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ORIGINAL ARTICLE

Future cities: Speculation on the case for vertical biophilic cities

Benz Kotzen

School of Design, University of Greenwich, London

E-mail address: b.kotzen@gre.ac.uk

Abstract - As the world's population increases and as populations of cities increase there is a real need to find solutions to accommodate these people. Vertical cities may provide a solution. Whilst megastructures have been built as individual buildings, thus far there are no vertical cities, but the existing megastructures indicate this is possible. The skyscrapers of vertical cities can be integrated in the skies as well as below ground as earthscrapers and host all the functions of the city including green spaces such as parks and gardens and urban agriculture. The current model of a central city core area and expansive suburbs does not provide a solution for future growth. Past and future losses in ecosystem services through extensive horizontal development cannot be sanctioned. This is an 'ideas paper' which speculates on the forms of future vertical cities and the necessity of integrating biophilia into the vertical city as not only do vertical cities provide an answer to accommodating the world's burgeoning population, but the compact footprint of the city allows for an increase in nature, access to nature, allowing land that would be swamped by development to be used for farming, water collection, forests and other land uses that host the ecosystem services that are required by people and the planet.

Key words - Vertical Biophilic Cities, biophilia, biophilic cities, future cities, ecosystem services

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INTRODUCTION

The conditions of our physical world have always been in flux, but the scientific view is that it is changing ever faster and there is scientific consensus that this is largely due to the way man works with or rather against our planet's key systems, for example by increasing greenhouse gases in the atmosphere. Climate change is happening at an ever-increasing rate and this is particularly worrying in the light of population growth. The Department of Economic and Social Affairs of the United Nations Secretariat notes that the world's population will grow from 7.550 billion in 2017 to 8.551 billion by 2030, 9.772 billion by 2050 and 11.184 billion by the year 2100 (DESA, 2017). This is an additional 3.634 billion people, The fact is that with the population we have now and the health and wellbeing of the Earth's population is not equitable across the planet with much greater wealth in developed countries compared to developing countries and with population growth, inequality may further rise, despite the fact that it is seen to be decreasing (Borunda, 2019).

Whilst wealth can be correlated directly to health, where government and community spending per person can be linked to the economy, it is more difficult to equate wellbeing with wealth. If we define wellbeing '*as the state of being comfortable, healthy, or happy*' (EOLD), then this state of being can be affected by many more variables; economic, social and environmental. However, whilst wealth is directly related to health, the reverse is true as well, as better health leads to higher incomes (Bloom and Canning, 2000, Garau et al., 2105).

Whilst wealth means health at the macro scale, with regard to the environment, the benefits of integrating nature and green infrastructure into every-day life is now an environmental enhancement that is becoming increasingly recognised. Numerous studies (Wood et al., 2017, Montgomery, 2015) have noted the benefits on physical health and mental wellbeing. Wood, et al. (2017) in their research note that '*both the overall number and total area of public green spaces were significantly associated with greater mental wellbeing'*, and that '*mental health was not only associated with parks with a nature focus, but also with green spaces characterised by recreational and sporting activity'*. The study demonstrated that the appropriate provision of local, public, green space, within walking distance '*is important for positive mental health*' (Wood et al., 2017). The benefits of having public parks and gardens, private gardens, community and allotment gardens have been enjoyed for years across the world. Starting with Birkenhead Park, the world's first publicly funded open access park, designed by Joseph Paxton and opened on 5 April 1847, the arrangement of vegetation (trees, shrubs, bedding, hedging etc.), provide sensory delight, visual and physical amenity in often times stark and antipathetic urban areas (Figure 1). The open space that is provided for both active and passive recreation stands in contrast to the often times dense, claustrophobic highly trafficked urban fabric.

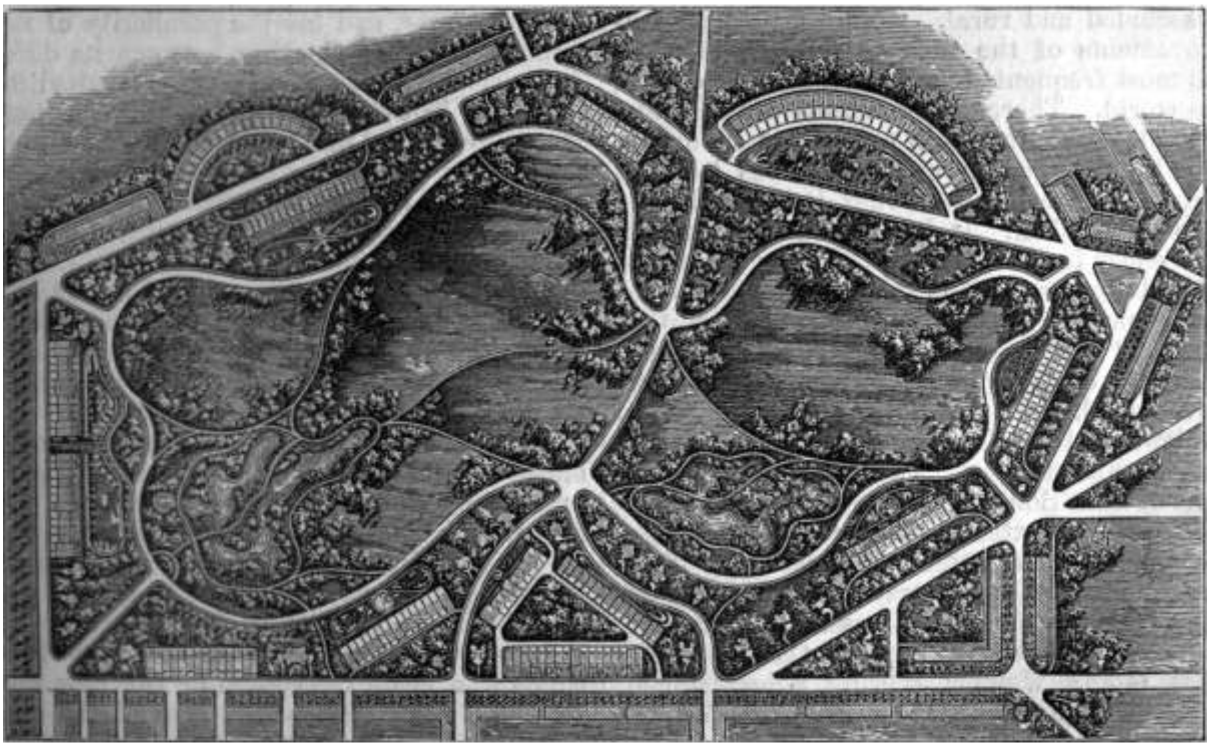

Figure 1. Map of Birkenhead Park, Birkenhead, Liverpool, England (The American Cyclopaedia v.13, 1879, p. 3)

The first allotment gardens, although reputedly around since Anglo-Saxon times (410-1066 AD) (NSALG), were designed also, in response to the industrial revolution, as well as the lack of welfare, as a way to provide food for the working poor (NSALG). Whilst industry provides jobs and thus a way to improve local and national economies, they have often created environmental and health problems. The significant rise in population brought about by the industrial revolution is indelibly linked '*to the increased use of natural and man-made resources, energy, land for growing food and for living, and waste by-products that are disposed of, to decompose, pollute or be recycled'* (McLamb, 2011). The exponential population growth '*led to the exponential requirements for resources, energy, food, housing and land, as well as the exponential increase in waste by-products'*(McLamb, 2011). One way of responding to the poor living conditions in England and elsewhere in the world was the concept and realisation of Garden Cities. Whilst there are a number of references to the term garden city pre Ebenezer Howard, it was he who was the first '*to outline the basic elements and tenets of garden-city planning*' (Shoemaker, 2001). The 3 Magnets diagram from Ebenezer Howard's 1898 book 'To-Morrow: A Peaceful Path to Real Reform' and in the revised and more commonly known 1902 version, 'Garden Cities of To-Morrow' (Figure 2) is one of the most famous planning and development diagrams ever created. It proposes that combining the benefits of the countryside with the benefits of the city would provide the foundations for a more prosperous, more cooperative and more liberated human experience, removing workers from inner city slum conditions, providing them with the health and other benefits, rural conditions can offer (Ross et. al., 2014). In essence much of the envisaged benefits of the beauty of nature, meadow, forest, fresh air and bright sunshine are biophilic and deserve to be part of any well planned city. In more detail, Howard in Garden Cities of Tomorrow (1898) illustrates how a garden city of 32,000 people should be planned with a central core of 1000 acres (405 hectares) and an outer core of 5000 acres (2023 hectares) that is destined for new forests, cow pastures, fruit farms, brickfields, convalescent homes, asylums, water reservoirs etc. (Figure 3).

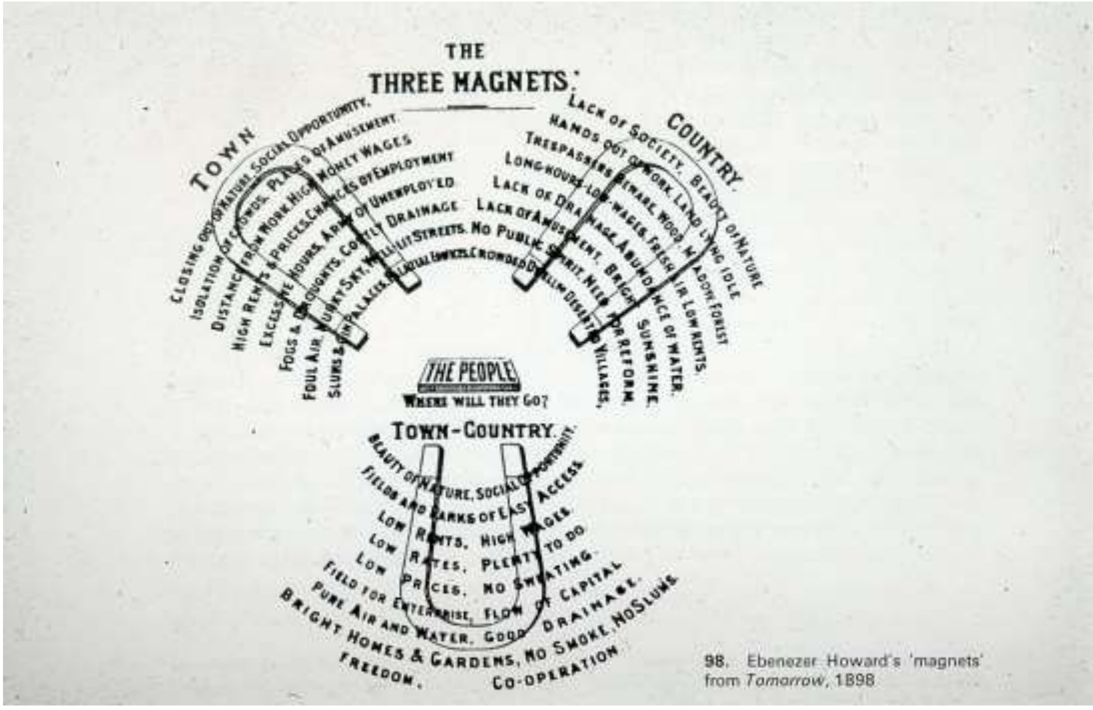

Figure 2. Magnets diagram by Ebenezer Howard. The benefits of the countryside are brought alongside the benefits of the city ("Three Magnets Diagram" by The JR James Archive, University of Sheffield is licensed under CC BY-NC 2.0).

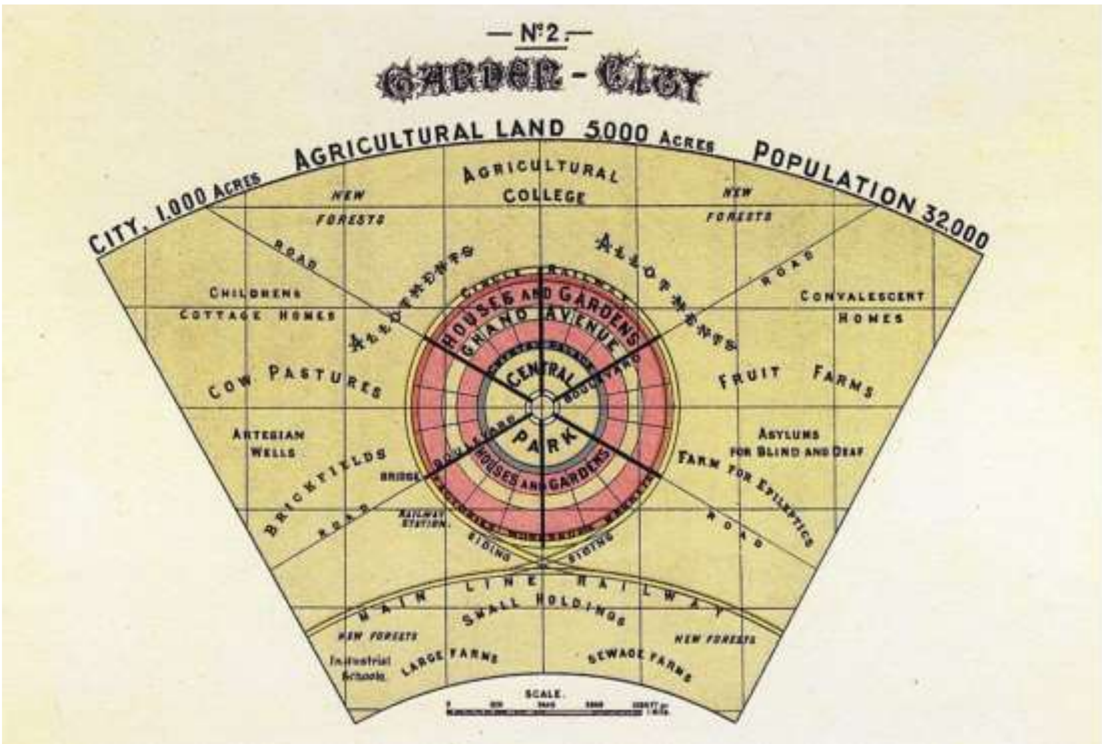

Figure 3. "Garden City Diagram" Ebenezer Howard, Public domain, via Wikimedia Commons

As the world's population increases, demographic studies indicate the increase in urban populations. The UN notes that 55% of the world's people live in cities and this will increase to 68% by 2050 (UN DESA). Whilst there are some cities that show a decline in population, most of them will grow and expand, competing with the megacities that exist; Tokyo (38 million), New Delhi (29 million), Shanghai (26 million,) and Mexico City and São Paulo (22 million) inhabitants each (UN DESA). The reality that we have to become used to is that cities will tend to grow as the world's population and specifically, urban populations increase. However, in order for us to prosper with respect to health and wellbeing this paper suggests the only way to do this is to grow vertically and not horizontally and to do this whilst integrating nature.

THE ENVIRONMENT AND BUILDING TALL

Sustainable development was defined by the so-called Bruntland Report (Report of the World Commission on Environment and Development chaired by Gro Hartland Bruntland) in 1987 as *'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'* (Bruntland 1987). Subsequently sustainable development was seen to be based on balancing the triple bottom line (TBL) as defined by Elkington in 1994, which includes balancing the needs of profit (economy) as well as people (society) and planet (environment). This concept originated in the business world to provide a more encompassing look of business success that was not only reflected in the single bottom line of monetary profit. Writing in 2018, nearly 25 years later, Elkington says that he '*proposes a strategic recall'* … '*to do some fine tuning'* of this concept (Elkington, 2018). He, (Elkington 2018) notes that 25 years later the successes in delivering the '*wellbeing of billions of people and the health of our planet', and the sustainability sector's record in moving the needle on those goals has been decidedly mixed'*. Furthermore, he states that whilst there have been some successes the world's '*climate, water resources, oceans, forests, soils and biodiversity are all increasingly threatened'*. In addition, he says, '*it is time to either step up — or to get out of the way'* (Elkington 2018). Elkington notes the TBL was not just a new accounting system but was '*intended as a genetic code, a triple helix of change for tomorrow's capitalism*' (Elkington 2018). The TBL is often illustrated with 3 equal Venn diagram sections, (Figure 4), which begs the question "are each of the values as important as the next"? We know that business would not exist without profit, but how much profit is enough and how much damage to the environment or to society is acceptable? In terms of the environment, it would be ludicrous to promulgate a balance which allows the planet to be destroyed and life as we know it, with its richness and diversity turned to dust. Are we at the tipping point, heading down the route of self-destruction?

The numerous effects of climate change that have become increasingly evident include drought, ice sheet loss, large scale losses of coral reefs, and permafrost thawing (Lenton et al., 2019). In order for mankind to take note of this situation, Lenton et al., 2019 says '*we should do the maths*' using an equation which defines an emergency:

$$E = R \times U = p \times D \times \tau / T$$

E= an emergency*, Risk (R) is defined by insurers as probability (p) multiplied by damage (D). Urgency (U) is defined in emergency situations as reaction time to an alert (τ) divided by the intervention time left to avoid a bad outcome (T).The situation is an emergency if both risk and urgency are high. If reaction time is longer than the intervention time left (τ / T > 1), we have lost control'* (Lenton et al., 2019). They note that the intervention time left to prevent tipping could be close to zero and '*the stability and resilience of our planet is in peril'*. (Lenton et al., 2019).

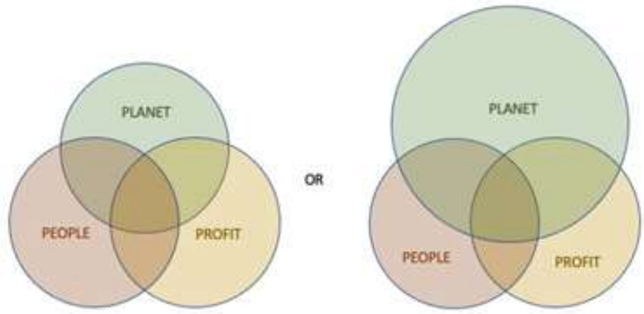

Figure 4. The triple bottom line Venn Diagram illustrating on the left a balance in the 3 parts of sustainable development. The diagram on the right indicates that perhaps the environmental part (planet) should be considered more important as without a habitable planet people and the economy will not survive.

The incentive to build taller which is the focus of this paper, has at its core, the need to condense development thereby enabling growth in city populations whilst at the same time protecting other lands for the ecosystem services they provide. Take Malé, the capital of the Maldives as an example (Figure 5), the capital has no room for horizontal growth. Grey, 2017 notes '*caged by the sea, they have no more land to spread onto, yet the city's population has soared by nearly 52% since 2006. The last census in 2014 counted 158,000 people crammed into the city's 2.2 sq miles (5.7 sq km) of space, and officials say the figure has since grown further.*' Furthermore, up to 40 people can be crammed into the space of a small studio flat (23.2 m^2) with significant increases in crime, drugs and domestic violence (Grey, 2017) As a result, building heights have increased from an average of 2 storeys in the 1990's to 8 storeys and up to 25 storeys high (Grey 2017). Regarding the potential significant likelihood of a social, health and environmental emergency which will be caused in Malé then using the equation above E = High probability x High Damage x Reaction Time which is slower than the intervention time required, there **is** an emergency that needs mitigation now. As the population grows, the only way for the society, economy and environment to flourish is for the city to grow significantly in height.

Figure 5. Male the capital of the Maldives has no more space for horizontal development. The only way to increase accommodation to avoid an emergency is to build taller. "Male City, Maldives" by Simonsees is licensed with CC BY 2.0.

The above reflection only looks at the emergency in terms of environmental loss of control, but with this loss there would also be devastating social and economic damage. Thus, a planet without an environment within which people can be healthy and happy and be economically successful is likely to fail and we are likely to end up with a dystopian world as envisaged in many a science fiction movie or computer game.

Most representations of vertical cities appear to be dystopian and this results from some man-made or external catastrophic event. For example, science fiction "hive cities"(see https://warhammer40k.fandom.com/wiki/Hive_City) (Figure 6), are environmentally and socially catastrophic. These cities are overly large, dumping their waste into surrounding environments, creating toxic air pollution. In a hive city the lower classes live in the bowels of the city whilst the nobility live in lofty spires in the clouds. This would be a truly unacceptable scenario. However, the version or vision of the biophilic vertical city is neither utopian nor dystopian. Rather the vison is based on providing pragmatic solutions to real world problems that cannot readily be answered in other ways.

With regard to CO_2 emissions, in 2015 '*buildings accounted for 39% of all global energy-related CO_2 emissions, with 28% due to the energy needed for their day-to-day operations and a further 11% related to emissions from the construction industry'* (Oldfield P., 2019). However, there is good news '*as building related energy is falling, from 185 kWh/m² in 2000 to 150 kWh/m² in 2015'* This, resulting from '*improved building envelopes and more energy-efficient technologies and systems'* Oldfield P., 2019).

In terms of the environment, the biophilic vertical city could provide all the best of city living, with the benefits of concentrated resources, integrated with nature and natural elements at the same time reducing the need for long distance commuting, whilst maintaining and/or giving back space to nature and for the common good of the people in terms of nature, recreation, water and food supplies. Thus, Vertical Biophilic Cities, increasingly appear to offer a solution by providing accommodation which promotes health and wellbeing, whilst minimizing land take which can be better used for other important functions such as proposed by Ebenezer Howard, (Figure 3) providing carbon sinks as well as water, agriculture, nature conservation and amenity uses etc. The next aspect that now needs some discussion is the economics of building tall.

Figure 6. "Warhammer 40k Imperial Hive City" by taumich is licensed with CC BY 4.0.

THE ECONOMICS OF BUILDING TALL

The first tall buildings or skyscrapers as they began to be known were made possible by the invention of the elevator and metal/steel skeletons which allowed lighter weight cladding to be used as the outer skin and the increases in skyscrapers in the USA had to do with the need for office space allied with growing urban populations (Gottman, 1966). The functions of skyscrapers evolved from offices and hotels to include other services such as medical centres, where easy interconnectedness was made available through elevators (Gottman J., 1966). Gottman (1966) notes that the main reason for the growth in skyscrapers was not the real estate market but rather a response of urbanization and the move of farmworkers and miners to cities. Furthermore, he notes, that the real estate market also did very well, although this was not the main driver (Gottman, 1966).

The economists Ahlfeldt and Bahl (2020) write in their blog that there are understandable reasons in '*the trend toward taller buildings'*. In the first instance urban land is '*provided inelastically'* as this is land that is finite and this implies that 're*nts generally increase in real terms over time'* and '*if the amenity value of height rises over time, this further pushes up average heights*' (Ahlfeldt and Bahl 2020). Furthermore, they note that '*even moderate reductions in construction costs can lead to substantial increases in building heights in places where rents are high, such as in central business districts in major cities*'(Ahlfeldt and Bahl 2020). But the development costs must stack up. The land and the cost of construction of each additional floor has to be taken into account and perhaps this is the reason that most tall buildings are less than 200 meters high and 99% of the world's skyscrapers are less than 350 meters tall (Barr, 2018). Barr (2018) notes that out of all the tall buildings those over 400 meters tall measure only around one-half of one percent where the *"regular-talls"* (under 50 stories) are the most common and the number of super giants, '*only make up a tiny, tiny fraction of the world's skyscrapers.*'

There is some consensus amongst a number of authors that these super tall buildings are created as status symbols, and for a short time at least, usually only for approximately 10 years, becoming the tallest buildings in the world. Barr (2018) furthermore notes that the development of the world's skyscrapers is consistent with the concept of '*Economic Height'*. In a continued discourse on tall buildings Barr (2019) terms this economic height, 't*he sweet spot'* where there is a balance between costs which increase with every floor going upwards and the revenue that can be achieved. In simple terms the equation reads:

'Economic Height = (Market Price Per Floor)/(Construction Costs Index Value)' or

'H=P/C'

where H = the economic height, P = the market price per floor and C is the labour and materials costs (Barr, 2019 Part IV).

In a presentation titled 'Economics of Vertical Cities' at the 1st Vertical City Conference, Tianjin, China, October 13-14, 2016, (https://verticalcity.org/news.html), Yian (2016) questions why do people pay 60,000 (Chinese Yen)/m^2 in Shanghai, Beijing and Shenzhen when the costs of the construction are only 3,000 Chinese Yen/m^2 (Yian, 2016, slide No. 22). (1 Chinese Yen = US$ 0.15 and thus US$1 = approximately 6.7 Chinese Yen). He asks, '*where did all this money go*', noting, that it has to do with land prices which are raised because of various factors around connectivity, association, living standards, job opportunities etc. He says the cost of the property exceeds the construction costs by between 8-10,000 Chinese Yen/m^2 (US$1,195 – US$1,492 m^2) (Yian, 2016, slide No. 22), which means the value of property is based on a number of variables other than cost.
This brings into question whether vertical cities should be developed on sites that have these high land values or rather where the cost of construction and infrastructure determines the price that residents pay. Yian provides a theoretical equation which outlines how property can be valued (Yian, 2016, slide 23) as follows:

'$V=A^{0.7}\times Q\times S\times N\times As\times O\times T$' where

A is the area (size) of the property, Q is the quality of the environment, air quality, weather & climate (temperature & humidity), comfortability, S is safety and security factor, natural disaster free, accidents free, low crime rate, surveillance coverage, …, N is neighbourhood & community nice index, As is the accessibility to services, gym, school, commercial center, …, (noting that accessibility is much greater in vertical cities as they are more compact and connectivity is greater which allows for '*easier access to all services*' and for businesses '*more customers, lower costs*' and a greater supply of labour (Yian, 2106, slide 24).*O is opportunity to jobs, friends, marriage, doing business, …, T is technology, such as city smartness, foreseeable future technology ready (robots, automatic delivery, information connectivity, …)*

Whilst the above parameters may be attainable in both vertical and horizontal cities, vertical cities do have the advantage with regard to accessibility, where access to services, jobs, friends and family may be closer, simpler and easier. Most importantly, it is very likely that vertical cities will significantly reduce the time and costs of commuting as well as carbon emissions. Perhaps when all vehicles are electric, and all power is from renewable sources this may not be an issue, but if commuting times for each commuter is reduced then individual and collective carbon emissions will be reduced.

Critics of high-rise may say that the aesthetics of vertical cities would not be comparable to horizontal cities, perhaps because of the access to open space, green and water space, however this would be likely if this verticality concept did not incorporate high levels of nature and biophilic elements integrated vertically and horizontally within each building, across buildings and up and down buildings.

In a publication by the Lincoln Institute of Land Policy, Campoli and MacLean (2007) note that the expansion of cities outwards has been going on for the past 50 years, noting the alternative is to '*grow in and up*'. In 2007, they note that the negative costs of horizontal expansion are beginning to be known and building compactly is beginning to be appreciated, saving money for governments, boosting the economy and helping '*us to prosper, protect the environment and strengthen our communities*' Regarding the issue of where vertical cities should be located, especially with regard to land prices, it may be optimal to locate them away from or adjacent to existing cities, for example on existing brownfield sites so that the cost of these new cities is linked more to their construction and infrastructure costs rather than being based on inflated land prices. Ahlfeldt and McMillen (2104) illustrate the comparative land values spreading out from the central business district of Chicago (USA) comparing 1913, 1990 and 2005 (Figure 7). Campoli and MacLean (2007) note that although most people would not consider cities to be environmentally friendly places '*by most significant measures they are...* (and) *…city dwellers use fewer energy resources and generate less pollution than their suburban and rural neighbours*' (Campoli and MacLean, 2007). They note that one of the benefits of density is the potential to '*save land from development*' and being able to access this natural land for recreation may be an incentive towards people accepting living in dense neighbourhoods (Campoli and MacLean, 2007).

The Visualizing Density publication was and is unique in allowing development associated stakeholders to better understand what density means through aerial photography and associated diagrams within a range of less than 1 unit per acre (2.2 units per hectare) to 300 units per acre (660 units per hectare). A simple calculation using this data means that if 1ha can accommodate 660 housing units at an average of 3.3 people per unit in the USA (2178 people) then 10ha will accommodate 21,178 people, 100ha, 217,800 people, 1000ha, 2,178,00 people and 10,000ha, 21,780,00 people which is approximately the size in population terms of Cairo, Mexico City and Sao Paolo. At this density a 10,000ha city (10km x10km = 100km^2) is nowhere as expansive as the sprawling cities of Cairo (2,010km^2), Mexico City (2,385km^2) and Sao Paolo (3237km^2) (Wikipedia – List of Largest Cities). But of course, with a vertical city we are talking about much taller buildings and much higher densities.

If buildings are doubled in height with double the population density, then 1ha will accommodate 4,356 people, 10ha will accommodate 43,560 people, 100ha, 435,600 people, 1000ha, 4,356,000 people and 10,000ha, (100km^2) 43,560,00 people. This equates almost to the size of Tokyo which has 37.5 million people with a footprint of 8,231km^2, which is 80 times greater in area than what is proposed with a vertical city. If one doubles the height again then such a city could be condensed into half the size of 5,000ha (50km^2) enabling the rest of the areas to be used for ecosystem services.

The People Fixing the World Podcast, '*How to reuse a demolished building'* (BBC, 23/09/21) highlights the potentials for reusing / rebuilding using the materials and even the foundations of existing building once they become untenable. It is possible but unlikely that existing skyscrapers in the world's inner city areas, would be pulled down to be redeveloped taller, as the cost of the land is likely to be prohibitive, so the question then is: Where next to build these cities? Analysing the cost of development land in Chicago (Figure 7), it is most likely that the city would not be built where land prices are very high and also where land is largely green. Rather it would appear to make sense, either to build in areas which are adjacent to the land with the highest land prices or to build on areas that are highly developed but where land prices are relatively low. Thus, the price per unit would be closer aligned to the costs of construction and infrastructure, thus making these cites more economically viable at least in terms of costs per m^2.

The biophilic vertical city concept does not preclude the necessity for the cost benefit of building tall, but building tall is a response to economic drivers as part of the process of urbanisation where the clustering of people and business creates efficiencies in the creation of goods and services and the ability of countries to build skyscrapers is directly related to the size of its economy (Barr 2018). Poor countries do not build skyscrapers (Barr 2018). This, however, is not an indication that high rise construction is not an answer to the accommodation problems of less wealthy countries because they do not have the funds. They usually also do not have adequate funds to spend on other key aspects of urban life such as infrastructure (water, sanitation, energy, roads) that meets the needs of the people and that would promote health, wellbeing and economic success.

The argument for and against tall buildings is complex. There are issues of aesthetics, skyline, carbon and ecological footprints, national pride, ego, vanity, prestige and economic diversification and urban regeneration (Barr, 2019, Part III). From the above, it is taken that poor countries cannot afford to build tall, but where rich countries can afford it, on the whole these developments were part of national and regional strategies to create '*spillovers*' (Barr 2019, Part III), to increase economic growth and well-being.

Oldfield (2019) notes that '*financial drivers still play the most important role in the formation of skyscrapers today steering every aspect of their design articulation'.* Skyscrapers he says are costlier to construct per unit floor because of increased structural, lifting and service requirements as well as due to the complexity of materials and construction. Additionally, there is usually '*reduced net-to-gross ratio*' as '*tall building have less net lettable floor area per unit gross floor area than low rise buildings, due to greater structural and core requirements with increased height'*, e.g. with the need for larger supports and more elevators (Oldfield P., 2019). But, the economic costs of building tall also relates directly to materials and labour costs where labour costs differ considerably across the world.

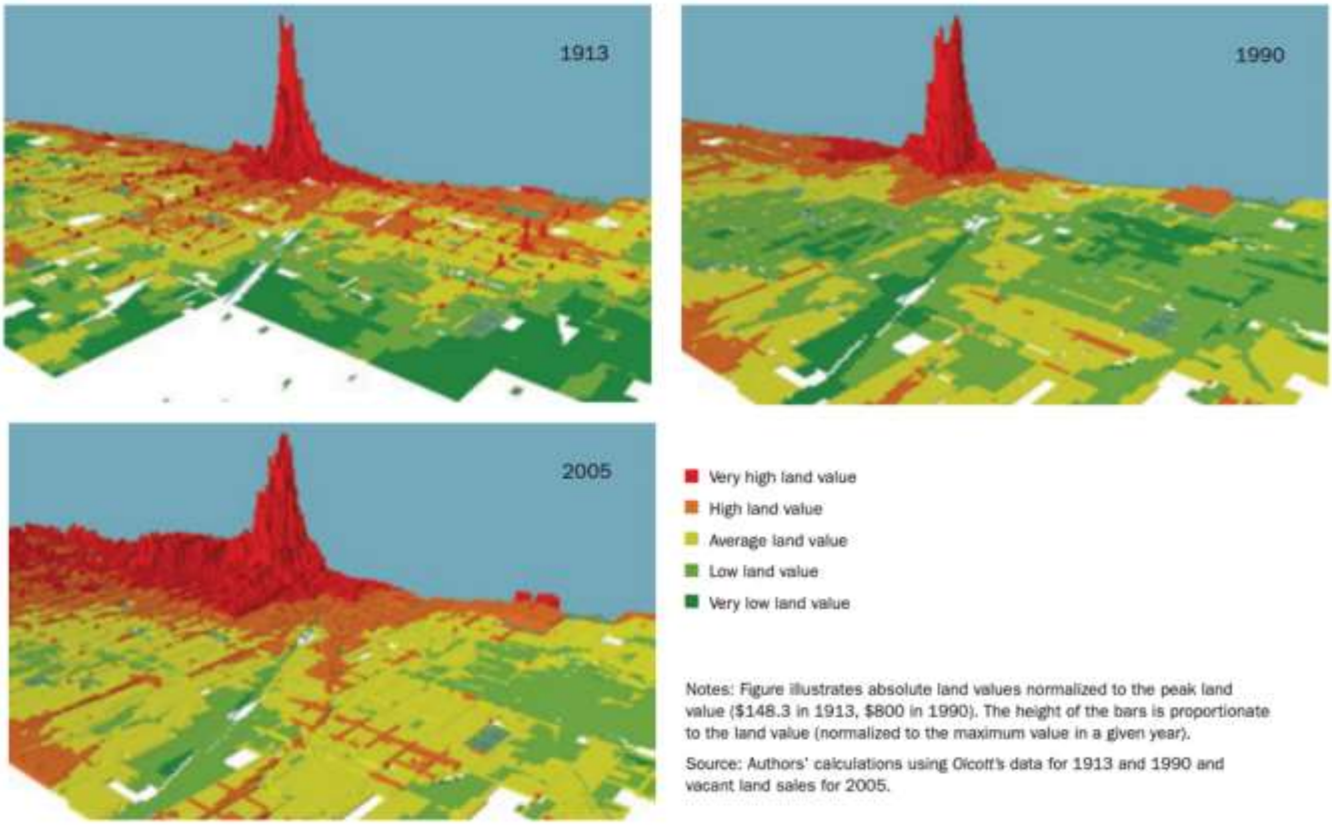

Figure 7. Chicago land values 1913, 190 and 2005 illustrating higher land values closer to the central Business District, from Ahlfeldt and McMillen (2104).

In the USA, in non-inflation adjusted US dollars, a floor in the One World Trade Center (2014) cost $37 million, the Shanghai Tower, Shanghai, China (2015) $19.8 million, the Shard, London, U,K. (2013) $26 million, Taipei 101, Taipei, Taiwan (2004) $17.4 million and the Burj Khalifa, Abu Dhabi (2010) $9.2 million (Barr 2019, Part IV).The costs of going tall is therefore linked to location, and labour, but also to materials, where more materials, in terms of concrete and steel are required at the bottom levels to support taller structures and additional materials are required to make taller buildings more rigid to counteract swaying. Gabriel Ahlfeldt and Jason Barr in an article for the London School of Economics (LSE) note that '*computing software and wind tunnel testing has allowed engineers to design more efficient structures based on simulated tests*' and that '*such technological change reduces the costs of building tall buildings, increasing the economic height*' (Ahlfeldt G. and Barr J., 28 July 2020).

This paper conjectures that if vertical cities are considered to be a way of developing more sustainably taking account of urban population growth, then 1) vertical cities will be created incrementally with a continuous construction of tall buildings and 2) that these cities will be constructed within and as part of existing cities, where existing buildings will be removed as they are no longer deemed fit for purpose and/or they are not environmentally sustainable and economically efficient. In this respect, based on studies in the USA, Canada and Australia, in terms of transportation and infrastructure the costs of urban sprawl, i.e. the development of urban fringes, was almost 3 times of what it is in inner areas (Trubka et al., 2010).

The infrastructure costs of horizontal growth, i.e. building of greenfield sites is approximately 2 to 4 times the cost of infill development (SGS, 2016). However, these advantages in infill development relate largely to the capacity found in existing infrastructure whereas greenfield development requires all new infrastructure (SGS, 2016). This, however, would not necessarily be the case when creating clusters of tall building which increase urban density, where new facilities, for example schools and hospitals would be required and other infrastructures such as power supply, water and sewage provision would likely need to be upgraded. Road provision would be a plus as these may need some reconfiguration but will not need to be built from scratch.

SOCIAL IMPACTS OF BUILDING TALL

There is a presumption that tall buildings are not conducive to social sustainability and that they are '*less successful in forming attractive residential communities*' but in reality, Oldfield (2019) notes that it is difficult to compare the social sustainability of low versus high-rise due to various non-architectural factors that shape occupants' experiences of living there. These include '*socio-economic status, local economy, building governance and whether residents chose to live there or if it was their only option'* (Oldfield P, 2019). With regard to crime, surveyed residents in tall buildings were more fearful of neighbourhood crime but were less fearful of crime in the home '*due to the protection offered by being lifted above the ground in an apartment'* (Oldfield P., 2019). Building tall is also associated with higher densities and as noted previously, higher densities offer residents easier access to local community services and facilities '*which tend to be more generous in city centre locations'* (Oldfield. P., after Dempsey et al., 2012). Oldfield notes that while the '*criticism of high-rise is focused on western failures, in Singapore where 80% of the population live in high-rise social housing 91% ... were found to be satisfied with doing so'* (Oldfield 2019, quoting Yuen et al., 2006).

A criticism of high rise is that there is the lack of open space, defensible space, social space, space which can be overseen (Oldfield P., 2019), but there is no reason that these can all be incorporated within well designed high-rise buildings and associated elevated green infrastructure which takes cognisance of these issues.

Regarding population density, in Vancouver, there is a paradox. The more people that populated the city, the more people wanted to live there (Montgomery, 2015). Every year Vancouver sits at the top or near the top of cities with the best quality of life, and this density which reduces energy use and transportation, means it has the lowest per capita carbon footprint of any city in the USA (Montgomery 2015). The arrangement of building is however crucial as the citizens of Vancouver are vociferous in their determination to keep views to the mountains both from the buildings and from ground level. Thus, planners have to be prudent in how the buildings are arranged (Montgomery 2015) and view protection zones have been initiated (City of Vancouver [1], City of Vancouver [2]) (Figure 8), although there is criticism that this policy is affecting the city's '*true economic potential'* (Chan, 2017). The result is restricted building heights and, in some cases, thin building profiles. Changes in the massing of buildings was also initiated in New York's 1916 'Zoning Resolution' (Figure 9) where building were stepped back to enhance light reaching the streets at ground level.

Montgomery (2015) notes that the increase in density needs to correspond with repaying the city with a public park or a plaza or a day centre. He says that as the city gets denser its residents should enjoy more public space. Another problem with dense cities, which would correspond with tall cities is the psychosomatic illnesses (sleeplessness, irritability, nervousness) that people may encounter due to the close proximity of people. In this regard Montgomery (2015) furthermore says that '*crowding is a problem of perception'* that can be addressed by design and understanding sociability. '*It is easier to tolerate other people when we can escape them*', and this can be achieved by having quiet internal spaces in buildings as well as easily accessible external public spaces (Montgomery, 2015). Montgomery (2015) furthermore notes that younger people want to live in more dynamic places, which is not possible with urban sprawl, so densification is the answer. However, this type of lower rise densification may be what people want in an ideal situation, but we may have passed the tipping point where building "nice" does get the world away from the tipping point of climate change disaster.

One other social issues of high-rise living that has been raised is the lack of community and social interaction that is lacking as people are restricted to establishing relationships mainly with only those people, they share a floor with. This can be counteracted, however, by skybridges, sky gardens and other facilities, (fitness gymnasiums, swimming pools, other sports facilities, winter gardens/indoor parks that are established at upper levels (Figure 10).

The COP26 (the United Nations Framework Convention on Climate Change – 26th Conference of the Parties) held in Glasgow in October 2021, drew the world's attention to the potential climate change initiated disasters awaiting the world. How cities and societies respond is key to whether we can avoid significant current and future problems. The COP is asking for radical changes and the way most people live in cities is likely to have to change as well, by being denser and taller. Including nature within, on and around buildings at all levels, will allow people to benefit from their connectivity but also allow them to escape for their mental and physical wellbeing.

WHAT IS A VERTICAL CITY?

Whilst there are many definitions of what a city is, the clear constituents of a city are that it:
- has a large population;
- has an arrangement of numerous buildings which provide accommodation for living,
- provides places for working, civic functions, including health and education and amenity purposes;
- provides shops and offices that provide, food goods and services;
- provides infrastructure and the means of transport for people to move between places;
- is organised with an infrastructure that provides energy, water and the means to manage waste; and
- provides the infrastructure for food to be brought into the city by road, rail an air and markets.

Regarding vertical cities, King and Wong state that a vertical city '*is a series of interlinking, environmentally friendly, self-sustaining, mega towers that extend as high as a mile skyward'*(Kickstarter) (Figure 11). This definition suffices as a kickstart description as it defines most of the key conditions of a vertical city:
1) they are extremely tall, as high as a kilometre or a mile;
2) they comprise megatowers;
3) these are interlinked;
4) they are self -sustaining; and
5) they are environmentally friendly.

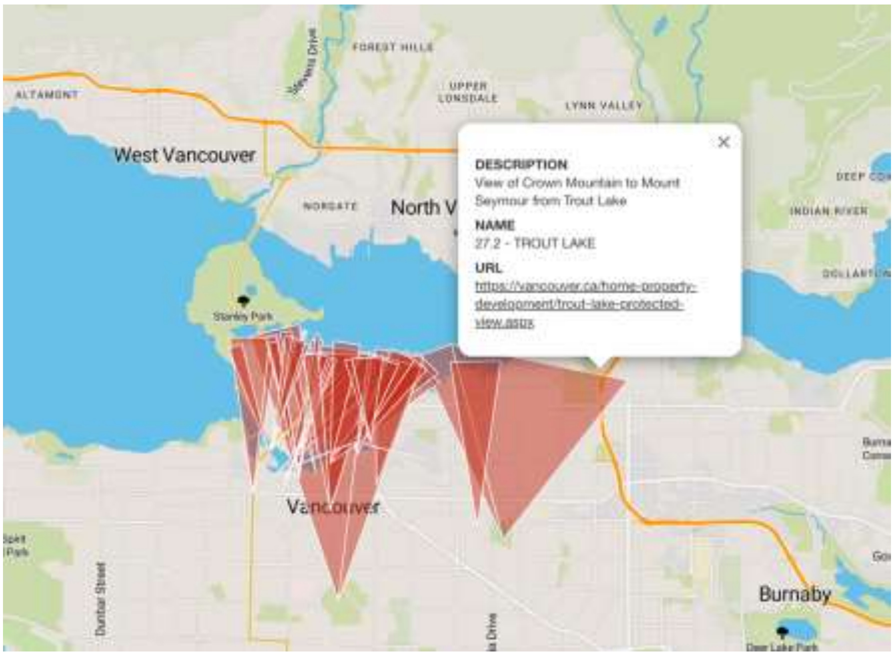

Figure 8. Vancouver View Cones maintain views to the sea and mountains to the north, Open Data from https://opendata.vancouver.ca/explore/embed/dataset/view-cones/map/?location=11,49.28214,-122.81582

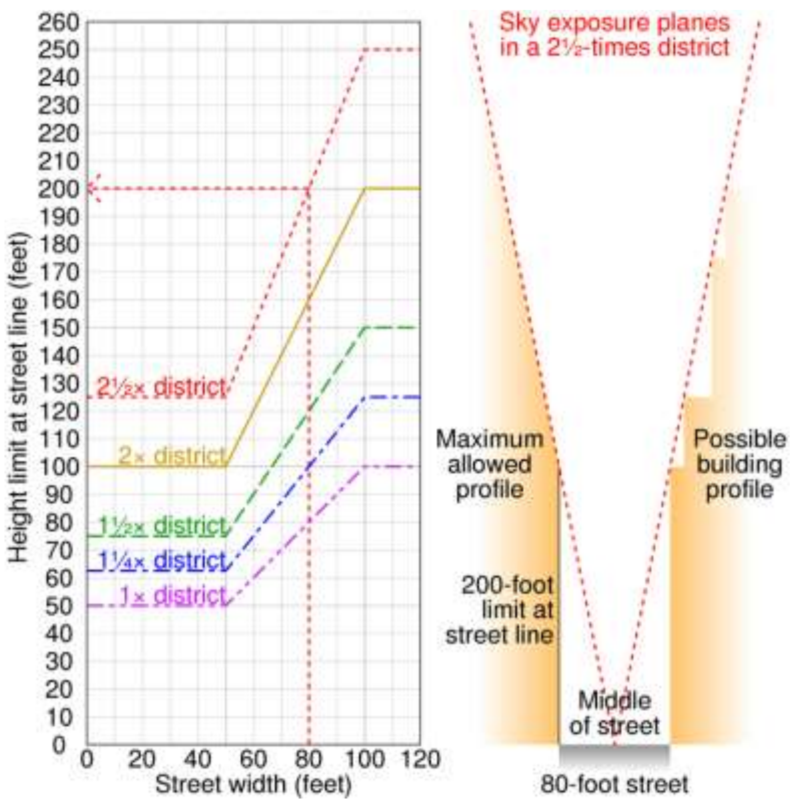

Figure 9. Graph of the 1916 New York City zoning ordinance with an example elevation for an 80-foot street in a 2½ times height district by CMG Lee based on data at http://buildingtheskyline.org/revisiting By Cmglee - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=82541740 GNU Free Documentation License.

Figure 10. 42nd-floor 'skybridge', Raffles City project, , Chongqing, China , Creative Commons licence, architect Moshe Saffie - By Junyi Lou - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=81872456

The key conditions for a city to be termed a vertical city are considered as follows:

1. Height

Defining particular determining heights for buildings in a vertical city is something that is perhaps for future practitioners and theorists to define. What we can probably say, is that whilst numerous tall buildings have been constructed around the world, for example in New York, Shanghai, Taipei and Dubai, these cannot be seen as components of a vertical city, largely because they have been conceived individually and although many individual buildings may be considered tall enough as megatowers, these are usually created as individual towers. Whilst the engineering skill towards creating megastructures is illustrated in the world's tallest buildings, the Burj Khalifa, Dubai (828m), the future Burj Mubarak al- Kabir, Kuwait (1001m), the Jeddah tower (1008m), it is the 'Petronas Towers' (451m) with 88 storeys, comprising twin towers that are joined by a 'Skybridge' 170 metres up (Figure 12), that indicates the potential connectivity of these buildings which is a necessary component of the vertical city discussed in the section below. Access to tall buildings is not an issue as elevators have speeds over 35km/h, and it is possible to reach buildings over 95 stories in 45 seconds. It is however predicted that elevators could not go faster than 86km/h because of an issue with air pressure and to solve that, the building would need to be pressurised (CNN Style).

As most tall building are less than 400 metres tall it would be prudent to surmise at least in the short to medium term that buildings in vertical biophilic cities could be of that order. If that is the case and we estimate 3.5 - 4.0 metres per story, which takes account of the construction floor slabs then the main vertical components would be 100-114 storeys.

Whilst most people would conceive of the vertical city as being in the air, it is conceivable that these could readily be extruded underground as well, especially because, some functions do not need natural light and also because megastructures are already constructed on foundations that delve deep into the ground – the Petronas Towers, for example have foundations up to 125 metres deep (Civil Engineering World). Mexico City has conceived a 75 storey underground 'Earthscraper' by BNKR Architectura (Figure 13). Constructing deep underground is not just in the realm of ideas as is evidenced by the Large Hadron Collider in Switzerland, which is 175 metres deep, the Jinping Laboratory, China is 2,407 metres down and the world's deepest mine in South Africa is over 4km down (The B1M). Going deep has thermal implications as does going high. Away from the earth's tectonic plates, the temperature rises approximately 2.5°C/100m as one goes down and cools down by approximately 1°C/100m as one rises above ground level (Energy Education) and thus both above and below ground structures would need to take these temperature changes into account.

2. Multi-Level Connectivity

A key attribute is that the megatowers are required to be interlinked, so that access and circulation is possible at many levels and not only on the ground plane, which is the current condition in most of our cities. Downtown Toronto in Canada is an exception, with the PATH, where multi-level connectivity is provided below ground, with over 30km of interlinked pedestrian walkways, linking 70 buildings and used by 200,000 workers daily (Toronto Financial District) (Figure 14). This system has had a significant economic contribution as it allows people to access shops and other venues readily during the cold winter months (Toronto). Connectivity in the vertical city, may be underground and at various levels above ground, but of course also needs to be vertical by elevators/lifts to gain access to the building's floors. Whilst connectivity at ground level is relatively simple for pedestrians and vehicles, a similar type of connectivity may be more difficult due to high wind speeds, but these could surely be overcome by sky tubes, with pedestrian walkways and travellators. Developments in travellators include magnetic levitation 'maglev', which will propel pods and there are proposals to develop elevators that move both horizontally and vertically (CNN Style). Early ideas of skywalks can be seen in the 1927 movie 'Metropolis' directed by Fritz Lang and in the poster by Boris Bilinski (Figure 15). There are many more illustrations of this type but whilst they show outdoor walkways and larger piazza type spaces, they are rather grim looking, being devoid of any natural elements except sky and clouds.

Figure 11. A vertical city as illustrated in King and Wong's 'Vertical City: A Solution for Sustainable Living

Figure 12. Petronas Twin Towers, Kuala Lumpur, Malaysia, (photo by Luke Watson (Lukeaw_ - Own work).

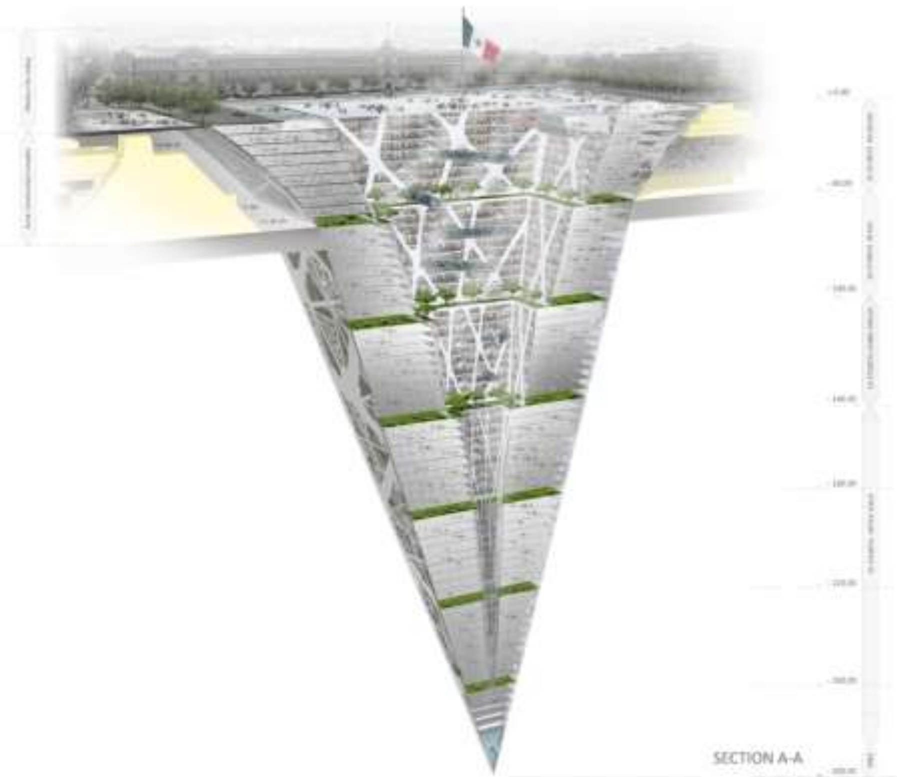

Figure 13. Mexico City's proposed 75 storey underground scraper by BNKR Arquitectura illustrates a vision for underground buildings in the future. (With kind permission from BNKR Arquitectura).

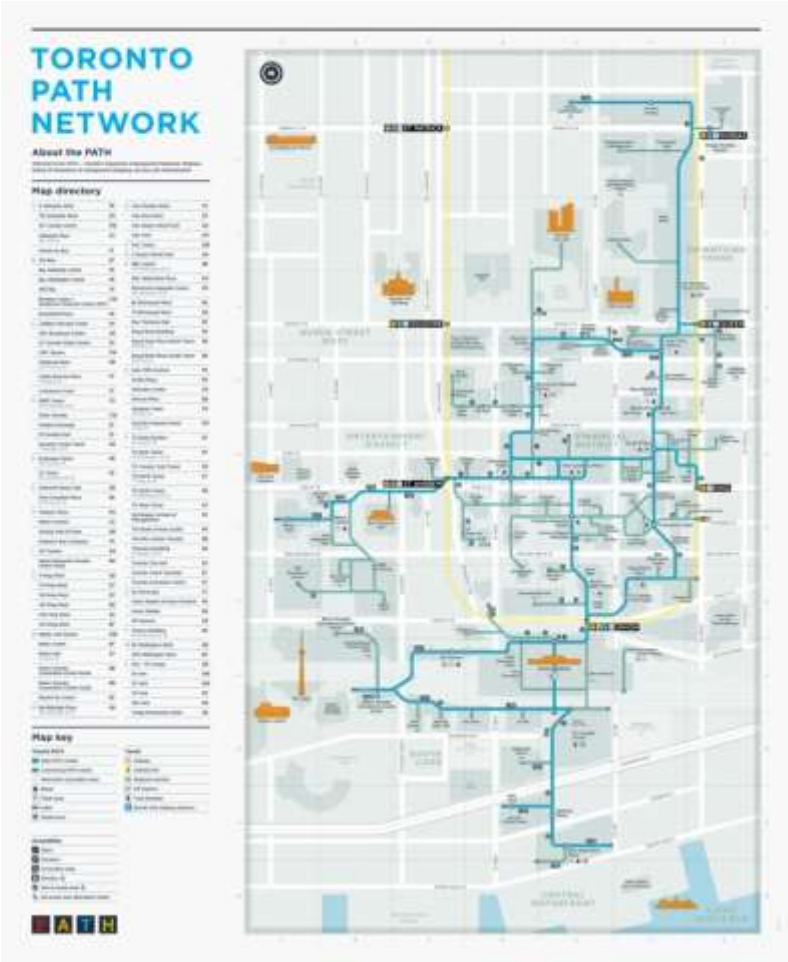

Figure 14. Toronto's PATH network which provides underground links across a broad area. There is no reason that a similar system could not be developed in the sky as well linking buildings in a vertical city.

Figure 15. Metropolis movie poster. The image illustrates the concept of the future city with skybridges. (1927 Boris Bilinski: Plakat für den Film Metropolis, Staatliche Museen zu Berlin)

3. Multi-Functionality

One of the issues facing today's cities, is that at the core, many of them are not multifunctional and they are workplaces that are used by commuters during the day, becoming largely vacant at night time. Whilst there are some good examples of multifunctional building complexes which include towers with shopping and other amenities at lower and underground levels, (Vancouver and Hong Kong for example), towers are generally uni-functional hosting either apartments or office space. There are towers that include gyms and apartments at upper levels but there are very few buildings which have elevated integrated amenity space. 20 Fenchurch Street is an exception with the inclusion of a sky garden at the top of what is called the 'Walkie Talkie' building (Figure 16). The Marina Bay Hotel in Singapore has an iconic surfboard style roof deck with an infinity edge pool that illustrates the potential for designing amenity spaces at high level (Figure 17). The multi-functionality of the vertical city can incorporate all aspects of city life including homes, offices, factories, warehouses, hospitals, theatres and cinemas, restaurants, galleries, food production, parks, gardens and perhaps even functions such as cemeteries, crematoria and waste management facilities. However, some of these functions may be more difficult to achieve, having to change mindsets and traditions.

Whilst the form of the vertical city requires height and multi-level integration and multi-functionality, it is the premise of this paper that without the final attribute of biophilia, the mistakes of the past, where the incorporation of nature is green wash or tokenistic, will just be repeated. Thus, the fourth and final element for a functioning vertical city is the integration of nature into the city.

4. Biophilic Content

Biophilia means the love of life or living systems and the benefits of people having contact with nature was the key focus and philosophy popularised by Edward O. Wilson's in his 1984 book 'Biophilia'. There are a number of key organisations and authors/researchers working in the field of biophilia, including Tim Beatley, founder and director of the Biophilic Cities organisation, who note the importance of conserving and celebrating nature and biodiversity and the benefits of having '*daily contact'* as part of having '*a meaningful urban life'* (Biophilic Cities). This new idea of 'biophilic urbanism' is discussed by Peter Newman, as part of a new planning paradigm for Singapore (Newman P., 2014). It is worth noting Terrapin Bright Green, as a key authority and publisher in biophilia and biophilic concepts and development, having been set up in 2006 '*seeking to answer the challenges of high-performance design in the 21st century*' and '*to reaffirm … environmental and social values*'(Terrapin Bright Green – Creating a Healthier World).

In the Chapter 'How to be Closer' in Happy City, Montgomery (2015) says that we '*are at war with each other'* in the dichotomy of requiring proximity to each other as well as times for isolation. We need to balance the needs of density and dispersal through design and as we get closer, we need more nature (Montgomery 2015). This may not be the nature we naturally think of as Montgomery (2015) points out the numerous studies undertaken that illustrate that glimpses of trees and indeed images of landscapes help to heal patients in hospital, increase the memory capacity of staff in correctional facilities and reducing stress in dental surgeries.

It is becoming increasingly evident that not only are there benefits in integrating nature into our everyday lives and environment, for our health and wellbeing, but that it is becoming essential for us to do so, in order to mitigate and address the poor negative trends that people have created. Mankind is realising that we have to work with nature, in order for our species to survive and to live healthy lives. Plants and other natural elements such as soil and its billions of microbes, for example, help to clean our water and air and help to mitigate the urban heat island effect. They provide niches and food for other wildlife which are necessary to our survival. Nature also provides food for our very survival. The lack of greening in our urban jungles, which are largely devoid of the essence of "jungle" which is nature, needs to be redressed in all our cities and will need to be part and parcel of the vertical city as well. The ever increasing path towards a technological lifestyle, where nature is plundered, abused and omitted is no longer viable. The industrial revolution steered mankind on a path where we are today, both for good and ill. The loss of nature that started then, has to be redressed through the integration of green infrastructure, on top with green roofs, on the sides with living walls, and within our buildings and on the streets with trees and rain gardens as well as in gardens and in parks. Certain foods can and should be grown as close as possible to market, reducing carbon and ecological footprints and where the field to plate timespan is kept as short as possible in order to maximise freshness and nutritional content. This is a necessity for vertical cities as well where food can be grown above or indeed below ground. It is important to note here that there are 3 types of nature that are relevant here, 1) NATURE (all capital letters), 2) Nature with a capital N, and 3) nature (all lower case)[1]:

1. NATURE – The capitals used to spell nature emphasise that this is untarnished pure nature where man has not had access and has not disturbed it by any immediate physical presence. These areas are few and far between and include parts of the Antarctic and potentially areas of rainforest in Africa and South America. These areas remain in the same relationship to the vertical city as they do to any city. Mankind and cities should not have any direct influence on NATURE;
2. Nature – Nature with a capital N, describes those areas that are accessed by people but are largely ecologically intact and

[1] Note this hierarchy was developed as part of the author's PhD research some time ago.

viable. These areas are under threat and would become larger and more viable in the long term when people are concentrated in vertical cities; and

3. nature – This is biophilic nature that is installed within human environments which add pleasure and function to peoples' lives. This includes the simplest pot plant on someone's desk, to sophisticated integrated green roofs, living walls and urban agriculture systems.

Figure 16. The Sky Garden at 20 Fenchurch Street, London.

Figure 17. Infinity edge pool on the top of the Marina Bay Hotel, Singapore. (Photo by Walter Lim)

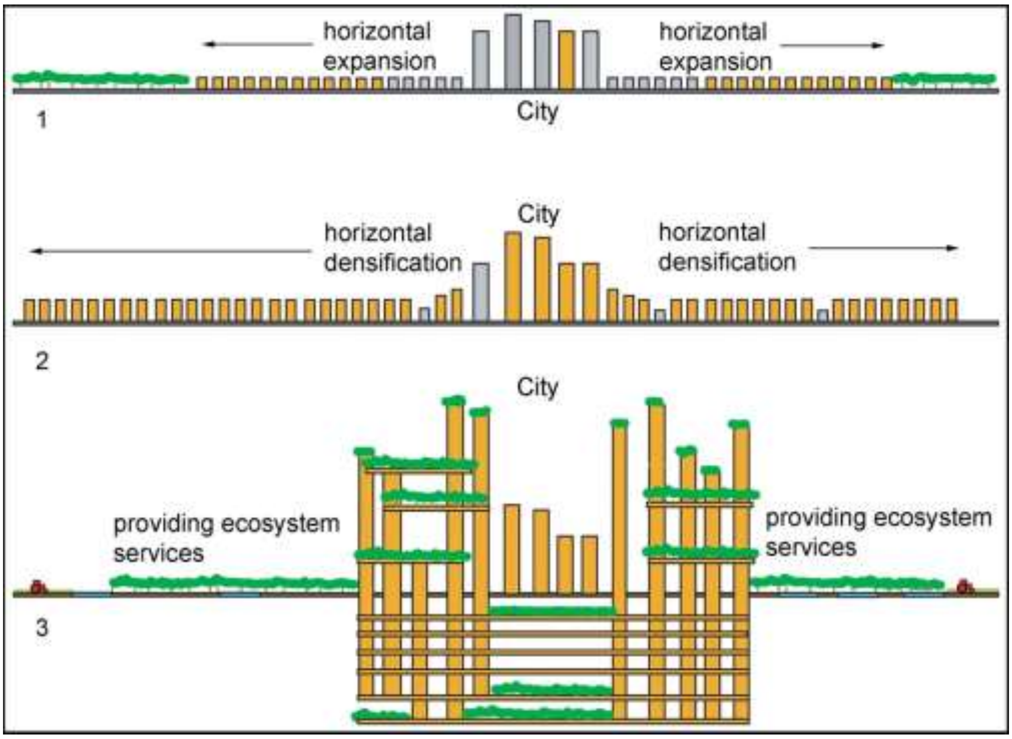

Figure 18. Three hypothetical options to accommodate future urban populations: 1. Carry on currents trends with ever increasing horizontal expansion, 2) After Montgomery (2015) increasing density overall 3) The Biophilic Vertical City option, creating the vertical city around the existing city (in order to reduce payments for land and releasing land to be put back to ecosystem services provision. Eventually the existing city will be replaced and become integrated into the Biophilic Vertical City.

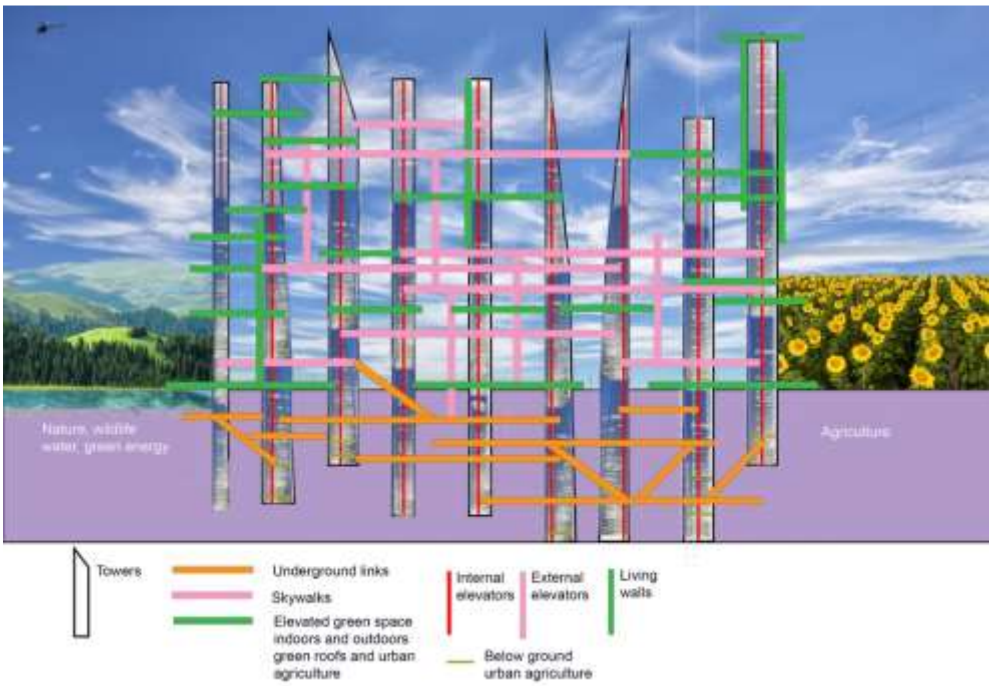

Figure 19. Concept of the Biophilic Vertical City.

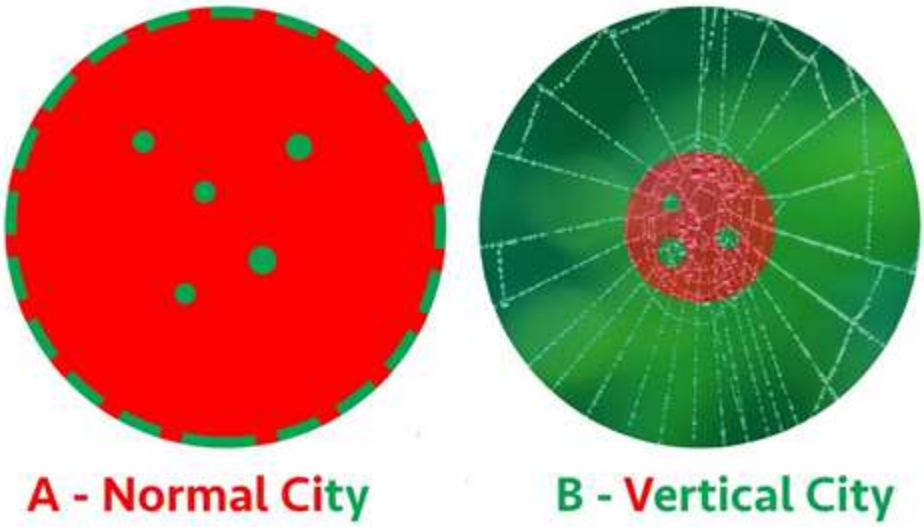

Figure 20. Diagram of the 'Normal City' where built development footprint (red) dominates with small pockets of nature and food production (green) compared to 'Vertical City' where development is concentrated with a network of connected open spaces allowing most of the space to be used for nature and food production.

There is one other aspect that all cities need to have to be successful and this is that they have to be "liveable". The World Economic Forum (WEF) suggests 3 critical factors, (some of these are addressed above) that make cities liveable as follows:

- residents need to feel and be '*safe, socially connected and included'*;
- the cities need to be '*environmentally sustainable'*; and
- people need '*access to affordable and diverse housing options'* being '*linked via public transport, walking and cycling infrastructure to employment, education, local shops, public open space and parks, health and community services, leisure and culture'* (WEF).

These are the essential ingredients for a liveable community. They are needed to promote health and wellbeing in individuals, build communities and support a sustainable society.

With regard to the design of cities accessing, incorporating and integrating with both Nature and nature in points 1 and 2 above Terrapin Bright Green have listed 14 different aspects of biophilic design which can and should be incorporated within cities and the lives of people (Terrapin Bright Green-14 Patterns of Biophilic Design) including visual, non-visual and stochastic and ephemeral connections to nature, natural experiences of airflow, water and light and the connection to natural systems including being able to be aware of temporal changes. Other patterns include symbolic references to nature, using natural materials and elements and '*creating spatial hierarchies characteristic of a healthy* ecosystem'. Additionally, providing views across distances (prospect) and places away from main activities (refuge), inviting people to explore nature and to identify threats. The 14 patterns of biophilic design relate directly to people and their experiences of nature. Our buildings, never mind our urban environments, do not allow for many of these experiences, but there is no reason why vertical cities should not be able to do this.

CONCLUSIONS

Whilst there are numerous possibilities for creating habitation on and in the Earth's oceans and seas, through floating islands and submerged cities, there are three main terrestrially based options as to how we accommodate all the people that we are going to have to in our cities (Figure 18) We can continue to build on greenfield sites, expanding horizontally, but this would not be acceptable in terms of the lack of connectivity and increasing damage to habitat and ecosystem services (Sketch 1, Figure 18). Sketch 2 illustrates a scenario suggested by Montgomery (2015) where existing areas are densified. No new land is required and new taller denser hubs could be created to provide the connectivity that is desired. However, the existing format is flawed as the damage that has been done to the past ecosystems largely remain and connectivity is still extensive. Sketch 3 illustrates the existing city bound by parts of the new Biophilic Vertical City. Over time it is likely the existing city will become taller as well, whilst the vacated large hinterland areas can be converted back into natural habitat, water bodies and farms which provide multiple ecosystem services for the inhabitants of the city.

In the UK, the debate on tall buildings, focuses not so much on their benefits to the planet, but on their aesthetics, such as with The Shard, the 'Walkie Talkie', the Gherkin, all in London and with the visual impact they make on the skyline and the historically protected views to St Pauls Cathedral. The planning arguments centre on the location of tall buildings and the discussions on creating vertical cities appears to be in the distant future. But the reality is that we should be planning for these, right now. Vertical cities, in part, are biophilic cities, in the sense that they will concentrate populations on smaller footprints, allowing the rest of the world to be used for nature, for agriculture, for water harvesting and cleansing, for power production through green energy sources and for amenity purposes. The diagram in Figure 19 illustrates the essential elements of the vertical city with its vertical elements both below and above ground, the biophilic introductions of nature and biodiversity on the green roofs and living walls and in parks, gardens and urban agriculture at all levels and the concentration of the city that allows more space for nature, accessing nature and for farming. Whereas the 'Normal City' expands to marginalise nature, pushing ever deeper and negatively influencing boundary habitats, the Biophilic Vertical City is less greedy with land, making it available for farming, nature and amenity (Figure 20). Whilst the Normal City has isolated parks, gardens and reluctant green infrastructure, the Biophilic Vertical City has a network of green spaces working 3 dimensionally across the city, above ground and below ground and beyond being integrated with the natural habitats outside the city (Figure 19).

Vertical cities have yet to be built, based on any model let alone the model suggested above which calls for not only tall buildings, but development and connectivity that continues below ground as well, with the integration of biophilic elements in the forms of green roofs, living walls, urban agriculture, greenhouses, closed and open parks and gardens. The basic element is however the tall building and The Council on Tall Buildings and Urban Habitat's research paper 'The Other Side of Tall Buildings: The Urban Habitat'[2] (Safarik, 2016 from Wood and Henry 2015) states that '*the impact of a tall building is far wider than the building itself*' and that '*projects should demonstrate a positive contribution to the surrounding environment, add to the social sustainability of both their immediate and wider settings, and represent design influenced by context, both environmentally and culturally'*. Whilst technologies have met the challenge for building tall and are likely to meet the challenges to build ever taller, there are unknowns, for example how societies will react and develop in response to these types of developments. But what we do know is that the current status quo of horizontal expansion is untenable and that many social, cultural and environmental ills have arisen from how we have developed cities in the past. It is most likely that vertical cities will arise and we need to ensure that they include nature as a key component, keeping in mind also that the incorporation of nature will assist technology to improve the quality of life for people, mitigate the urban heat island, reduce flooding, clean the air etc., and so we must meet the challenge of this new type of city, by learning from the mistakes of the past and developing cities that are socially, economically and environmentally rich and that allow the resources of nature to be brought into these cities and to protect and enjoy the expanse of Nature outside the City that will be protected from increasing expansion.

The OECD (The Organisation for Economic Co-operation and Development) notes that, '*in a way, the amount of buildings and infrastructure per person in a metropolitan area is similar to the body mass index or BMI*' where '*the amount of built-up area per person indicator could be seen as a "City Mass Index" where cities with low levels should seek to build more and cities with high levels should seek to build less'*. However, they acknowledge that '*a crucial limitation in the approach'…'is that it does not consider building heights*' where the replacement of low-rise with high-rise buildings '*can reduce crowding without increasing the amount of built-up land*' (OECD). A goal of the United Nation's New Urban Agenda 2 and its Sustainable Development Goal (SDG) 11 is to restrict urban sprawl (OECD). Goal 11 includes an indicator that compares changes in land use and changes in population. (OECD). The UN's SDG no. 11 reinforces the protection of the environment by stating that '*by choosing to act sustainably we choose to build cities where all citizens live a decent quality of life, and form a part of the city's productive dynamic, creating shared prosperity and social stability without harming the environment'(UN Sustainable Development Goals)*. This is the whole point about biophilic vertical cities. Building tall, increases the population density, whilst minimizing horizontal configured construction, allowing more areas of land to be put towards the provision of beneficial ecosystem services, benefitting both people and nature and most importantly leaving existing greenfield sites alone. As noted, building tall is not enough. In order to enhance quality of life and nature, biophilic elements need to be incorporated as well. The connectivity that arises with a vertical city, which is an indicator and driver of economic and social success, needs to be reinforced with nature and natural elements.

There are many who criticize the vision of the vertical city, mainly because they deduce that it will be too expensive and socially detrimental to some groups. Oldfield (2019), states that '*in conclusion, it is challenging to say whether tall buildings are more or less sustainable than other building types. In reality there are a number of factors both for and against tall buildings, across the full spectrum of environmental, social and economic dimensions'*. However, the world already has many social problems that have not been reduced through city planning and the arrangement of

[2] The Council on Tall Buildings and Urban Habitat is based in Chicago, USA, which has striven *toward the dissemination of information and the stimulation of research on tall buildings throughout the world. It continues to have a major concern with the role of tall buildings in the urban environment and their impact. It is not an advocate for tall buildings per se; but in those situations in which they are viable, it seeks to encourage the use of the latest knowledge in their implementation'* (CTBUH)

buildings and infrastructure, and which have little to do with the heights of buildings. There are many that are also sceptical as they deduce the building will be ugly. Not so, as architects can build beautiful as well as brutal and there are numerous tried and tested means to place parks with trees and water and swimming pools in the sky, to create salad greens and mushroom farms underground, to create easy vertical and horizontal connectivity at multiple levels, that ensures commercial and social success. The question arises: What are the constraints on building biophilic vertical cities and why have none been built? In the authors mind, this has little to do with cost but more to do with governments' responding to problems with short term, incremental reactions, whereas what is really required is an Ebenezar Howard type leap in vision that matches the future problem of how to accommodate the predicted year 2100 population of 11.184 billion people, when we are 7.8 billion at present (GOV.UK 2021). Regarding the scepticism of vertical cities, what is offered instead? Oldfield (2019), who is sceptical about building tall says '*if we are to limit global warming to meet and better the targets of the Paris Agreement',* (COP 25) '*significant and radical changes will be needed across all aspects of* life'. And, as Elkington (2018) says, the world's '*climate, water resources, oceans, forests, soils and biodiversity are all increasingly threatened* '*it is time to either step up — or to get out of the way'* (Elkington 2018).

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