

Christo Vosloo

Prof. Christo Vosloo, Graduate School of Architecture, Faculty of Art, Design & Architecture, University of Johannesburg, P.O. Box 524, Auckland Park, 2006, Johannesburg, South Africa.
Phone: +27 (0) 11 559 1105,
E-mail: <cvosloo@uj.ac.za>
ORCID: <https://orcid.org/0000-0002-2212-1968>

DOI: <http://dx.doi.org/10.18820/24150487/as27i1.6>

ISSN: 1023-0564

e-ISSN: 2415-0487

Acta Structilia 2020 27(1): 144-177



Published by the UFS

<http://journals.ufs.ac.za/index.php/as>

© Creative Commons With Attribution (CC-BY)

How to cite: Vosloo, C. 2020. Early sustainable architecture in hanging skyscrapers – A comparison of two financial office buildings. *Acta Structilia*, 27(1), pp. 144-177.

EARLY SUSTAINABLE ARCHITECTURE IN HANGING SKYSCRAPERS – A COMPARISON OF TWO FINANCIAL OFFICE BUILDINGS

Peer reviewed and revised March 2020

Published June 2020

**The authors declared no conflict of interest for the article or title*

ABSTRACT

Reuse, or the ability to continue using an item or building beyond the initial function, is a key concept in the literature on sustainability. This implies that a building should be designed in a way that will allow it to be repurposed when changing circumstances require changes in its layout or function; being energy efficient and environmentally sensitive is not enough. The building also needs to be financially viable and the people whose lives are impacted by it should wish to have it retained. As far as flexibility of high-rise or skyscraper buildings is concerned, the structural system and layout are some, but not the only aspects that are of particular importance in this regard. Upside-down or 'hanging' buildings, because of the reduced use of columns, can potentially provide advantages when viewed from such a widened understanding of sustainability. Two such buildings are the Hong Kong and Shanghai Bank (HSBC) headquarters building in Hong Kong and the Standard Bank Centre (SBC) in Johannesburg. The SBC stands virtually unused and in disrepair, while the HSBC remains fully operational and revered by the population of Hong Kong. This article

compares the design and construction processes of the two buildings to determine why these two buildings ended up in such divergent situations. The aim is to make recommendations regarding structural systems and other factors that could assist in ensuring that future skyscrapers will be more sustainable, in addition to being energy and resource conserving. Furthermore, this comparison sheds some light on the historical development of the understanding of sustainability and the difference between green design and sustainable design.

Keywords: Hanging buildings, sustainable design, adaptability

ABSTRAK

Hergebruik, of die vermoë om 'n produk of gebou se lewensduurte vir so lank as moontlik te verleng nadat die oorspronklike funksie of gebruikspatrone verander het, is 'n sleutelbegrip in die literatuur oor volhoubaarheid. By implikasie is dit belangrik om geboue so te ontwerp dat hul uitleg en funksies aangepas kan word om hul bruikbare leeftyd vir so lank as moontlik te verleng. Omgewingsvriendelike ontwerp is nie genoeg nie en daar is meer aspekte wat 'n rol mag speel. Ander faktore is finansiële volhoubaarheid en die verhouding tussen die gebou en diegene wat dit voortdurend gebruik. Wat toringblokke betref, speel die strukturele stelsel (onder meer) 'n sleutelrol in hierdie verband. Onderstebo- of 'hangende' geboue kan hier groot voordele inhou aangesien die verminderde aantal kolomme groter aanpasbaarheid beteken. Dit beteken egter nie dat hierdie tipe geboue noodwendig meer volhoubaar is nie. Twee van hierdie tipe geboue het in wyd uiteenlopende situasies beland. Die gebou van die Hong Kong and Shanghai Bank (HSBC) se hoofkwartier in Hong Kong word ten volle benut en is 'n gewaardeerde landmerk in die stad; hierteenoor is daar die Standard Bank Sentrum (SBC) in Johannesburg waarvan die gebou en die openbare ruimte daaromheen grootliks in onbruik verval het. In hierdie artikel word die ontwerp asook die ontwerp- en konstruksieprosesse van die twee landmerkgeboue vergelyk ten einde te bepaal hoekom hulle in sulke kontrasterende situasies verkeer. Die doel is om aanbevelings te maak rakende die verskillende struktuurtypes en ander faktore wat die volhoubaarheid van toekomstige toringblokke kan beïnvloed. Die vergelyking sal ook lig werp op die ontwikkeling van die begrip 'volhoubaarheid' en die verskil tussen groen en volhoubare ontwerp.

Sleutelwoorde: Hangstrukture, volhoubare ontwerp, aanpasbaarheid

1. INTRODUCTION

Two topics that feature commonly in current conversations about architecture are sustainability and high-rise or skyscraper buildings. While some might be of the opinion that these are mutually exclusive, they are not. The noted author on, and practitioner of green architectural design Ken Yeang highlights that skyscrapers are not “energy-hungry parasites” when considering the

entire life cycle of the building within the context of the overall interrelated framework of human and environmental systems. Furthermore, he contends that the chances of eventually recycling the materials used in this type of building are far greater, due to the quantities involved. In addition, the higher densities and associated compact cities that can result from this building type, considered with the aforementioned, mean that skyscrapers constitute a viable alternative to the low-rise, low-density alternative often associated with sustainable architecture (Yeang, 1999: 18).

A review of works on sustainable design shows that definitions and discourses on sustainability, particularly when it comes to buildings, even more so commercial buildings, tend to focus on energy efficiency and resource conserving design, and often ignore the financial and investment-related aspects, specifically the need for investments to provide sustainable returns on investment (Yeang 1999; Gauzin-Müller, 2002; Sassi, 2006; Yeang & Spector, 2011; Edwards, 2014). This is not surprising, considering the high levels of embodied energy and the resources that are trapped in high-rise buildings, aspects that could be detrimental to the lifespan of such buildings. However, a building's financial and investment prospects are equally important aspects that need to be considered, since they could also impact on the longevity of a building (Fischer, 2010: 18).

A second aspect of sustainable design that does not feature prominently enough is the need for flexibility in design: allowing for change and a reconfiguration of the uses or layouts to accommodate changes in technology or workplace protocols which can extend the usefulness and, hence, the lifespan of a building, thereby resulting in the sustained use of the embodied energy and resources (Akadiri, Chinyio & Olomolaiye, 2012: 143).

A third aspect that could affect the longevity of a building is the attitude towards it of the people whose experience is impacted by a building. A building that is appreciated by society has a better chance of surviving changes in lifestyle and technology (Holmgren, Kabanshi & Sörqvist, 2017: 146). A much broader view of sustainable design is, therefore, proposed.

Hanging, suspension or upside-down structures, where floors are suspended from a small number of vertical supports, can provide greater flexibility, because the cross-sectional area of the hangers can be significantly smaller than that which columns in a conventional layout might have had. While a suspended structure is not the only type that can offer greater flexibility, the manner in which it is applied in a building can provide greater or lesser flexibility. Used correctly, this type of structure could thus further improve the sustainability of a high-rise building (Schierle, 2012), particularly office buildings, where reconfiguration is easier than it would be in the case of residential buildings.

- Sassi supports Yeang's contention that skyscrapers can be environmentally friendly and points out that land is a limited resource that must be used judiciously (Sassi, 2006: 12). However, for this to hold true, it remains imperative that new skyscrapers are designed with a broader view on sustainability. To support the call for such a broader view on the concept of sustainability, this article compares two financial office buildings built in different parts of the world to show that there are a range of aspects that can lead to more sustainable environments. Comparing these two buildings shows that the difference in the situations of the two buildings, one clearly suffering because of its 'unsustainability', can be found not only in their designers' attitude to climatic and environmental matters, but also in the flexibility of their general layouts, coupled to their relation with the people whose lives are impacted by them.
- The purpose of the article is to provide a cursory oversight of the development of the construct 'sustainability' and to make recommendations for the design of future skyscrapers using hanging or conventional framed structures. It also aims to provide greater clarity about the difference between sustainable design and green design.

2. LITERATURE REVIEW

To understand sustainable skyscraper design, it is important to review the current theory on sustainable design and skyscraper buildings. However, to fully appreciate the designs of the two buildings in question, a concise exploration of late-modernism and high-tech architecture and hanging buildings is required.

2.1 Sustainable and green design

- Sustainability has been defined as "the quality of being able to continue over a period of time" (*Cambridge Business English Dictionary*, 2019; Vosloo, 2020: 57) and "for humans [...] the potential for long-term maintenance, of well-being, which has environmental, economic and social dimensions" (Eberhardt, 2012: 3). When considering a building from a cost point of view, its potential in this regard has, for a long time, formed part of any thorough economic feasibility assessment. However, 'sustainability' is equally important from an ecological and environmental point of view, due to the resources and embodied energy captured in the completed building. It is important that the new building remains usable for as long as possible, in order to maximise the benefit that can be derived from the resources and embodied energy captured by it, even if some of

it could be recycled at the end of the building's useful life. The term 'sustainable design' is often used loosely in exchange with 'green building design'. The World Green Building Council (s.a.) defines a green building as "a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment. Green buildings preserve precious natural resources and improve our quality of life.". The World Green Building Council (s.a.) holds that a number of features can make a building 'green'.

These include:

- Efficient use of energy, water and other resources;
- Use of renewable energy, such as solar energy;
- Pollution and waste reduction measures, and the enabling of reuse and recycling;
- Good indoor environmental air quality;
- Use of materials that are non-toxic, ethical and sustainable;
- Consideration of the environment in design, construction, and operation;
- Consideration of the quality of life of occupants in design, construction, and operation, and
- A design that enables adaptation to a changing environment.

With the exception of the last bullet, nothing relating to ensuring a long lifespan features in this description.

Yeang (1999: 8, in Vosloo, 2020: 57) holds that 'green' or ecological building design entails the following:

"... building with minimal environmental impacts, and where possible, building to achieve the opposite effect; this means creating buildings which have positive, reparative and productive consequences for the natural environment, while at the same time integrating the built structure with all aspects of the ecological systems of the biosphere over its entire life cycle."

He believes that such a holistic approach is crucial to stop the human species from overloading earth's capacity to sustain all species and natural systems.

Vallero and Brasier (2008: 168-169) hold that green architecture "allows people to become more in touch with the environment in which they live" and incorporates site characteristics and conditions (microclimate, light exposure, vegetation and urban factors) into the design.

Yet, sustainability implies more than what is said in any of the foregoing definitions of 'green design'. At the same time, there is no generally accepted

definition for sustainable development. One of the more readily recognised definitions, the so-called Brundtland definition, describes it as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Edwards, 2014: 28). Foster and Partners define sustainable design as “creation of buildings which are energy efficient, healthy, comfortable, flexible in use and designed for a long life” (Edwards, 2014: 28, in Vosloo, 2020: 57). Alternative definitions describe sustainable design as “environmentally conscious, energy saving and utilises responsive and renewable materials and systems” (Newman, in Ali & Armstrong, 2008: 2), or the creation of a balanced system wherein “society and its economic activities consumes minimal natural resources with the goal of sustaining the planet for future generations” (Winchip, 2011: 7). From the foregoing, it appears that the two terms could essentially describe similar concepts. However, Sassi reminds us that “no matter how energy- and water-efficient a building might be, it becomes a waste of resources and a potential detriment to the community if no one wants to occupy it” (Sassi, 2006: 9). Thus, she links sustainability to usability, both of which are key to this study. She also includes two additional aspects, namely community and culture (Sassi, 2006: 155). Moreover, as indicated at the beginning of this section, and as underscored by Winchip, sustainability also has economic and, hence, financial and investment connotations.

More recently, Robertson (2018: 133), suggested a change in the thinking about sustainability, by proposing the adoption of a new paradigm:

“At the centre of the new paradigm must be human beings. Climate change is a social, technical and cultural problem, and the needs of people should be at the heart of our decision making. Buildings and infrastructure should be intuitive, data visualisations legible, and interactions easy and meaningful. Fundamentally, we must learn from interactions between humans and buildings to improve performance and ensure that we are meeting our needs and allowing future and distant people to meet theirs. Buildings should be robust, built to last, adaptable to functional change and climate change. They must be for us, our neighbours, our peers and our descendants, wherever they are.”

Therefore, to be sustainable, designs must not only be designed with a focus on energy usage, but the designers must also consider how human beings relate to them (Akadiri *et al.*, 2012: 128). The designs have to be flexible and adaptable, in order to be reconfigured easily in the face of changing circumstances, practices, requirements, and technologies (Akadiri *et al.*, 2012: 129). However, sustainable design must also take into account financial and economic requirements (Akadiri *et al.*, 2012: 130). Clearly, ‘sustainability’ and ‘green’ have different meanings, aims, objectives, criteria, and implications.

It must furthermore be noted that, despite the emphasis on green and/or sustainable design that has become evident since the energy crisis of 1979, the importance of considering local climatic and environmental conditions was well recognised before then. Books on the subject included *Design with climate* (Olgay, 1963); *Man, climate and architecture* (Givoni, 1967), and *Thermal performance of buildings* (Van Straaten, 1967). During the 1960s, even lay people knew that orientation and insulation were important for interior comfort levels.¹

2.2 Late-modernism and high-tech architecture

Jenks (1980: 6, in Vosloo, 2020: 57) dates the ultimate death of modern architecture as July 1972. This resulted in a phase to which he refers as late-modern architecture. He viewed late-modern architecture as a “single-coded” architecture in which the characteristics of modern architecture were taken to “an extreme, exaggerating the structure and technological image of the building in an attempt to provide amusement, or aesthetic pleasure” (Jenks, 1980: 8). To him, prime examples of this style are Norman Foster’s Sainsbury Centre (1974-1978) and Piano and Rogers’ Pompidou Centre (1971-1977). Jenks (1980: 32, in Vosloo, 2020: 58) claims that the first signs of the late-modern period appeared as early as 1960 and that it continued in parallel to post-modernism, as the periods that followed modernism. Based on his description of late-modernism, it could be argued that many of the recent buildings designed by Foster and Partners still fall within this category. However, the hanging buildings that were built during this period neatly fit his description (see section 5 in this article).

Quantrill (2018: 18) refers to many of the buildings listed above as exemplars of “High-Tech” architecture. She explains that, since the end of the 1960s, this term was used to describe “any conspicuous display of technical composition in buildings – especially when exposed steel structure and mechanical systems were placed on the outside of the envelope” (Quantrill, 2018: 18). To her, Foster and Partners’ HSBC Bank Building was a prime example. She cites Davies who held that

“[a]nalyse[s] of high-tech architecture tend [sic] to trace an arc from the so-called experimental architecture of Archigram and Cedric Price, through cultural buildings such as the Centre Pompidou, to projects for industrial clients or financial clients like HSBC, a lineage that depicts the transformation of anti-establishment ideas about flexibility and freedom into instruments of capitalist expansion” (Davies, cited in Quatrill, 2018: 118).

1 The author can remember his mother (a housewife) insisting that their house had to be ‘north-facing’.

While the HSBC Bank Building and others (see above) might fit neatly into the high-tech category, as described above, many of the most prominent hanging buildings do not fit this description, but they comply with Jencks' criteria. Thus, on the whole, hanging buildings can be described as late-modern buildings.

2.3 Hanging buildings

Hanging buildings were mostly constructed between 1969 and 1985. The Torre Cepsa in Madrid, designed by Foster and Partners and built between 2003 and 2009 (Foster & Partners, [s.a.]), is the most recent example.

While the large number of suspension bridges found throughout the world meant that suspended structures were not unusual, this period saw hanging structures becoming more common, due to the popularity of late-modernism and high-tech architecture. Some of the buildings and structures constructed in this way during this period include the Torres Colon in Madrid, by Antonio Lamela (1976) (Palau, 2017 [s.p.]); Rhone and Iredale's Westcoast Transmission Tower in Vancouver (1969); the Standard Bank Centre, Johannesburg, by Hentrich and Petschnigg (1970) (see Figure 2); the Munich Olympic Stadium, by Frei Otto (1972); the BMW Headquarters in Munich, by Karl Schwanzer (1973); Gunnar Birkerts' Federal Reserve Bank building in Minneapolis (1973); Bea and Walter Betz's Hypo Bank in Munich (1980); Suncorp Place in Sydney, by Joseland & Gilling Architects (1982) (Suncorp Place, [s.a.]); Torre Cepsa in Madrid, by Foster and Partners, and the Hong Kong Shanghai Bank, by Norman Foster (1986) (Schierle, 2012; Archdaily [s.a.]); Duprè (2013: 92) (see Figure 1).

The advantages of hanging structures are the following (Vosloo, 2020: 58-59; Zunz, Heydenrych & Michael, 1971: 30):

- The ground floor can be free of columns and load-bearing walls (the main vertical support excluded). Should the ground floor be enclosed in glass, the inside could merge with its surroundings.
- The absence of columns results in an increase in the useable or lettable floor area of each floor, enhancing the feasibility of the project.
- The reduction in support structure could result in increased flexibility.
- Hangers can have a smaller sectional area than columns, giving better space utilisation.
- The elements that transmit the loads to ground level are normally heavily pre-stressed and, therefore, able to resist bending moments imparted by lateral forces.

- This method allows for top-down construction and, in the case of multiple stacks or banks (such as the SBC), working at different levels simultaneously.

Another advantage of this type of structure is that it, like suspension bridges, allows building in areas where site constraints such as rights of way and other servitudes might make building using conventional load-bearing or framed structures difficult if not impossible (Miller, [s.a.]: online)

Various suspended high-rise structural systems exist (Scherlie, 2012: 2). Typically, two structural types are often used in skyscrapers (Scherlie, 2012: 2-7): a central core from which is hung the different floors, either by cables from the top as with the Torres Colon (the hideous green cap visible in Figure 4 was not part of the original design) or prestressed concrete hangers as at the Standard Bank Centre. Alternatively, the support structure was split in two and moved to the (normally eastern and western) sides with cross-members acting as supports from which the floors are suspended. This option was used in the Suncorp Place, HSBC building, and Torre Cepsa.

3. RESEARCH METHODOLOGY

The article compares two financial office buildings to identify aspects that can lead to more sustainable environments emanating from more financially sustainable buildings. The study made use of a qualitative comparative case study design based on literature reviews. Boote and Beile (2005: 5) believe that “[a] thorough, sophisticated literature review is the foundation and inspiration for substantial, useful research”. In this study, two buildings built in different parts of the world, but with many commonalities, are compared as cases that used hanging or conventional framed structures as building design. The reason for collecting qualitative data is to elaborate on specific findings from the comparative analysis such as similarities and differences of sustainable design among the two buildings (cases) (Yin, 2014).

3.1 Rationale for selecting case studies

In this article, sustainability will be considered with the aim of identifying aspects that can lead to more sustainable environments emanating from more financially sustainable buildings. This will be done by comparing two buildings built in different parts of the world, but with many commonalities. They were both commissioned by commercial banks that were founded during the colonial period in British colonies; they were both intended to be symbols of their owners’ financial success; they both came to be landmark buildings in their respective cities; their physical form was influenced by the desire of the respective cities to create more public open space in exchange for relaxed height restrictions in the most sought-after areas in their cities; both demanded considerable innovation and ingenuity from

their designers and builders; both were designed by foreign architects; they shared the same (foreign) structural designers (Ove Arup and Partners, London); both were designed at a time when the first warnings of imminent socio-economic, political and technological changes became part of the academic and social discourse. One building is standing derelict and for the most part unused, while the other is still fully functional.

The buildings are the Hong Kong and Shanghai Bank (HSBC) Headquarters building in Hong Kong, designed by Foster and Partners (1978-1985) (Figure 1) and the Standard Bank Centre (SBC) in Johannesburg, designed by Heinrich-Petschnigg and Partners (1966-1970) (Figure 2).



Figure 1: NHBC Building, Hong Kong
Source: Image by author



Figure 2: Standard Bank Centre, Johannesburg
Source: Image by author

3.2 Case study 1: The Standard Bank Centre (SBC)

In 1967, the Johannesburg City Council amended the Town Planning Regulations for the Central Business District (CBD). They sought to ease the congestion in the area. To this end, they revised regulations, in order to allow higher buildings in return for the creation of public open space around the new building (Chipkin, 2008: 136; Vosloo, 2020: 60).

Standard Bank sought to build a prestigious new headquarters building in the Johannesburg CBD. In doing so, they intended to build a high-rise or skyscraper building as a symbol of their success. To give effect to their ambitions, they set down two objectives:

- To construct a prestigious headquarters building that could bring national, and possibly international, recognition for them.
- The building must provide an adequate return on investment.
- Furthermore, they required that the new building must
- incorporate the bank's executive offices and the bank's most important divisions;
- include the branch of the bank operating on the site for quite some time;
- provide office space of a high standard, and
- maximise the site's opportunities to the limits imposed by the Town Planning restrictions (Zunz *et al.*, 1971: 30; Hentrich, 1970: 16).

In terms of the revised regulations, to be allowed a high-rise building (25-30 storeys), Standard Bank was required to restrict the tower's coverage to less than 26% of the area of the site. Figure 3 shows the location of the building and Figure 4 shows the site layout.

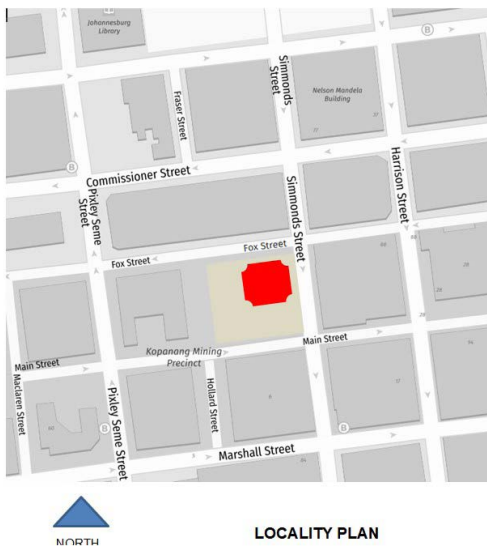


Figure 3: Location of Standard Bank Building
Source: Author, based on map from mapz.com

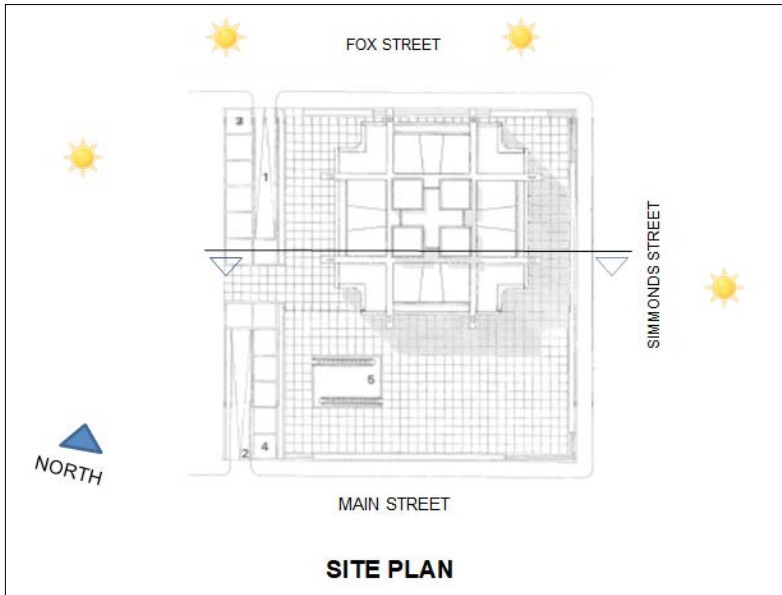


Figure 4: Site layout of Standard Bank Centre

Source: Author, based on figure in Hentrich, 1970: 15

The first step taken was the appointment of a planning consultant who was asked to undertake a number of pre-design studies. Prof. Wilfred Mallows, the planning consultant, made several recommendations; the most relevant for this article was that the design should opt for a deep-space office plan and that the lower ground (or first basement) floor should have easy access and commercial activity (Zunz *et al.*, 1971: 30; Vosloo, 2020: 61).

Prof. Mallows recommended that Hentrich-Petschnigg and Partners from Düsseldorf, Germany, be appointed as architects. The motivation was that the firm was renowned for their skyscraper buildings such as the Dreischeibenhaus (1957-1960) or the Thyssen Steelworks Building, one of the most noteworthy post-war buildings in Germany (Zunz *et al.*, 1971: 30). Ove Arup and Partners (London-Johannesburg) were appointed as structural engineers (Hentrich, 1970: 6).

3.2.1 Design and layout

The architects ignored Prof. Mallows' recommendation regarding deep-space office layouts. They developed a concept that prioritised the creation of "an open plaza with no obstructions at groundfloor [*sic*] level at all except the core of the tower" (Hentrich, 1970: 27). No commercial activity would be

included at ground level and even the banking hall was relegated to the first level below the piazza, albeit linked spatially with the entrance foyer via a multi-volume space (see Figures 3 and 4). Hentrich describes their design approach as follows:

“In order to reduce the office tower to a structural minimum on ground level [and] to create a plaza as open as possible, the architects decided to design the entire building as a hanging structure [...] the only structures at street level are the four cores measuring 5,48 m by 5,48 m” (Hentrich, 1970: 27).

Unfortunately, this preoccupation with a minimalistic open space resulted in a space devoid of any planting or other features that would have encouraged its usage by the general population (see Figure 4). The question is: Beyond providing spatial relief, what is the advantage of a ‘public’ open space if the public cannot use it? Hence, the aims of the City Council were also ignored.

3.2.2 Structural design

The main support structure comprised four squares housing vertical movement facilities and service ducts. The four squares supported the 35-storey, 139 m high office tower. The tower is square in shape with the four corners cut out (Zunz *et al.*, 1971: 30). Thirty floors are used for office space. They are arranged in three banks of ten floors, with the remaining floors used for services. Each of the ten floor banks is suspended from eight reinforced concrete cantilever beams connected to the central core (see Figure 5). Precast and prestressed concrete hangers were used to support the precast, prestressed concrete floors in combination with the central core (Zunz *et al.*, 1971: 31). The basement comprised five floors, the first level being used for banking and the remaining floors housing parking and technical facilities. The underside of the first-floor slab was set at 10.8 m above ground level, in order to augment the spatial character of the design concept.

The final form of the building was the result of the design of the structural system (see Figure 5). The more common suspension system that utilised an umbrella-like structure at roof level could not be used, as it would interfere with the service runs (Zunz *et al.*, 1971: 31; Vosloo, 2020: 63). It was thus decided to use the prestressed concrete cantilever beam system mentioned earlier. Mechanical plant rooms are housed in the spaces between the cantilever beams.

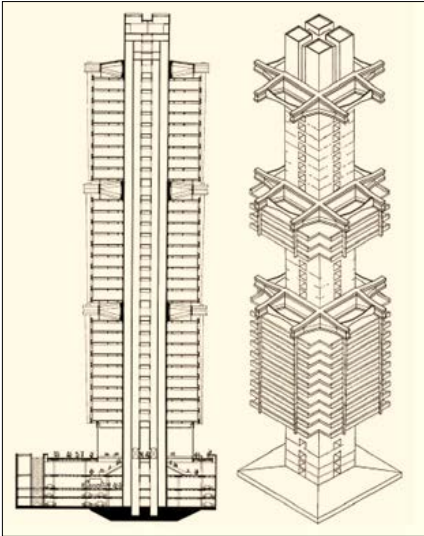


Figure 5: Standard Bank Centre: Section and isometric showing structural system
Source: Artchist, 2016: online

3.2.3 Sustainable elements

The initial planning started in 1963, construction started in 1966, and the building was completed (ahead of schedule) in March 1970. While this was well ahead of the current focus on green/sustainable or environmentally compatible design, the building did include steps to reduce the energy load of the building: two thermal storage systems to serve all the air-handling plants were included. Through their use, energy costs could be reduced by heating the water at night when the unit cost of electricity was lower. However, one of the fundamental principles of creating shelter (let alone 'architecture') has always been to attempt to create comfortable environmental conditions with the least possible use of energy. The architects' brief required an 'adequate' return on investment, which implies keeping the operating costs as low as possible. Much of this has always been part of good design and common sense; architects cannot claim that these aspects were not important in 'those days'. Hence, the choice of a square floor plan (see Figure 6) (meaning that up to 50% of all windows face either east or west), as a result of the central core and supporting structure, must be questioned, particularly when considering that this type of layout has a negative impact on the flexibility of the office areas. Surprisingly, the central core type of layout remains popular for high-rise buildings.

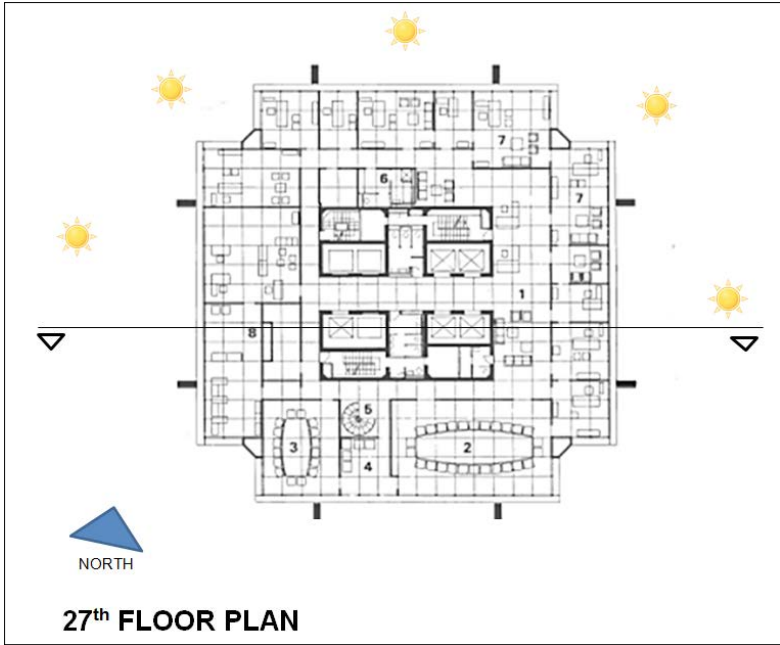


Figure 6: Standard Bank Centre: Office floor plan

Source: Author, based on figure in Hentrich, 1970: 15

While the extensive use of concrete in the external skin of the building – a feature that is commendable, given the large diurnal temperature variations in Johannesburg – is appropriate and commendable because of the moderating effect this will have on interior temperature fluctuations, the windows on the eastern and western sides did not receive any treatment that would have reduced the heat gain of the offices on those sides. This would have increased the heat load and, eventually, the operating costs of the building. The inclusion of the thermal storage tanks indicates that this imperative was not lost on the entire design team, but that it did not suit the simplistic architectural and structural concept not to have all elevations looking the same. Another positive was that, by dividing the office floors into three banks with mechanical and electrical plants housed in the intermediate floors, the effectiveness of the air-conditioning systems was enhanced by the relatively short service runs. Likewise, the negative impact of the “tyranny of the central lift core” (Sudjic, 2010: 178) on the productivity and job satisfaction of the workforce was not considered. This type of layout isolates each floor from the others, interfering with the flow of information and people through the building. The exception, in this instance, is the spatial linking evident between the banking hall in

the first basement level and the double-volume entrance foyer. As with the disregard of the needs and comfort of the general public displayed by not providing facilities that would enhance the use of the public space, the architects did not pay enough attention to the productivity, comfort and satisfaction of their clients' workforce.

This elegant and sculptural building (see Figure 7) became one of the iconic skyscrapers in Johannesburg. Sadly, Hentrich's disregard for Prof. Mallows' suggestion that the plan should allow for deep-space office layouts as well as the inflexible layout meant that, when Standard Bank took the decision to build a new headquarters building in 1978 (only eight years after moving to the Standard Bank Centre!), the brief (to Prof. Mallows' firm), among other things, was for the following (Standard Bank, 1982: 8; Vosloo, 2020: 76):

- A low-rise building that allowed for quick and easy vertical movement, and
- A deep-space layout that would provide a completely flexible office layout system.

Standard Bank chose to remain in the central city, as did some of the other major South African banks, and the new building is only a few street blocks to the south of the SBC. Currently, the building is mostly unused. One of the reasons mentioned in informal conversation with an architect, who was commissioned to conduct a survey of the building during the recent past, was that asbestos was used in a number of applications and that the removal and replacement thereof was financially unviable.

It seems that the bank had learned a lesson; buildings have to be designed in ways that will ensure their continued and sustained use, and that consider the comfort and productivity of those working in it (Akadiri *et al.*, 2012: 128). Planning and feasibility studies should, from the outset, consider the complete life cycle of the building, as proposed by Yeang (1999: 18; Akadiri *et al.*, 2012: 130; Vosloo, 2020: 76). This should include considering where technology is going and what future users might require.



Figure 7: Standard Bank Centre at completion
Source: Image by J.G. Boss, in Hentrich, 1970: 47

3.3 Case study 2: The Hong Kong and Shanghai Bank (HSBC) building

3.3.1 Design and layout

During the early 1980s, discussions on Hong Kong's future started between the British and Chinese governments (Quantrill, 2018: 120). The discussions led to concerns and uncertainty about the territory's future. During this period of uncertainty, the Hong Kong Shanghai Banking Corporation headquarters building (1978-1985) was being constructed and served as a statement of confidence. The aim was to create the best bank building in the world (Foster & Partners, [s.a.]b). It is situated at 1 Queen's Road Central, Central Hong Kong, on one of the most prominent sites on Hong Kong Island, facing onto Statue Square, with no other buildings blocking its view of Victoria Harbour (see Figure 8) (HSBC Building, [s.a.]). Due to this unique situation, a Feng Shui geomancer was brought in, which resulted in a process of questioning as to what should be the nature of banking in Hong Kong and how this should be expressed in built form. "In doing so it virtually reinvented the office tower" (Foster & Partners, [s.a.]).

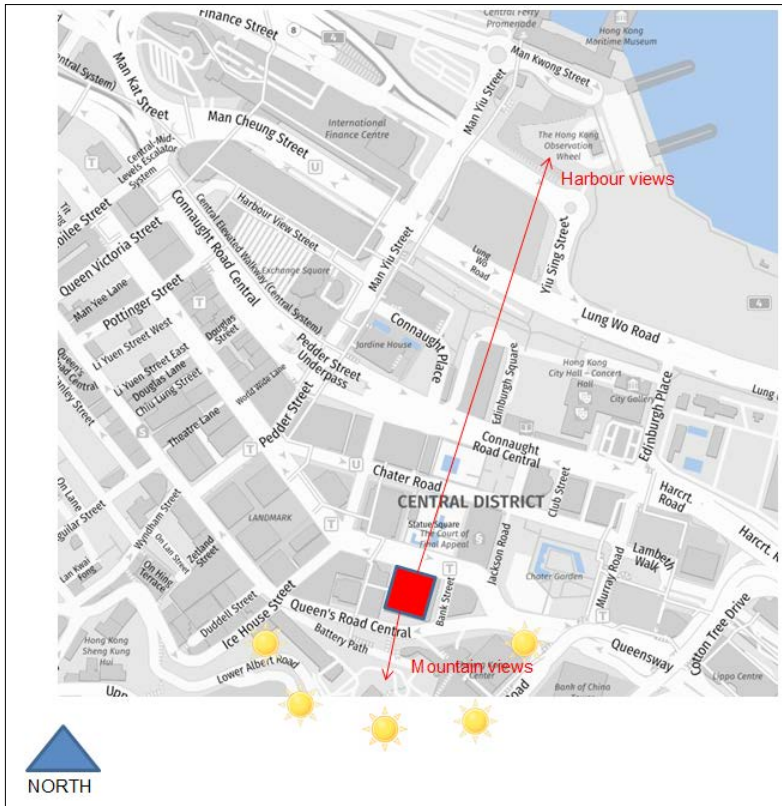


Figure 8: Location of Hong Kong and Shanghai Bank Building

Source: Author, based on map from mapz.com

One of the steps taken was to hoist the bank up (therefore, using a hanging structure) in such a way that it would allow the space beneath the banking hall to link to Statue Square, also allowing the public to get a glimpse into the interior of the building as they passed beneath it (Sudjic, 2010: 171). In doing so, the airflow in this part of this predominantly hot and humid city was improved and sea breezes allowed deeper into the city. The welcoming gesture has resulted in the space becoming a public meeting place for Filipino women, in particular. Foster negotiated a higher plot ratio with the planning authorities to extend the public space underneath the building, which increased the value of the tower.

Another drastic departure was Foster's insistence that the lift shafts be moved from the centre to the sides of the building, thereby ending the "tyranny of the central lift core" (refer to Figure 9) (Sudjic, 2010: 178). This was because he

realised that this centralised arrangement was inflexible, limiting the way in which the floors could be used (Sudjic, 2010:178). The internal movement pattern was further altered by only allowing the high-speed lifts to stop at the five double height floors. From here, movement is by escalator (Foster & Partners, 2005: 248). Another was the decision to incorporate a bridge-type structure, so that the new structure could span right across the old banking hall (Foster & Partners, 2005: 248). Foster regards this as “quite an efficient building in energy terms, with its extensive use of shading, displacement ventilation and sea water cooling” (Hongkong and Shanghai Bank, 2011).

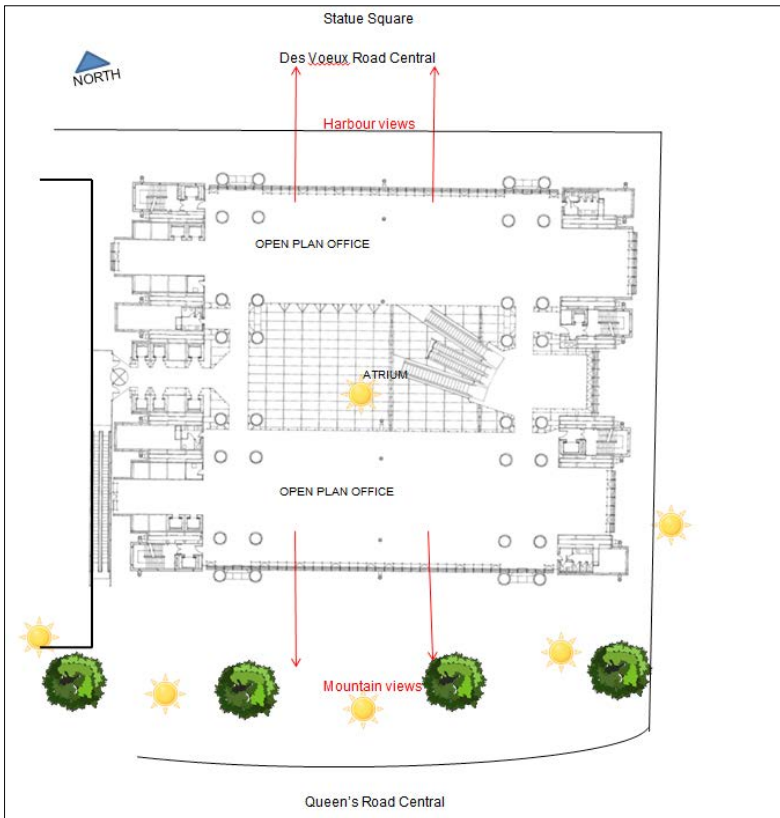


Figure 9: Hong Kong and Shanghai Bank Building: Typical lower stack floor plan

Source: Author, based on Foster & Partners, [s.a.]b

3.3.2 Structural design

Developing this idea led to the adoption of what was known as the ‘chevron scheme’: a steel structure, supported by double sets of masts comprising four sets of inclined steel columns (see Figure 10). The steel masts are linked by suspension trusses (Pawley, 1999: 75). The floors could be hung from this structure, thereby keeping the office floors as open and flexible as possible (Pawley, 1999: 169). This aspect was greatly enhanced by the decision to move the service and movement cores to the edges of the building.

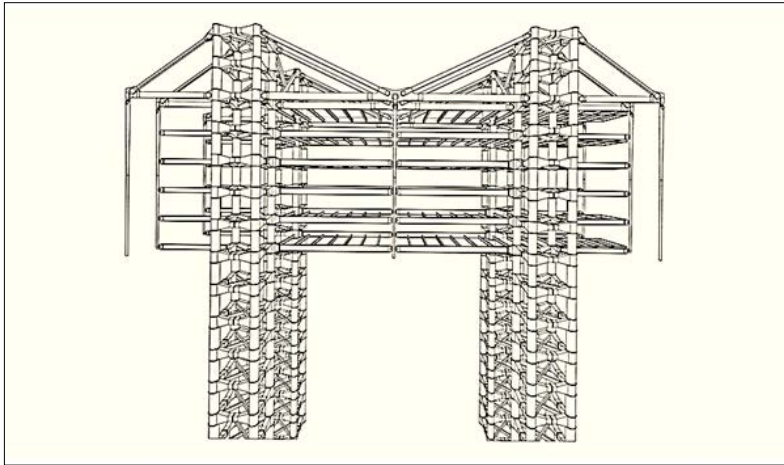


Figure 10: Hong Kong and Shanghai Bank Building: Structural system

Source: Foster & Partners, [s.a.]b

The decision to use a hanging structure was also a result of the time-related pressures: it would allow construction to take place upwards and downwards at the same time (Foster & Partners, 2005: 248). The speed at which the building had to be constructed also led to the large-scale use of prefabrication (Foster & Partners, 2005: 248) and modules being shipped in from, among other places, the United Kingdom.

Financial viability was of great importance and various studies were undertaken in an effort to include the cost advantage of various pioneering design aspects. Nonetheless, massive cost overruns occurred (Quantrill, 2018: 119). At completion, the cost per square meter was substantially higher than that of other bank headquarters buildings. However, a specialist consultant persuaded the bank’s board that it was satisfactorily cost effective and that it would provide the bank with a positive rate of return (Quantrill, 2018: 122): “Exploited to offset the costs undertaken in the production of a

new space for financial operations, flexibility and precision assumed value in and of themselves” (Quantrill, 2018: 132).

Planning regulations also influenced the design in other ways: the profile of the tower was a response to regulations seeking to prevent overshadowing at ground level. These regulations influenced the decision to divide the building into three bays, each of varying height (see Figure 11). Hence, the central bay rises to 47 floors, while the bay closest to Statue Square contains only 28, and the one on the opposite side comprises 35 floors (Sudjic, 2010: 178).



Figure 11: Hong Kong and Shanghai Bank Building: Side view

Source: Foster & Partners, [s.a.]b

At the lower levels, the floor slabs in the centre bay make space for a 52 metre-high cathedral-like space (see Figure 12). This is the space visitors

enter after rising from the plaza via escalators (refer to Figure 9). At the top of this space is a set of mirrors that are used to reflect light into and down the atrium space (Pawley, 1999: 78).

Transparency is a strong theme permeating the project. A transparent building was part of the original concept (Quantrill, 2018: 125). Developing and testing various glazing systems received a substantial part of the budget (Quantrill, 2018: 125). Even the ‘underbelly’ (the floor of the atrium) was made of glass, allowing the sun that was reflected down this space by the ‘sun scoop’ mirror to reach street level. The design used a dramatic aluminium-clad steel exoskeleton and glazed curtain walls (Hongkong & Shanghai Bank Headquarters, [s.a.]). The use of lightweight materials here and in the building structure is appropriate from a heat-retention viewpoint when considering that the building is located in a hot, humid climate zone with low diurnal temperature variations.

Although basic open plan offices have been widely criticised (Open Plan, 2020), and Quantrill expresses her misgivings about the success of the focus on transparency and continuous sight-lines (Quantrill, 2018: 118). Sudjic² (2010: 176) regards this building as the clearest expression of the view that

“architecture is an industrial process in which the ultimate objective is the creation of highly serviced, limitless flexible internal spaces and where formal values are eschewed in favour of exteriors that are made legible, expressing how they are made and what they do”.

2 Deyan Sudjic OBE is a noted architecture and design critic.



Figure 12: Hong Kong and Shanghai Bank Building: Atrium and banking hall

Source: Foster & Partners, [s.a.]^b

3.3.3 Sustainable elements

Arup ([s.a.]), the structural engineers of the project, contend that “though completed more than 20 years ago, is still considered one of the most sophisticated and technology-savvy buildings in the world”. They list the following as elements that, technology wise, make this a sustainable building: using sunlight through a light scoop to light up the atrium to the public plaza; an eight-metre diameter tunnel [constructed beneath the building] to provide seawater for use in the air-conditioning system, and an underfloor air-conditioning system (access flooring).

While the view across Statue Square determined the orientation of the building, it also made it possible to have the main views toward the North and South Victoria Peak and Victoria Harbour, the most important natural landmarks in the area. The decision to move the service and movement

cores to the perimeter of the building meant that they took up much of the problematic east- and west-facing sides. Sunlight was drawn into the heart of the building. Yet, despite having the basics in place, the building incorporates what is described as “a flexible assembly of components, comprising perimeter glazing, [including adjustable blinds], air conditioning, ceiling and lighting systems floor outlets, [and] partitions ...” (Quantrill, 2018: 131), in order to provide “precise environmental management” that could be operated locally. Given Hong Kong’s climate and the deep-space layout achieved, this is not surprising.

Quantrill (2018: 131) believes that “the substantial cost to the building’s envelope and environmental systems indicated their importance to the client”. Furthermore, the clients’ strong forward-looking stance was augmented by the adaptability offered by the flexible layout and the provisions made for changing technology and procedures by including features such as moveable suspended floor plates (access flooring) with adaptable power sockets and air-conditioning outlets (Quantrill, 2018: 122). The use of access floors meant that ventilation could be directed with greater accuracy, thus reducing the quantity of cooled air that had to be provided. It also reduced the fire rating and the need for firewalls, because the absence of suspended ceilings meant that they were no longer required.

The clients insisted on an envelope that acted spatially, materially and visually to stimulate productivity. Employee satisfaction was a priority. As a result, design and material development processes focused not only on technology, but also on cultural issues. They also regarded energy efficiency as critical as was a precisely controlled interior climate – at minimal cost. Employee gratification was viewed as a direct link to commercial gains (Quantrill, 2018: 130). Various alternative glazing systems were proposed and tested to ensure good isolation, coupled with quality views from the inside. The architects, in turn, strove for transparency and refused to accept proposals to use reflective glazing. The building’s floor space is configured around a central indoor atrium surrounded by blocks of office floors clustered as a series of vertically stacked clusters. The boundaries of the office clusters are, like those of the SBC, visually expressed on the exterior of the building. However, in this instance, the divisions have been made more pronounced by large triangular trusses framing double height floors that serve as communal areas.

Although the focus was on creating a flexible and efficient layout supported by electro-mechanical systems to enhance comfort and productivity, the design of the building incorporates links to anchor it into the local landscape and, in doing so, also demonstrates sensitivity to local spiritual beliefs.

Quantrill (2018: 131) submits that “[u]pon completion, the HSBC headquarters promulgated a paradigm of environmental efficiency for commercial prosperity”.

4. DISCUSSION

In considering these buildings, both held in high regard by the architectural community, it would be unfair not to conduct such an analysis without bearing in mind that the design of the SBC started in 1964, whereas that of the HSBC started in 1979. The 15-year period between these two dates saw many and dramatic changes, including the rise in computer and communications development and the energy crisis of 1979. Furthermore, it must be noted that the buildings are both viewed in hindsight through the lens of 2020, almost 80 years after the start of the SBC’s planning process. It is also pertinent to bear in mind that the comparison is not done to determine which is superior, but rather to identify the lessons that can be learnt from the current situations of both buildings and the long-term effects of the various design decisions taken at the design stages of the buildings.

4.1 Design and layout

While the buildings share a number of common attributes (see 3.1), they also differ in a number of ways: their designers responded differently to the physical, environmental, technological, social and urban contexts in which they were conceptualised and designed. The HSBC was anchored and rooted in the city’s public spatial system, geography and beliefs, among other things, and took great pains to include the local population in the building and to find solutions that satisfied the needs of their clients and their own priorities. By contrast, the designers of the SBC ignored all local needs, climate and recommendations and gave the ‘Johannesburgers’ a minimalistic design, more suited to the cold climates of northern Europe.

4.2 Sustainable elements

The architects of the HSBC foresaw and made specific provision for the dramatic developments in the application of computer technology. While the SBC did include a computer centre (Hentrich, 1970: 27) and a central control facility (Hentrich, 1970: 59), there is no indication that the architects made any attempt to provide for the technological developments that some forward thinking or life-cycle planning would have indicated. While it might be unfair to expect those responsible for the design of the SBC to have foreseen the dramatic changes in information technology that took place in the years following the building’s completion, they could have done more to allow for future developments. The building was designed for mainframe computer systems, indicating that the designers were aware of the latest

technologies and that they cannot claim complete ignorance regarding future changes. Designers (in this instance, architects and engineers) have to be forward-looking, because our buildings need to remain usable for at least 50 to 100 years, if not more. In fairness, those from Standard Bank who compiled the brief and signed off on the final design must share in the blame in this regard. One would expect that, with open-plan offices becoming more popular in the 1960s (Open Plan, 2020), they too should have been aware that technology and workplace protocols were undergoing rapid development. In addition, the SBC designers blatantly disregarded suggestions that would accommodate changes in the working environment and opted for a square plan form with central movement and a services core, while paying no regard to orientation. The only possible reason could be that they were seduced by the simplistic sculptural form that would result from it.

Having created the required public open space, the SBC architects finished it off as a minimalistic open space with no regard for the 'public' aspect, particularly the need for shade and seating that would have invited the public to use this space. The banking hall was relegated to the first basement level with limited commercial facilities to support it. The general population was not important to them and neither were any local traditions or beliefs or the comfort of the workers in the building – particularly those who were unlucky enough to end up with east- or west-facing offices. The building is an event in itself, an exercise in navel gazing that disregards the city and its people.

By contrast, the architects for the HSBC building embraced the local population and endeavoured to create the maximum open space possible for their benefit, although they too could have done more to provide street furniture that would have provided comfort to the users of the space. In addition, the space so created becomes part of a network of public open spaces in the heart of this congested city. Not only is the project anchored in a spatial network, the spatial network purposely recognises local beliefs and sensitivities. Furthermore, it takes in the most dramatic views and geographic features of its environment.

The HSBC building also incorporates the latest technology, often at great cost, to ensure that the building will remain functional over the long term by having a layout that is flexible and that allows for functional and technological changes. Furthermore, the comfort of those working in the building is important: they are afforded opportunities to adjust climatic conditions; views of their city and its environment was a priority.

The HSBC banking hall becomes a celebrated and dramatic space, the most prominent in the building; clients are welcomed into the building and their experience is prioritised. The building has become a popular landmark in the city and the population warms to it, even choosing it as a congregation point. In this way, it becomes a revered international landmark that achieves

the initial aims of both the bank and the architects: it is regarded by many as the best bank building in the world and an example of how office towers should be designed in order to remain functional. In addition, it provides the architects with the knowledge that informs future hanging structure skyscraper designs.

4.3 Structural design

While both buildings have hanging structures, the central vertical support chosen for the SBC has a number of negative implications, particularly in creating an inflexible layout and a plan form that is not suited to the local climate. It complicates the floor-to-floor movement of employees who have to wait for lifts to arrive, creating not only frustration but also negatively impacting on productivity. In the HSBC, the vertical supports (including lift shafts) are moved to the eastern and western sides of the building, the sides not suited for offices, with cross-members acting as supports from which the floors are suspended. In this way, the central part of the building is cleared, allowing for greater flexibility. Vertical movement is facilitated by high-speed lifts that only stop at certain floors. Movement between the intermediate floors is by escalator, avoiding productivity-sucking and frustration-causing delays.

5. COMPARE WITH CURRENT SUSTAINABILITY DESIGN

In order to compare the two buildings in light of current views on sustainability, the two buildings have been compared on the basis of Robertson's (2018: 133) construct (see 2.1 above) extended to include economical sustainability: "At the centre of the new paradigm must be human beings. Climate change is a social, technical and cultural problem, and the needs of people should be at the heart of our decision making."

In this regard, the HSBC building stands head and shoulders above the SBC and, on this score, the time difference between the buildings cannot be offered as an excuse for the SBC's failure. The human experience has been key to most (if not all) of the architectural theories. With the exception of the new public open space, the building does not provide the general public much benefit or positive response other than the novelty of the 'floating' superstructure and a sculpturally elegant building to appreciate and admire. The public space provides no more than spatial relief and a shortcut to those who cross it diagonally. Nearly half of the people working in the building will do so in offices that, at certain times, could be uncomfortable, whereas all will be frustrated while waiting for lifts as they endeavour to move vertically through the building. On the positive side, most of them will sit next to a window, allowing them views out of the building (of neighbouring buildings).

Much has been written about the negative aspects of open-plan offices as originally conceptualised; this, at least, they will be spared.

The HSBC, by contrast, in addition to providing an open space, does it in a way that extends the current open spatial structure, allows cooling breezes to penetrate deeper into the city, and offers the experience of sunlight in this open space, even though it is underneath the building. Those who use the space are made part of it by being allowed to look up into the atrium space into the banking hall. It also considers the spiritual and philosophical sensibility of the population (Feng Shui). The comfort and experience (views and comfort) of those who work inside were a priority of both the architects and the bank.

“Buildings and infrastructure should be intuitive, data visualisations legible, and interactions easy and meaningful. Fundamentally, we must learn from interactions between humans and buildings to improve performance and ensure that we are meeting our needs and allowing future and distant people to meet theirs” (Robertson, 2018: 133).

Hiding the SBC’s banking hall – the interface between the bank and its customers – in a basement as part of a tiny shopping area that cannot in any way be sustainable is counter-intuitive and transmits the wrong message and complicates interactions. On the other hand, turning the banking hall into the centrepiece of the building, opening it up for all to see and admire, results in an experience to look forward to, giving customers the feeling that they are valued and that the bank is not only about top management. In addition, the exterior of the building has become a landmark that transmits the institution’s symbolic technological prowess to the locals and visitors arriving by ferry or when looking down at the core of Hong Kong’s historical centre.

“Buildings should be robust, [economically viable over the short, medium and long term], built to last, adaptable to functional change and climate change. They must be for us, our neighbours, our peers and our descendants, wherever they are” (Robertson, 2018: 133).

In 1983, the cost of the HSBC was estimated to be eight billion Hong Kong Dollars (Quantrill, 2018: 121). At the time, it was the most expensive building ever constructed. A specialist consultant appointed by the HSBC concluded that the building was “satisfactorily cost-effective” (Quantrill, 2018: 120). Time has confirmed this assertion. Quantrill (2018: 131) holds that “[u]pon completion, the HSBC headquarters promulgated a paradigm of environmental efficiency for commercial prosperity”. However, one may ask: Has it stood the test of time? The renowned German architectural journal *Detail* contends that it is one of only a few buildings that seemingly do not age (Hongkong and Shanghai Bank, 2011). In the same interview, Foster (2011) reports that the design

“... has given the Bank huge flexibility. For example, they were able to introduce a large trading floor quite easily and without disruption – something that could never have been anticipated when the building was designed. No traditional bank headquarters building has anything like this degree of flexibility, which is a consequence of relegating the normal central core to the edges of open, flexible floors. Interestingly, if you talk to the Bank, they will tell you that they link their consistent financial growth and strong world rating to the way the building has been able to adapt to suit changing needs.”

Despite Standard Bank's insistence that the building should be financially viable, this also is not enough to assure its sustainability. The current state of the two buildings confirms the validity of Robertson's construct as extended by the author, and as the above analysis confirms, the need for a broader understanding of what constitutes 'sustainability' as argued for in the introduction of this article.

6. CONCLUSIONS

From a sustainability point of view, hanging structures can have a number of important advantages. They can allow for a high degree of flexibility, which could significantly extend the usable lifespan of a building; can allow building in areas that otherwise would have been considered impossible to build on (resulting in the optimal use of land in city areas), and create public open spaces that will enhance the urban quality and experience in densely developed areas. Moreover, they can create qualitative positive and visually dramatic spaces that will resonate with communities, thereby creating an affinity between the building and the people affected by it.

An earlier analysis of the SBC (Vosloo, 2020: 75) found that this building fails when evaluated from a green design perspective when analysed using Yeang's model (Yeang, 1999: 65), and that its inflexible structural layout, particularly the central position of its main services and movement core, a layout often used with hanging structures, has contributed, directly and indirectly by forcing substantial east- or west-facing exposure, to its unsustainability and, hence, its current state.

Based on the analysis presented in this article, it was found that the SBC designers' preoccupation with the building and its structure led to a building that turns its back on its local environment, its public, its users and those working in it. Furthermore, it was found that the designers did not foresee or provide for the dramatic changes in technological, environmental, social and political environments which the late 20th century would hold. There is hardly any evidence of forward-thinking or pro-active design. Thus, the design led to an unsustainable building, seen from any particular understanding of sustainability. The main causes of the current state of the building are

the overtly simplistic concept and the preoccupation of all involved with solving the technical and construction challenges without considering the 'bigger picture'. From a sustainability viewpoint, the advantages a hanging structure could offer were lost.

The HSBC building did not fall into this mode of thinking. The architects

- recognised it as an integral part of the city of Hong Kong and its belief systems;
- responded to the local geographical context;
- understood it as a part of global technological developments;
- allowed for development and future changes, and
- showed a concern for the people who will use and even those who will simply pass by it.

In this way, it became a building that "the community [...] wants to occupy" (Sassi, 2006: 9). Groups regularly meet and have gatherings in the building (Foster and Partners, 2005: 248). Moreover, it remains fully functional and revered as one of the key buildings of Hong Kong. This building complies with the criteria for sustainability.

This comparison provides lessons to architects and the architects of skyscrapers with sustainability objectives, in particular. First, hanging structures can enhance the sustainability of high-rise buildings, but the hanging (or other) structure selected must be configured to allow for a high level of flexibility. Secondly, the design must respond to the socio-geographical and economic contextual issues listed above if the building is to be sustainable. Feasibility studies should regard associated costs as opportunity costs, since they create value that will ensure the sustainability of the project.

However, despite this experience to tap into, many new skyscraper developments such as London's One Blackfriars, the One World Trade Centre in New York, and Strata SE1 buildings still fall foul to "the tyranny of the central lift core" (Sudjic, 2010: 178). Many still regard sustainable design as a purely technological and material matter only. The truth is that all the fundamental attributes associated with 'good' architecture are required for a building to be truly sustainable, but that might not suffice.

Finally, it has been shown that the current understanding of sustainable design has developed to now include a wide variety of aspects, including human and economic/financial concerns: the relationship between the building and the natural environment, and economic, cultural and communal considerations, while green design concerns itself almost exclusively with the relationship with the natural environment and natural systems. Therefore, a building can be 'green', but not 'sustainable'. It is unlikely that it can be 'sustainable' without including significant attention to 'green' aspects.

REFERENCES

- Akadiri, P.O., Chinyio, E.A. & Olomolaiye, P.O. 2012. Design of a sustainable building: A conceptual framework for implementing sustainability in the building sector. *Buildings*, 2, pp. 126-152. <https://doi.org/10.3390/buildings2020126>.
- Ali, M. & Armstrong, P.J. 2008. Overview of sustainable design factors in high-rise buildings. In: Wood, A. (Ed). *Proceedings of the CTBUH 8th World Congress*, 3-5 March, Dubai, UAE, pp. 282-294.
- Archdaily. [s.a.]. Munich Olympic Stadium. [Online]. Available at: <<https://www.archdaily.com/tag/munich-olympic-stadium>> [Accessed: 12 December 2018].
- Artchist. 2016. Standard Bank in Johannesburg by Hentrich Petschnigg. [Online]. Available at: <<https://artchist.wordpress.com/2016/06/24/standard-bank-in-johannesburg-by-hentrich-petschnigg/#jp-carousel-3974>> [Accessed: 28 April 2020].
- ARUP. [s.a.]. HSBC Main Building. [Online]. Available at: <<https://www.arup.com/projects/hsbc-headquarters-1-queens-road-central>> [Accessed: 20 April 2020].
- Boote, D.N. & Beile, P. 2005. Scholars before researchers: On the centrality of the dissertation literature review in research preparation. *Educational Researcher*, 34(6), pp. 3-15. DOI 10.3102/0013189X034006003
- Cambridge Business English Dictionary*. [Online]. Available at: <<https://dictionary.cambridge.org/dictionary/english/sustainability>> [Accessed: 4 February 2019].
- Chipkin, C.M. 2008. *Johannesburg transition: Architecture and society from 1950*. Johannesburg: STE Publishers.
- Duprè, J. 2013. *Skyscrapers: A history of the world's most extraordinary buildings*. New York: Black Dog & Leventhal.
- Eberhardt, J.P. 2012. Sustainability and neuroscience. In: Rasia, S.T. & Pardalos, P.M. (Eds). *Sustainable environmental design in architecture: Impacts on health*. New York: Springer.
- Edwards, B. 2014. *Rough guide to sustainability: A design primer*. 4th edition. London: RIBA Publishing.
- Fischer, E.A. 2010. Issues in green building and the federal response: An introduction. Congressional Research Service report for congress. Report number 40147.
- Foster and Partners. 2005. *Catalogue Foster and Partners*. Munich: Prestel.

Foster and Partners. [s.a.]a. *Torre Cepsa*. [Online]. Available at: <<https://www.fosterandpartners.com/projects/torre-cepsa/>> [Accessed: 4 December 2019].

Foster and Partners. [s.a.]b. *Hong Kong and Shanghai Bank Headquarters*. [Online]. Available at: <<https://www.fosterandpartners.com/projects/hongkong-and-shanghai-bank-headquarters/>> [Accessed: 10 December 2019].

Gauzin-Müller, D. 2002. *Sustainable architecture and urbanism*. Basel: Birkhäuser.

Givoni, B. 1967. *Man, climate and architecture*. Amsterdam: Elsevier.

Hentrich, H. 1970. *Standard Bank Centre Johannesburg*. Johannesburg: Standard Bank Investment Corporation.

Holmgren, M., Kabanshi, A. & Sörqvist, P. 2017. Occupant perception of “green” buildings: Distinguishing physical and psychological factors. *Building and Environment*, 114, pp. 140-147. <https://doi.org/10.1016/j.buildenv.2016.12.017>.

Hongkong and Shanghai Bank Headquarters. [s.a.]. [Online]. Available at: <<http://www.engineering-timelines.com/scripts/engineeringItem.asp?id=1445>> [Accessed: 21 April 2020].

Hongkong and Shanghai Bank – 10 questions to Lord Norman Foster. 2011. [Online]. Available at: <<https://www.detail-online.com/article/hongkong-and-shanghai-bank-10-questions-to-lord-norman-foster-14368/>> [Accessed: 20 April 2020].

HSBC Building (Hong Kong). [s.a.]. [Online]. Available at: <[https://en.wikipedia.org/wiki/HSBC_Building_\(Hong_Kong\)](https://en.wikipedia.org/wiki/HSBC_Building_(Hong_Kong))> [Accessed: 10 January 2020].

Jencks, C.A. 1980. *Late-modern architecture and other essays*. London: Academy Editions.

Mapz. [s.a.]. Map editor. [Online]. Available at: <<https://www.mapz.com/>> [Accessed: 20 April 2020].

Miller, K. [s.a.]. Seventeen advantages and disadvantages of suspension bridges. [Online]. Available at: <<https://futureofworking.com/8-advantages-and-disadvantages-of-suspension-bridges/>> [Accessed: 11 May 2020].

Olgay, V. 1963. *Design with climate*. Princeton, NJ: Princeton University Press.

Open Plan. 2020. [Online]. Available at: <https://en.wikipedia.org/w/index.php?title=Open_plan&action=history> [Accessed: 20 April 2020].

Palau, N. 2017. *A documentary in memory of Antonio Lamela, the architect who designed the Torres Colon*. [Online]. Available at: <<https://blog.ferrovial.com/en/2017/11/antonio-lamela-architect-torres-colon/>> [Accessed: 4 December 2019].

Pawley, M. 1999. *Norman Foster: A global architecture*. New York: Universe.

Quantrill, A. 2018. The value of enclosure and the business of banking. *Grey Room*, 7(144), pp. 116-137. https://doi.org/10.1162/grey_a_00244.

Robertson, C. 2018. Aim high pressing for a radical and global approach to sustainable design. SU plus RE: Sustainable and resilient design systems. In: Nastasi, J., May, E., Snell, N. & Barry, B. *Architectural Design*, 88(1), pp. 128-133. <https://doi.org/10.1002/ad.2268>.

Sassi, P. 2006. *Strategies for sustainable architecture*. New York: Taylor & Francis. <https://doi.org/10.4324/9780203480106>.

Schierle, G.D. 2012. *Suspend high-rise*. [Online]. Available at: <<http://www.arch.mcgill.ca/prof/sijpkcs/aaresearch-2012/12-student-files/suspended-structures.pdf>> [Accessed 12 December 2018].

Standard Bank. 1982. "Superblock": The standard bank administration building. Unpublished booklet. Supplement to planning and building developments, September/October.

Sudjic, D. 2010. *Norman Foster: A life in architecture*. London: Weidenfeld & Nicolson.

Suncorp Place, Wikipedia [Online]. Available at: <https://en.wikipedia.org/wiki/Suncorp_Place> [Accessed: 4 December 2019].

Vallero, D. & Brasier, C. 2008. *Sustainable design: The science of sustainability and green engineering*. Hoboken: John Wiley and Son. <https://doi.org/10.1002/9780470259603>.

Van Straaten, J.F. 1967. *Thermal performance of buildings*. Amsterdam: Elsevier.

Vosloo, C. 2020. Sustainable skyscrapers: The Standard Bank Centre, Johannesburg. *Athens Journal of Architecture*, 6(1), pp. 53-78. <https://doi.org/10.30958/aja.6-1-3>.

Winchip, SM. 2011. *Sustainable design for interior environments*. New York: Fairchild.

World Green Building Council. [s.a.]. *What is green building?* [Online]. Available at: <<https://www.worldgbc.org/what-green-building>> [Accessed: 4 December 2019].

Yeang, K. 1999. *The green skyscraper: The basis for designing sustainable intensive buildings*. Munich: Prestel Verlag.

Yeang, K. & Spector, A. 2011. *Green design: From theory to practice*. London: Black Dog Publishing.

Yin, R. 2014. *Case study research: Design and methods*. 5th edition. Thousand Oaks, CA: Sage Publications.

Zunz, G.J., Heydenrych, R.A. & Michael, D. 1971. The Standard Bank Centre, Johannesburg. *Die Siviele Ingenieur in Suid-Afrika*, February 1971. <https://doi.org/10.1680/iicep.1971.6459>.