PRAGMATIC ENGINEERING AND LIFESTYLE

RESPONSIBLE ENGINEERING FOR A SUSTAINABLE FUTURE

EDITED BY

DAVID S-K. TING & JACQUELINE A. STAGNER

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INVESTOR IN PEOPLE

To everyone who practices responsible engineering and living.

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Table of Contents

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Book Description

Pragmatic Engineering and Lifestyle draws together international experts from engineering and architecture to disclose the latest insights into forging viable means to sustain tomorrow's needs. It focuses on breaking through barriers and fully realizing promising remedies by explicitly including the social aspect in the equation. The best way to engage the entire society is to involve them in the development and execution of the solutions. This book covers, among other topics, simple and responsible engineering and living, ecological and socially friendly buildings and infrastructures, socially resilient farming, and agroecology. This is an indispensable volume for tomorrow's engineers, architects, and policymakers. Veridically, every soul should be acquainted with, and be part of, *Pragmatic Engineering and Lifestyle.*

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Preface

Tall buildings will continue to be an integral part of tomorrow's society. Pragmatically, measures must be taken to design them to be socially, economically, and environmentally sustainable. Al-Kodmany maps out the unsustainable aspects and furnishes the remedies for improving the sustainability of tall buildings whenever and wherever they are constructed in Chapter 1, "High-Rise Developments: A Critical Review of the Nature and Extent of their Sustainability."

Replacing fossil-fuel-based fibers in engineering applications such as reinforcing building materials is inevitable. The selection of the most appropriate natural fiber for a specific task with the required engineering properties such as strength, on the other hand, is not a simple process. In Chapter 2, "Application of Expert Decision Systems for Optimal Fiber Selection for Green Building Design Components," Balo and Sua present an approach for selecting the best fiber. For this green building case study, a reference is established using materials from different places.

To sustain a thermally comfortable living standard, traditional air conditioning systems must be transformed into renewable-energy-driven ones. Deshmukh et al. present the latest "Advances in Solar driven Air Conditioning Systems for Buildings" in Chapter 3. The emphasis is on reducing energy usage and, for this, solar adsorption is a promising method as it is a green technology that uses solar energy for driving the cycle.

For most developed countries, heated water is a life necessity. Tapping into solar energy can result in substantial savings in heating bills, both financially and environmentally. Singh et al. present the use of water-based Trombe walls, along with appropriate thermal energy storage, for providing heated water in Chapter 4, "Evaluating Water-based Trombe Walls as a Source of Heated Water for Building Applications." They find superior performance in terms of supplying heated water for building applications and reducing the heating load during typical Canadian winter days.

Gökgöz and Yalçin present "Investigating Waste Management Efficiencies and Dynamics of the EU Region" in Chapter 5. We cannot live responsibly if we do not manage the waste that we produce responsibly. The European Union scenario is analyzed using Slack Based Measure and Super Slack Based Measure in this chapter. Reuse and recycling resonate, and zero-waste-oriented policies are effective tools for increasing waste management efficiency.

A case study of a zero-waste-to-landfill site is disseminated in Chapter 6, "The Multipronged Approach of Solid Waste Management toward Zero Waste to Landfill Site: An Indonesia and Thailand Experience," by Permana et al. It is critical that we understand 'zero waste,' meaning no waste to the landfill rather than no waste produced. To dump no waste in one's backyard, a multipronged approach involving all stakeholders from all levels of government to every individual is required. It is found that the waste management activities realized by individual households and communities are the prerequisite for the upper levels of governing bodies.

Another way to look at zero waste is conservation, that is, start with waste reduction and proceed to zero waste. Yazdani and Lakzian detail the creation of measures to limit waste volume and toxicity in Chapter 7, "Conservation; Waste Reduction/Zero Waste." The idea is to preserve and recover resources rather than burying or burning them. A pragmatic approach is the engineering of cradle-to-cradle products, where the end of one product becomes the beginning of another. As expected, zero waste can only be accomplished with the participation of all stakeholders.

Kanda et al. enlighten us with "Adoption of Green Building Practices in Kenya: A Case of Kakamega Municipality" in Chapter 8. The aim of the study is to further green building adoption in developing countries. To do so, a better understanding of the state of green buildings is realized via a detailed survey. With that, the promotion of health and well-being, along with minimal impact on the environment via green building, can be furthered with the help of incentives including legislation and certification programs.

Furthering renewable energy is a necessary element for a sustainable future. Compressed air energy storage is one of the most promising technologies for mitigating the intermittency of renewable energy and the mismatch between energy supply and demand. In Chapter 9, "Transient Thermodynamic Modeling of Heat Recovery from a Compressed Air Energy Storage System," Ebrahimi et al. expound on the transient behavior of a compressed air energy storage system with heat recovery from the compression process and using it for heating the air during the expansion phase. Heat recovery is the key to mitigating CO_2 emission while simultaneously boosting efficiency.

Healthful nourishment is essential to sustain tomorrow and, thus, responsible fishing is included as Chapter 10, "Trawl Fisheries Management and Conservation in Malacca Straits." In this chapter, Wong and Yong convey a systematic analysis of trawl fisheries management and conservation measures in Malacca Straits. They highlight resolving of unclear and conflicting national and international territorial waters rights, strengthening national and multilateral research collaboration, employing effective and cost-saving ecological tools to identify and expand marine-protected area, and other measures to further sustain marine fisheries.

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It has been a pleasure working with the wonderful Emerald publishing team; this goes all the way back to the summer of 2021 with Kimberley Chadwick. Also, a big shout-out goes to Gabriella Barnard-Edmunds, Tony Roche, Hemavathi Rajendran, Lydia Cutmore, and those working behind the scenes. We are most grateful to the 32 experts around the world who contributed the 10 chapters that made up this volume. Also invited to savor the fruits of this labor are the anonymous reviewers who ameliorated the manuscripts. Above all, providence from above sustained this endeavor from start to finish.

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Chapter 1

High-Rise Developments: A Critical Review of the Nature and Extent of Their Sustainability

Kheir Al-Kodmany

Abstract

This chapter outlines complex and conflicting issues related to designing tall buildings. It gathers a vast amount of fragmented criticism and concerns and organizes them around the three pillars of sustainability: social, economic, and environmental. Mapping out the "unsustainable" aspects forms the foundation for addressing them in future research and tall building developments. The chapter engages the reader with a preliminary discussion on potential solutions to the outlined problems. It also balances extensive criticism by highlighting the virtues and advantages of tall buildings. Consequently, this chapter forms a foundation for improving the sustainability of tall buildings whenever and wherever they are constructed.

Keywords: Sky living; economic viability; social well-being; environmental safety; vertical urbanism; urban density

1. Introduction

1.1 Tall Building Construction Boom

In recent years, urbanization has been equated with building massive high-rise developments. This phenomenon is true in Asian cities (e.g., Shanghai, Beijing, Shenzhen, Tianjin, Tokyo, Mumbai, Taipei), Middle Eastern cities (Dubai, Abu Dhabi, Doha, Istanbul); European cities (London, Warsaw, Moscow), and American cities (e.g., New York, Chicago, Miami). The driving forces for building tall include massive migration from rural to urban areas, rapid urban renewal, skyrocketing land prices, active agglomeration, globalization and global competition, human aspiration, symbolism, and ego. Indeed, in dense places

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where available sites for development are scarce and small, developers and landowners have no choice but to build up. Simultaneously, the increasing urban population puts tremendous demand on limited desirable places, reinforcing the need to build up. With rapid urbanization, high-rises provide various options for housing, retail, entertainment, offices, services, and amenities (fitness and health clubs, restaurants and cafes, cultural spaces, museums, etc.), allowing a city to grow without sprawling into green space and farmland. High-rise developments are becoming the global model for managing the growth of cities that need to accommodate one million incomers every week (Al-Kodmany, 2020).

1.2 Purpose of the Study

Upon scanning the social science, architecture, and planning literature, we find a plethora of scholars who critique tall buildings (Alexander et al., 1977; Ali & Moon, 2018; Barr, 2018; Kunstler, 1993; Yeang, 2022). This chapter intends to identify, collate, and consolidate fragmented concerns and critiques of tall building developments and presents them in an accessible manner. It aims to help architects and planners to attain higher levels of sustainable tall building developments by avoiding and addressing common "unsustainable" aspects. This chapter forms a knowledge base for learning and examining unsustainable practices in tall buildings. It offers a "checklist" of topics and issues important to the sustainability of tall building development. It alerts about critical and unexamined issues or provides a reminder of pitfalls and ill practices. The chapter employs sustainability as a framework to consolidate critiques and pitfalls of tall building developments and uses sustainability's three pillars (social, economic, and environmental) to guide the discussion (Du et al., 2016; Safarik et al., 2016; Yeang, 2022).

1.3 Sustainability as a Framework

Sustainability is a buzzword and a current policy, planning, and grant-writing trend. Undoubtedly, urban sustainability continues to help guide and support architecture and urban developments. The United Nations has been using sustainability to shape its universal agenda. In 2015, it adopted the 2030 Agenda for Sustainable Development, which details 17 Sustainable Development Goals (SDGs) and 169 Actionable Targets to be realized by 2030. In particular, Goal #11 refers to creating sustainable cities and communities. Further, the United Nations World Urban Forum (WUF), the world's premier conference on urban development, has embraced "sustainability" as an overarching theme for its agendas. The commitment to SDGs has been apparent since WUF's first meeting in 2002, titled "Sustainable Urbanization," in Nairobi, Kenya, through the latest in 2020, titled "Cities of Opportunities: Connecting Culture and Innovation," in Abu Dhabi, United Arab Emirates. The meeting attendance has increased from 1,200 in 2002 to 13,000 in 2020. Other important organizations, such as the World Bank, the Global Environment Facility (GEF), Local Government for

Sustainability (ICLEI), and Global Platform for Sustainable Cities (GPSC), have worked on and supported local and global sustainability projects, initiatives, and programs (Al-Kodmany, 2022).

This research uses "sustainability" as an overarching theme that guides the literature review, analysis, and synthesis. Sustainability offers a comprehensive framework represented by its three pillars (social, economic, and environmental). It seeks to balance these three dimensions. Its tripartite structure is illustrated via three intersecting circles (social, economic, and environmental) with sustainability at the intersection, emphasizing that sustainability strives to balance competing forces, needs, wishes, profits, and the availability of resources. Sustainability is a valuable framework for analyzing issues separately and collectively. Researchers have been increasingly using it to synthesize complex problems and phenomena. Some studies benefit from such a framework to compare analysis according to short- and long-term goals. Others use the framework to compare research and findings across geographic scales – from individual habitats to neighborhoods, communities, cities, regions, countries, continents, and planet Earth (Al-Kodmany, 2018; Pruetz, 2012). These pillars or dimensions are also expressed by the 3Es (equality, economics, and ecology) or the 3Ps (people, profit, and planet). In this model, "people" refers to community well-being and equity; "profit" refers to economic vitality; and "planet" refers to the environment and resource conservation. They are also known as the triple bottom line TBL or 3BL. Overall, sustainability offers a helpful universal framework for examining issues of various kinds. This research uses sustainability to discuss topics related to high-rise living (Fig. 1).

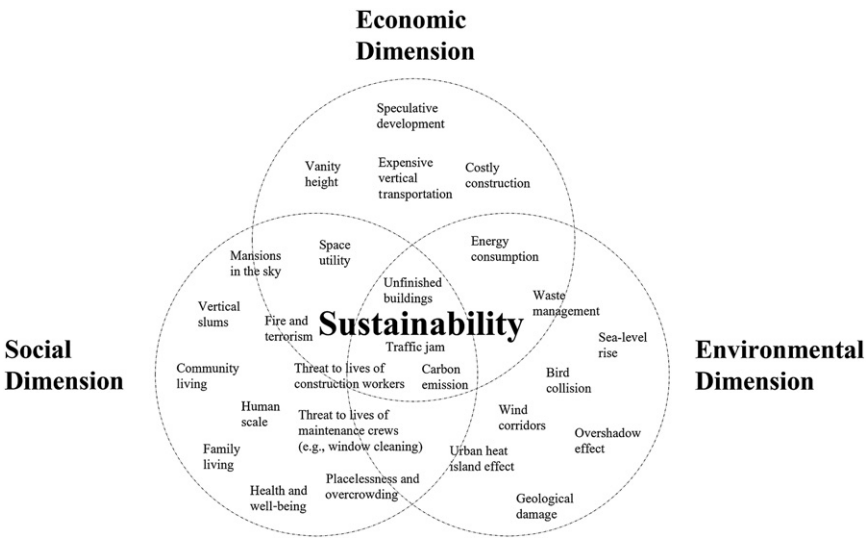

Fig. 1. Sustainability Provides a Valuable Framework for Organizing and Discussing Issues Related to Tall Building Developments.

2. Social Dimension

Social science literature reveals that people have multiple concerns about high-rise living. Scholars highlight issues related to suitability for family living and raising children, neighborly relationships and helpfulness, personal behavior and comfort, perception of safety, tenants' relation to outdoor spaces, and connection to street life. These environments may make inhabitants feel claustrophobic, creating a rat-cage mentality. Further, high-rise living could promote poor interpersonal relationships and weak neighborly interactions, resulting in psychological depression. Further, scholars argue that low-rise living is closer to nature and facilitates a more robust community-oriented social life. As structures grow taller and taller, tenants may perceive that they become increasingly out of touch with city life (Argent, 2008; Bee & Im, 2016; Delmelle et al., 2013; Kearns et al., 2012).

2.1 Family, Community Living, and Well-Being

Sky living disconnects residents from the outside world, making them feel like they live in social isolation. Internally, they may experience social anonymity, confinement, and crowdedness. Research shows that people living in tall buildings experience more "mental health problems, higher fear of crime, fewer positive social interactions, and more difficulty raising their children" (Barr, 2018). Serious mental health problems have been correlated to building height. For example, mothers who lived in high-rises suffered more from depressive symptoms and psychological issues than those in low-rises.

Many studies found that tenants in tall buildings experience emotional stress and other adverse psychological conditions. Research indicates that undesirable social interaction among tenants because sharing floors and amenities creates pressure and tensions. In addition, the greater the degree of sharing space and utilities, the greater the stress level. Further, the high density of a building population, poor design and layout, high traffic of people in and out, and the lack of outdoor recreational and social spaces are likely to exacerbate these problems. In particular, tall buildings in poor neighborhoods suffer from a high concentration of population, overcrowding, tiny outdoor and social spaces, and a high degree of space and utility sharing. In contrast, tenants of high-end high-rises may suffer from isolation and loneliness (Gifford, 2007; Govada, 2011; Holland, 2007).

Children suffer from the feeling of living in a locked-in environment. They lack a spontaneous play environment on the upper floors that fosters exploration of the world, which is essential for their growth. Urban psychologists suggest that children (ages between two and seven) become independent by permitting them to leave to experience the natural world progressively (e.g., corner stores, shops, playgrounds, alleyways, neighborhoods, streetscapes, gardens, friends, and neighbors) and return home. This interplay between dependence and autonomy that earns a child a sense of competence is missing in a high-rise environment (Hubbard et al., 2004).

Overall, the problems of raising children in high-rises vary from essential child development matters to daily activities such as playing. One research concluded

that infants' development above the fifth floor is prolonged compared to those raised below. Another study has concluded that the progress of many skills, such as clothing, assisting, and proper urination, was sluggish. As is expected, kids who reside in upper floors play outdoors less often than those in lower floors. Consequently, families with small children who can afford to live in single-family homes usually move to the suburbs.

Further, high-rises are often the habitats of smaller household sizes (the number of individuals living in a household) with fewer children critical for promoting a sense of community (McKenzie-Mohr, 2011; Worrel, 2012). High-rise residents may be afraid of heights or that a child or a loved one will jump from a window. They may fear strangers living close to their apartments or not being able to escape the building in case of fire, terrorist attack, or earthquake. Post-COVID-19, high-rise residents may fear becoming ill from infectious diseases generated by the masses living there (Delmelle et al., 2013; Gifford, 2007).

2.2 Human Scale, Placelessness, and the Public Realm

Because of their great heights and sizes, tall buildings, by default, harm human scale – they are likely to cause passersby to feel small, dwarfed, and irrelevant (Jacobs, 1963). Pedestrians at the street level are often unable to connect visually with high-rise tenants, architecture, ornamentation, decorative art, and personalized details. For example, pedestrians cannot see the flowerpots in the upper-story windows, hindering a human touch. Pedestrians cannot ultimately view the high-rise building; instead, they see "urban canyons" that make them feel visually disoriented (Gehl, 2010; Krier, 2009; Kunstler, 1993).

Similarly, tall buildings have often contributed to the problems of placelessness because of their massive size and great height. In central business districts (CBDs), tall buildings frequently evoke the image of a nerve-racking, workaholic business environment. Speaking about Manhattan, Robert Freedman (2014) contrasts high-rise with low-rise neighborhoods on the same island. He explains that in walk-up apartment neighborhoods in Manhattan, a resident or a passerby would immediately feel a warm welcome not found in the towering, elevator-skyscrapers developments that proliferate through most of Manhattan. Freedman argues that vernacular brick, wood, and stone low-rise neighborhoods are more humane than glittering, steel-and-glass high-rise neighborhoods. Tall building developments drastically alter vernacular and traditional environments (Evans et al., 2003; Kendig & Keast, 2010).

Tall building developments often hurt the public realm. Towers function as singular, autonomous structures – some are experienced as lonely sculptural objects in the cityscape. They usually do not contribute to the public sphere because they are self-contained, introverted, and privatized. Often, tall buildings require significant parking structures. Since it is costly to accommodate them underground, architects often place them above ground, thereby taking away from the street social life and unstimulating the public realm. Parking garages

above ground are a "street killer" because they disconnect the social life of urban space, engender spatial disorders, and create "eyesores" in the city. Further, tall buildings adversely affect the microclimate due to wind funneling and turbulence around their bases, causing discomfort to pedestrians. These buildings cast shadows on nearby buildings, streets, parks, and open spaces, and they may obstruct views, reduce access to natural light, and prevent natural ventilation (Wood & Salib, 2013).

Importantly, current practices of tall buildings make cities worldwide look alike. For example, downtown Melbourne looks similar to Pudong, Shanghai, Miami, or Dubai. The expected shortfall of these skyscrapers is that the design has not paid attention to local tradition, geography, and climate. In particular, the steel-and-glass tower, which invaded cities, has made them look homogeneous and similar, ignoring local identity and culture.

Aesthetically, tall buildings often create contextual problems when placed near historic structures. As cities become denser and land values skyrocket, older historic structures are threatened to be demolished to make room for new taller buildings. This problem accelerates as demand for space increases and developable lots are progressively scarce. Tall buildings also could negatively affect the neighborhood character and the city skyline. Overall, historic preservation issues are often contentious and require an interdisciplinary team to make sound decisions (Ascher & Uffer, 2016).

2.3 People's Choice, Fit, and Comfort

Many governments have used high-rises to house masses of residents. For example, in the United States, from the 1960s to the 1980s, the federal government used this building typology for "affordable housing." Many residents were resentful of this living, but they had no choice. The problems in these buildings progressively became worse and worse, rendering them "vertical slums." Crime prevailed, and authorities had to take them down. Archetypal projects include the Pruitt–Igoe in Saint Louis, Missouri, and Cabrini Green in Chicago, Illinois. In other incidences, residents would refuse to live in high-rises in the first place. For example, the Chinese government has recently constructed high-rise cities to house villagers. However, they shunned these places, favoring low-rise living. Chinese people have nicknamed these cities "modern ghost cities." Ordos Kangbashi in China is one of several new high-rise cities that suffered from this problem (Al-Kodmany, 2018).

Using high-rise buildings as affordable housing has often featured poor design and living conditions. As we see in Section 3, tall buildings are costly by default. The only way to reduce costs is to compromise on the quality of building materials, finishes, interior design, appliances, amenities, services, and the like. The US authorities demolished public housing high-rises partially because of poor design. Overall, tall buildings require high maintenance, and any malfunctioning has a rippling effect. For example, a water leak will affect the floor where the problem occurs and all the lower floors. Likewise, fire has an upward rippling effect as it

spreads vertically rapidly. Wall cracks are likely to expand and threaten larger portions of the building. Unexpected foundation settlement may endanger the entire structure. Elevator malfunction is also a common problem, which has a rippling effect on the ground floor lobby, where people gather most, and throughout the building. Usually, people exhibit anxiety and discomfort after waiting 30 seconds in a commercial building and 45 seconds in a residential building.

It is important to note that ultraluxury and expensive tall buildings are not immune to these problems. For example, 432 Park Avenue of New York City in the so-called Billionaire's Row, the residence of some of the world's wealthiest and most potent, recently faced "water damage from plumbing and mechanical issues; frequent elevator malfunctions; and walls that creak like the galley of a ship,... Residents at 432 Park complained of creaking, banging, and clicking noises in their apartments and a trash chute 'that sounds like a bomb' when garbage is tossed" (Chen, 2021).

2.4 Construction, Repair, and Maintenance

Constructing tall buildings, particularly supertalls, could be risky. Over the years, thousands of workers lost their lives because of accidents, equipment malfunction, or hazardous working conditions. Unfortunately, building tall buildings relies on workers who manually carry out duties. For example, façade assembly and exterior cladding depend on workers who grab panels from cranes and place them in assigned spaces. Workers repeat this process until they complete each façade. These tasks are more hazardous on upper floors where wind velocity is high. As architects design more complex forms and shapes of buildings (including tall ones), construction workers face more significant risks (Bao et al., 2015).

Similarly, routine repair and upkeep of tall buildings risk workers' lives. For example, tall buildings' window cleaning remains a frequent reason for the laborers' demise, who carry out duties by gradually falling the building's total height while dangling on ropes and holding water containers and washing tools. Some workers daze and fall, while others bounce into walls and windows due to forceful wind. Overall, the task could be daunting. For example, it takes 36 workers four months to wash Burj Khalifa's 26,000 windows (Al-Kodmany, 2015).

Further, window cracking and breaking are common problems in supertall buildings. Indeed, glass ages and weakens over time, and any deficiencies in manufacturing or installation could lead to cracks or breakups under wind pressure. For example, Willis Tower (formerly Sears Tower) in Chicago has experienced several incidences where some windows on the upper floors were shattered under a forceful wind. Debris fell on sidewalks, damaged properties, and hurt pedestrians. For safety considerations, police blocked streets and rerouted traffic, causing inconveniences and traffic congestion in adjacent neighborhoods. Reinstalling glass and repairing cracks are also formidable tasks. Further, elevators require close monitoring and maintenance. As such, building

managers need to hire resident engineers who should be experienced in mechanical and electrical systems, IT networks, software, and programming languages.

3. Economic Dimension

Skyscrapers are costly buildings. Their costs are higher than that of low-rise buildings holding the same square footage due to their high embodied energy, i.e., the resources needed to build them. They need more robust structural systems to withstand the natural forces of wind, gravity, and earthquakes and resist severe weather conditions such as hurricanes, tornados, and typhoons. Tall buildings demand enormous amounts of steel and concrete and require expensive vertical transportation such as elevators and escalators and tremendous energy to pump water to upper floors. They suffer from diseconomies of vertical construction systems (e.g., taller cranes, jumping cranes, "kangaroo cranes," jumping boards, and hydraulic pistols). Pumping concrete to higher floors demands powerful pumps and special concrete that can travel long distances without stiffening too soon, resulting in clogging hoses. Skyscrapers also feature a lower "net-to-gross" ratio referring to the net useable space in the building – about 70% for high-rise buildings compared to more than 80% for low-rise buildings (Al-Kodmany & Ali, 2016; Ali & Moon, 2018; Du et al., 2016).

3.1 Space Efficiency

High-rise buildings use space less efficiently than low-rise buildings. For example, they need many elevators simply because they are the prime mode of transportation – people are usually unwilling to walk up more than a few floors. Second, people do not tolerate long waits. Therefore, engineers compute the needed number of elevators so that tenants do not wait for elevators for more than a certain number of seconds – about 30 seconds for commercial office buildings and 45 seconds for residential ones (Eappen, 2017). Indeed, if an elevator malfunctions, overcrowding develops quickly in the lobby. Skyscrapers also need multiple elevator types (e.g., local, express, service, freight, firefighters). Therefore, elevators add high costs to the building and consume significant useable space. Post 9/11, authorities have placed more stringent requirements on all vertical transportation. For example, new codes require stairways to be wider to accommodate two flows of people – a flow of tenants escaping the building and a flow of firefighters going up to rescue tenants. Overall, as we are building higher, architects must incorporate advanced elevator systems to allow tenants to reach their destinations swiftly while ensuring their comfort and safety (Al-Kodmany, 2020).

In addition to "wasting" spaces to house elevators and mechanical, structural, and damping systems, skyscrapers may "waste" areas for merely boosting height. The Council on Tall Buildings and Urban Habitat (CTBUH) has coined the "vanity height" term to refer to the wasted space between a skyscraper's highest