (GBCA), 2015; Green Building Council of South Africa (GBCSA), 2015; United Kingdom Green Building Council (UKGBC), 2015; United States Green Building Council (USGBC), 2015), which has anecdotally resulted in green building advocates claiming that occupants based in green certified office buildings are more productive than their contemporaries located in conventional (non-green) buildings. There have been previous researchers who have attempted to link green building features and initiatives (GBFIs) to productivity to office building occupants. This has yielded mixed results due to the variety of methods and organisational contexts (Nurick and Thatcher, 2021b). Some researchers have found that certain GBFIs do enhance individual productivity (Harter *et al.*, 2003; Schwede *et al.*, 2008; Vischer, 2008; Singh *et al.*, 2010; Fisk *et al.*, 2011; Wiik, 2011; Gou *et al.*, 2012a; Gou *et al.*, 2012b; Alker *et al.*, 2014). Other researchers have found mixed results (Thatcher and Milner, 2012; Feige *et al.*, 2013; Byrd and Rasheed, 2016; Bortoluzzi *et al.*, 2018). Furthermore, Haynes (2008) states that the nature of human interaction (or distraction) in an office environment has the greatest direct impact on productivity. Miller *et al.* (2009) assessed the connection between the physical environment of green certified buildings and productivity but did not examine the psychological mechanisms that underpin these connections, such as mental well-being and overall health. Additionally, research by Newsham *et al.* (2017) indicated that some conventional (non-green certified) buildings outperformed some green certified buildings in terms of organisational productivity metrics.

1.1 Rationale

Typically, the implementation of GBFIs has underpinned green building certification. GBFIs have focused on both structural (materials and design) and operational (utilities) components of the building. Furthermore, some GBFIs are linked to IEQ in the form of location and amenities, spatial factors and ambient conditions, which impact the user experience of the building. Figure 1 developed by Nurick and Thatcher (2021a) exhibits the relationship between the implementation of GBFIs to well-being, health, comfort, work engagement and productivity. The aforementioned factors that influence productivity are interrelated, and therefore do not sit in isolation. Well-being (individual mental status) and health (individual physical condition) contribute to overall comfort (satisfaction with the physical working environment), which in turn has an impact on work engagement (ability to concentrate on a task), and thus productivity (ability to efficiently perform a work-related task) (Ildiri *et al.*, 2022). The theoretical model (Figure 1) indicates that if individual productivity is enhanced due to the implementation of GBFIs, then this could be transferred into improved organisational performance. The latter question about organisational performance was tested within the context of financial services companies (FSCs) based in green and non-green buildings by examining returns of South African financial products (Nurick, 2022), which indicated that there was improved performance in a group of FSCs located in green buildings compared to FSCs in non-green buildings in terms of the five-year annualised returns. The measurement of individual productivity within an office environment is somewhat challenging as output is not linear as would be the case in a factory/assembly line environment. Therefore, one of the common approaches to assessing individual productivity is to interview or survey office workers to ascertain their



Source: Nurick and Thatcher, (2021a, p. 29)

Figure 1.
Linking GBFIs to individual productivity and organisational performance

perceptions of what influences productivity in terms of physical and psychological comfort, engagement, organisational commitment and the ability to perform their work. This is either conducted via longitudinal or cross-sectional studies, which involve interrogating many of the aforementioned factors in relation to the physical building components that relate to IEQ (Wyon, 2004; Roulet *et al.*, 2006; Akimoto *et al.*, 2010; Fisk *et al.*, 2011; Chadburn *et al.*, 2017). It should be noted that much of the prominent research attempting to link individual productivity and organisational performance was conducted in the period between 2000 and 2020 (Nurick and Thatcher (2021b). This is due to uptake of green buildings in the late 1990s and early 2000s where advocates claimed that enhanced IEQ resulted in improved individually productivity, which resulted in many researchers investigating this claim with varying levels of success. However, generally, there have been no categorical results that have either supported or refuted the proposition that there is a direct link between enhanced IEQ and improved individual productivity and organisational performance. The relatively small number of peer-reviewed papers that have been published in the past five years have attempted to re-address this link, with a different theoretical lens, by taking a more philosophical approach in the form of developing theoretical models and the compilation of systematic and scoping literature reviews (Browning *et al.*, 2020; Mirzaei *et al.*, 2020; Sadick and Kamardeen, 2020; Bueno *et al.*, 2021; Colenberg *et al.*, 2021; Zitras *et al.*, 2021).

This paper addresses the following research question:

RQ1. What perceived impacts do green building features and initiatives have on individual productivity and organisational performance within an office environment?

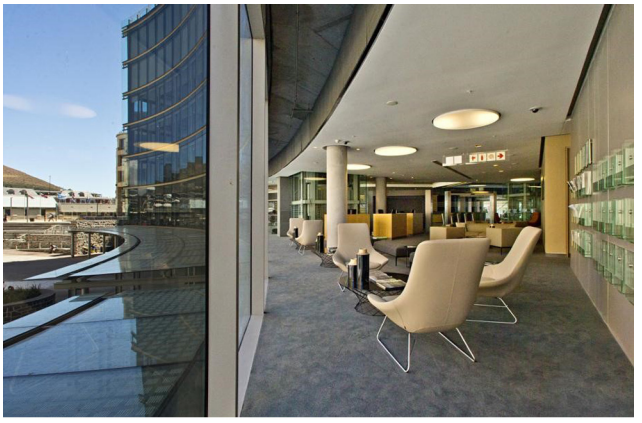
This paper focuses on individual productivity, as the organisational performance component of the research question is addressed in Nurick (2022). The unit of analysis in this study is the individual office worker located in a green certified building.

2. Method and research question(s)

2.1 Method

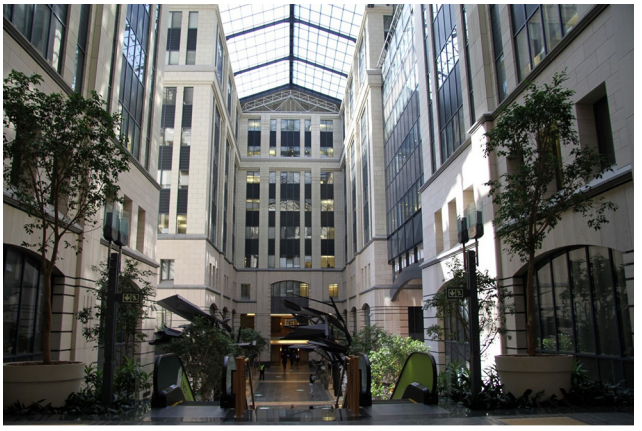
Data were collected via semi-structured interviews across two FSCs, which occurred over a two-day period for each FSC in 2022. Semi-structured interviews were deemed to be the optimum data collection method as this allowed for in-depth discussions with respondents to extract their thought processes in relation to GBFIs and their perceived impact on their individual productivity levels. The respondents, all skilled knowledge workers (i.e. university graduates), were purposively selected to represent employees contributing to the FSCs investment decisions who had been in the FSC for at least five years, so as to be comparable to Nurick (2022). The sample comprised individuals across different age ranges and levels within the respective FSCs. An email was sent to each FSC requesting respondents that met these specific criteria, as this was aligned with the quantitative research conducted by Nurick (2022) using FSCs. Employees who did not meet the aforementioned requirements were automatically excluded from participating in the study. Employees who met the inclusion criteria were emailed and invited to participate in the study. The engagement regarding the respondents thought processes and their reasoning would not have been possible using surveys. Case study 1 (CS1) is an investment company located in a Green Star South Africa (GSSA) six-star rated building in Cape Town, and received its as-built rating in 2014. The headline GBFIs are the double-skinned glazing that cover the entire external façade of the building, where there are two layers of windows, which are 1 m apart as a form of thermal insulation, and the

heating ventilation and air-conditioning system that makes use of sea water and the associated built-in floor air flow reticulation system. Case study 2 (CS2) is a bank located in a GSSA four-star rated building in Johannesburg, which obtained its certification in 2009, as a result of its "campus" design in a heavily urbanised commercial area. The main GBFIs associated with CS2 are the water and electricity management systems that future-proof the building from infrastructure failures, which tend to occur more often in Johannesburg. These systems also contributed to the centralised control of temperature and ventilation in the building. Figure 2 provides an insight in the interior fitout and external glazing of CS1, while Figure 3 is an image of the atrium of CS2. The main GBFIs and externalities for both cases are listed in Table 1. CS1 and CS2 comprised eight and seven respondents, respectively. Qualitative data was acquired and analysed using NVivo in the form of thematic analysis.



Source: Collaboration, (2014)

Figure 2.
CS1 interior fitout and external glazing



Source: Solid Green Consulting, (2011)

Figure 3.
CS2 atrium

Table 1.
Key GBFIs and externalities of CS1 and CS2

CS1	CS2
Double skinned glazed that covers the entire external façade	Water and electricity management systems
HVAC system using sea water and linked to built-in floor air flow reticulation system	Centralised control of temperature and ventilation
Internal atrium, which provides large amounts of natural light	Atrium, which provides large amounts of natural light and can be used for corporate functions
Green roof for functions and breaks from work with views of nature	Green spaces within the campus design of the building
Walkable access to a mixed use urban precinct, comprising shops, thus reducing the carbon footprint of the building occupants	A shopping centre across the road that contains grocery stores, thus reducing the carbon footprint of the building occupants
Showers and bicycle storage facilities, thus reducing the carbon footprint of the building occupants	Non-opening windows allowing for temperature and ventilation control, in addition to acting as a barrier from traffic-related noise pollution

2.2 Interview schedule and procedure

The set of semi-structured interview questions was developed from the sources cited in the literature review conducted by Nurick and Thatcher (2021a). This resulted in questions that focused on the physical indoor working environment (lighting, noise, temperature and ventilation), physical comfort, engagement, psychological well-being and presenteeism.

The respondents were volunteers who were purposively selected across the two case studies and had been at their respective organisation from 5 to 22 years. Furthermore, the two FSCs that participated in this study were included in the quantitative study that focused on organisational performance (Nurick, 2022). The in-depth interviews were conducted at each of the respective office buildings over a period of two consecutive days (total of four days of interviews), where an hour was allocated for each respondent. The actual interview times ranged from 30 to 45 min, where the older respondents tended to speak for longer, as they had more to draw on from their careers working in office buildings within the context of FSCs. Data saturation occurred relatively quickly at each location, which supported the relatively small sample size, i.e. similar responses were being expressed across the sample of respondents for each of the FSCs.

2.3 Sample

The age range across the respondents was large, and varied from late 20s to early 60s. All of the respondents were university graduates and held positions in their respective organisation that ranged from a specialist analyst to executive director, within the investment division. All the respondents were similarly positioned with regard to their work station. In other words, they were each in close proximity to a window, printer and bathroom. However, some of the respondents in CS1 were positioned near a central atrium that runs through the centre of the building, which is a source of natural light. Table 2 provides a breakdown for each of the 15 respondents in terms of their general characteristics. CS1 comprised three female and five male respondents, with the majority in middle or senior management positions. The tenure of the sample for CS1 ranged from 5 to 21 years ($\bar{x} = 10.25$, $S = 6.04$). CS2 comprised three female and four male respondents, with roles ranging from a analyst to executive director. The range of tenure for the respondents from CS2 was 5 to 22 years ($\bar{x} = 14.71$, $S = 6.63$). The average and standard deviation for tenure for the entire sample (both case studies) is $\bar{x} = 12.60$ and $S = 6.62$,

	Gender	Position	Tenure
Respondent CS1			
CS1R1	Female	Senior manager	12 years
CS1R2	Female	Senior manager	8 years
CS1R3	Male	Middle manager	5 years
CS1R4	Male	Executive manager	21 years
CS1R5	Male	Middle manager	20 years
CS1R6	Female	Middle manager	5 years
CS1R7	Male	Middle manager	6 years
CS1R8	Male	Middle manager	9 years
Respondent CS2			
CS2R1	Female	Senior manager	17 years
CS2R2	Male	Middle manager	6 years
CS2R3	Male	Executive manager	22 years
CS2R4	Female	Analyst	5 years
CS2R5	Male	Senior manager	19 years
CS2R6	Female	Executive manager	22 years
CS2R7	Male	Senior manager	12 years

Table 2. Respondent characteristics

respectively. Each respondent was coded anonymously, which only refers to the case study and respondent number, respectively. For example, the first respondent in CS1 was coded CS1R1.

2.4 Method of analysis

The chosen data acquisition approach was in the form of semi-structured interviews to ascertain the perceptions of respondents with regard to the impact of the indoor environment on their productivity. Due to the differing roles and tenure of the respondents, gauging productivity in an office environment can be somewhat subjective, as the optimum level of IEQ attributes (temperature, humidity, lighting levels and ventilation) is not absolute, because it is dependent on the individual office occupant, underpinned by the nature of the work (sitting versus standing versus moving around), clothing (type, amount and style), gender, body shape and overall physical health. Thematic analysis was used to analyse the data collected from the semi-structured interviews, where the theoretical model (Figure 1) was used as a framework. The semi-structured interviews were recorded and transcribed for the purposes of processing via NVivo (qualitative data analysis software) to identify prominent themes. Five global themes emerged from the data, namely:

(1) IEQ awareness;
(2) productivity drivers;
(3) productivity barriers;
(4) access to nature; and
(5) enhanced organisational culture.

Thematic analysis is an approach for systematically organising qualitative data into groups (themes) that express consistent meaning (Braun and Clarke, 2012), where themes have a singular focus, linked but do not overlap, but can build on previous themes. Most importantly, the consolidation of the data within all the themes should address the main research question (Braun and Clarke, 2012). Thematic analysis comprises several stages, which include: transcribing the interview recordings where the researcher familiarises

themselves with the data, coding the data by using specialist qualitative data software, searching for and reviewing potential themes and identifying the global themes. It should be noted that thematic analysis is not a linear research method with one correct answer, but rather an iterative approach where the researcher can review the data to infer results that are not quantifiable, which is considered a robust approach in the field of both deductive (based on a philosophical framework) and inductive coding (themes emerging from interviews) (Fereday and Muir-Cochrane, 2006; Braun and Clarke, 2021). This form of data collection results in obtaining thick descriptions, which comprise one or more of the following attributes:

- interpretation of data within a certain context;
- capturing thoughts and emotions;
- assigning motivations and intentions;
- rich account of details; and
- the meaningfulness of a given situation(s) in detail (Drew, 2022).

3. Results and discussion

3.1 Indoor environmental quality awareness

Two sub-themes emerged from the global theme of IEQ awareness, namely, ambient conditions and the age of respondents. These two sub-themes are inter-related as the respondents' engagement with the ambient conditions or lack thereof was underpinned by their age.

3.1.1 Ambient conditions. Elements of ambient conditions that are commonly found in the literature tend to focus on IEQ and/or sick building syndrome (SBS) in terms of perceptions of office building occupants. This was typically conducted using a building user survey (BUS) (Thatcher and Milner, 2012; Gou *et al.*, 2013, 2014; Thatcher and Milner, 2014, 2016), which lacks in-depth data in the form of thick descriptions. All the respondents across the two case studies had some form of awareness of the GBFIs that contributed to their indoor environment, as they were all aware that their respective company was located in a green certified building. The main IEQ components that were highlighted formed part of the ambient conditions – ventilation and temperature. The main challenges with these two components is that due to the "smart design" of the green building occupants did not have individual control. Building occupants are required to log a call with the facilities management team if there is a problem or modification to air flow and/or temperature was requested. A secondary IEQ component that was raised by some of the respondents was the quality of natural and artificial light, where it was only deemed a problem if there were power outages. These timed electricity outages (known as load shedding in South Africa) can cause disruptions to the working environment. However, both green buildings had uninterrupted power supplies (UPSs), resulting in a minor disruption to the power supply, as there is a very small time delay (approximately a minute) when converting from the national grid to on-site power generation. The UPS in the office (or an equivalent thereof) were not necessarily available at the private residences of many knowledge workers. This variability in non-municipal power supply negatively impacted the quality of internet connectivity, artificial light, ventilation and residential security when working from home. A less consistent and lower level of IEQ in a domestic environment negatively impacted individual productivity levels.

3.1.2 Age of respondents. The age of the respondent underpinned their IEQ awareness (CS2R3). Respondents that had careers spanning more than 25 years were very aware that

they were in a high-quality building, as they had spent the bulk of their careers in lesser quality (non-green) buildings where many IEQ factors were not adequately addressed. One respondent recalled when smoking was permitted in office buildings and how this would be considered intolerable today. On the contrary, respondents (in their late 20s to mid-30s) were relatively less aware of the level of indoor environmental quality of their office. This was due to them not being exposed to the office environments of the 1980s and 1990s, and therefore taking for granted good quality ventilation, temperature management and lighting to the point where these building attributes were considered to be the norm and hardly considered important by these participants.

3.2 Productivity drivers

There were two sub-themes that underpinned drivers of productivity, namely, the physical office environment in terms of spatial factors and ambient conditions, and physical comfort.

3.2.1 Spatial factors and ambient conditions. Although ambient conditions were cited as a contributing factor to productivity, spatial factors also played a vital role in impacting individual productivity levels. Previous research on spatial factors predominantly applied longitudinal studies; however, these approaches all applied high-level survey type data collection instruments, which lacked in-depth engagement with office building occupants (Heerwagen, 2000; Thatcher and Chunilal, 2015; Candido *et al.*, 2016; Mallawaarachchi *et al.*, 2017). The main drivers of productivity related to GBFIs cited by the majority of respondents across both CS1 and CS2 were access to dedicated work space, ambient noise levels in an open plan office environment (not too loud), quality lighting (natural and artificial), temperature control (or lack thereof), the physical quality of the office environment (furniture), building management support services (e.g. a broken light), access to break away zones and refreshment stations (location and amenities) that can be used as informal collaborative space, physical comfort in terms of having the option of sitting versus standing desk, knowing that there are external amenities within walking distance (e.g. groceries) and access to privacy when required. A combination of spatial factors and ambient conditions in terms of the aforementioned GBFIs influenced individual productivity. When one or more of these GBFIs was deemed to be unsatisfactory by the building occupants then productivity was negatively impacted. Due to the nature of the type of employee (skilled knowledge worker) in both case studies and the calibre of the FSCs (blue chip companies), there was a high expectation in terms of both spatial factors and ambient conditions.

3.2.2 Comfort. Comfort has been heavily researched within the context of structured interviews, Likert-type scales, and physical measurement; however, all of these approaches lacked in-depth engagement with office building occupants (Hedge *et al.*, 1996; Wargocki *et al.*, 2002; Fang *et al.*, 2004; Bordass and Leaman, 2005; Leaman and Bordass, 2007; Feige *et al.*, 2013; Mulville *et al.*, 2016; Chadburn *et al.*, 2017; Laughton and Thatcher, 2018; Elnaklah *et al.*, 2020). The aforementioned spatial factors and ambient conditions were directly linked to comfort, and thus, these productivity drivers may also be associated with psychological well-being, for example, a well maintained and clean office environment with efficient facilities management support could enhance work engagement (concentration) and reduce residual frustration (distractions), which indirectly improves productivity (CS1R1, CS1R4, CS2R3, CS2R4, CS2R6, CS2R7):

> "[. . .] psychological aspect in that, okay, I am at work, this place is well looked after and that also means I want to bring my best in terms of work and personal interactions. . ." CS1R1

High levels of natural light also enhanced psychological well-being, as different shades of natural light improved mood and potentially work engagement.

> "[. . .] not having the feeling like I am working in a casino and they just want you to work not knowing whether it is day or night". CS1R2

A main factor cited by respondents in both CS1 and CS2 that contributed to psychological well-being, which underpinned productivity was safety. This was defined as personal safety in the building, i.e. high-quality access control and security, and safety regarding personal assets, for example employees cars. The issue of safety is prevalent social factor, both within domestic and corporate environments, as South Africa experiences relatively high incidents of crime. Therefore, all respondents (especially women) highlighted safety as a contributing factor to both psychological well-being, which impacted overall comfort in the office environment.

> "Am I worried about getting to my car, no. Am I worried that my car is still going to be there, no [. . .]" CS2R1

Unique to South Africa, is the reliability of the associated services such as water and electricity. CS2R1 and CS2R4 noted that their organisation ensured uninterrupted power and water, regardless of temporary service outages that do occur relatively regularly. In this regard, the office environment is safer than many of the respondents' domestic environments, as areas remain well lit, which eliminates potential criminals from entering the premises and/or unassumingly approaching building occupants in the basement parking lot.

3.3 Productivity barriers

Barriers to productivity also related to the quality of the ambient environment in terms of noise levels, temperature variability that can potentially lead to physical symptoms (e.g. headaches and nausea) that can force certain employees to go home (CS1R6) or require more breaks to recover from the temperatures that are too hot or cold (CS2R3). Physical SBS symptoms commonly found in green certified buildings are throat irritation, lethargy/tiredness, stuffy nose, dry/irritated throat and dry skin (Tham and Willem, 2010; Tham *et al.*, 2015). Lighting in private rooms was motion-sensitive, which often switches off especially if they have been sitting still for long periods of time. Older office furniture that would not be considered ergonomic in a modern office environment was also considered to reduce productivity. The location of the office building geographically was also viewed as a potential barrier to productivity (CS2R4), as this may have require excessive commuting times. Psychological well-being was negatively affected if the building's IEQ standards were not maintained (CS1R7, CS1R8). The aforementioned barriers to productivity are consistent with the literature, and are partially or fully related to SBS, which can still occur in green certified buildings (Ghaffarianhoseini *et al.*, 2018).

3.4 Access to nature

Access to nature is a prominent feature for the majority of respondents in relation to productivity. Access to nature is defined by respondents in CS1 as views of natural features (i.e. a view of the ocean or the mountain), as these respondents were located in a building which only has glazing as the material for the external envelope. Respondents from CS2 defined access to nature as the ability to take a break from work in one of the green spaces located as central outdoor atria, where there was a lawn, benches and barbeque facilities. This is an important feature as CS2 was located in a heavily built-up urban precinct, and

these green spaces were shielded from urban noise pollution, for example, traffic. Access to nature was cited by several respondents as a positive contributing factor to their psychological well-being (CS1R6, CS1R8):

> "[. . .] my desk right next to the ocean window is quite nice, the light that comes from that is excellent. . ." CS1R8

3.5 Enhanced organisational culture

Organisational activities that make use of the building enhance psychological well-being. For example, CS2 used their indoor atria to host musical performances and formal company functions. Spatial factors, such as informal collaborative spaces in the form of noise reducing meeting pods and tea/coffee areas, allowed for relatively short face-to-face interaction. Formal spaces were designed in the form of making all the office spaces open plan (CS1) and the majority of the office spaces were open plan (CS2), where only executive directors are given private offices, in the latter. This resulted in more meeting rooms being provided that each contain smart technological amenities, e.g. flat screens for presentations and conference calling capabilities (CS2R2). The location of the building (CS1) also fed into the organisational culture, as building occupants have walking access to a nearby urban precinct (CS1 and CS2), which hosts other blue chip companies, thus permeating an ambitious and professional ethos outside of the building. This greater urban environment provided another subtle contributing factor to the organisational culture. CS2 was located on what many respondents refer to as the "campus", which has outside green areas – a rarity in their urban node. This allowed employees to enjoy each other's company during a short break or at an organised outdoor event (CS2R3), which subtly re-enforced the organisation's culture.

3.6 Cross-case analysis

Both cases exhibited similar high level findings across the five main emergent themes. Physical indoor attributes, such as lighting noise, temperature and ventilation were highlighted as important to a higher or lesser degree in their relation to impacting individual productivity, physical comfort, engagement and psychological well-being. A finding that was consistent across both cases studies, which is very important within a South African context due to the relatively high crime rate, was safety – both personal safety and protection of assets. There were some minor differences, which are underpinned by location, organisational culture and access to certain amenities. Presenteeism (physically being at work but mentally drifting off) is not a major finding, as this did not occur often nor for long periods of time. Many of the findings are consistent with foreign literature, with regard to self-assessed productivity (El Tohamy *et al.*, 2018) in relation to an indoor environment of an office building, and also in terms of reaching data saturation relatively quickly.

3.7 Re-visiting and revising the theoretical model

The majority of the findings from the semi-structured interviews can be linked back to the theoretical model (Figure 1). Some of the components from Figure 1 were more prevalent than others, for example, ambient conditions, which led to health, comfort, work engagement and the subsequent impact on individual productivity. Location and amenities were also referred to by respondents in both case studies, which contributed to psychological well-being and convenience, which also had a positive impact on individual productivity. One respondent (CS2R7) explicitly stated that employee retention was underpinned by the relationship, or lack thereof, with one's line manager. However, CS2R5

stated that employee attraction was somewhat influenced by the building's location and amenities:

> "[. . .] the garden spaces. As well as the easy location. And almost a sense of park-like atmosphere and it is called a campus site so, I think it is it definitely used to attract a lot of staff". CS2R5

Personal safety and security of personal assets were cited as new contributing factors that indirectly influenced productivity, especially within the context of South Africa, and perhaps also within the realm of financial services, as these knowledge workers were relatively well remunerated. Safety was also defined as reliable infrastructure services to the building (i.e. water and electricity) when compared to the domestic environments of some of the respondents.

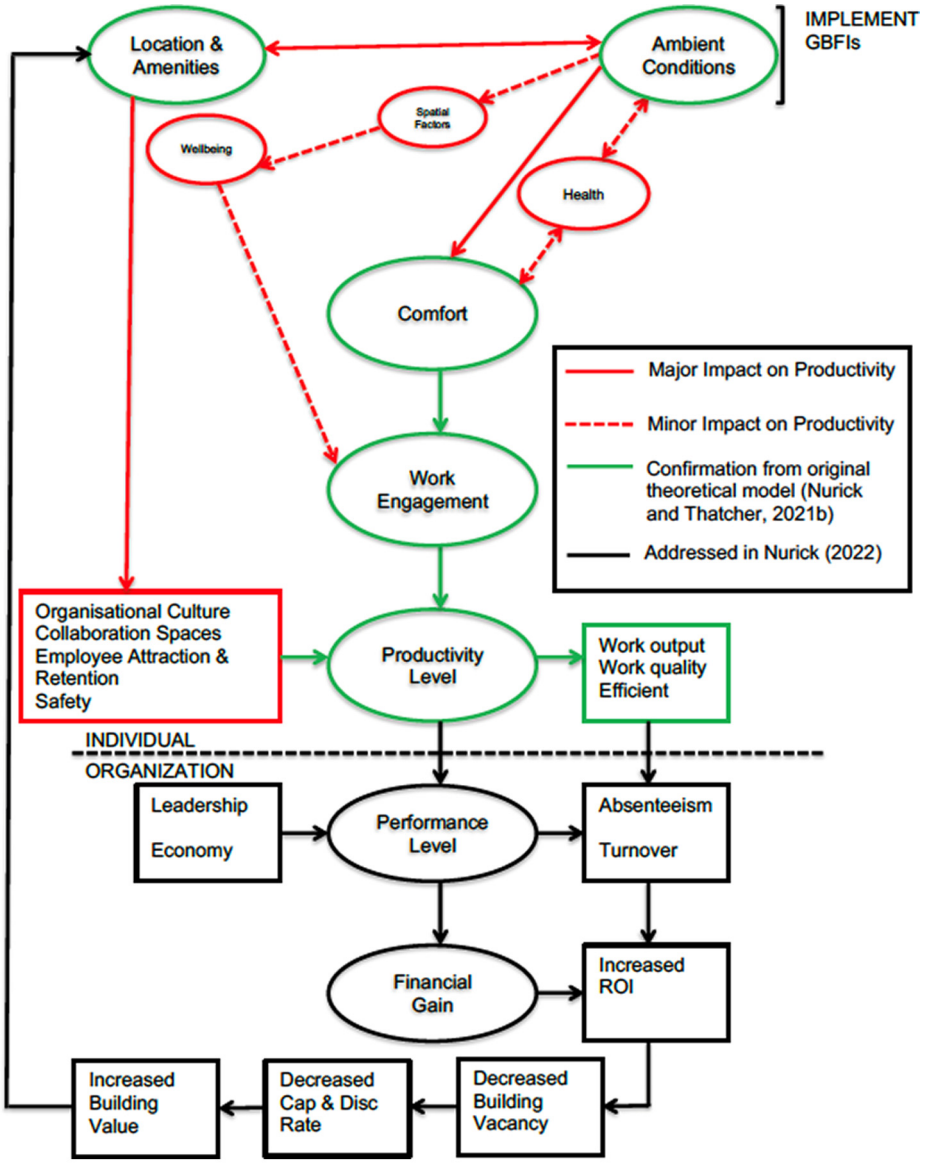
Components of Figure 1 that received direct minor attention were spatial factors and overall well-being, which are represented as shrunken ovals, when compared to the original theoretical model. This was partially due to both cases studies having relatively flat hierarchical structures, i.e. most working spaces are open-plan. Furthermore, most respondents acknowledged that external factors, not related to work, are the major influences on their psychological well-being:

> "[. . .] concerned about what is happening at home or my baby [. . .]" CS2R4

The finding resulted in a revision of the theoretical model (Figure 1), to a new model (Figure 4) that more accurately reflects the main components linked to IEQ that have a major (solid red line) and minor impact (dotted red line) on individual productivity in this study. The revised components of Figure 4 are indicated in red with updated one-way and two-way relationships. Furthermore, those components that had a minor impact on productivity have been reduced in size (well-being, special factors and health) relative to other components, when compared to their respective roles/positions in Figure 1. Additionally, the solid green lines represent confirmation of components and linkages from the original model (Figure 1), while black components and links are those addressed in Nurick (2022).

4. Conclusions

Assessing individual productivity of knowledge-based workers in relation to the office indoor environment is not an exact science, and therefore relies on self-assessment, which is underpinned by a level of subjectivity. This form of data gathering in this field of research is deemed acceptable, as previous researchers have applied this same approach (Feige *et al.*, 2013; Mallawaarachchi *et al.*, 2016, 2017). A theoretical model (Figure 1) was used as a framework to explore the relationships between various components that potentially impact individual productivity. The findings provided more clarity with regard to which components played a major and minor role on the impact on productivity in FSCs. Ambient conditions that directly influenced physical comfort (Gou *et al.*, 2013; Gou and Siu-Yu Lau, 2013; Thatcher and Milner, 2014; Elnaklah *et al.*, 2020) and work engagement (Schaufeli *et al.*, 2002; Schaufeli *et al.*, 2006; Demerouti and Bakker, 2008) were the major contributing components of the indoor environment. Additionally, location and amenities also influenced the organisational culture, collaboration spaces, employee attraction and retention and general safety of personnel and their associated assets. All of these new factors that are presented in Figure 4 were commonly mentioned by respondents across both case studies to impact their individual productivity, to a greater or lesser degree. Due to the research being conducted in South Africa, there are unique findings, which can be linked to a green building market that is still in its infancy, when compared to developed real estate markets



Source: Authors' work

Figure 4.
Revised theoretical model

in North America, Europe and Australasia. South Africa's socio-economic climate makes it a relatively unsafe country, partially due to a relatively high unemployment rate, and therefore safety, is a major consideration when designing modern office spaces. This is because knowledge workers employed by FSCs are relatively well remunerated and are

potential targets for criminal activity. Another finding that seems to be more prevalent in South Africa with relation to green buildings is employee attraction and retention, where the former plays a larger contributing role, as many South African graduates come from previously disadvantaged backgrounds (due to the legacy of apartheid) where they aspire to work in a modern office building, which is often the antithesis of their domestic environment in their formative years. Graduates from previously disadvantaged backgrounds could possibly be hampered by a variety of factors when not in a supported office space, for example, unreliable public service delivery – irregular electricity and water supply, inconsistent and noisy refuse collection, poor internet connectivity, crowded/noisy households containing cross-generational occupants and a lack of access to office hardware such as scanners and printers. It should be noted that the legacy of apartheid still exists in South Africa, coupled with South Africa's status as a developing country, which results in the country experiencing a combination of first and third world challenges, where the latter often pertains to relatively poor public infrastructure. This impacts the domestic and professional lives of knowledge workers, especially those who are descendants of the historically marginalised segment of the population. Aspiring to work in modern premium grade buildings is often seen as a sign of early success for contemporary university graduates whose parents did not have access to quality tertiary education, and therefore, the opportunities offered for employment in blue chip firms were limited, which could potentially result in lucrative corporate career progression. This was mentioned by CS2R1, a senior manager who is directly involved in recruitment across the organisation. The research is limited to FSCs occupying green certified buildings located in South Africa. The chosen research method does not require a relatively large sample. Qualitative research in the form of semi-structured interviews is typically an in-depth data collection method, which yields thick descriptions (Drew, 2022). Therefore, a large sample size was not required, as would be the case for survey based research (Yin, 2012). Furthermore, given the focus on FSCs in South Africa, the generalisability of these findings to other countries or industries is questionable.

Opportunities for further research in this area could potentially be targeting knowledge-based workers in a different sector, for example auditors, lawyers, physiotherapists, architects, etc. In closing, the reason that knowledge workers based in FSCs were selected for this research is that it was the qualitative continuation of the quantitative research conducted by Nurick (2022) where the organisational performance component of Figure 1 was tested at an organisational level, which focused on FSCs. The main reason for selecting employees at FSCs is that these type of workers are typically office-bound. Other knowledge worker roles, which are not fully office bound due to the nature of their job (e.g. consultants), would be less likely to have their individual productivity levels impacted by the quality of the IEQ at their corporate headquarters. Therefore, this may provide similar and/or different findings due to nature of the work of these different professionals. Future research could also include investigating individual productivity of workers located in different property sectors, such as retail, industrial and educational buildings. Therefore, a wider context needs to be take into consideration regarding future additional research, which goes beyond the IEQ, but also general building related factors, for example, the location of the building (CBD versus de-centralised node), average commuting time and the employees perception of organisational culture. Furthermore, research into the impact of COVID-19 on knowledge-based workers is also warranted, as these types of workers have re-evaluated if they need to go into the office every day, which reduces the tension resulting from commuting and exposure to the physical working environment. In addition, organisations have re-assessed the need for the employees to be in the office every day. Thus, a reduction in daily on-site work could potentially dilute the

impact or awareness of the quality of IEQ (when compared to their domestic environment) and the impact of individual productivity within an office environment.

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Corresponding author
Saul Nurick can be contacted at: sd.nurick@uct.ac.za