

TALL BUILDING DELIRIUM:
THE SECOND LIFE OF THE METLIFE BUILDING

A DARCH PROJECT SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF
HAWAI'I AT MĀNOA IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF

DOCTOR OF ARCHITECTURE

MAY 2016

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Keywords: Tall Buildings, Renovations, Adaptive Re-use, Re-development, Conversion, Façade,
Public Space, Ecological Design, and Environment

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ABSTRACT

For over one hundred thirty years our cities have been serving as urban testing grounds for tall building experiments. Tall Buildings have been the basis for massive urban agglomerations, living far beyond their anticipated lifespan, leaving cities with experimental relics, successful or unsuccessful. As our global cities embrace for growth, tall buildings continue to be used as catalysts for new urban developments, technologies, and economies. The evidential urban fabric lives through a causal existence. Using a triangulation approach to analytical case studies of tall buildings and research compilations, successes found through failures are documented, making the missteps of the past clearer while exposing the solutions that can correct the undoings of the past. Tall buildings of the past pose the potential to remain relevant, contributing members of the urban fabric. Design revelations are demonstrated on the MetLife Building (formally known as the Pan Am Building), an existing tall building in New York City, giving the a second life based on critical theory. The design revelations include aspects of passive strategies, ecological interventions, urban cognizance, energy efficiencies, public space rehabilitation, physiological improvements, and climatic responsiveness. Re-developing and adapting existing tall buildings allows cities to react to current and future challenges with existing infrastructure becoming a sustainable platform for renewal. Existing tall buildings prove to be resilient urban experiments capable of evolutionary transformation.

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PREFACE

Four and a half years ago I arrived on the island of Oahu attending University of Hawai'i at Mānoa's, School of Architecture in pursuit of the Doctorate of Architecture degree. Arriving with a Bachelors of Science degree in Business and Marketing, years of professional work, I knew at my age I needed to create with purpose to live contentedly. In my very first semester, I came across Le Corbusier's quote; "To send architectural students to Rome is to cripple them for life," that is to say the pursuit of ornamentation, proportion, symmetry, and style like the Romans is to disregard function. Resonating with me throughout of my studies, I have yet to visit Rome, but now I have a corollary sentiment, "To send architectural students to Honolulu is to plague them for life." The built environment of Honolulu is in a state of constant violation and degradation to the beauty that surrounds it.

"Belgrade is the ugliest city in the world in the most beautiful place in the world."

-Le Corbusier

My sentiment toward the city of Honolulu is the same of that of Le Corbusier's to Belgrade. The city of Honolulu is nestled between the Koolua Mountain range and a beautiful bay of the Pacific Ocean. There are four hundred and eighty-four tall buildings in Honolulu. The majority of the tall buildings stretch between the mountains and oceans (mauka and makai) between ten city blocks, not what one expects when they picture paradise. Living here I realized the powerful effects of tall buildings on the city. The more I studied to learn the inner workings of the city and the tall building, I realized that a specialized focus of architecture in one particular area would not answer my question of why tall buildings are the way they are and how they effect the city and its people, because what I was trying to uncover was based on delirium. Delirium is defined as an acutely disturbed state of mind, illusions, incoherence of thought and speech, and wild excitement leading towards a double life of utopia. Delirium is found in the economics, design, sourcing, construction, and reactions to tall. Honolulu was built with delirium, and the tall building was the outcome.

Delirium has been a debated topic and title for my dissertation, one that I could not abandon. Honolulu is not a written part of my dissertation, but the more research I did on tall buildings, I realized delirium followed tall buildings and Honolulu. Honolulu is simply my muse.

I realized a specialized focus would negate the real issues with tall buildings and not fully equip me for the real world. I needed to understand the “why” for when I am outside the confines of the university. Therefore the “why” and “how” are the footholds of my dissertation.

INTRODUCTION

Tall buildings are the measuring devices of a city. The modern city embraced vertical scale. Over time modernity changed. New tall buildings changed too, implementing mechanical, technical, and social ideals of the time, where most existing tall buildings received a coat of paint or two, new windows, curtain walls, and fresh plaster. As our cities fill, space for new tall buildings requires either demolition, urban adaptations— as in the case of Hudson Yards in New York where new development is made possible by placing platforms over existing rail yards or new tall building typologies, such as the ultra skinny towers. Almost one hundred and thirty years later, from the start of the first generation of tall buildings, for the first time in history there has been a time span long enough to fully understand the impact of tall buildings in all stages of evolution—

The First Generation: Beginnings to the 1916 Zoning Law

The Second Generation: 1916 Zoning Law to 1950

The Third Generation: Mid-Century Age of Innocence

The Fourth Generation: 1973 Energy Crisis, The Age of Consciousness

The Fifth Generation: Rising Up Tall 2000 – 2015

The Sixth Generation: The Future: Collective Intelligence

For tall buildings, defined as twelve floors or taller, to be global leaders they must embrace social and cultural shifts while designed for opportunity. The dense, sometimes historic, environment of the city requires developers to overcome significant economic and physical challenges that are inherent to the fabric of the city. These challenges are not insurmountable. Renovating tall buildings minimizes the risk.

Unraveling the history of tall buildings shows that the future of tall buildings is accomplished through de-evolution. The development of tall buildings has come full circle. Its evolutionary period on pause, the new focus is to de-evolutionize the typology, reverting it back to basic principles through twenty-first century renovation interventions.

PART ONE:

THE RESURGENCE OF TALL BUILDINGS

1.1 The Significance of Tall

Tall buildings are conundrums plagued with scrutiny. Tall buildings, skyscrapers, high-rise, regardless of namesake are primarily developed for economic wealth, formalizing into symbols of power and urban landmarks. Being tall they are associated with many issues such as, micro-climatization, excessive energy consumption, massive material use, gentrification, isolation, overpopulation, and subjectively large eyesores that outlast a lifetime.¹ Despite this delirium of issues, tall buildings resolve issues at grand scales.

The United Nations is forecasting that seventy percent of the world's projected nine billion will be urbanized by the year 2050. This is an increase from originally stated, fifty-one percent of seven billion urbanized as of 2010.² The impact of this total figure is better understood when broken down; translating to 2.8 billion people moving into cities over the next forty years. Perhaps easier to comprehend is the annual rate of seventy million people per year, or the daily rate of nearly 200,000.³ As quoted by the Council of Tall Buildings and Urban Habitat, "...it means we need to build a new or expanded city of more than one million people every week for the next forty years to cope with this urban growth. In the context of these numbers, it is clear that a continued horizontal spread of cities

1 Lollini, Tom. "Tall Buildings, Tight Streets." In *Second Century of the Skyscraper* (Springer US, 1988), 275.

2 Burdett, Richard, and Deyan Sudjic. *The Endless City: The Urban Age Project by the London School of Economics and Deutsche Bank's Alfred Herrhausen Society* (London: Phaidon, 2007), 22.

3 Wood, Antony, and Ruba Salib. *Natural Ventilation in High-Rise Office Buildings, CTBUH Technical Guides* (New York: Routledge, 2013), 12.

is unsustainable. Our urban agglomerations need to become much denser.”⁴
The majority of urbanization is occurring in China and India, however, US urban centers are indeed seeing growth. This alone gives rise to a vertical city as a justifiable solution, which necessarily must be approached carefully.

ACCELERATING THE PACE OF CHANGE

City regions of 1 million people or more. While there were only a handful of city regions of this scale up to the mid-century, the number soared to 450 by 2005.

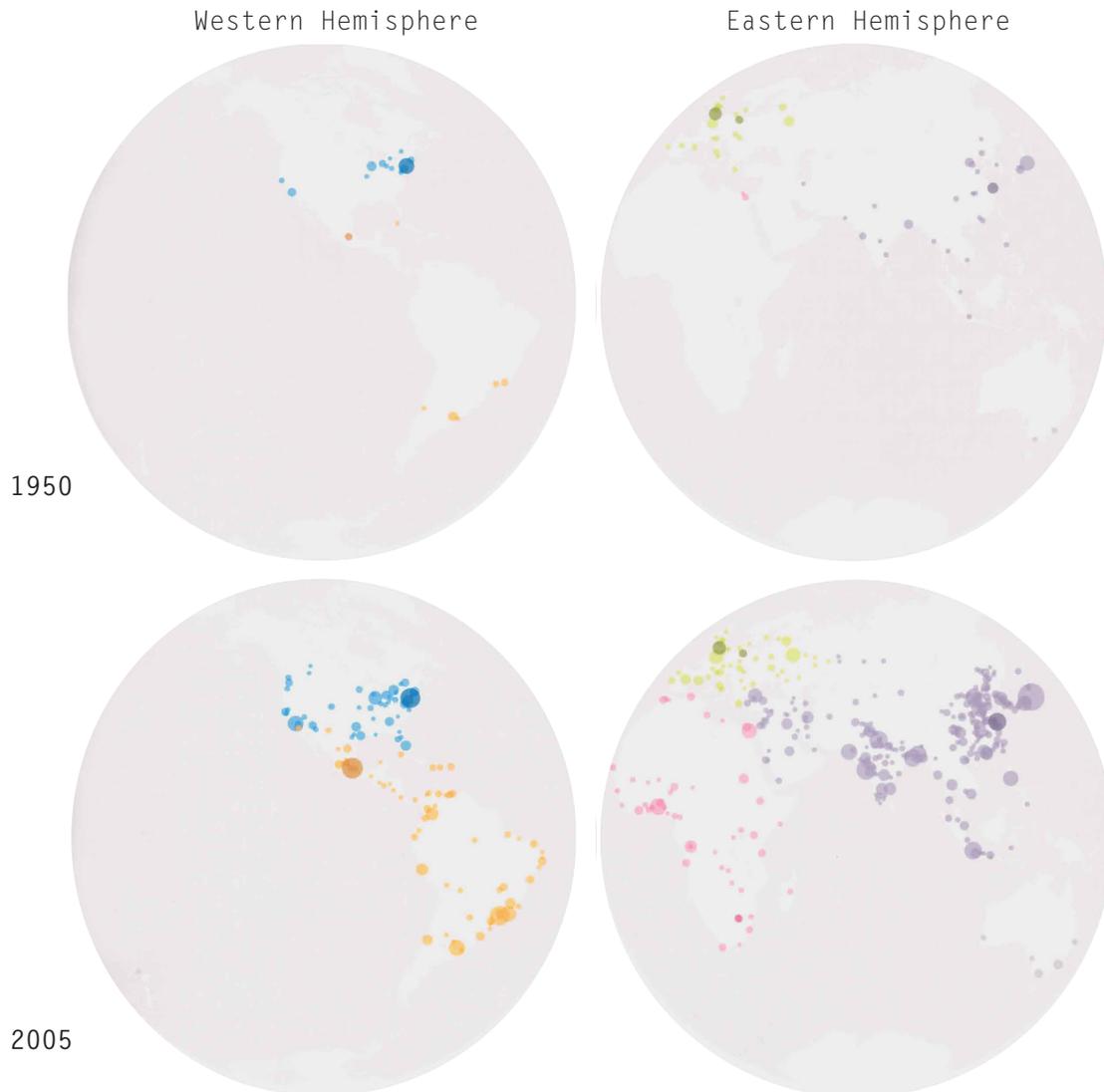


Figure 1: Accelerating the Pace of Change

(Source: Burdett, Richard, and Deyan Sudjic. *The Endless City: The Urban Age Project* by the London School of Economics and Deutsche Bank’s Alfred Herrhausen Society. London: Phaidon, 2007.) * modified by author.

4 Wood and Salib. *Natural Ventilation*, 9.

“At the metropolitan and regional scale, it is clear that more compact urban development provides the only sustainable answer to global urban growth. This is not true only because less sprawl leads to a reduction in energy use and pollution—and cities contribute seventy percent of world CO₂ emissions—but also because dense cities require less investment in public transport, infrastructure, and services to make them work.”⁵

When asked to achieve density in cities, no other typology can handle major populations shifts as quickly as the tall building, creating viable solutions for urban centers. Therefore, tall buildings are arguably the most influential urban building type. Moving into their second mid-century of existence, tall building’s progressive powers deserve unraveling. Standing over twelve floors tall, tall buildings have a small footprint with enormous verticality giving rise to neigh-

WHERE THE BIG CITIES ARE

While every region of the world has a number of cities with over 1 million inhabitants, a new generation of megacities with over ten million people is developing.

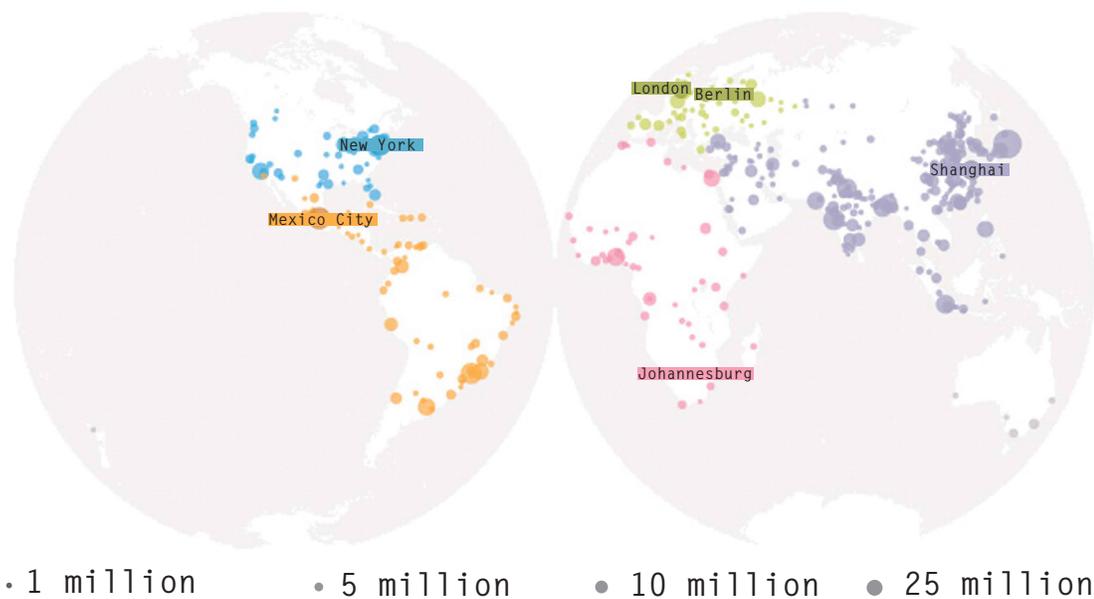


Figure 2: Where the Big Cities Are

(Source: Burdett, Richard, and Deyan Sudjic. *The Endless City: The Urban Age Project* by the London School of Economics and Deutsche Bank’s Alfred Herrhausen Society. London: Phaidon, 2007.) * modified by author.

5 Burdett and Sudjic. *Endless City*, 22.

borhoods and industries, and becoming a city within a city. This microcosm of a city shapes cultural ideologies identifying the city. Tall buildings are a direct snapshot of time, captured as a representation of current economics, politics, building codes, and municipal zoning laws. As our cities scale, so will ideals, economies and knowledge, making the city's tall building a measuring device of transformation and evolution.

Tall building prowess has grown through an evolutionary process, success by way of failure. Although still arguably in an experimental stage spanning over one hundred and thirty years, tall buildings are the most efficient way to live and work when considering vertical threshold to that of horizontal placement, therefore, holding the greatest impact when implementing methods of energy consumption, social interaction, and quality of life measures. This is often why tall buildings become a point of scrutiny. If not designed for these likenesses, they can become a drain on society with costly expenses and maintenance. Every misstep is felt exponentially. In spite of it all, tall buildings offer advantages such as less material (and thus reduced carbon) needed for enclosure per square foot of usable floor space created, a smaller surface area between floors (especially heat energy in colder climates), plus the potential for harvesting solar and wind energy at height.⁶ Tall buildings can become the answer to urban sprawl and continued renewal of the city when applying newfound knowledge. As said by the late Lynn S. Beedle in 1988, an American structural engineer who founded of the Council for Tall Buildings and Urban Habitat, "Less and less will tall buildings be designed to meet new needs, and more and more will they be instruments for renewal and the inevitable recycling of the city."⁷

1.2 Tall Cities

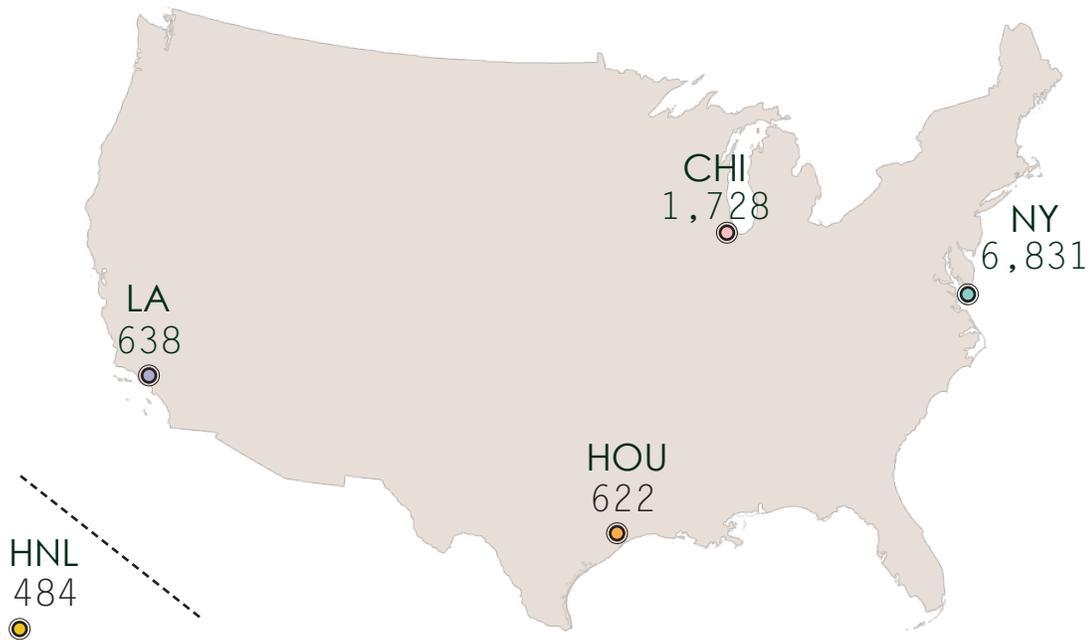
What does this mean for the United States? The US contains twenty-seven cities with more-than one hundred tall buildings for a sum of almost thirteen thousand tall buildings. Urban density, that was thought to have plateaued in the 1980's due to tall building construction limitations, has been revitalized. New technologies have emerged allowing virtual testing of new construction techniques

⁶ Wood and Salib. *Natural Ventilation*, 10.

⁷ Beedle, Lynn S. Preface to *Second Century of the Skyscraper*, by Council on Tall Building and Urban Habitat (New York: Van Nostrand Reinhold Company Inc., 1988), xix.

allowing reformulation of building codes and reassurance of safety. Since then we have also seen focus around “sustainability” associated with organizations setting design and energy guidelines in a reward based system driven by tax write-offs and bragging rights that drive renovations.

TOP 5 US CITIES WITH MOST TALL BUILDINGS



NY= New York CHI= Chicago LA= Los Angeles HOU= Houston HNL= Honolulu

Figure 3: Top Five US Cities with the Most Tall Buildings
(Source: emporis.com - accessed March 23, 2015)

In terms of population growth and existing buildings it is important to know that the sum of two hundred thousand people a day moving into our cities will more than likely be dispersed across the globe into the two thousand eight hundred and ninety-six cities with populations over 150,000. The realization of population growth could be distributed into the five tallest US cities, such as New York which lead the nation with 6,831 tall buildings; Chicago with 1,728, Los Angeles with six hundred and thirty-eight, Houston with six hundred and twenty-two, and Honolulu with four hundred and eighty four tall buildings, given some renovation and new development before 2050.

As of 2010, the total US building stock reached two hundred and seventy-five billion square feet. Every year around one hundred and seventy-five billion square feet is demolished, with five billion square feet being added and another five billion square feet renovated.⁸ This proves there is an unprecedented future for architecture, where the focus of building will be evenly split between building new and transforming the existing.

1.3 Life Cycle of Tall

Tall buildings are susceptible to the passing of time just as other building typologies. However, structural integrity is rarely affected by aging. The main reason tall buildings decline is due to functional obsolescence, no longer meeting expectations of occupants in terms of internal comfort, functionality, environmental performance, and cost.⁹ On average major renovations are needed every thirty-three years after the building's completion. For office towers, renovations are focused around attracting and maintaining big named tenants in the legal, consultancy, and banking industries. As far as an economic analysis of tall buildings, "At some point in its life, an asset such as a tall building has deteriorated so much that it is worth nothing to its owner and must be replaced. Because that deterioration occurs over a period of years, tax policy makers have consistently agreed that some part of the asset's initial value should be written off annually, just as bad debt or an employee's salary should be deducted in computing taxable income."¹⁰ The result is a depreciation schedule over the "life of the building," amortized for a set amount of years (until the property is to be resold), deducting the building's value until it reaches zero. The effects of depreciation methods, inflation, and financing arrangements of taxes fluctuate affecting real estate investors' long-term decisions.

8 2030 Challenge. "A Historic Opportunity." Accessed 5/3/15 4:11:12 pm http://architecture2030.org/the_solution/buildings_solution_how

9 Trabucco, Dario, and Paolo Fava. "Confronting the Question of Demolition or Renovation" CTBUH Journal, Retrofit. no. IV (2013) 38.

10 Wenzelberger, John P., and Henry Malcolm Steiner. "A Preliminary Model for the Economic Analysis of Tall Buildings." In *Second Century of the Skyscraper*, ed. Beedle, Lynn S. (Springer US, 1988) 88.

1.3.1 Renovations

Based on importance, frequency, and impact on building use, three distinct areas are primarily the focus of tall building renovations: the vertical transport system, removal of asbestos, and façade renovation.

TALL BUILDING RENOVATIONS: PERCENTAGE OF TOTAL COST

Average %	Building Element	Probabilty
20.6%	Frame & Upper Floors	Very unlikely
19.9%	Design & On-site Costs	NA
18.4%	External walls, windows & doors	Very likely
16.5%	MEP	Very likely
7.7%	Lifts & Stairs	Likely
7.6%	Substructure	Very unlikey
5.8%	Internal walls, partitions & doors	Very likey
1.9%	Floors & Ceiling finishes	Very likey
1.6%	Furniture & Fittings	Very likey

Figure 4: Tall Building Renovations: Percentage of Total Cost
(Source: Watts & Kalita 2007. * modified by author)

Lifts

“The vertical transport system (lifts) is one of the most distinctive features of a tall building.”¹¹ In most cases the vertical transport system is renewed to meet the updated requirements of new users and on average are renovated every forty years.¹² There is an energy correlation between lifts and air conditioning systems: the more energy efficient the lift is, the more it saves on operating en-

11 Trabucco and Fava. “Confronting the Question,” 40.

12 Ibid, 40.

ergy costs as well as a decreased load on the air conditioning system. A recent example, The Empire State building went under a five hundred million dollar renovation including a complete lift overhaul. Results delivered a decreased travel time of twenty to forty percent and also a decrease in energy consumption of seventy percent based on a new system that captures kinetic energy from the lifts into electricity.¹³ Since the service core functions are all intercon-

REASONS FOR RENOVATION			
%	Cause	Type	Examples
41%	Facade renovation caused by decay of the curtain wall properties, or change in architectural style	Substitution of the curtain wall with similar or different elements	Pirelli Tower, Milan; Lake Shore Drive Apartments, Chicago; Lever House, New York; Tour Europlaza, Paris; Stock Exchange Tower, London
21%	Internal ameliorations, change of use, modification of the building mass/volume	Alterations to the building mass or internal spaces to meet new/different market needs	Tour First, Paris; Tour TSR, Paris; Empire State Building, New York; Blue Cross Blue Shield Building, Chicago & GE Building, New York
15%	HVAC under performance, excessive costs, improvement of energy efficiency	Improvement of the environmental performance of the HVAC systems	60 Wall Street, New York; Empire State Building, New York; Deutsche Bank, Frankfurt; Torri Garibaldi, Milan
11%	Building health	Removal of asbestos	Tour Montparnasse, Paris & Bank One Tower, Fort Worth
7%	Poor lift performance, new tenant needs	Substitution of cabins/lift engines, upgrading of the control system	Chicago Board of Trade, Chicago; Torre Picasso, Madrid; Empire State Building, New York
4%	Structural Issues/ threats	Reinforcements, substitutions of structural elements	Citigroup Center, New York; Hancock Center, Boston

Recent renovations on tall buildings in US, Canada, and Europe.

Figure 5: Reasons for Renovation

(Source: Trabucco, Dario, and Paolo Fava. "Confronting the Question of Demolition or Renovation." CTBUH Journal, Retrofit. no.IV (2013): 40.)

¹³ Ibid, 41.

nected in tall buildings, major overhauls to the vertical transport system are only completed in conjunction with a total building renovation. The cost associated with changing out new cabins, lift engines, and upgrades to the control systems make lift renovations expensive.¹⁴

Health

Asbestos removal is a costly and timely process. Used as a thermal insulator, before it was found to be cancer causing, it can be found in concrete-based product, paints, and a wide range of building materials. Its use was mostly banned in 1989, but in 1991 the rule was vacated and remanded by the Fifth Circuit Court of Appeals therefore overturning most of the 1989 rule. The United States Environmental Protection Agency banned asbestos containing products—corrugated paper, rollboard, commercial paper, specialty paper, flooring felt, spray-on application, and pipe insulation. According to the EPA, asbestos-containing products not banned include cement corrugated sheet, cement flat sheet, clothing, pipeline wrap, roofing felt, vinyl floor tile, cement shingle, millboard, cement pipe, automatic transmission components, clutch facings, friction materials, disk brake pads, drum brake linings, brake blocks, gaskets, non-roofing coatings, and roof coatings.¹⁵ Despite the overturning, vacancy rates dramatically increase when word is leaked about the presence of asbestos whether deemed friable or non-friable (RCM). In case of removal of asbestos from the building while tenant occupied, costs have been estimated at \$40 million dollars over thirty-six months (Tour Montparnasse, Paris). In other cases complete renovation including transformation of uses and removal of asbestos totaled \$65 million and was completed in ten months (Bank of Tower, Fort Worth).¹⁶ In a cost comparison to a total building renovation, asbestos removal accounts for eleven percent of tall building renovations.¹⁷

Facades

Façade renovations are the most frequent type of renovation. The façade system requires repairs and renovations due to their exposure to heat and solar

14 Ibid.

15 US EPA, OCSPP. "U.S. Federal Bans on Asbestos." Overviews and Fact Sheets. Accessed May 3, 2015. <http://www2.epa.gov/asbestos/us-federal-bans-asbestos>.

16 Trabucco and Fava. "Confronting the Question," 41-42.

17 Ibid., 40.

stresses, and especially when environmental performance is needed. Renovation of the façade is classified into three categories (beyond that of simple maintenance):

- Refitting: complete or partial replacement of the façade with new elements without altering the architectural appearance. Examples include: Mies van Der Rohe's Lake Shore Drive Apartments, and Skidmore, Owings & Merrill's Lever House
- Overcladding: adding a second "skin" to the façade to alter the architectural appearance of the building. Overcladding takes place from the exterior needing no internal access, therefore not disturbing or displacing tenants. Examples include: China Resources Building, Hong Kong and CIS Tower, Manchester.
- Recladding: complete replacement of the existing façade with new components that alter the architectural appearance. Recladding is meant to increase façade performance and is considered the most radical of renovation types with countless examples.¹⁸

Energy

Energy, as in energy consumption and embodied energy, is an important part of the life of cycle of tall buildings because it is a driving factor to renovate and a reason not to demolish. Energy consumption is often a motivator behind tall building renovations, especially when recladding. Building owners who renovate to lessen energy consumption are typically looking to reduce operating costs and to maintain existing and attract new tenants by achieving an energy efficiency rating. New technologies and advancements in energy efficiencies are quite vast and now measurable during the design process using 3-d modeling software. New York City is also requiring tall buildings to report energy consumption to the city on an annual basis. The topic of energy consumption and embodied energy is currently quite popular. The US Department of Energy 2010 results indicated building operations alone are responsible for almost forty two percent of all energy consumed in the US. Embodied energy from building construction during erection and making of building materials are responsible for an additional six percent of total US energy consumption, making the building sector responsible for forty eight percent of US CO₂ emissions in 2010.¹⁹ These results

18 Trabucco and Fava. "Confronting the Question," 41-41.

19 Wood, Antony, and Ruba Salib. *Natural Ventilation in High-Rise Office Buildings* (CTBUH Technical Guides. New York: Routledge, 2013) 9.

decimate the reality that existing tall buildings, despite the newly conscious era of building, are not performing or meeting potential. Knowing, the building sector industry is the biggest CO₂ consumer, the most logical way to combat CO₂ emission is to renovate existing buildings rather than building new. Renovating buildings takes advantage of the already expended energy known as embodied carbon while implementing new energy saving methods and technologies.

Renovations often result in an increase in energy demands, based on New York City Local Law 84 requiring large buildings with a gross floor area over fifty thousand square feet to publicly release energy consumption data.²⁰ Newly renovated office buildings attract new tenants with bigger energy demands. For instance, a non-renovated pre-1930s office building does not usually attract en-

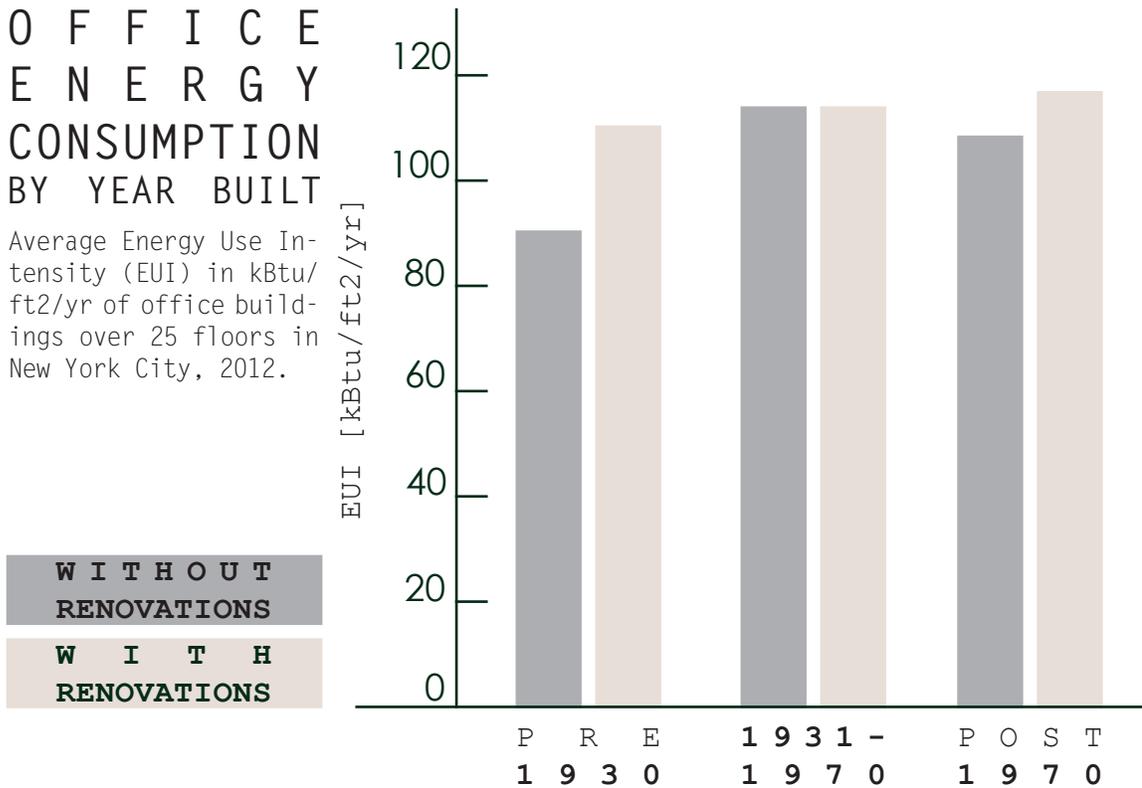
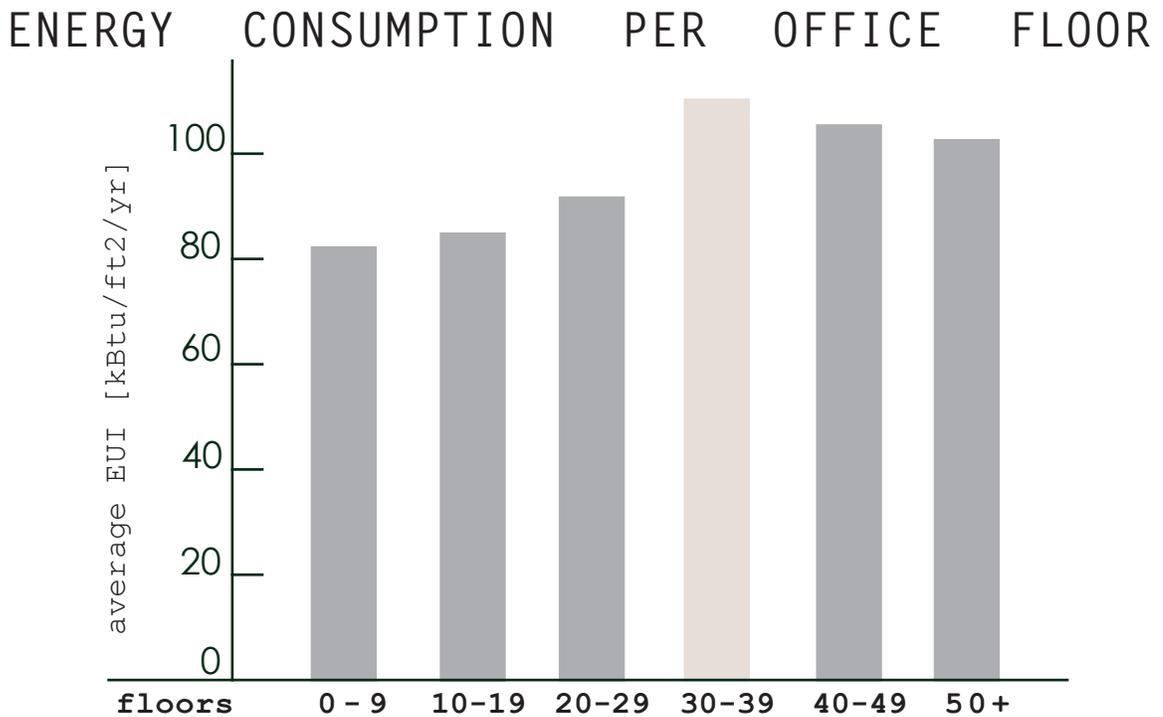


Figure 6: Energy Consumption by Year Built

(Source: International Journal of High-Rise Buildings Volume 2 Number 4, 288. * modified by author)

20 Oldfield, Philip, Dario Trabucco, and Antony Wood. "Five Energy Generations of Tall Buildings: An Historical Analysis of Energy Consumption in High-Rise Buildings." *The Journal of Architecture* 14, no. 5 (October 2009) 592.

ergy intensive tenants such as banks needing large, energy dense trading floors. Therefore, when renovated, energy consumption increases due to a change of tenants, regardless of any new energy efficiencies implemented. Moving forward, building owners should not be deterred from energy efficient renovations, but rather benchmark new energy efficient standards on needs of new energy intensive tenants.



Average EUI [kBtu/ft2/yr] of all New York office buildings reported by The City of New York as a function of total number of floors.

Figure 7: Energy Consumption per Office Floors

(Source: International Journal of High-Rise Buildings Volume 2 Number 4, 287. * modified by author)

Results also show office buildings that are thirty to thirty nine floors tall, consume the most energy. Any additional building height over thirty nine floors tall results in a decline in overall energy consumption, ultimately height optimization in regards to energy consumption continues to decrease when fifty floors or taller.

Currently, the University of California is researching and compiling a project, "Building Façade Retrofit: A Database of Completed Projects," that will study

façade-design optimization projects undertaken on existing tall buildings. This research proposal was chosen out of thirty entries from eleven countries, confirming the possible range and vast amount of renovated facades.²¹

As stated before, the structural integrity of the building frame is rarely an issue, therefore new light is being shed on its life cycle. Funding sponsor, ArcelorMittal has provided \$300,000 in grant monies to the Council for Tall Buildings and Urban Habitat to assess the life cycle of tall building's structural systems. The research will create a comparison of the life-cycle implications of steel, concrete, and composite systems while developing a methodology for the assessment of life cycle energy and carbon use in tall building structural systems. Results were published at their annual conference in October 2015. This research could influence how the structural system of tall buildings is perceived, changing how we approach building renovations in terms of life cycle analysis.²²

1.3.2 Demolition Delirium

"In contrast to European societies, which tend to reject tall buildings in the historical centers of their cities, America put their skyscrapers in the central business districts. Thus, the question of how to best fit tall buildings into the surrounding urban environment is usually a more complicated issue in American cities."²³ This sets the difficult scenario of how to demolish tall buildings in densely inhabited districts within the city. The difficulty is increased if the building is concrete requiring a kinetic demolition, where as steel is a piece-by-piece removal process. Explosives are cheaper and quicker compared to a piece-by-piece removal process. The potential damage to neighborhood buildings and underground infrastructure is extremely risky. There is also a problem of dust, noise, and vibrations generated by the explosion.²⁴ If asbestos is present, the

21 CTBUH, "CTBUH 2014 International Research Seed Funding," <http://www.ctbuh.org/Tall-Buildings/ResearchDivision/ResearchSeedFunding/ResearchSeedFunding2014/tabid/6413/lan-guage/en-US/Default.aspx> (accessed 5/2/15 10:22:27pm)

22 CTBUH, "CTBUH 2014 International Research Seed Funding," <http://www.ctbuh.org/Tall-Buildings/ResearchDivision/ResearchSeedFunding/ResearchSeedFunding2014/tabid/6413/lan-guage/en-US/Default.aspx> (accessed 5/2/15 10:22:27pm)

23 Ruchelman, Leonard I. "The Urban Ecology of Tall Buildings." In *Second Century of the Skyscraper*, ed. Lynn S. Beedle. (Springer US, 1988), 88.

24 Trabucco, Dario, and Paolo Fava. "Confronting the Question of Demolition or Renovation." *CTBUH Journal, Retrofit*. no.IV (2013), 39.

process of demolition will be altered to maintain containment, thus increasing time and costs. Once demolished, the question of what to do with the waste arises. Many materials can be recycled into new building materials, but this is not the case with bricks, tiles, coated glass, concrete, etc. The chance for reusing them is limited to mostly civil engineering infill projects, such as roads; otherwise the demolished materials end up in a landfill. Once in a landfill, the energy used to produce the materials is lost forever.

Demolition should only occur when there is no viable option left. Tall buildings become unworkable when the floor-to-ceiling height does not allow for new equipment, or if the economic viability to supplement rentable area is outweighed by the total costs of demolition and new construction. "Renovation of a tall building can cost fifty to ninety percent less than the demolition of the present building and the erection of a brand new tower of a similar size."²⁵ In addition to cost savings there is a time advantage, as renovation takes less than half the time of demolition and construction of a new building. Furthermore in regards to building renovations, an existing building affords important savings in building materials. As it is possible to reuse existing foundations, structures, and cores, there is a sustainable aspect to building renovation resulting in a reduction of embodied energy.²⁶ Renovations offer a sustainable and economical approach to revitalizing the city compared to demolishing and building new.

It is also important, beyond that of financial responsibility, to determine the historical context associated to the property in question early in the planning phase. Historic Preservation is a whole other juggernaut that will dictate the realm of renovation possibilities. Guidelines are set forth to enrich cities beyond that of our lifetime. Therefore it takes a wealth of knowledge, patience, and historical input to renovate a historical building to the original architect's intent but can also add to a building prestige. In the case of San Francisco, zoning laws from the mid 1980s protected two hundred and fifty-one architecturally or historically significant buildings from demolition and offered partial protection for

25 Trabucco, Dario, and Paolo Fava. "Confronting the Question of Demolition or Renovation." CTBUH Journal, Retrofit. no.IV (2013), 39.

26 Trabucco, Dario, and Paolo Fava. "Confronting the Question of Demolition or Renovation." CTBUH Journal, Retrofit. no.IV (2013), 39.

more than two hundred other structures.²⁷ This protection has led to one of the tallest seismic retrofits in North America, 140NW. Located in the heart of San Francisco, 140NW, a 1925 Category I Historic Building is eligible to register for the National Register of Historic Places.

Historic Preservation has an extremely important role in architecture and is a special renovation type. However, is not included in the general category of “renovations” explored in this discourse unless noted. 140NW is explored further only to demonstrate how current technologies are being used to measure carbon and to display an analysis of carbon saved through renovations compared to building new.

CARBON COMPARISON

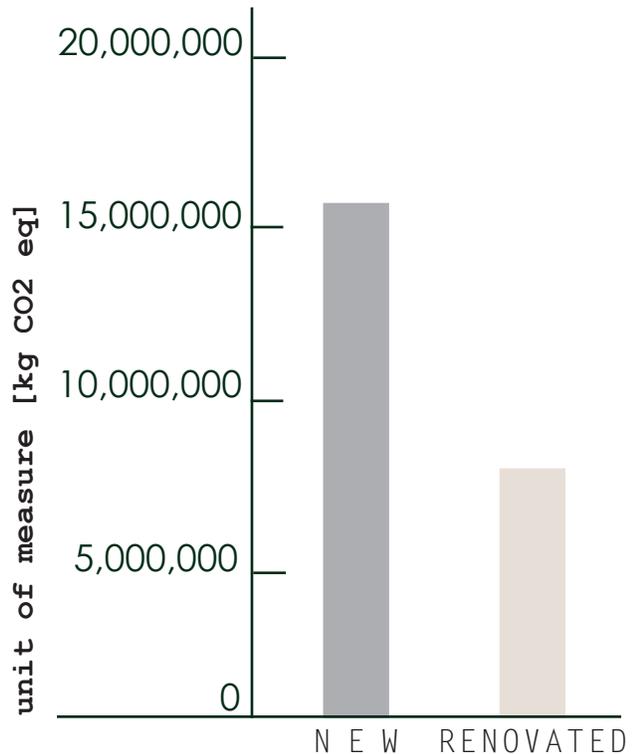


Figure 8: Carbon Comparison

(Source: “Sustaining a Historic High-Rise Structure,” CTBUH Journal, 2015 Issue I, Retrofit/Seismic, pg. 39.)

The new developer of 140NW purchased the building in 2008 and focused on attracting creative entrepreneurs and companies in the technology sector. The building had to provide state-of-the-art technology based infrastructure and a flexible workspace, hence a design team was engaged to spend the next few years following these guiding principles along with restoration parameters with strict seismic retrofitting. Ninety-five percent of the existing structure was reused. The numbers were compiled in “Athena’s Impact Estimator,” for LCA (life cycle analysis) with the most common metric, Global Warming Potential.²⁸ The results

27 Mahjoub, Nina, Megan Stringer, and Bill Tremayne. “Sustaining a Historic High-Rise Structure.” CTBUH Journal, Retrofit / Seismic, I (2015), 35.

28 Mahjoub, Nina, Megan Stringer, and Bill Tremayne. “Sustaining a Historic High-Rise Structure.” CTBUH Journal, Retrofit / Seismic, I (2015), 35.

confirmed that renovation resulted in a little more than one third of the carbon associated with global warming potential compared to a similar new building.

Demolition delirium is fading based on successful renovations, financial opportunity, and sustainable building practices. "It is often said that the most sustainable building is the one already built."²⁹ William Pedersen of Kohn Pedersen Fox (KPF) an architectural firm with thirty-four projects that fall under a KPF category, "Repositioning and Transforming," stated in regards to sustainable vertical urbanism, "There has been a major transition in the sense of the value of the tall building and what it can contribute to the urban realm, and society in general. This transition moves the tall building away from just an instrument of financial exploitation and toward a development highly concerned with its impact on the city, the environment, and the urban habitat." The large firm is indeed embracing renovations by putting their own twist on the typology, paving the way for category of growth as a more sustainable option than demolition.

Overall, understanding the life cycle of tall buildings is relatively new and building height capabilities have out paced demolition/dismantling capabilities. While building heights have reached one thousand meters, demolition/dismantling has only reached two hundred meters.³⁰ Like it or not, the newly constructed towers will be here to stay (by default) for easily one, maybe two hundred years from now, making tall building renovation that much more significant.

1.4 Lifestyles of Tall

Tall living is a relatively new way of living when considering mankind has lived over millions of years and only one hundred of those years vertically. In this short time span, tall buildings used as 'a small city' in vertical development have often left its users in isolation. The psychology of skyscraper living has been channeled as "requiring a special type of behavior, one that was acquiescent, restrained, perhaps even slightly mad...whose residents' thrived on the rapid turnover of acquaintances, the lack of involvement with other, and the total self-sufficiency of

29 Mahjoub, Nina, Megan Stringer, and Bill Tremayne. "Sustaining a Historic High-Rise Structure." *CTBUH Journal, Retrofit / Seismic*, 1 (2015), 39.

30 Wood, Antony. "Rethinking the Skyscraper in the Ecological Age: Design Principles for a New High-Rise Vernacular." *International Journal of High-Rise Buildings* 4, no. 2 (2015), 91–101.

lives which, needing nothing, were never disappointed."³¹ However draconian tall building living might be described, as the underpinnings of psychological issues that emanate from a 'collective solitude.'

Not to become disenchanted by psychological factors associated with tall living, but 'tall living' is not going away anytime soon. Perhaps, the more troubling factor facing tall buildings today is sociology. "Who is living in the high-rise, and under what conditions?" While the architect cannot address the first part of the question directly, architects are however equipped to address the second part. Through design, architects can make the public spaces more transparent, inviting, and more sociable. This is of course dictated by the client. Humans are more comfortable with what the eye can see. Anything more than six stories away (sixty feet) is typically out of human comfort range. Adapting public space within the tall building to a 'visual comfort' distance incorporated with a proven aspect of transparency, welcoming and sociable elements, will benefit the social culture of the building and surrounding areas.

Urban city lifestyles are vastly different than suburban lifestyles, besides the obvious difference in verticality. The city strives to offer 'walk-able diversity,' meaning one can encounter a variety of mixed-use buildings, food courts, and social spaces on foot from their dwelling. Suburban lifestyle is centered on a 'main street' of sorts with all amenities sprawling spaciouly outward, resulting in 'unwalk-able' space. The city aims for diverse mix of neighborhood functions to accommodate residential, working, shopping, entertainment and leisurely needs. In the city, street life should be lively attracting people at all times of day with an adequate mix of public and private places. The tall building, the forefront of the cities' development must be sensitive to promoting health and vitality in the community and neighborhood life.³²

The street-level is to be as equally important as the skyline, as it is critical to a project's integration into the culture and vitality of a city. For instance, the con-

31 Vanderbilt, Tom. "The Psychology of Skyscrapers," in *The future of the Skyscraper*, SOM Thinkers 2015, ed. Philip Nobel, Matthew Ygeasias, Diana Lind, Will Self, Emily Badger, Michael Govan (New York, Metropolis Books, 2015),

32 Ruchelman, Leonard I. "The Urban Ecology of Tall Buildings." In *Second Century of the Skyscraper*, ed. Lynn S. Beedle. (Springer US, 1988), 81.

cept of the agora, a lively marketplace in ancient Greece where business and commerce created a place where one could observe community events, meet friends, or sit leisurely, reading, people watching or time in the sun—the modern agora is not much different from its historical counterpart; they still strive to enhance the use of public space by drawing people in to take advantages of the amenities they offer.³³ “Hundreds of high-rise developments from the sixties to the eighties have sought to create grand public spaces. For the majority, the results have been little more than windswept, oversized, stone doormats or vaulted lobbies that have more in common with mausoleums than the vital link between the horizontal and vertical cells of the city that they could be. The truly successful developments can be counted on one’s hand, Rockefeller Center in New York, Embarcadero Center in San Francisco and Citicorp Center in New York began to capture the imagination of the public as truly urban places.”³⁴ Moving forward, one of the key challenges of tall buildings in the city is to keep its streetscapes permeable, indelicate and reminiscent of the ancient agora. Creating balanced streetscapes with informed public realm treatments aids in psychological perception of tall buildings.

1.5 Tall Advancements: Moving Towards Sustainable Renovations

“Energy shortage, global warming, urban sprawl, air pollution, overflowing landfills, water shortage, disease, and global conflict will be the legacy of the twenty-first century unless we move quickly towards the notion and implementation of sustainability. Survival of the human race depends on the survival of the cities—their built environment and the urban infrastructure.”³⁵ Accomplishing this will require a shared vision from multiple entities such as, government, policy makers, experts, public citizens, as well as collaboration between urban planners, architects, engineers, politicians, academics, and community groups. While this task seems nearly impossible, it is reassured that progress towards the notion and implementation of sustainability is present and currently exists in tall buildings. However, without the force of regulations made by government entities,

33 Lollini, Tom. “Tall Buildings, Tight Streets.” In *Second Century of the Skyscraper*, ed. Lynn S. Beedle, 275–85. (Springer US, 1988), 277.

34 Lollini, Tom. “Tall Buildings, Tight Streets.” In *Second Century of the Skyscraper*, ed. Lynn S. Beedle, 275–85. (Springer US, 1988), 278.

35 Ali, Mir. M, and Paul J. Armstrong. “Overview of Sustainable Design Factors in High-Rise Buildings.” Paper presented at CTBUH 8th World Congress, Dubai, UAE, (March 3-5, 2008), 2.

or by demand of its users and community groups, developers and/or owners in the US are left to implement sustainable attributes on goodwill. Developers and owners need to offset costs and other liabilities to make financial sense. The cost savings in renovating compared to building new allows developers to implement sustainable systems, thus, making sustainable practices more achievable and practical to the developer with the added benefit of lower operational costs.³⁶

Currently the word and idea of “sustainability” is so frequently used and abused by numerous industries, it has lost its foothold. Therefore it is vital to define its role in architecture. P. Newman, author of *Sustainability and Cities: The Role of Tall Buildings in the New Global Agenda*, published in 2001, defines “sustainability” as, “Sustainable architecture is environmentally conscious, energy-saving, and utilizes responsive and renewable materials and systems. Ecological and environmental concerns have expanded beyond the issue of consumption of non-renewable energy sources. Sustainability essentially aims for ecological balance.”³⁷ To achieve an ecological balance, an integrated design process is required (refer to 1.6). Many aspects of building elements will be informed and affected by the design. For instance, designing for daylight, which involves elements of site, orientation, building form, façade design, floor-to-floor height, interior finishes, electric lighting controls, and cooling loads. An integrated design process is still equally important for a renovation design. Again, using the example of designing for daylight, most urban skylines have changed drastically over time; Honolulu being a great example, the original daylight the building once received maybe now be in constant shadow, therefore requiring a new design approach than employed by the original architects. Regardless, if the architect is designing new or renovating old, their typical prism of focus; building configuration, passive measures, and improved façade design, will be transformed by collaborative focus experienced in an integrated design process. Integrated design projects generally utilize sophisticated engineering; this allows buildings to be responsive to their climatic contexts.³⁸ However, sophisticated engineering is

36 Ali, Mir. M, and Paul J. Armstrong. “Overview of Sustainable Design Factors in High-Rise Buildings.” Paper presented at CTBUH 8th World Congress, Dubai, UAE, (March 3-5, 2008), 3.

37 Ali, Mir. M, and Paul J. Armstrong. “Overview of Sustainable Design Factors in High-Rise Buildings.” Paper presented at CTBUH 8th World Congress, Dubai, UAE, (March 3-5, 2008), 2.

38 Ali, Mir. M, and Paul J. Armstrong. “Overview of Sustainable Design Factors in High-Rise Buildings.” Paper presented at CTBUH 8th World Congress, Dubai, UAE, (March 3-5, 2008), 5.

THERMAL BUOYANCY IN TALL BUILDINGS

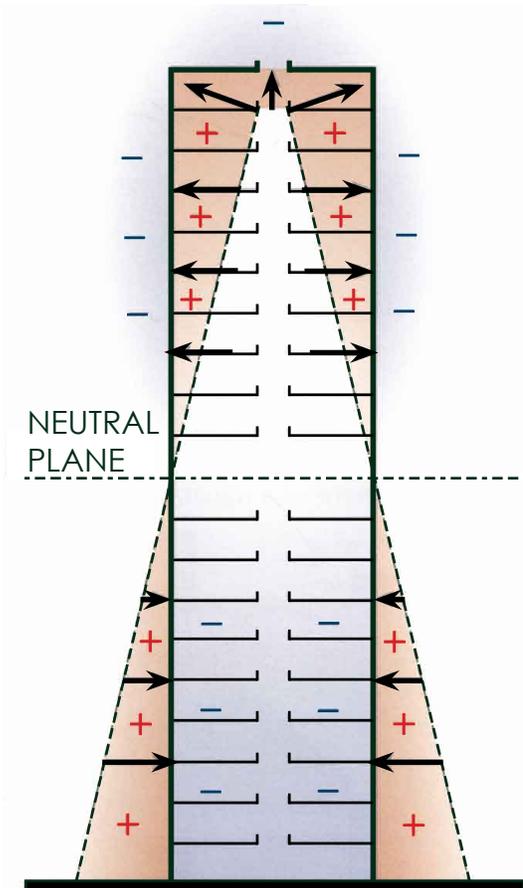


Figure 9: Thermal Buoyancy in Tall Buildings

(Source: Antony Wood and Ruba Salib, *Natural Ventilation in High-Rise Office Buildings*, 18.)

Service Core

The service core in and of itself is not a sustainable element, however when designed a certain way, can serve as an integral role in a sustain-

not needed to design a bioclimatic responsive building. In general, "the principle design factors that are crucial for achieving a high performance tall building are site context, environment, structure and use of materials, energy consumption, ecological balance, and community development."³⁹ If these principles are addressed and included in the design process, more than likely, the building will be correctly defined as 'sustainable.'

The future of tall buildings will aim towards the use of sustainable building elements.

1.5.1 Role of Sustainable Building Elements

STACK-VENTILATION

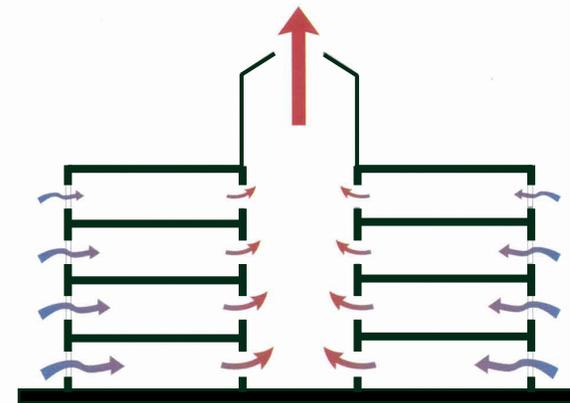


Figure 10: Stack Ventilation

(Source: Antony Wood and Ruba Salib, *Natural Ventilation in High-Rise Office Buildings*, 19.)

39 Ali, Mir. M, and Paul J. Armstrong. "Overview of Sustainable Design Factors in High-Rise Buildings." Paper presented at CTBUH 8th World Congress, Dubai, UAE, (March 3-5, 2008), 3.

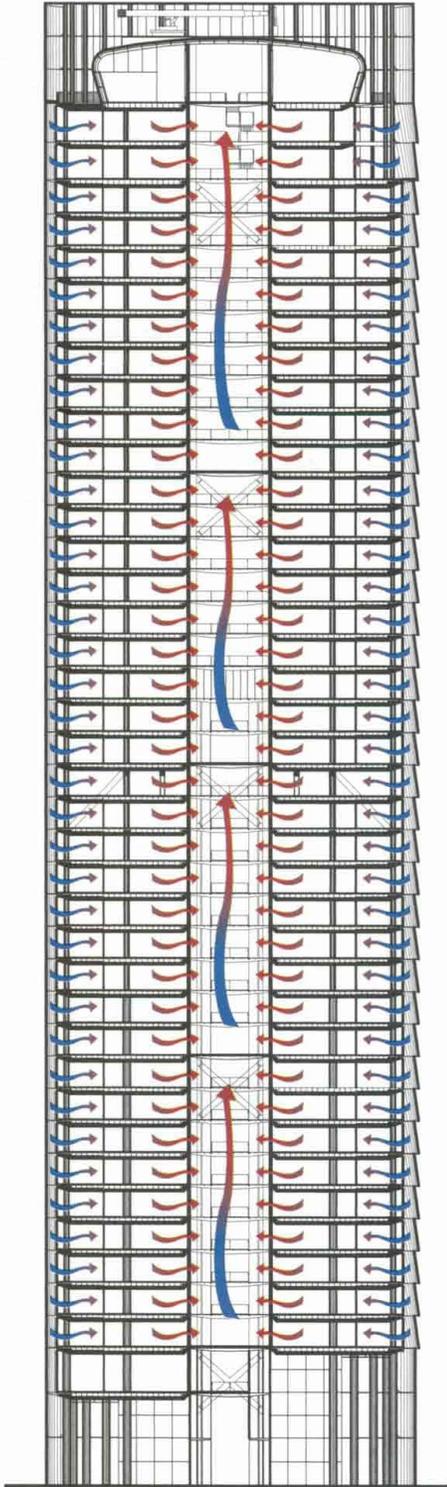
able tall building. For instance, a centrally placed service core featuring large voids can be used to facilitate natural ventilation using the buoyancy effect. Centrally located cores are the most common in tall buildings; because of this it is also common to see the use of atria in tall buildings. An atrium supporting the function of natural ventilation utilizes the physical mechanism that drives air, drawing hot air up and out of the building. This is also known as buoyancy-induced ventilation or the “stack effect,” or “chimney effect.” The physical mechanism that drives air is reliant on density differences caused by variations in temperature and height between the inside and the outside or between certain zones within a building. In order to achieve effective buoyancy - induced ventilation, there has to be a significant temperature differential between the inlet and outlet of air, and minimal internal resistance to air movement within the interior space.⁴⁰ Variance in temperature differential varies between buildings, locations, and seasons, but in general air traveling through a building is heated by the internal gains and building occupants. Thermal buoyancy in tall buildings, where indoor/outdoor temperature difference results in a different pressure gradient is shown below.

In general stack-ventilation involves moving fresh air that enters from the lower levels on the building and exhausting it at higher levels. Stack ventilation occurs because of the temperature, density, and pressure differences that occur at higher level in tall buildings. As previously mentioned, central atriums are the most common architectural development of this concept, however chimneys or elevated elements of the building perform in the same way.

Displacement of the service core from traditional central locations to the exterior can be used to cool or heat the building. The exterior core should be placed on the sunny side of the building to help cool or placed on the north side to aid in heating. The displaced north side core works best in very cold, windy locations as it helps to reduce heat losses through principles of thermal inertia. SOM's Inland Steel and One Bush Building (Crown Zellarbach headquarters) located in Chicago and San Francisco respectively are early examples of exterior placed cores. Newer buildings such as Ken Yeang's Menara Mesinaga, Menara

40 Wood, Antony, and Ruba Salib. *Natural Ventilation in High-Rise Office Buildings*. CTBUH Technical Guides (New York: Routledge, 2013), 18.

SERVICE CORE: CENTRAL ATRIUM



POST TOWER- Bonn, Germany

The natural ventilation strategy of the building is based on a double-skin facade system which supplies air to the offices, and a central atrium sky garden exhausts it.

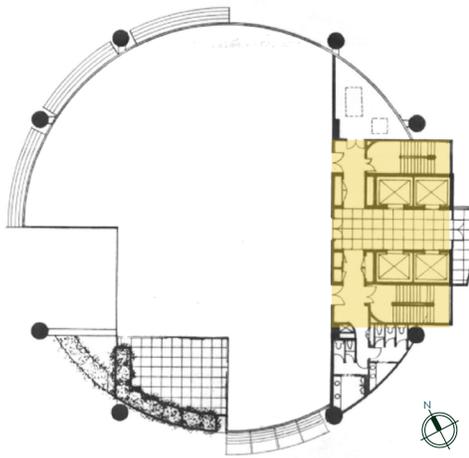
Figure 11: Service Core: Central Atrium

(Source: Antony Wood and Ruba Salib, Natural Ventilation in High-Rise Office Buildings, 76.) Base drawing © Murphy/Jahn Architects

Boustead, and IBM Plaza all located in Kuala Lumpur are examples of external service cores used for shading purposes. External service cores can also be naturally ventilated, reducing the total volume to be mechanically conditioned as well as mitigate the heat loads they can generate.⁴¹ For tall building renovations a change in service core location can be utilized when changing its use or moving towards a mixed-use function.

Passive Solar Gain

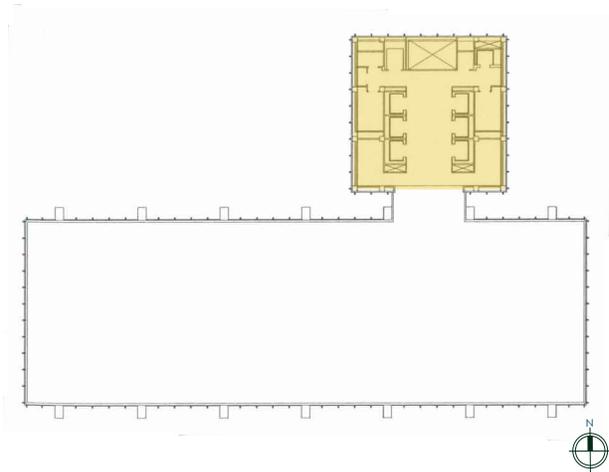
SERVICE CORE: DISPLACED-EXTERIOR



MENARA MESINIAGA, Kuala Lumpur. The service core shade the building protecting it from solar radiation. © T.R. Hamzah & Yeang Sdn.

Figure 12: Service Core: Displaced-Exterior Menara Mesiniaga

(Source: Dario Trabucco, "Historical Evolution of the Service Core", 47 * modified by author.)



INLAND STEEL, Chicago. The north placed service core utilizes thermal mass to protect from the cold.

Figure 13: Service Core: Displaced-Exterior Inland Steel

(Source: NEU, Efficiency, An Analytical Approach to Tall Office Buildings, 19 * modified by author.)

Solar radiation greatly impacts thermal control and performance in tall buildings. The seasonal paths of the sun across the sky affect the design and the buildings' orientation. The orientation of the building is a significant design decision in regards to solar radiation. Tall buildings in cold climates should be oriented to

41 Trabucco, Dario. "Historical Evolution of the Service Core." *CTBUH Journal, CTBUH Technical Paper*, no. 1 (2010), 46–47.

maximize solar gain with opposite being true for hot regions, minimizing solar gain.

For cold climates building orientation slightly east of south is recommended. A slightly east of south orientation exposes the building to longer periods of morning sun than afternoon sun enabling the building to heat during the day. In the winter, passive solar gain can offset heating costs. When passive solar gain in temperate and cold climates is well considered, the building will be designed to bring the sun "in" as well as keep the sun "out," without over heating. Designing for the summer sun requires shading in every climate type. In general southwest and west facing facades are prone to overheating as they receive sunlight most of the year later in the day when the interior is already warm. The overheating is exaggerated by internal heat gains seen in office buildings with high density and massive computer equipment. Tall building renovations can resolve issues of overheating and diminish heat loss caused by solar gains through an overcladding or recladding of the façade. In extreme renovations where floor plate shape can be altered, the circular floor plate affords the least surface exposure in terms of solar gain and the rectangular shape affords more solar control.⁴²

Façade Technology

Daylighting and shading are usually the key aspects for a sustainable façade de-

ANNUAL PERCENT OF REQUIRED SHADING + SOLAR HEATING

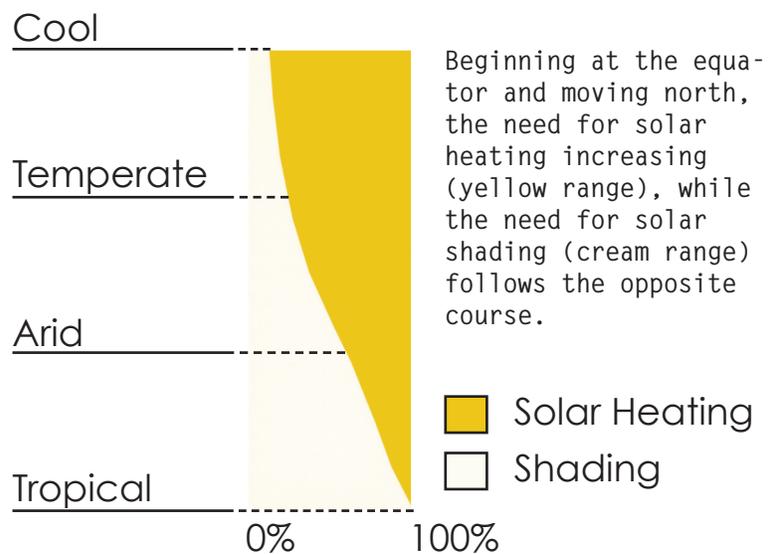


Figure 14: Annual Percent of Required Shading + Solar Heating

(Source: Ken Yeang, *Ecodesign, A Manual for Ecological Design*, 201.)

42 Yeang, Ken, *Ecodesign: A Manual for Ecological Design*. (Chichester: Wiley, 2008), 199.

sign. The façade covers over ninety to ninety-five percent of the external building surface area in a tall building. The roof area is almost insignificant compared to the façade areas. Thereby, the energy gain or loss of a tall building is dependent upon the materiality and technology employed in the façade. Facades create the building's aesthetic and controls internal conditions of the building as it represents the building's envelope or skin. The latest advancement is double-skin facades. A double skin façade consists of two skins placed apart from each other to create a cavity. The cavity allows airflow to be controlled either mechanically or naturally. Solar shading is incorporated into the cavity. Double and triple pane glass panels filled with argon are recommended for cold climates.⁴³

Natural Ventilation

"Given that HVAC systems in tall office buildings typically account for somewhere between 30-40% of overall building energy consumption, the elimination of these systems with natural ventilation could be argued to be the most important single step we could take in making tall buildings more sustainable."⁴⁴

Natural ventilation strategies for tall buildings vary by climate zone and are influ-

OFFICE ENERGY CONSUMPTION BY SOURCE

Average energy consumption of a typical tall office building built after 1980 in various climate zones across 16 US cities.

- 33% HEATING AND COOLING**
- 31% EQUIPMENT**
- 29% LIGHTING**
- 6% FANS, PUMPS & CONTROLS**
- 1% WATER SYSTEMS**

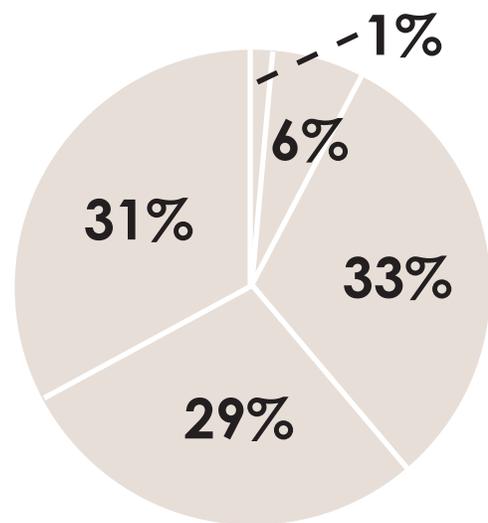


Figure 15: Office Energy Consumption by Source

(Source: Antony Wood and Ruba Salib, *Natural Ventilation in High-Rise Office Buildings*, 11.) * modified by author)

43 Yeang, Ken, *Ecodesign: A Manual for Ecological Design*. (Chichester: Wiley, 2008), 233.

44 Wood, Antony, and Ruba Salib, *Natural Ventilation in High-Rise Office Buildings*. CTBUH Technical Guides, (New York: Routledge, 2013), 10.

enced by overall building height, floor-to-ceiling height, and floor plate width.

Building Management Systems

Innovative building technologies such as computer-based smart or intelligent building systems can play a major role in managing the energy usage. The increasing reliance on computer technology and automated systems can be directed toward achieving a sustainable function of skyscrapers. The Building Management System (BMS) is a centralized control system such as fire protection, security, communication, networks, elevators, and HVAC systems.⁴⁵ The environmental data collection and control system is usually incorporated within the BMS. Additionally the BMS can also be used to automatically trigger the opening and closing of windows and/or shading devices to support passive features.⁴⁶

Harnessing Solar Energy

There are two categories of solar energy: passive and active. Passive solar is used through direct gain, indirect gain or isolated gain. A direct-gain system allows sunlight to pass through windows into an occupied space. In an indirect-gain system a part of a building absorbs and stores solar heat and then is transferred through the rest of the building through conduction, convection, or radiation. In an isolated-gain system, solar energy is absorbed and stored in a separate area then distributed to areas through ducts. In active solar systems, solar collectors are used to convert the sun's energy into photovoltaic panels.⁴⁷ Photovoltaics produce a clean, quiet, and pollution-free energy source. One square meter of photovoltaic panels generates an average of one hundred watts of electrical energy. There are three main types of photovoltaic panels, monocrystalline, polycrystalline, and amorphous silicon cells.

Harnessing Wind Energy

Wind is a renewable energy source that can be advantageously tapped at higher altitudes of tall buildings where wind speed is considerably large. Tall build-

45 Ali, Mir. M, and Paul J. Armstrong. "Overview of Sustainable Design Factors in High-Rise Buildings." Paper presented at CTBUH 8th World Congress, Dubai, UAE, March 3-5, 2008.

46 Ali, Mir. M, and Paul J. Armstrong. "Overview of Sustainable Design Factors in High-Rise Buildings." Paper presented at CTBUH 8th World Congress, Dubai, UAE, March 3-5, 2008.

47 Yeang, Ken, *Ecodesign: A Manual for Ecological Design*. (Chichester: Wiley, 2008), 244.

ings can be shaped to funnel wind into a zone containing wind turbines and the profile of the structure can increase wind speeds to produce more energy.⁴⁸ Wind power is generated to the cube of wind speed and thereby is regarded as a great energy source. However, turbines come with great restrictions and are not recommended in dense areas. Recommendations suggest installation should be six meters higher than any obstruction within one hundred and fifty meters. If wind energy is to be used, it is recommended to use vertical axis turbines, since horizontal axis turbines are harmful to birds and bats, and requires monitoring of collisions.

Combined Heat and Power

A highly efficient technology for energy saving in densely built-up urban areas is the Combined Heat and Power system. Combined Heat and Power is the simultaneous production of power, heat, and occasionally, chilled water for air-conditioning, and is also known as co-generation or tri-generation. Combined Heat and Power avoids transmission losses as electricity is generated close to the point of use. The simultaneous production of electricity and heat in a useable form enables overall thermal efficiencies, which is to say that significantly less fuel is used for a given amount of work. The result is a reduction of cost and reduction of CO₂ emissions of over thirty percent with respect to generation from coal-fired power stations. Combined Heat and Power technology can be applied to individual tall buildings or groups of tall buildings where the electricity load and annual cooling requirements are similar. Combined Heat and Power is thus an attractive option since most of the energy is useful and it can be adapted into a low to zero carbon application due to its flexible system.⁴⁹

Fuel Cells

Fuel cells are electromagnetic devices that generate electricity like batteries, but without chemical energy storage. Fuel cells convert the chemical energy of a fuel that is fed into them to generate electricity, and can be considered as electro-chemical internal combustion engines. They take a continuous supply of fuel, in the form hydrogen, opposed to hydrocarbon. The most efficient way of extract-

48 Ali, Mir. M, and Paul J. Armstrong. "Overview of Sustainable Design Factors in High-Rise Buildings." Paper presented at CTBUH 8th World Congress, Dubai, UAE, March 3-5, 2008.

49 Ali, Mir. M, and Paul J. Armstrong. "Overview of Sustainable Design Factors in High-Rise Buildings." Paper presented at CTBUH 8th World Congress, Dubai, UAE, March 3-5, 2008.

ing hydrogen is from natural gas or methanol by using a reformer unit, which is then fed directly into the fuel cell. A fuel cell is essentially a reactor that combines hydrogen and oxygen to produce electricity, heat, and water. Therefore, its environmental qualification is immaculate. At this time, its cost is high but it is foreseeable to be more affordable in the future. Fuel cells are used in spacecraft and airplanes. Currently, the Conde Nast Building in New York uses fuel cells. Fuel cells are clean, quiet, and efficient with few moving parts. Their outputs are electricity, heat, and pure distilled water. One of the most common kinds of fuel cells is the proton exchange membrane fuel cell. Some other types are phosphoric acid fuel cell, solid oxide fuel cell, alkaline fuel cell, and molten carbonate fuel cell. Fuel cells require platinum as a catalyst. Overall, the fuel cell has great potential as a carbon neutral energy source of the future, but if it were to replace all existing types of energy, it would deplete the earth's supply of platinum.⁵⁰

Biomass Energy/Fuel

In addition to solar and wind energy, another source is bioenergy. Biomass is organic matter, living matter such as wood or vegetative matter containing carbon and oxygen. Biomass can be converted to fuel in the form of chemical energy, a carbon neutral process. The carbon emitted when the energy is burned equals the carbon absorbed during the life cycle.⁵¹

Geothermal Energy

Although not widely exploited, geothermal energy currently makes up only 0.1 percent of total world energy, showing potential as a renewable energy resource. Hot water and steam, which lie deep beneath the earth's surface in volcanic rock, geysers and hot springs, can be converted into electricity.⁵² The geothermal gradient increases temperature an average of 36.5 degrees to 37.5 degrees Fahrenheit per every three hundred and thirty feet of depth. Modern drilling technology can reach depths of six miles into the earth. Geothermal energy can also be combined with heat pump technology, a technology that has

50 Ali, Mir. M, and Paul J. Armstrong. "Overview of Sustainable Design Factors in High-Rise Buildings." Paper presented at CTBUH 8th World Congress, Dubai, UAE, March 3-5, 2008.

51 Ali, Mir. M, and Paul J. Armstrong. "Overview of Sustainable Design Factors in High-Rise Buildings." Paper presented at CTBUH 8th World Congress, Dubai, UAE, March 3-5, 2008.

52 Yeang, Ken, *Ecodesign: A Manual for Ecological Design*. (Chichester: Wiley, 2008), 247.

improved incrementally through applications in United State and Europe.⁵³

Water Recycling Systems

Good quality water is a diminishing resource. Only three percent of the world water supply is fresh water with two thirds of that being ice. The remaining ninety seven percent is salt water. The renewable freshwater of earth in the form of rainfall is only 0.008 percent of all global water. Although about four trillion gallons of water (rainfall) falls globally daily in the form of precipitation, two thirds of this is lost in evaporation, transpiration, and runoff. Urbanization, which leads to an increase in the impervious surfaces on our built environment, has long been recognized as a process that alters the water quality of urban and suburban aquatic systems. In urban areas, storm water runoff can be captured in storm-water storage cisterns. Reusing “grey water” is another method to reduce wastewater or not to create it at all. Through the use of new environmentally friendly techniques, purification of water can be treated by ultramembranes and ultraviolet light. The ultramembrane pores are so fine they can physically screen cells. Once or twice filtered, ultraviolet light is used for an “after-disinfection” safety guard. Ultraviolet light can also be used through the entire disinfection process, using a photochemical process to create powerful oxidizers to break down organic compounds to be consumed by aerobic bacteria in the active carbon filters.⁵⁴

Green Walls

Green walls can have significant benefits simultaneously upon implementation—to both the building and the wider urban surroundings. The benefits of green walls include reducing building operating energy for heating/cooling by either insulating or shading the façade, increasing occupant satisfaction and productivity by connecting the inhabitant directly to natural elements, filtering population for improved internal air quality, potentially providing agriculture, reducing urban noise filtering to the building, and increasing property values (studies show up to twenty percent increase).⁵⁵ Building with substantial green

53 Ali, Mir. M, and Paul J. Armstrong. “Overview of Sustainable Design Factors in High-Rise Buildings.” Paper presented at CTBUH 8th World Congress, Dubai, UAE, March 3-5, 2008.

54 Yeang, Ken, *Ecodesign: A Manual for Ecological Design*. (Chichester: Wiley, 2008), 247.

55 Wood, Antony, Payam Bahrami, and Daniel Safarik, *Green Walls in High-Rise Buildings*. CTBUH Technical Guides, (New York: Routledge, 2014), 27.

elements not only have a positive impact on the health, but also provide productive places to live and work, secure higher rents and prices, attract tenants more quickly, and reduce tenant turnover. The benefit on an urban scale include reduction of the urban heat island effect, improving urban air quality, sequestering carbon from the atmosphere, absorbing urban noise, improving aesthetics, and increasing biodiversity. Although this typology is immensely diverse including green facades, living walls, vertical gardens, hanging gardens, bio-shaders, and bio-facades, the integration of these elements is also diverse. Green walls are comprised of four main parts including plants, planting media, structures that support and attach plants to the façade, and the irrigation system.

Sustainable building elements are most effective when used and designed in conjunction with one another. For renovations, it may not be possible to use all of the sustainable building elements, but more than likely passive measures will be the most obtainable.

1.5.2 Tall Sustainable Authority

In today's building industry there are many organizations that look to certify, prescribe, assess, and market sustainable buildings. Although some of the organizations offer a "check-list" approach to sustainability, sustainability can be served through the highest level of environmental integration by a design appropriate to that particular site and system.

BREEAM

BREEAM, is short for Building Research Establishment Environmental Assessment Method. Established in 1990, it is the longest established method of rating, assessing, and certifying sustainable buildings. There are more than half a million BREEAM certified developments and over two million registered buildings. The organization looks to enhance the well being of people while making attractive property investments focused on generating sustainable environments.

LEED

LEED stands for Leadership in Energy and Environmental Design. The United States Green Building Council developed the LEED Green Building Rating System to promote sustainable design. LEED is recognized and used all over

the globe. It is a voluntary program rating sustainable measures of buildings ranging from regular certification to silver, gold, or platinum. The rating system measures building performance on the basis of comprehensive criteria that are grouped under the following six parameters: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor air quality, and innovation and design/build process. The LEED rating system offers a checklist for commercial buildings, but it does not address high-rise residential construction nor does it explicitly cover all aspects of sustainable design that would yield a bioclimatic impact, infrastructure, social systems, and community development.⁵⁶

HQE™

HQE™ stands for “La Haute Qualité Environnementale,” and is the French “High Environmental Quality” certification awarded to building construction and management as well as urban planning projects. HQE™ promotes best practices, sustainable quality in building projects and offers expert guidance throughout the lifetime of the project.

1.6 Tall Ecological Constituents: Designing for Nature

Every living thing on the earth is affected in some way by the state and stability of its environment and every act of building changes the environment. It is known that the influence of humans on other animals is profound. Anthropogenic factors affect ecosystems by changing land cover, using resources, producing waste, and changing native communities of fauna and flora.⁵⁷ Urbanization directly affects species survival, population structure, reproduction, and behavior. As urbanization increases so does the importance of understanding how animals respond to human-dominated landscapes in order to successfully conserve and encourage biodiversity.

Examining biodiversity exposes the causal relationship between distribution of flora and fauna and human interaction. The flora and fauna are not haphazardly located on the surface of the earth; each species has a geographical range. The geographical range accounts for the distribution of species based on geology

56 Ali, Mir. M, and Paul J. Armstrong. “Overview of Sustainable Design Factors in High-Rise Buildings.” Paper presented at CTBUH 8th World Congress, Dubai, UAE, March 3-5, 2008, 4.

57 Clucas, Barbara, John M. Marzluff, “Attitudes and Actions Toward Birds in Urban Areas: Human Cultural Differences Influence Bird Behavior.” *The Auk* 129, no. 1 (January 1, 2012), 8.

and climate including specifically, patterns and distributions of soils, topography, water regimen, yearly temperature profile and rainfall, and the distribution of other species. In addition to these variables are the added extent of human action and activity already inflicted on that locality.⁵⁸ The relationship between ecosystems is not isolated by fences, walls, and property lines, but extends and interacts beyond that of man-made boundaries. Here, at this extension and interaction beyond man-made boundaries, lies the opportunity for ecological renewal within urban confines. One tall building performing as an ecological respite can serve beyond its property lines using its skyward prowess to deliver rehabilitation of degraded ecosystems.

To deliver an ecologically performing tall building, the design approach must be a designed system, where the end product is a process of the environment and the system interacts with the environment, just as an ecologist's design approach is inclusive, including all parts of the whole---the physical (inorganic) parts of the building and the biological (organic.) The same design approach can be used

ECOSYSTEM CONSTITUENTS

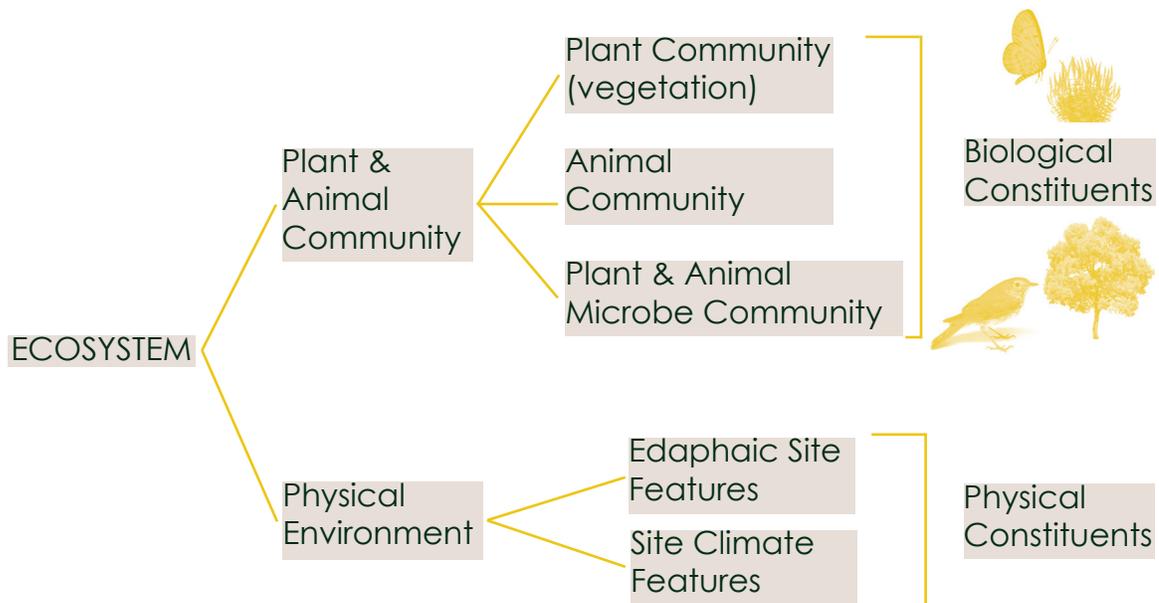


Figure 16: Ecosystem Constituents

(Source: Yeang, K., *Ecodesign: A Manual for Ecological Design*, 32
* modified by author)

58 Clucas, Barbara, John M. Marzluff, "Attitudes and Actions Toward Birds in Urban Areas: Human Cultural Differences Influence Bird Behavior." *The Auk* 129, no. 1 (January 1, 2012), 18.

towards renovation. A tall building renovation possess a more challenging opportunity working with already established conditions. For instance the point at which a New York tall building touches the earth is complicated by its foundation straddling subterranean platforms of rail lines—to the contrary any ecological adjustment already has an increased benefit. The chart below shows the interstitial relationships of an ecological design approach in regards to ecosystem components.

1.6.1 Designing for Plants and Animals

Integrating the designed system's inorganic mass vertically and horizontally requires a counterbalance of organic mass, called biomass. Our human-made built environment is increasing, causing the biosphere to become more impervious, inert, inorganic, and artificial, thus reducing natural habitats.⁵⁹ Trees and shrub-by forest (ground cover) still cover about forty percent of the world's landmass, but the amount is diminishing and the quality of land cover is declining. The reduction of land cover increases the endangerment of species both large and small. Plants contribute to the environment in many ways—producing oxygen, absorbing carbon dioxide, controlling and filtering water, cooling and filtering the air forming still air pockets, holding soil, producing food, producing energy, and providing food enclosures and cover for wildlife.⁶⁰ Plants and animals working in an ecological symbiosis balance a healthy carbon dioxide / oxygen exchange. Overall the more species an ecosystem contains, the more efficient it is considered.

Biomass can be brought into the urban environment vertically, by moving continuously upward starting with a linked densely green zone at the ground plane. Climbing diagonally along the façade the green zone should step up vertically, stopping at mid-level, transfer floors, turning up again diagonally on the other side of the tall building, then ascending vertically to the roof.

Increasing biomass requires awareness of accompanying organic life, as there are a number of species of creatures that affect human life, species that humans

59 Yeang, Ken, *Ecodesign: A Manual for Ecological Design*. (Chichester: Wiley, 2008), 133.

60 Yeang, Ken, *Ecodesign: A Manual for Ecological Design*. (Chichester: Wiley, 2008), 134.

would rather not share their spaces. These creatures tend to exist without any help at all—cockroaches, rodents and rats, spiders, fruit flies, ants, dust mites, molds, and fungi. Therefore it is paramount for the designer to understand this relationship and design accordingly, mitigating these organic life forms while attracting more undemanding faunal species, such as birds, through habitat management.⁶¹

Integrating avian habitat into urban landscapes, specifically tall buildings, is to support survival by providing site and nutrient sources needed during migration, wintering, and breeding season while mitigating bird collisions. Birds play many vital roles acting as seed spreaders, pollinators, pest controllers, and cleaning crews in the urban condition. Avian research shows that birds respond to implementation of habitat, basically, “if you build it, they will come.”⁶² However, it cannot be expected that breeding will occur as habitat selection is based on many conspecific factors. However the benefits are mutualistic. Simple efforts in creating natural habitat such as planting trees can prove mutualistic between species such as humans and birds (*homo sapiens* and *aves*), where the interaction between the two organisms will be beneficial to both participants. Habitat loss is by far the main cause of declining avian populations, although humans do play a role in killing birds. In the United States, in the year 2014 alone, it was estimated that humans and the built environment were responsible for 3.2 billion bird deaths, resulting from cats, building collisions, automobiles, power line collisions, communication towers, power lines, electro - conductions, and wind turbines.⁶³

It is estimated that five hundred ninety-nine million birds die each year in the United States from building collisions. Tall buildings are a majority contributor due to the extensive use of glass. Birds’ visual acuity is exceptional, however it is unknown why birds cannot see glass or pick up on other visual cues such as window mullions. Reflective glass is even worse, reflecting surrounding habitat so that birds fly at full force to the reflections of trees resulting in collision with

61 Yeang, Ken, *Ecodesign: A Manual for Ecological Design*. (Chichester: Wiley, 2008), 145.

62 Marissa A., John Faaborg, “Avian Habitat Management Meets Conspecific Attraction: If You Build It, Will They Come?” *The Auk* 123 (2). (American Ornithologists’ Union: 2006), 301–12.

63 State of the Birds 2014 The United States of America, “Preserving Abundance, Other Drivers for Design.” Accessed January 29, 2016 10:10am. <http://www.stateofthebirds.org/abundance/anthropogenic>

SPOTLIGHT ON BUILDING HEIGHT AND MIGRATION

UPPER LEVELS: NOCTURNAL MIGRANTS AND FLEDGLING RAPTORS

While bird's migratory paths vary and with some birds traveling more than 10,000' high, radar tracking has determined that approximately 98% of flyter vertebrates (birds and bats) migrate at heights below 1,640 feet during the spring, with 75% flying below that level in the fall. Today, many of the tallest buildings in the world reach or come close to the upper limits of bird migration. Storms or fog, which cause migrants to fly lower, can cause disorientation, putting countless birds at risk during a single evening.

MID LEVELS: PRIMARY MIGRATION ZONE FOR SMALL BIRDS

This is the primary migration height for small birds. Migrating birds descend from migration heights in the early morning to rest and forage for food in the tree canopies and on the ground. Migrants also frequently fly short distance at lower elevations in the early morning to correct the path of their migration.

INCREASED COLLISIONS FOR LOCAL
BIRDS AND MIGRANTS SEARCHING FOR
FOOD AND SHELTER

LOWEST LEVEL - BIRD BUILDING COLLISION ZONE:

The most hazardous areas of all buildings, especially during the day regardless of overall height, are the ground and bottom levels. Here, birds are most likely to fly into glazed facades that reflect surrounding vegetation, sky, and other attractive features.

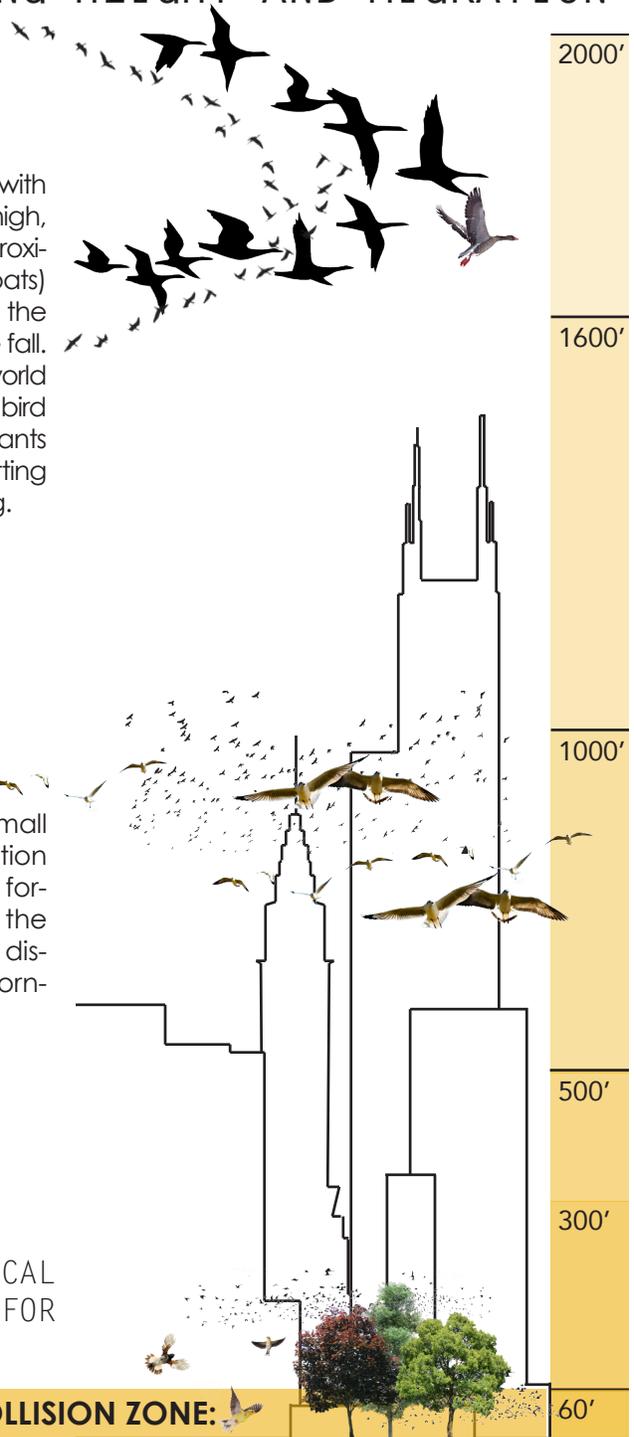


Figure 17: Spotlight on Building Height and Migration

(Source: Standards for Bird Safe Buildings- San Francisco Planning Department v.6.16.2001 www.sf-planning.org (accessed January 26, 2016). * modified by author)

the glass. Screens, fritting, tape, and netting can be added to the glass, alerting birds of its presence. Other methods require integration of design and material selections such as UV glass that reflects ultraviolet light—since birds can see four spectrums of colors, Red, Green, Blue (RGB), and UV. It is their fourth type of cone that allows them to detect ultraviolet, which humans cannot see—glass angled between twenty to forty degrees is somehow detectable by birds. In addition to building collisions, birds are also affected by city lights, especially above four hundred feet where migration starts to happen for small bird species and upwards to ten thousand feet for large bird species. Large lights captivate migrating birds distracting them from their normal visual cues, the stars and moon, causing them to become disoriented, flying in circles for hours until exhaustion. Despite the deadly encounters with the built environment, there are other ways human culture can influence bird behavior.

In fact, the human attitude towards avian creatures influences bird behavior. An encouraging attitude includes providing bird feeders, baths, nesting materials, or habitat, while a discouraging attitude includes actively repelling birds (e.g. chasing, shooting, and predator decoy), creating physical barriers (nets over ponds or spikes on building), and using scare tactics such as setting off bottle rockets. Studies have shown that human attitudes vary geographically and may be linked to cultural attitudes. After examining two cities, Seattle, Washington and Berlin, Germany, the results of a 2011 study were still representative of a 1993 study asserting that behaviors towards birds and wildlife in the United States had higher “negativistic” views (indifference, dislike, or fear of animals) and “utilitarian” views (interest in the practical value of animals) than Germans who had higher “moralistic” and “naturalistic” attitudes (concern for the mistreatment of animals and affection for wildlife or nature, respectively). It was also recorded that German’s “expressed an unusual willingness to sacrifice practical human benefits for the sake of nature and animals.”⁶⁴ Specifically, Berliners were less likely to discourage birds and more likely to feed them than Seattleites. The differences between Berlin and Seattle in humans’ discouraging behavior towards birds were reflected in how wary certain species were of humans.

64 Clucas, Barbara, John M. Marzluff “Attitudes and Actions Toward Birds in Urban Areas: Human Cultural Differences Influence Bird Behavior.” *The Auk* 129, no. 1 (January 1, 2012), 15.

As humans are still learning to share our cities and conducting future behavior in a mutualistic way, it is important to understand the mechanisms through which humans affect wildlife populations, communities, and ecosystems. The song of the urban songbird is foretelling. It is known that urban city life is causing them to adjust their song, singing at a higher sound frequency so as not be masked by low-frequency anthropogenic noise.⁶⁵ Similar to the urban songbird, whose song is merely a measuring device of response to the urban condition, tall building renovations should be a testament to become better earthly inhabitants responding to ecological conditions of the twenty-first century.

65 Cardoso, Gonçalo C., Jonathan W. Atwell, "On the Relation between Loudness and the Increased Song Frequency of Urban Birds." *Animal Behaviour* 82, no. 4 (October 2011), 835.

PART TWO:

SECOND CENTURY TALL ORDERS

2.1 Serving Up Tall, Super-Tall, and Mega-Tall

Not surprisingly the global chase towards height lives well into the second century of tall buildings. The resurgence of vertical scale is like fast food for our cities, feeding our cities an abundance of mass without a great deal of substance. 2014 was our tallest year on record with a total of ninety-seven buildings completed over two hundred meters. The new 2014 record beat the previous record from 2011 with eighty-one buildings. In fact, 2014 was the “tallest year ever” as the sum of all two hundred meter plus buildings across the globe totaled 23,333 meters smashing the 2011 record of 19,852 meters. The progress of tall buildings has increased three hundred and fifty-two percent since the beginning of 2000, increasing the number of existing tall buildings (200 meters plus) from two hundred and sixty-six to a staggering nine hundred and thirty-five, confirming unprecedented growth for the second century.⁶⁶

It could be said the term “tall” has been outgrown. Tall is now tiered into “supertall” and “megatall,” defined as three hundred meters plus and six hundred meters plus respectively. Even “tall” has changed over the years, now characterized and recorded by the industry height evaluators as two hundred meters plus. It is important to note that the original definition of a “tall” building as being twelve stories and beyond is still the basis for analysis unless noted differently. Since 2010 forty-six supertalls have been completed, eleven of them were built in 2014:

66 Safarik, Daniel et. al, “A Year in Review: Tall Trends of 2014, and Forecasts for 2015.” CTBUH Journal I (2015), 40.

1. One World Trade Center, New York City, USA, 541 meters / 1,776 feet
2. World Trade Center Abu Dhabi-The Residences, Abu Dhabi, UAE, 381 meters/1,251 feet
3. The Wharf Times Square 1, Wuxi, China, 339 meters / 1,112 feet
4. Wuxi Suning Plaza 1, Wuxi, China, 328 meters / 1,076 feet
5. Moi Center Tower A, Shenyang, China, 311 meters / 1,020 feet
6. Burj Rafal, Riyadh, Saudi Arabia, 308 meters / 1,010 feet
7. One57, New York City, USA, 306 meters / 1,005 feet
8. Wuxi Maoye City - Marriott Hotel, 304 meters / 997 feet
9. Heung Kong Tower, Shenzhen, China, 303 meters / 994 feet
10. Torre Costanera, Santiago, Chile, 300 meters / 984 feet
11. Abeno Harukas, Osaka, Japan, 300 meters / 984 feet ⁶⁷

The world got its first “megatall” in 2010, with another completed in 2012.

1. Burj Khalifa, Dubai, UAE, 828 meters / 2,717 feet (2010)
2. Makkah Royal Clock Tower Hotel, Mecca, Saudi Arabia, 601 meters / 1,972 feet (2012)

In 2015 there are five megatalls under construction with Shanghai Tower already topped out and another four more proposed (not mentioned):

1. Kingdom Tower, Jeddah, Saudi Arabia, 1,000 meters / 3,281 feet / 2018
2. Suzhou Zhongnan Center, Suzhou, China, 729 meters / 2,392 feet / 2021
3. Ping An Finance Center, Shenzhen, China, 660 meters / 2,165 feet / 2016
4. Shanghai Tower, Shanghai, China, 632 meters / 2,073 feet / 2015
5. KL118 Tower, Kuala Lumpur, Malaysia, 610 meters / 2,001 feet / 2019⁶⁸

Structural material choices are evolving. Composite structural construction grew to fifty-four percent in 2014 compared to the previous year at thirty-four percent (200 meters plus). Concrete as a predominant structural material fell to thirty-eight percent in 2014 from sixty-one percent in 2013 (200 meters plus). All-steel construction comprised only five percent of all 2014 completed tall buildings

67 Safarik, Daniel et. al, “A Year in Review: Tall Trends of 2014, and Forecasts for 2015.” CTBUH Journal I (2015), 47.

68 Skyscraper Center. “The Global Tall Building Database for CTBUH.” <http://skyscrapercenter.com/interactive-data/> (accessed April 24, 2015).

(200 meters plus), however, it is a small increase from three percent in 2013.⁶⁹

Shifts are seen in building function as well. All-office tall buildings (200 meters plus) have been in decline since 1970, from 1970 – 2014. Forty-seven newly completed all-office buildings were reported, forty-eight percent of the total. Compared to 2013, all-office tall buildings only made up thirty-four percent of the total with twenty-five new towers. On the contrary, mixed-use buildings increased to twenty-six up from twenty-two in the previous year. Residential fell from thirty percent to twenty percent in 2013, while hotel building function remained the same at five percent. Overall, throughout tall building evolution, all-office building function has seen the most dramatic decrease. This is a stark contrast, because prior to the second century, the tallest one hundred buildings in the world of an all-office building function never fell below eighty-six percent.⁷⁰

The second century of tall buildings is still in its early years and despite the craze for height, there are many more transcending achievements. New urban typologies such as the ultra skinny and urban-regeneration blocks are not only developing, but also doing so simultaneously. Technical innovations such as outrigger trusses, the increasing importance of resilient infrastructure combined with matters of carbon neutrality, as well as the quality of public space, are all evidence that tall buildings are in resurgence. Never before has the profundity of tall buildings exhibited its interconnectedness in our cities. These emerging indicators prove that at the present time of this massive industry, tall buildings still hold a viable future.

2.2 Making it Work: Developers Point of View

One thing remains regardless of time; considerable sums of money are involved. Tall building designers, developers, and investors are faced with making long-term decisions with constantly changing fiscal policy, changing on average every two years. Extreme changes range from generous tax incentives to tight tax-

69 Safarik, Daniel et. al, "A Year in Review: Tall Trends of 2014, and Forecasts for 2015." CTBUH Journal I (2015), 41.

70 Safarik, Daniel et. al, "A Year in Review: Tall Trends of 2014, and Forecasts for 2015." CTBUH Journal I (2015), 41.

tion of the business.⁷¹

“Developers are often willing to take risks on what rents are going to be; they are much less often willing to risk the amount of space they put on the market in a single location. We all know the adage about putting our eggs in a single basket. This wisdom is not lost on entrepreneurial developers, let alone conservative fourteen-member corporation boards, which would on the whole prefer egg substitutes, because of the breakage factor.”⁷²

“Most importantly, they must address the needs of our largest users-companies that alone are able to occupy more than fifty percent of a proposed tall building. To succeed, tomorrow’s skyscraper must represent unique-almost irresistible-opportunities for these large companies...a period of skyscraper construction that is more market sensitive, more major-occupant driven, than ever before...several development considerations will be key to achieving success: customized provisions for these major occupants’ privacy (security), quality of life offerings, access and parking, and flexibility. Fine architecture will be increasingly demanded. A crucial component in the formula will be public participation...”⁷³

To meet future needs tall buildings will be profoundly occupant driven, as in the case of Transco Tower in Houston, Texas, “a once “invisible” company has become most visible in Houston, day and night. The possible objections to the creation of a skyscraper, miles away from downtown never seriously surfaced. Instead the public has been invited by everyone involved in this Tower to participate in the romance of it. Abe Lincoln once said that “With public sentiment, nothing can fail; without it, nothing can succeed.” This building is an excellent example.⁷⁴ Published in 1988 to pay regard to the sociopolitical influences generated by tall building development, Leonard I. Ruchelman declared, “Such grandiose forms of development must be sensitive to pertinent ecological fac-

71 Wenzelberger, John P. and Henry Malcolm Steiner, “A Preliminary Model for the Economic Analysis of Tall Buildings” In *Second Century of the Skyscraper*, ed. Lynn S. Beedle (Springer US, 1988), 87.

72 Hines, Gerald D. “Developing Tall Buildings to Meet Future Needs: Transco Tower Case History.” In *Second Century of the Skyscraper*, ed. Lynn S. Beedle (Springer US, 1988), 328-9.

73 Hines, Gerald D. “Developing Tall Buildings to Meet Future Needs: Transco Tower Case History.” In *Second Century of the Skyscraper*, ed. Lynn S. Beedle (Springer US, 1988), 328-9.

74 Hines, Gerald D. “Developing Tall Buildings to Meet Future Needs: Transco Tower Case History.” In *Second Century of the Skyscraper*, ed. Lynn S. Beedle (Springer US, 1988), 335..

tors if they are to promote the health and vitality of community and neighborhood life. The following considerations are offered as guidelines for the development team:"

- Provide for the public as well as the private needs of the population's groups being served by large-scale projects. These needs should be identified as part of the overall planning process.
- Acknowledge the symbolic attachments of residents in determining spatial distributions and land use, including such ecological factors as open space, views, skyline effects, and historical and cultural landmarks.
- Preserve old buildings whenever possible and integrate them with the new buildings. Old buildings not only provide space for new low-cost enterprises, but they also break the visual monotony and perpetuate the historical and architectural character of the community.
- Provide for a mixture of neighborhood functions - residence, work, shopping, entertainment, leisure - to the extent that it ensures the presence of people and activity in public and private places during different times of the day and night.
- Account for street effects in the design plan of any large building, including consideration of shadows, wind currents, congestions, and availability of amenities likely to appeal to the pedestrian. Streets should be maintained as lively and interesting places.
- Preserve and possibly improve the range and variety of institutional facilities available to neighborhood residents including schools, hospitals, day-care centers, transportation, and recreation centers."⁷⁵

2.3 Absorbing Tall Cities: Application of Analysis

Cities require cohesion and a sense of identity. It is a fundamental part of success. That is why there cannot be a prescriptive blueprint for certain tall building type renovations. However, understanding the inner workings of a city creates cohesion, and that is interchangeable. In fact, most cities follow precedent, implementing systems that were successful in other cities. New York City is the most populous and urban of America's cities. For that reason, it is the focal point

75 Ruchelman, Leonard I. "The Urban Ecology of Tall Buildings." In *Second Century of the Skyscraper*, edited by Lynn S. Beedle, 79-85. Springer US, 1988.

of application for a research framework using generalizability.

2.3.1 People, Place, and Potency: New York City

New York City is a unique place with very particular properties. It is considered to be “succeeding as a city.”⁷⁶ New York frequently attracts new people and creates new jobs for them. It is an urban powerhouse, with an “impressive capacity to turn poor migrants into citizens with at least a foothold on the ladder to prosperity.” New York has made itself successful, especially when comparing the city to that of Los Angeles and Houston, and it has done so with relative restraint as far as the use of land and natural resources. Fifty-four percent commute to work in less than thirty minutes and many people still walk to work. Since 1982 the city has spent sixty-eight billion dollars on upgrading public transport. The city is of course not without issues. New York is bracing itself for growth and looking to address underinvestment, such as affordable housing and a stressed middle class. Part of what makes New York so unique is the city’s understanding of public realm. It is an essential ingredient needed to make a modern city living a contemporary lifestyle. The public realm allows strangers to come together to share the experience of city life.⁷⁷

People

People make the city. Twenty-one million residents live in the Metropolitan New York with eight million in New York City. Of that, 3.2 million are immigrant and sixty-five percent belong to an ethnic minority, making New York City a majority-minority city. In 1964 twenty-nine percent of the population were employed in manufacturing. By 1980 that number reduced to twenty percent and by 2005 only four percent of the population were employed in manufacturing. Currently, 2005 results show ninety-three percent of the jobs are in the service sector. Other 2005 results show that Manhattanites pay \$1.3 million for an apartment and \$225,000 for a parking space. Thirty-three percent of homes are owner oc-

76 Burdett, Richard and Deyan Sudjic, *The Endless City: The Urban Age Project by the London School of Economics and Deutsche Bank’s Alfred Herrhausen Society* (London: Phaidon, 2007), 78.

77 Burdett, Richard and Deyan Sudjic, *The Endless City: The Urban Age Project by the London School of Economics and Deutsche Bank’s Alfred Herrhausen Society* (London: Phaidon, 2007), 76.



Figure 18 : Building on Street Culture at Vanderbilt and MetLife

“A densely networked grid of street and public transport in New York City enables a majority of the city’s residents to use public transport to commute to work. With close to forty percent of Midtown Manhattan residents in the outer boroughs, meanwhile, rely on the city ageing subway infrastructure. During the 2003 black out, millions flooded the city’s streets, relying on either walking or bus transport to get home.”

(Source: Burdett, Richard, and Deyan Sudjic. *The Endless City: The Urban Age Project* by the London School of Economics and Deutsche Bank’s Alfred Herrhausen Society. London: Phaidon, 2007 79.)

cupied. Additionally, nineteen percent live below the poverty line.⁷⁸

New York also receives a lot of visitors; in fact forty-three million came in 2005 spending \$23 billion. One attraction is the observatory of the tall building. Once New York started building into the clouds, people wanted to experience the view. Tall building observatories offer a chance for visitors and locals alike to travel to the top of their buildings. In 1930 the Bank of Manhattan had the tallest building observatory, until the Empire State Building was built in 1931. Now the tallest observatory in New York is at the One World Trade Center, "Forever." This experience used to be free, but now is an extremely profitable venture from admission fees. Ever since the Empire State Building released its financials in 2013, reporting \$92 million in annual revenue from their observatory, many developers are looking to pursue similar investments. Chicago's John Hancock Center's observatory was bringing in nearly \$10 million and 530,000 visitors per year before installing "The Tilt." The Willis Tower's observatory is estimated to bring in \$25 million with a forty percent increase in admissions since building "The Ledge."⁷⁹ The tall building observatory is not city dependent, proving to be an unforgettable and worthwhile experience for developers and visitors alike.

New Yorkers are fast moving. The city officials, the mayor, city planners, leaders of the written word, and the streets all follow suit. It is a mindset that keeps bureaucrats and critics (leaders of the written word) successfully on watch. This quick paced city has always been able to voice an opinion, especially the city officials and critics. "City officials have protested over the enormous size of some of the projects, especially those planned for mid-town Manhattan, in Times Square, and the site of the New York Coliseum. The basic issue is how to preserve the traditional character of that part of Manhattan, which serves as an entertainment center in addition to performing office and retail functions. The critics worry that the theaters and specialty shops may disappear along with the

78 Burdett, Richard and Deyan Sudjic, *The Endless City: The Urban Age Project by the London School of Economics and Deutsche Bank's Alfred Herrhausen Society* (London: Phaidon, 2007), 76.

79 CTBUH Global News, "Hancock Center Considers Tilting Glass Deck Extension." CTBUH Global News, December 9, 2013, <http://www.ctbuh.org/News/GlobalTallNews/tabid/4810/Article/1022/language/en-US/view.aspx> (accessed February 24, 2015).

bright lights and active street life that give Manhattan its special quality.”⁸⁰ The sentiment is from 1988, however, it is a concern that remains relevant today. New York cultivates high-rise development is an economic engine for the city so the attitudes and perspectives’ of its leaders are of global sentiment.

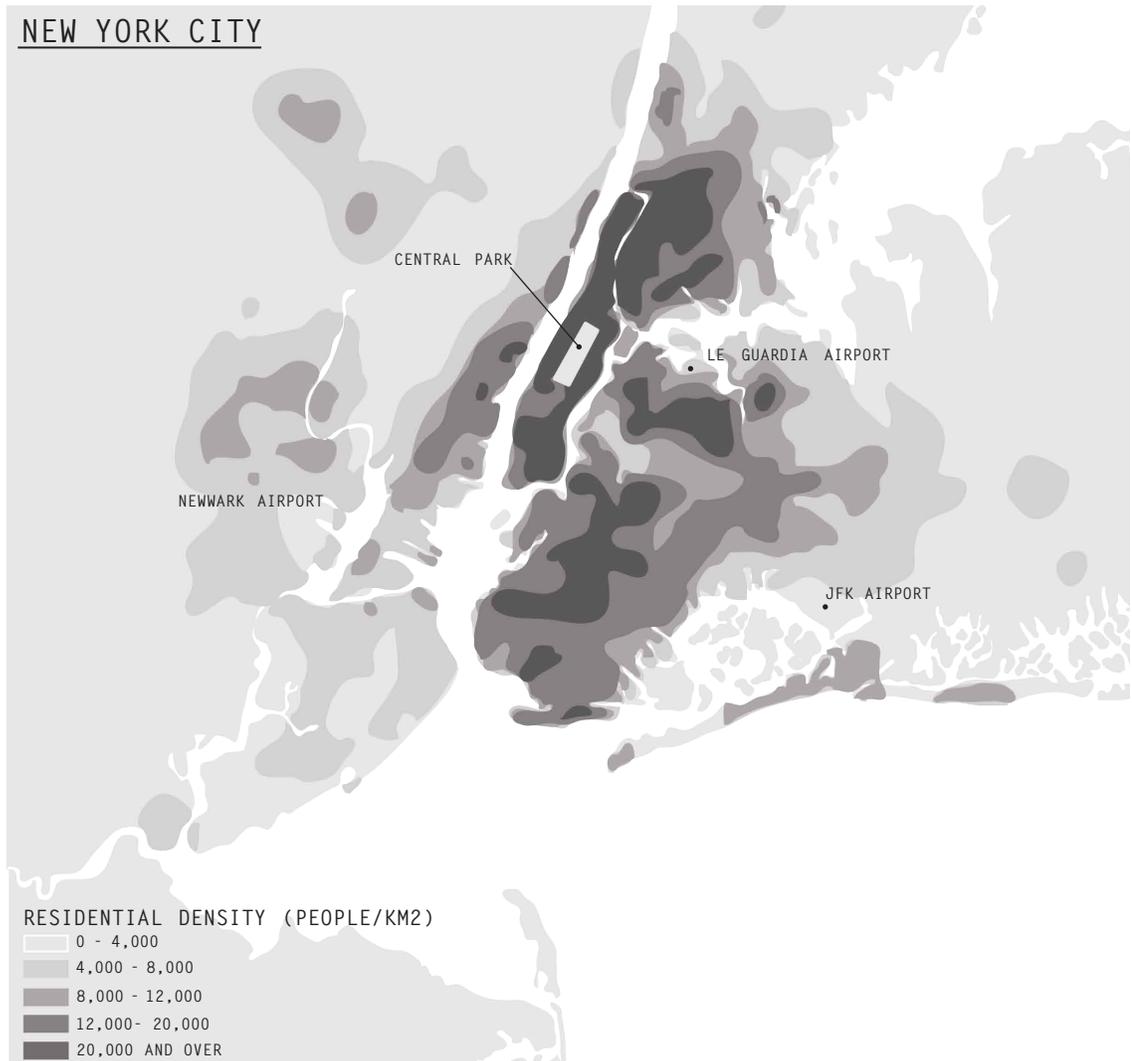


Figure 19: New York City Residential Density
(Source: Burdett, Richard, and Deyan Sudjic. *The Endless City: The Urban Age Project* by the London School of Economics and Deutsche Bank’s Alfred Herrhausen Society. London: Phaidon, 2007, 77.) * modified by author.

80 Ruchelman, Leonard I. “The Urban Ecology of Tall Buildings.” In *Second Century of the Skyscraper*, ed. Lynn S. Beedle (Springer US, 1988), 85.

Place

The density of Manhattan is twenty-four thousand people per square kilometer. The size of the city is 830 square kilometers with the surrounding Metropolitan area reaching 27,070 square kilometers. Fourteen percent of the city is open green space. Central Park is a 1.3 square miles “back yard” to Manhattan, also known as “the lungs of the city” boasting a 6.1-mile perimeter.

One constant thing about New York is change. On October 8, 2012, New York Mayor Michael Bloomberg asked for “sweeping changes in zoning for the historic 70 - block neighborhood around Grand Central Station,” in Mid-town Manhattan. Mid-town has four hundred buildings in the area, of which three hundred are more than fifty years old. This would allow for new towers to climb heights of sixty plus stories.⁸¹

Close to two-thirds of residents in New York’s five boroughs are part of an ethnic minority. The social cohesion among this vibrant mix of nationalities, religions, and ethnicities is fostered by two major factors: the protection each group enjoys in areas they inhabit, and the tradition of tolerance and acceptance that embrace the city’s diversity.⁸²

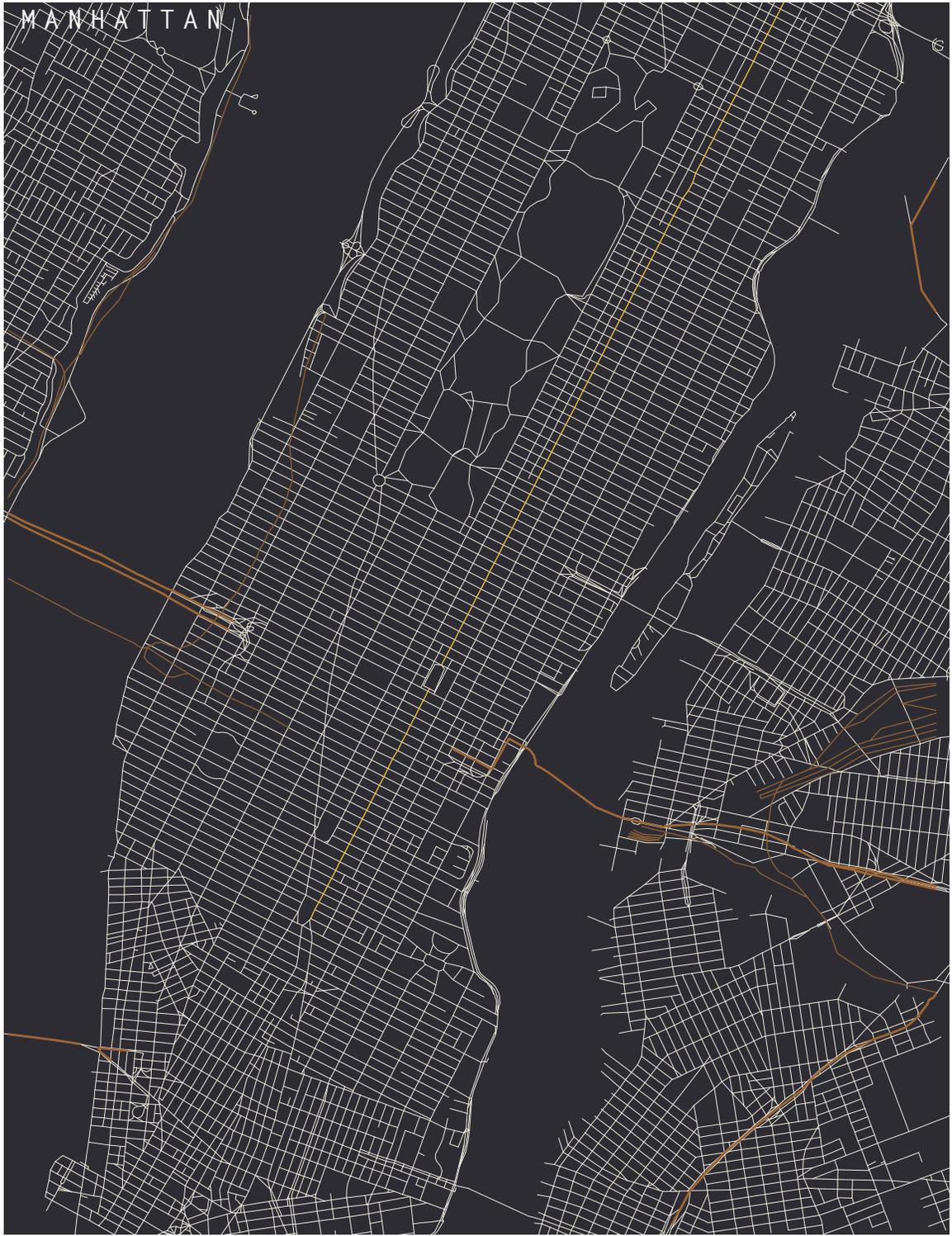
Potency

New York’s powerful prowess for tall had long been desired by others across the globe, but in 2008 CTBUH quantified it, “In 1930, 99% of the tallest one hundred were located in North America with 51% in New York City alone. By 2010 that will have decreased to only 22% and 5% respectively.”⁸³ New York City’s potency on the world is so vast; the effect is seen through reproductions, in diluted and exact replicas of its towers and its infamous Manhattan. For instance, Beijing wanted New York success so desperately, they copied Wall Street with an odd exactness. Then there is Frankfurt with its “Mainhattan.” “Despite its sta-

81 CTBUH Global News, “Bloomberg Calls for New Height Limits in New York City.” CTBUH Global News, October 8, 2012, <http://www.ctbuh.org/News/GlobalTallNews/tabid/4810/Article/1165/language/en-US/view.aspx> (accessed March 18, 2015).

82 Burdett, Richard and Deyan Sudjic, *The Endless City: The Urban Age Project by the London School of Economics and Deutsche Bank’s Alfred Herrhausen Society* (London: Phaidon, 2007), 86.

83 CTBUH. “The Tallest Buildings in the World: Past, Present & Future.” CTBUH Journal, “Tall Buildings in Numbers,” no. II (2008), 41.



— PARK AVENUE — HIGHWAYS — RAIL LINES — STREETS
Figure 20: The Manhattan Grid

tus and great importance to its metropolitan image, the skyline in Frankfurt has always carried some negative connotation, although its mocking moniker Manhattan gradually became widely accepted and turned into an asset for urban branding and tourism."⁸⁴ Manhattan has the power to affect global mindset. Regardless of other cities' desire to recreate or simulate Manhattan and its tall buildings, its rich history and public interest make it uniquely its own.

Manhattan's city is laid out in a uniform grid with streets running west to east and avenues running north to south.

The streets of New York are written and described as such, but in fact the "north" is actually nineteen to twenty degrees from north. The twenty degrees of separation represents many facets of the city's history, its people, and the history between Park Avenue and the MetLife Building.

Park Avenue's namesake came from its literal translation, a delightful park

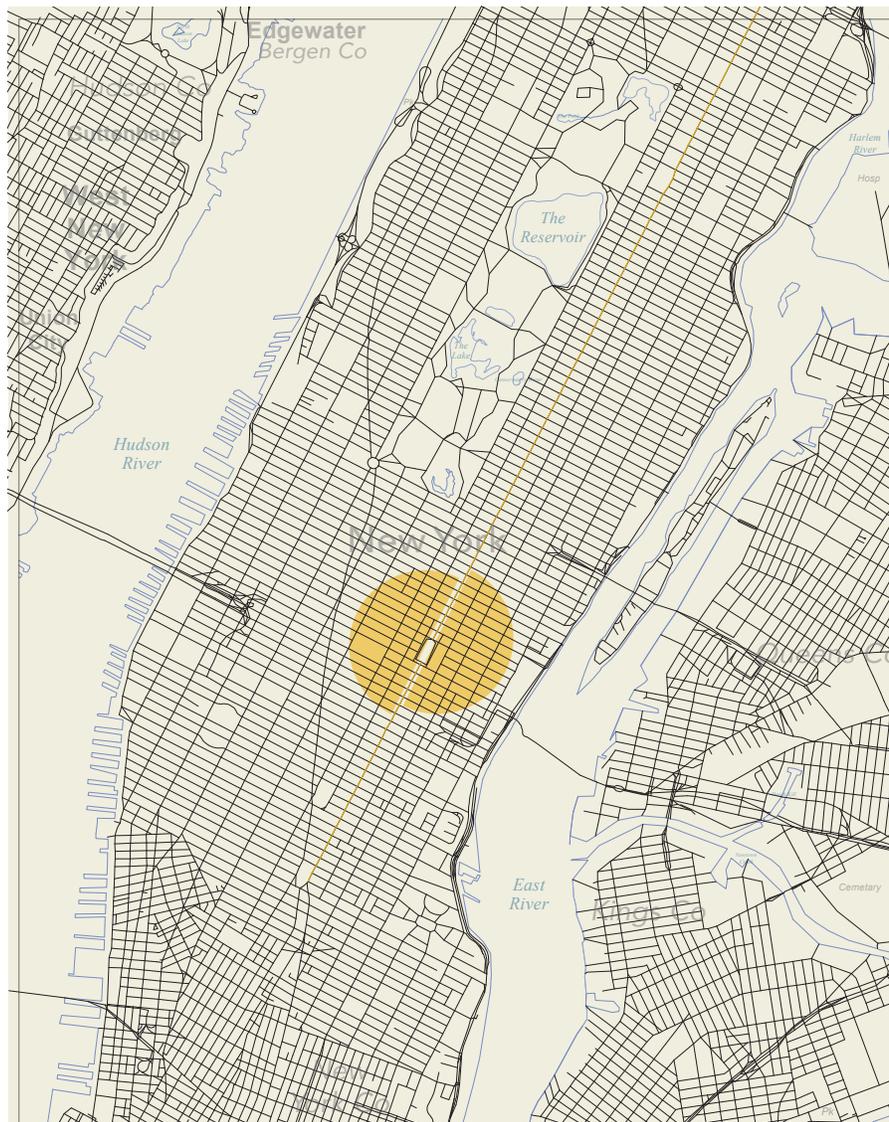


Figure 21: Twenty Degrees of Separation: Park Avenue and the Manhattan Grid

84 Čamprag, Nebojša. "Frankfurt and Rotterdam: Skylines as Embodiment of a Global city." CTBUH Journal, History, Theory & Criticism, no. 1 (2015), 26.



Figure 21: Park Avenue Looking North- 1922
(Source: Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. Cambridge, MA: MIT Press, 2005, 11.)

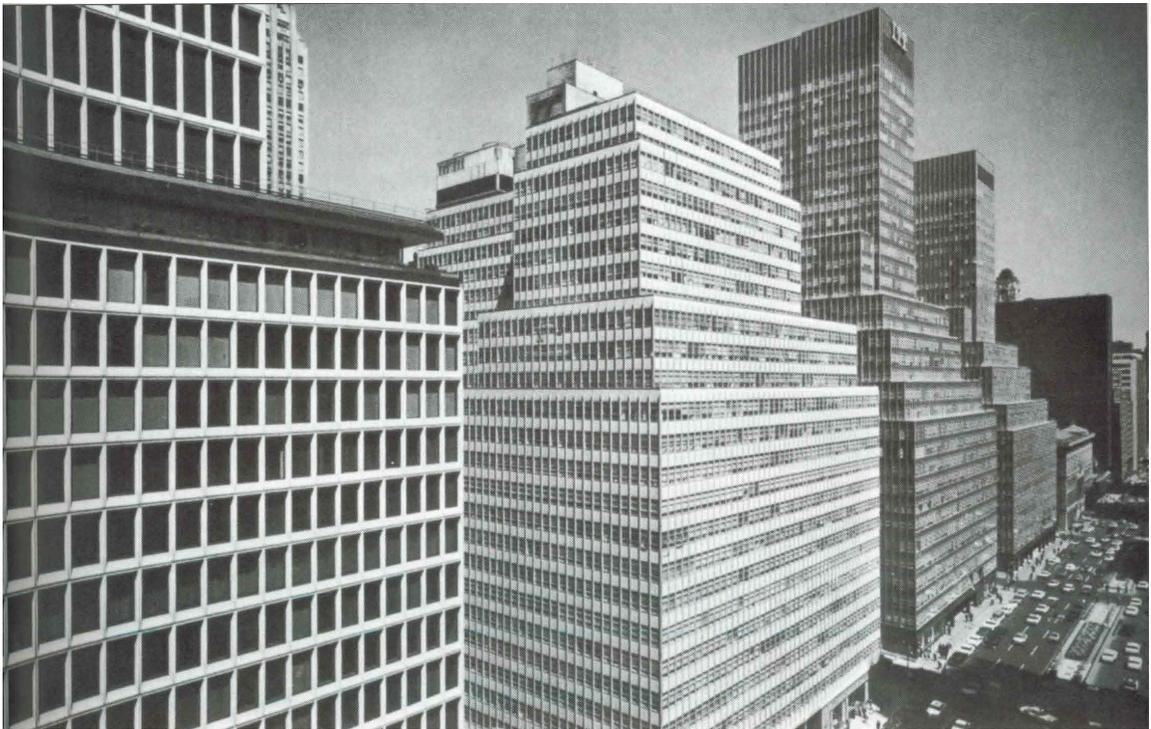


Figure 22: Park Avenue Looking North- 1955
(Source: Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. Cambridge, MA: MIT Press, 2005, 37.)



Figure 23: Park Avenue Looking South Before and After MetLife Building

(Source: Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. Cambridge, MA: MIT Press, 2005, 37. "Park Avenue pre-post Pan Am, from Vincent Scully, *American Architecture and Urbanism*, 1969.)

that ran in between residences. It started as a long park, serving as a pedestrian route for residents to circulate throughout the city, although after the war, it became a commercial hub, rapidly changing. Park Avenue led directly to Grand Central Terminal. Grand Central Terminal was the exception to the buildings on Park Avenue, as it faced north and south while other buildings faced inwards. Grand Central Terminal was deemed the gateway to the city's massive transportation hub. When the MetLife Building was built behind Grand Central Terminal in the same orientation, it greatly blocked views of Park Avenue. The arrival of MetLife Building secured the end of the old-world grandeur for Park Avenue.

New Yorkers detested it for many years to follow.

2.3.2 MetLife Building: Renovations for the City

MetLife Building
(formerly Pan Am):
200 Park Avenue,
New York City, NY
Architect: Emery Roth &
Sons, Pietro Belluschi,
(Walter Gropius)
Constructed: 1960-1963
Use: Office
Architectural Height: 808 ft.
/246.3 m
Floors Above Ground: 59
Tower GFA: 2,841,511 ft² /
263,985 m²
Elevators: 85 Top Elevator
Speed: 7.1 m/s

The Pan Am building (now MetLife Building) was conceived in 1958, but its deeply found origins started long before. The site of the Pan Am Building was owned by New York State Realty and Terminal Company, a subsidiary of the New York Central Railroad. Known as Grand Central, it was comprised of two layers of subterranean tracks (five platforms) at an intersection of two railroads and three subways lines servicing five hundred trains daily. It was, and still is a major transportation hub for the city. The underground business at the time was privately owned and it was extremely difficult to turn a profit. In 1955 records indicate the railroads annual operating costs were \$24 million and paying \$1.3 million per year in taxes. The money-losing business of rail was being taxed,



Figure 24: Pan Am Building at Opening
(Source: Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. Cambridge, MA: MIT Press, 2005, 212)



Figure 26: Roth Proposal

(Source: Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. Cambridge, MA: MIT Press, 2005, 31).

deemed by some as “one of America’s architectural masterpieces and one of the few whose appeal was universal,” and “belongs in fact to the nation,” was facing demolition. The classical Beaux-Arts terminal featured extravagant carvings, overhead celestial-story telling stonework, and large clerestory windows that bathed the station with sunlight. Below ground was evenly impressive, carefully planned levels intertwining pedestrian corridors with subway, train, and bus lines, all running together symbolizing “City Beautiful Movement” civic ideals. The brilliant engineering didn’t stop with circulation. Park Avenue was created as essentially a lid, covering three miles of below-grade railways with an overhead bridge. The visionary engineering of New York Central Railroad’s chief engineer, William J. Wilgus and his associates also developed the sturdy steel bridgework with foundation footings sunk below the tracks to support future development. Despite the talents and wisdom the building concealed and represented, it was used heavily in World War II, transporting two hundred and forty thousand passengers on six hundred trains daily and by the 1950’s was dilapidated. However its condition, its rich history fueled efforts to save it. The opposition “raised the question whether one should destroy a monument in the name of practicality, even if the owner’s tax and revenue problems and public convenience argue in favor of it.” Demolition talks were put on hold for many reasons largely due to a public campaign to stop redevelopment, but also largely due to the weakening economy and struggles of financing. Tragically, Robert Young, chairman of New York Central

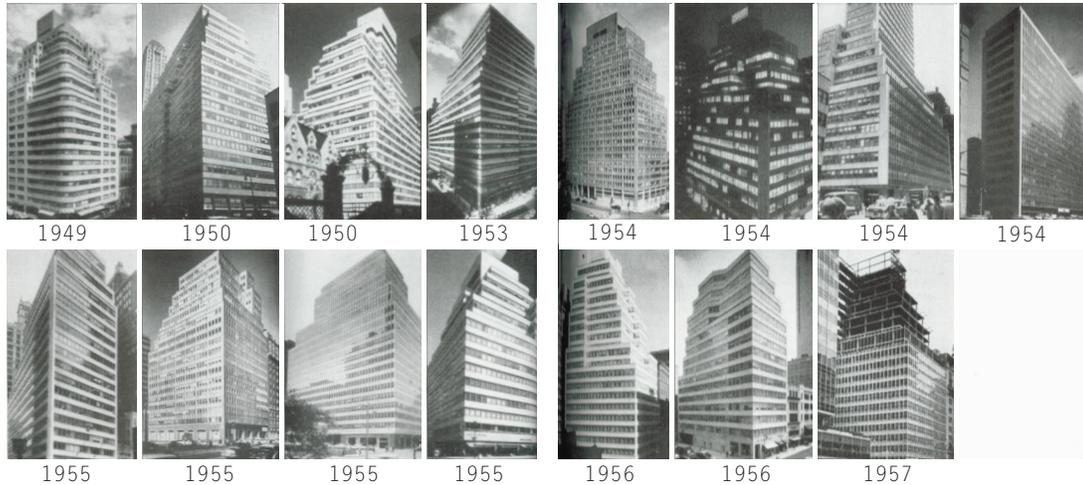


Figure 27: Roth Buildings, New York City

(Source: Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. Cambridge, MA: MIT Press, 2005, 39) *modified by author.

Railroad, who spearheaded the redevelopment, promising shareholders profits after gaining his position in June of 1954, shot himself in January 1958. His reasons were clouded, but the earnings of the railroad had been running in the red and suffering from major financial deficits. Upon his death, previous plans for the site were “revived in short order,” from no other than the well-known local architecture firm Emery Roth and Sons.⁸⁶

Putting the Team Together

Emery Roth and Sons had no plans to demolish Grand Central Terminal and promised to make the new office tower distinctly different. The speculative office building was estimated to cost over one million dollars, featuring a second story main lobby accessed by escalators, while the first floor connected commuters directly to Grand Central Terminal or to New York Central headquarters (now Helmsley Building) creating a thoroughfare right through the building.

The Roth firm was “armed with specifications; plot size, the building purpose, potential tenants, zoning requirements.”⁸⁷ It was a business based on speed, not by a distinctive look or unique design. Roth’s departure from conventional

⁸⁶ Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. (Cambridge, MA: MIT Press, 2005), 49.

⁸⁷ Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. (Cambridge, MA: MIT Press, 2005), 40.

design was 'inspired by...pure economics.' They arrived at what they considered an optimum module size and other dimensions for column spacing, floor-to-ceiling heights, and so on by the same reasoning... and once determined those dimensions

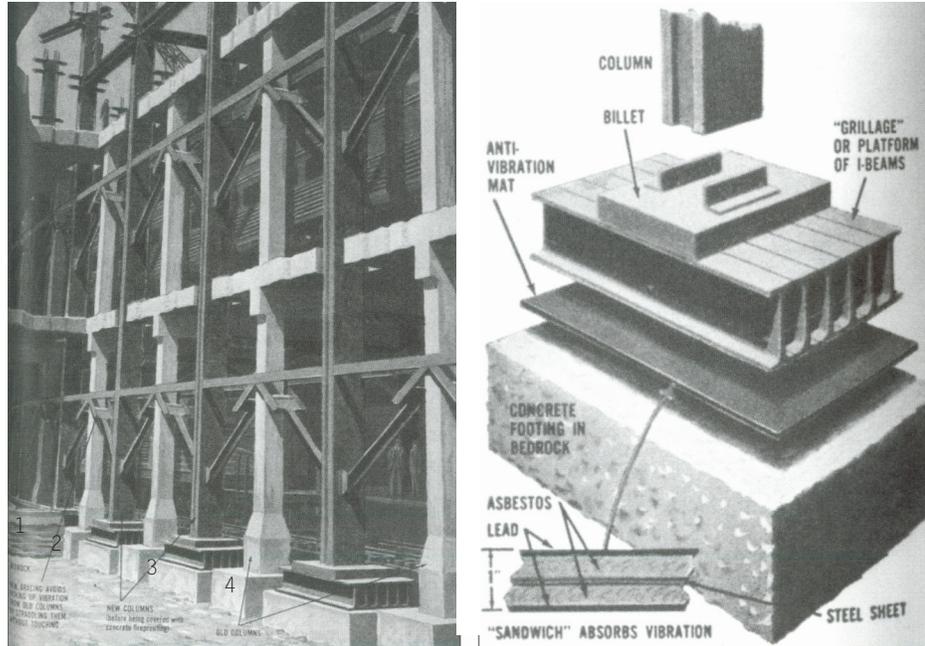


Figure 27: Structural Detail of Pan Am, Old and New Columns 1-Bedrock, 2- New bracing avoids picking up vibrations from old columns by straddling them without touching, 3- New columns (before being covered with concrete fireproofing, 4- Old columns (Source: Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. Cambridge, MA: MIT Press, 2005, 211) *modified by author.

became standard.”⁸⁸ Their methods made them highly successful at landing jobs with large-scale Manhattan developers rising to become “one of the most prolific postwar architectural firms specializing in high-rise office buildings.” Richard Roth candidly explained their goals were “not to create masterpieces,” but sought for efficient and economic buildings for their clients that could achieve profits through programmatic requirements.⁸⁹

It didn't take long for New York to grow tired of the Roth trademark “wedding cake style” modernized steel and glass offices, filling the site to the maximum allowed by code. Jane Jacobs, published an article in the *Architectural Forum* in

88 Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. (Cambridge, MA: MIT Press, 2005), 40.

89 Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. (Cambridge, MA: MIT Press, 2005), 40.

1957 on the current office boom, citing the number of dull new office buildings going up in Manhattan and the majority of them by the Roth firm, questioning “their uninspired, formula-tic work and its increased frequency. The firm name had become synonymous in the public eye with banal building geared solely towards profits, building second-rate Miesian derivatives.” To counteract the public thought and increasing awareness of the project due to the critical nature of the site, star architects Walter Gropius and Pietro Bellushchi, were secured as design architects for the project. Gropius and Bellushchi brought prestige that would also help to secure loans, quoted by the main builder and developer, Erwin S. Wolfson, making it “sell better to the money people,” and it in turn would attract high-end tenants.⁹⁰

The Gropius/Bellushchi/Roth project was a first for all involved. For the developer, Wolfson, it was his largest and most difficult endeavor both structurally and economically. As for Roth, it was a first for them to be merely the architect of record, surely an unwanted position. For Gropius, it was his first and probably his last chance to do a skyscraper, something he had desired since 1920 and was now at the age of seventy-five. Similarly, for Bellushchi it was the moment of a lifetime, the possibility to truly build something significant in the most prominent site in New York City, one of the most preeminent cities in the world.⁹¹ Despite the team’s divergent positions, all were modernists and generally shared a common notion that the architect could not let sentimentally stand in the way of progress.⁹²

The Design

The design team turned the broad sides of a “lozenge-shaped fifty-six story” tower to face Park Avenue (north and south), as a way to provide “forceful end views” and limit the amount of sun exposure to the west and east facades (reducing air conditioning demands). The square footage totaled 2.4 million making it the largest office building in New York, and also believed in the world. It beat out RCA and the Empire State Building making room for 25,000 workers and 2,000 cars. The size and orientation dictated by Gropius were to signify a

90 Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. (Cambridge, MA: MIT Press, 2005), 59-64.

91 Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. (Cambridge, MA: MIT Press, 2005), 78.

92 Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. (Cambridge, MA: MIT Press, 2005), 29.

new monument for New York, showing it as a dominating force of cultural and economic power. The tower rose from a low, eight-story site-filling base and was designed for the likeness of building core layout due to elevator, restroom, and stairwell efficiencies. The unusual shape juxtaposed itself to its square and rectangular neighbors and offset the massive bulk of the structure. Gropius was quoted as saying, "The inherent quality of the suggested octagonal tower will be that it creates an image subconsciously in the mind of the passer-by, totally different from the towers within the surrounding area or even with the whole of New York."⁹³

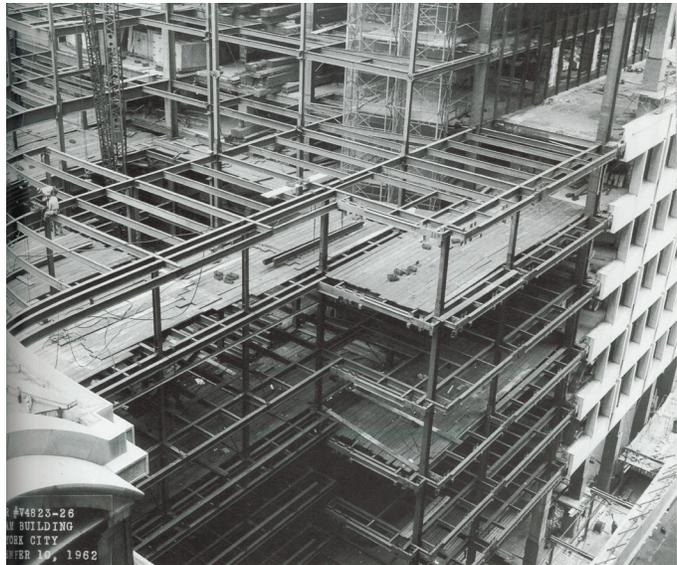


Figure 28: Steel framing with Mo-Sai Panels, September 1962.

(Source: Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. Cambridge, MA: MIT Press, 2005, 203).

The steel structural frame was believed to be the largest volume ever at 40,000 tons. Eight million dollars was dedicated to the building's elevators including six of the world fastest elevators traveling at 1,600 feet per minute, which was 200 feet per minute faster than the prior predecessor.

The façade was comprised of precast concrete panels, eggshell in color with exposed, quartz aggregate. It took a total of nine thousand precast panels to cover the building based on framing a window, in a four-foot wide by eight-foot high module. "Mo Sai" panels projected thirteen inches beyond the precast spandrel panels to impart the effect of the ribs to the façade. Each Mo-Sai panel weighed nine thousand pounds. The precast façade was described as "freshness of design and freedom of architectural expression," in terms of color, shape, and form, as well as for their economy. The granite used only at the base of the

93 Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. (Cambridge, MA: MIT Press, 2005), 78-84.

building was \$1.5 million dollars more than the entire Mo-Sai precast concrete panels, proving economical saving with the façade choice. Mechanical floors on the thirty-second and forty-fourth floors were façade free, so Gropius cleverly included extra columns to keep rhythm in the façade, placing columns sixteen feet on center instead of typical thirty-two feet.

Gropius suggested many design elements that were eliminated or not considered, including implementing two rooftop gardens along the broad sides, and planting trees alongside 45th Street between the elevated vehicular ramps. The heliport, originally designed by Roth, was dropped in 1958 but then revived again in 1960. Consequently, this necessitated retrofitting, as the design added three hundred extra tons of steel. The framework had to run from the twentieth floor up to support the twelve-inch thick concrete landing pad. All of this required modification of the roof and redesigning it for turbulent winds at the top of the building.

Construction challenges were exponential; flow of traffic could not be interrupted including all trains, pedestrians, and vehicles. The site was seriously cramped and provided a specific limited time span for construction. "Each step had to be scheduled, the schedule rigorously monitored, and all the operations flawlessly executed, as given the enormous costs involved, the ongoing railroad opera-

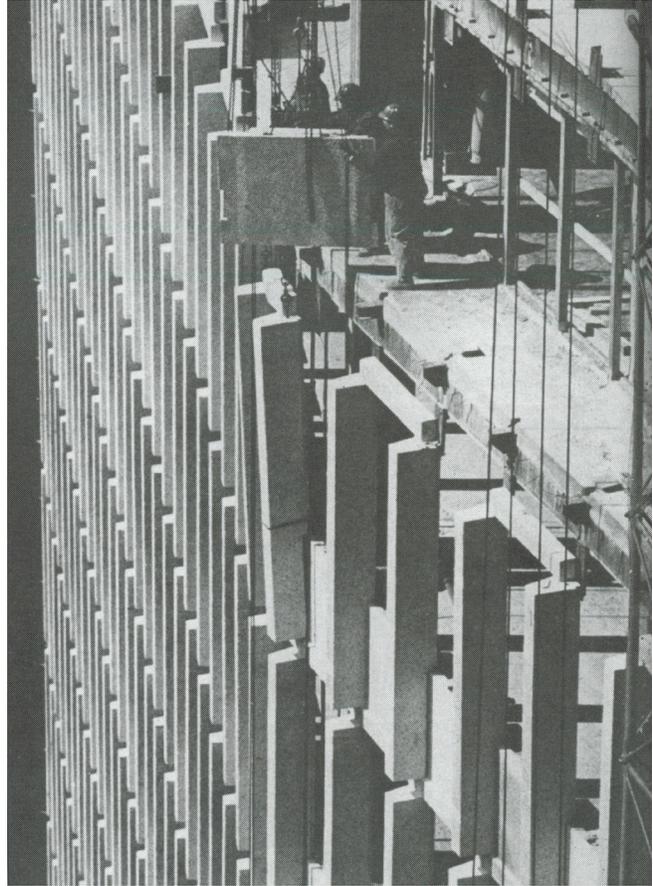


Figure 29: Mo-Sai Panels Hoisted into Place

(Source: Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. Cambridge, MA: MIT Press, 2005, 202).

tions, and the city traffic, there was little room for error.”⁹⁴ In this case the client and developer, Wolfson, the owner of the Diesel Construction Company, was also the contractor for the construction of the building, Wolfson employed his right hand man for the job, Carl A. Morse. Morse was credited for pioneering “construction management,” bringing new concepts to managing the project including working on a fixed fee, “fast track” where construction can start before the completion of architectural drawings, evolution in the role of contractor—being involved from the very beginning, knowing not only what but how it was going to be built; in other words, Morse brought logistics to the whole project.

By the summer of 1960, Wolfson had secured the largest tenant deal of the time leasing fifteen floors in the new skyscraper to Pan American, the nation’s leading airline. The negotiation included the building to be renamed, Pan Am. This deal was reflective of the times, signifying the end of rail and coming of the jet age. Solidifying the deal for Wolfson meant \$115,500,000.

Not only would the building keep the namesake of the airline, but Juan Trippe, founder, wanted thirty foot signs on all eight sides of the building. After hard bargaining with Gropius and the team, it was decided that only four, fifteen foot signs would be added. The north and south side of the building would bear the name, while the east and west side of the building would wear the Pan Am logo. “The Pan Am Building aroused such profound feelings (few buildings in recent times have generated so much hatred and been so staunchly opposed) that it served as a major catalyst in the collapse of modernism and became emblematic of modernism gone awry. It remains today a painful, persistent symbol in the eyes of many of how wrong matters in architecture and urbanism can go. Moreover, it signified a major turning point in attitudes away from modernism, with its new appreciation of the past. As such, the building marked a significant moment in the cultural life of the nation.”

94 Clausen, Meredith L., *The Pan Am Building and the Shattering of the Modernist Dream*. (Cambridge, MA: MIT Press, 2005), 114.

2.3.3 The Second Life of the MetLife: Driving Factors for Redesign



Figure 30: Second Life of the MetLife

In 2001 it was rumored that an investigation revealed age-related defects in the façade of the MetLife Building.⁹⁵ The precast façade was reaching the end of its life and with it was bringing a new opportunity. A new opportunity exists to address design issues related to site, energy use, observation deck, users, façade, and architectural legacy through renovation. The goal of using this well-known Park Avenue landmark is to demonstrate the power of renovations, and to show a sustainable way to renew the city. “The Second Life of the MetLife Building” is to bring relevance and to contribute positively to the twenty-first century.

The Site

The MetLife Building is bound by Vanderbilt Avenue to the west, East 45th Street to North, Depew Place to the east, and Grand Central Terminal to south. Park Avenue splits right in front of Grand

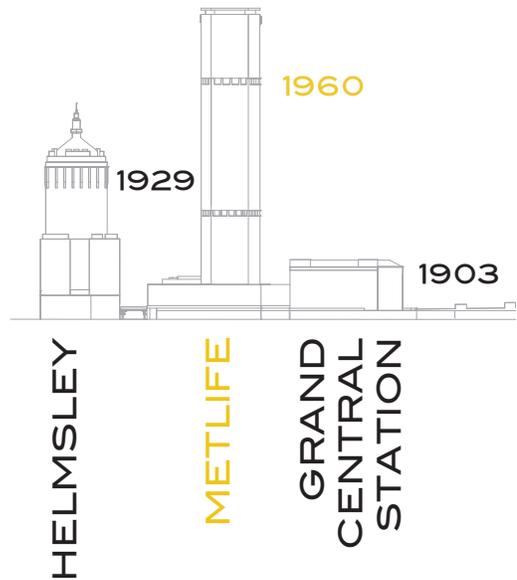


Figure 31: Historic Context

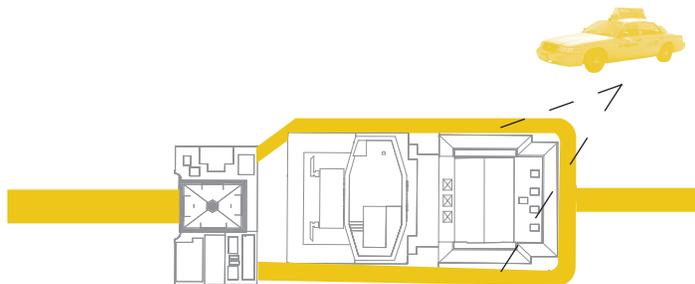


Figure 32: Plan View: Existing Park Avenue Viaduct

Central Terminal ramping up and splitting in front to the terminal, wrapping around the east and west sides of the MetLife Building and then passes through tunnels of the Helmsley Building. This section of Park Avenue is known as the Park Avenue Viaduct. The Park Avenue Viaduct is protected under landmark status, as well as Grand Central Station and the Helmsley Building. Its use is to carry cars and taxis. No pedestrian, bicycles, motorcycles, or buses allowed. Pedestrians travel along sidewalks of the aforementioned streets or through the base of the MetLife building. Each day on

⁹⁵ Design Brief. “Metals in Construction Magazine 2016 Design Challenge.” <https://metalsinconstruction.org/design-brief/> (accessed November 23, 2015).

Climate

New York is considered to be a humid continental climate (Dfb Köppen classification) meaning warm summers and cold winters. On average, the humidity is consistent, varying only by ten percent. The two driest months are April and October. On average New York receives ten days per month of precipitation. Wind primarily comes from the south with occasional wind from the north-northwest (NNW) and north-northeast (NNE). Temperatures range in winter months from the mid-twenties to low-forties. Summer months have a temperature range from

The monthly mean minimum and maximum daily temperature.

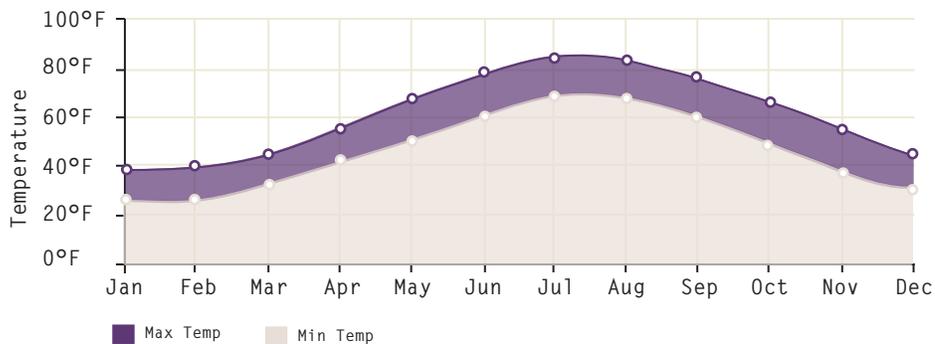


Figure 34: Average Minimum and Maximum Temperature Over the Year in New York

(Source: Copyright © 2015 www.weather-and-climate.com, accessed January 2016). *modified by author

The mean monthly precipitation, including rain, snow, hail, etc.

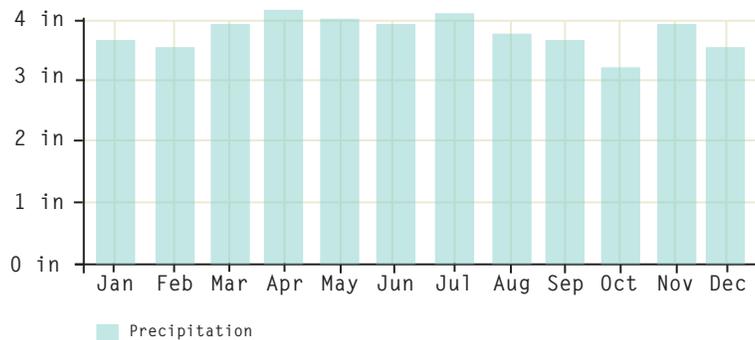


Figure 35: Average Monthly Precipitation Over the Year in New York

(Source: Copyright © 2015 www.weather-and-climate.com, accessed January 2016). *modified by author

the low-sixties to low-nineties. The average yearly temperature is fifty-five degrees Fahrenheit. New York receives on average one hundred fifty hours to three hundred hours of sunlight per month for winter and summer, respectively.

The monthly total of sunhours.

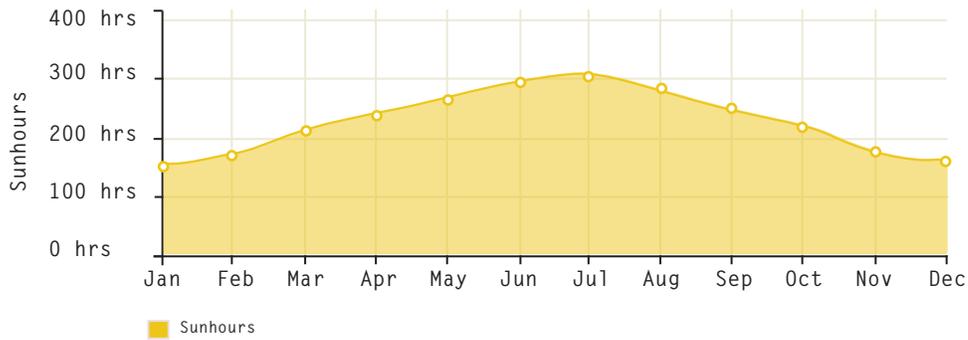


Figure 36: Average Monthly Hours of Sunshine Over the Year in New York

(Source: Copyright © 2015 www.weather-and-climate.com, accessed January 2016). *modified by author

The monthly mean wind speed in meters per second.

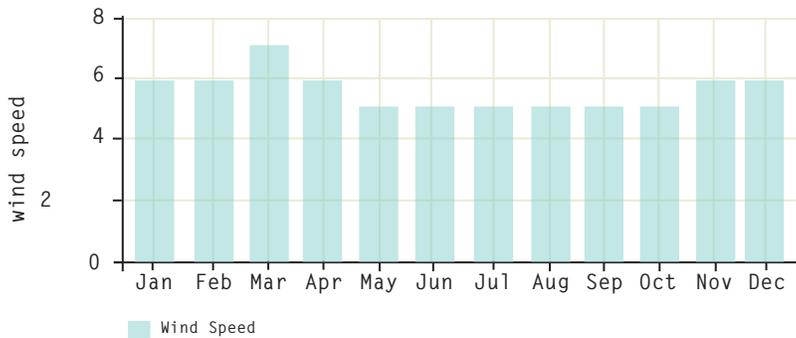
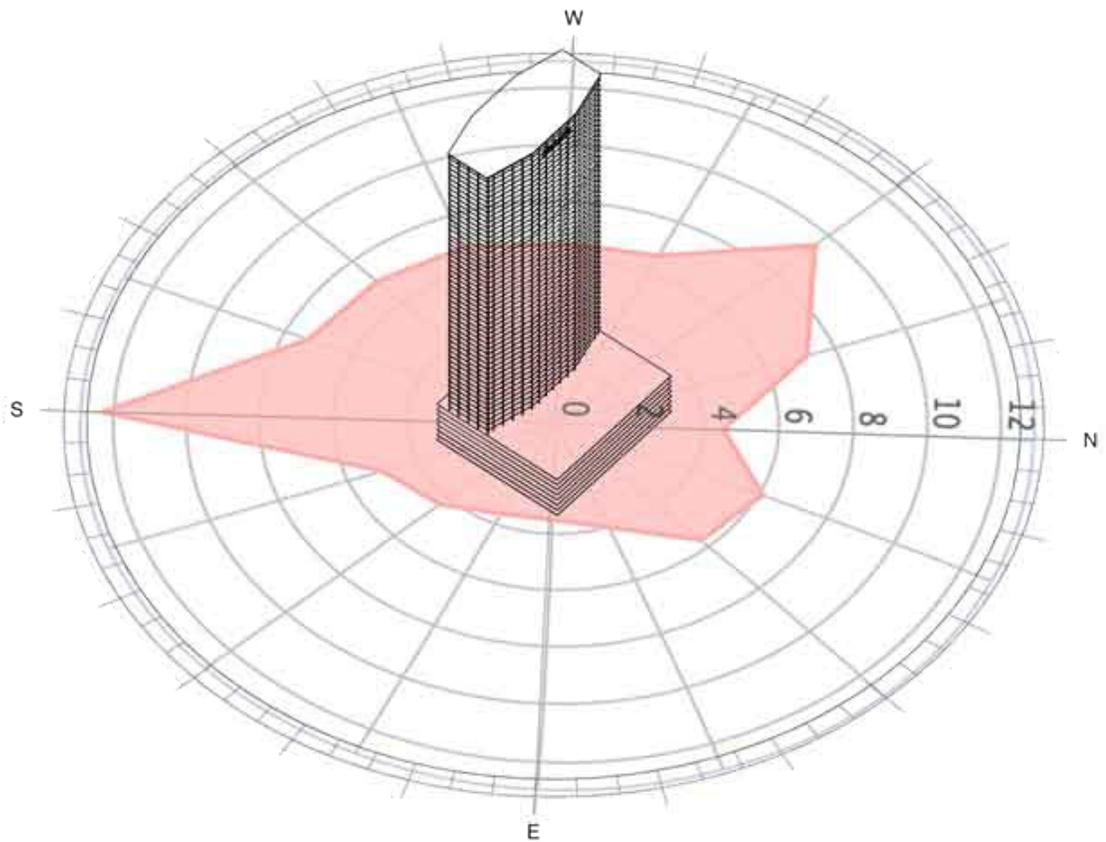


Figure 37: Average Wind Speed Over the Year in New York

(Source: Copyright © 2015 www.weather-and-climate.com, accessed January 2016). *modified by author



* in meters per second

Figure 38: MetLife Wind Rose- Yearly Average, New York

(Source: Copyright © 2015 www.weather-and-climate.com, accessed January 2016). *modified by author

Urban Regeneration: The Redesign of the Park Avenue Viaduct

The redesign of the Park Avenue Viaduct is an urban regeneration project creating open space in an historic setting. The design will permit and encourage pedestrian usage by transforming the western side of the Park Avenue Viaduct (above Vanderbilt Street) to pedestrian and bicycle use only. The goal is to create a safer place for commuters and cyclists as well as more public space. Beneficially being off the street offers protection as well as an opportunity for more retail tenant space. The pedestrian walkways offer interaction with historical buildings at new heights. Now visitors and commuters alike will be able to get up close and personal to the historical landmarks that surround the MetLife Building. When entering or exiting, pedestrians will pass by the magnificent marble statues that adorn the exterior of Grand Central Terminal, or walk through

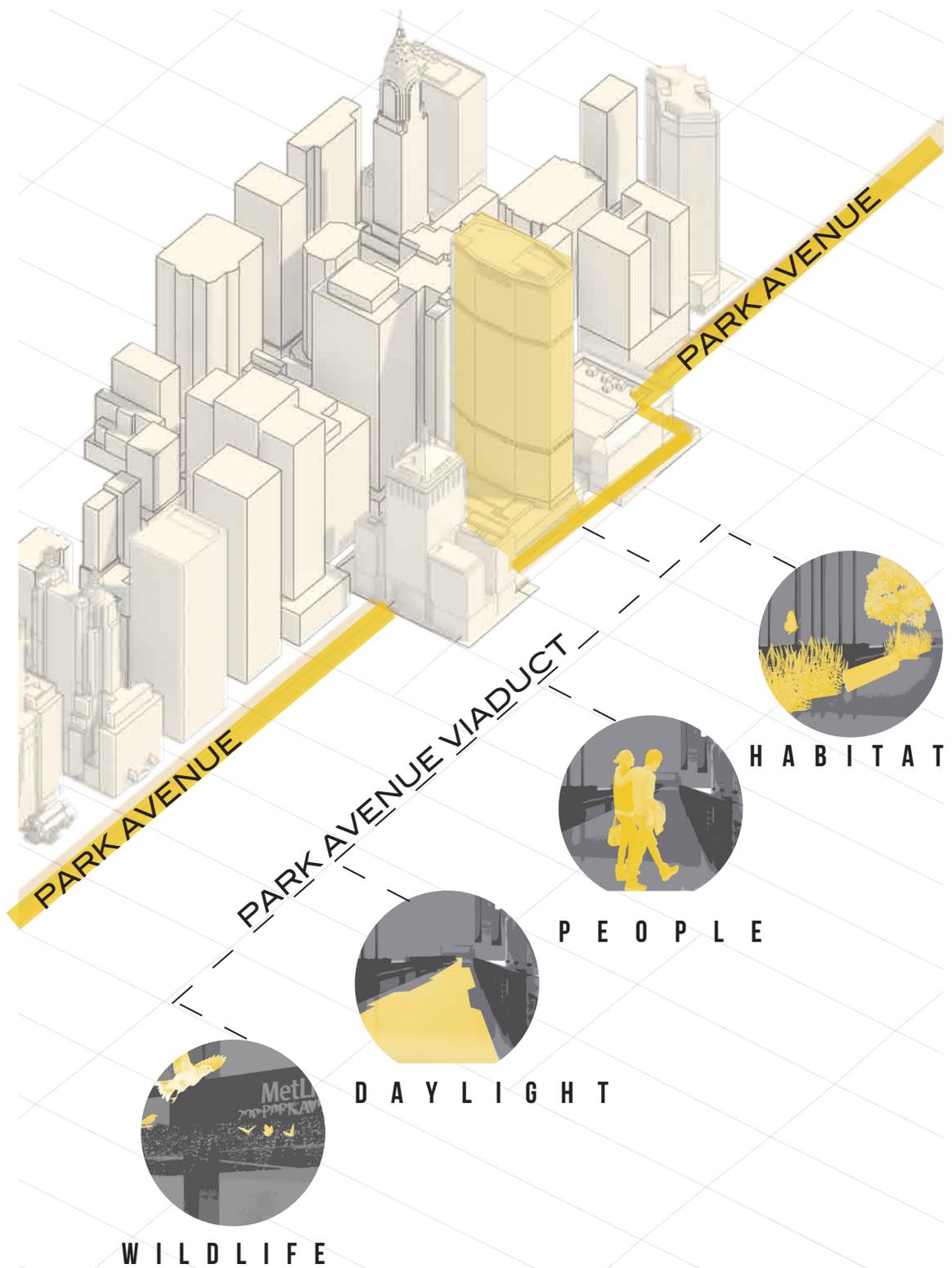


Figure 39: Urban Regeneration: Open Space in an Historic Setting
 the tunnel of the New York Central Building (now Helmsley Building), the transitional space between the two historic buildings surrounding the MetLife Build-

ing. The outermost part of the path is dedicated to pedestrians, demarcated by transparent panels. The transparent panels allow light to penetrate below while creating a “window” for the street. The transparent panels serve as an invitation to the second-level walkway. The outer edge railing integrates a view area of plants and animals and street life below. Flowing landscape and benches soften the edge of the pedestrian path, and create a buffer zone between the two uses. The bicycle lane eases arrival and departure to and from the office by avoiding the busy first level escalators. The Park Avenue Viaduct is a site intervention to address alternative ways to accommodate increasing density while encouraging social interaction by reinstating balance between pedestrians and vehicles in the twenty-first century.

The Park Avenue Viaduct creates a habitat for wildlife and people, human and non-human users. The majority of the users will be commuters and tenants. One hundred thousand commuters walk daily through the first floor of the MetLife Building attracting up to two hundred and fifty thousand people a day to the site. On average twenty-five thousand-office workers occupy the MetLife Building. Neighboring Grand Central Station, receives seven hundred and fifty thousand people daily. Currently, the diversity of animal and plant life is dismal, but is representative of the area. Besides the city rat that lives mostly subterranean, the city pigeon at street-level, and the miraculous yearly nesting of two peregrine falcons in the “MetLife” sign, not many animals are present. More than likely the falcons are feeding on rats and pigeons; ninety-nine percent of their diet is avian. Plant life is limited to stainless steel planters on the first level. The lack of plants is indicative of the lack of animal life. Plants offer a food source, places to rest, protection, and reproduction— for humans it is roughly the same. More commonly, plants serve to clean the air, filter the water, protect from the sun, cool the air, and absorb sound.

The impact of nature on a building results in an integration of human and non-human space. The pedestrian pathway includes a landscaped buffer zone of tall grasses and bushes. The outer edge “railway” is used to serve plants, animals and humans. The “railway” becomes a living-wall accepting nature, letting it in while becoming an outdoor cinema. The exterior is a series of layers and openings creating perching and nesting areas for birds and other animals. The exterior wall base is a projecting planter. The planter is multipurpose. The planter

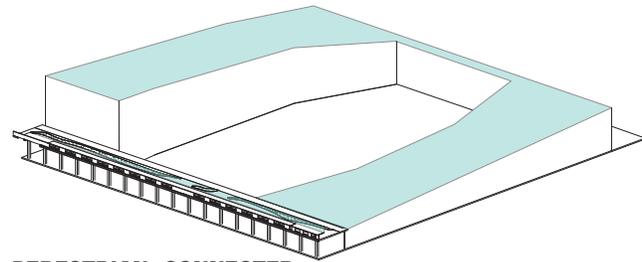


Figure 40: Creating Habitat for Wildlife and People, Section-Park Avenue Viaduct Wall is part of an proposed small urban park that promotes timely principles of ecological sustainability, urban regeneration, and adaptive re-use.

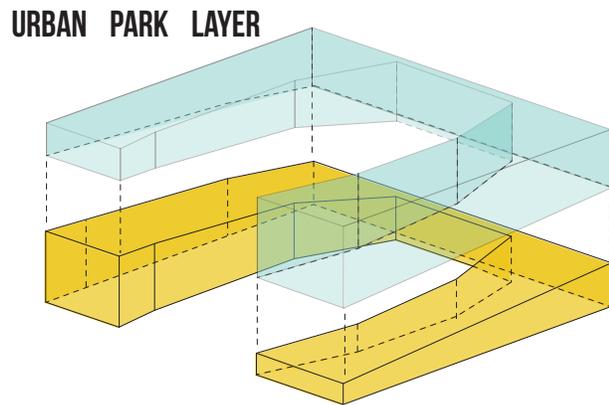
receives run-off water from the pathway. The run-off cleans up waste from the animals carrying it to the plants as fertilizer. The plants then offer protection, food, and nesting materials for the animals while enriching the aesthetics of the wall. The interior of the living wall is one-way glass allowing for rare viewing moments of animals in their "homes." Blurring the lines of exterior and interior, the living-wall allows for mutual integration increasing tolerance and awareness of ecological urban design. The Park Avenue Viaduct pathway and wall creates a small urban park that promotes timely principles of ecological sustainability, urban regeneration, and adaptive re-use.

Podium Modification

The original podium stands ninety feet tall on a 144,300 ft² base. The first floor has four main retailers, one at each corner. Access is centralized, intersecting from each side of the building. The podium modification is to become an economic generator by increasing retail visibility, increasing access to retail, creating courtyard space, and delivering more impactful spaces with an integrated green roof system. The lower portion of the podium is dedicated to retail space, by creating a street-like layer comprised of three floors, adding an additional 57,340 ft² of retail space. The grand total of retail space is 108,820 ft². The upper portion of the original podium is dedicated green space, creating an 65,500 ft² urban park, inspired by New York's Hi-Line. The urban park layer is connected

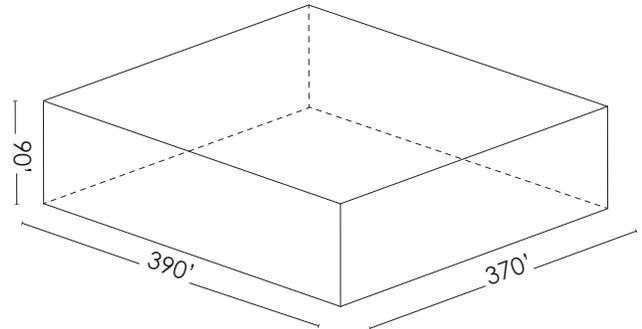


PEDESTRIAN CONNECTED



URBAN PARK LAYER

STREET-LIKE RETAIL LAYER



ORIGINAL PODIUM

Figure 41: Podium Modification Diagram

to the redesigned Park Avenue Viaduct pedestrian and cyclist pathway. This connection ensures traffic flow to the urban park but also to the retail spaces. The urban park is made possible through the green roof of the retail space below. The green roof connects to the southwest corner of the Park

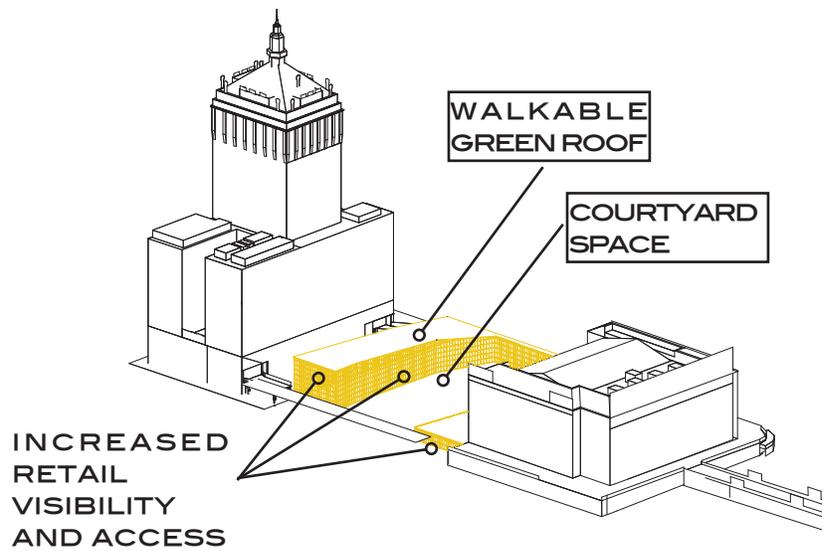


Figure 42: Podium Re-design-Economic Generator

PROPOSED TREES & GRASSES

SHALLOW ROOT SYSTEM DECIDUOUS

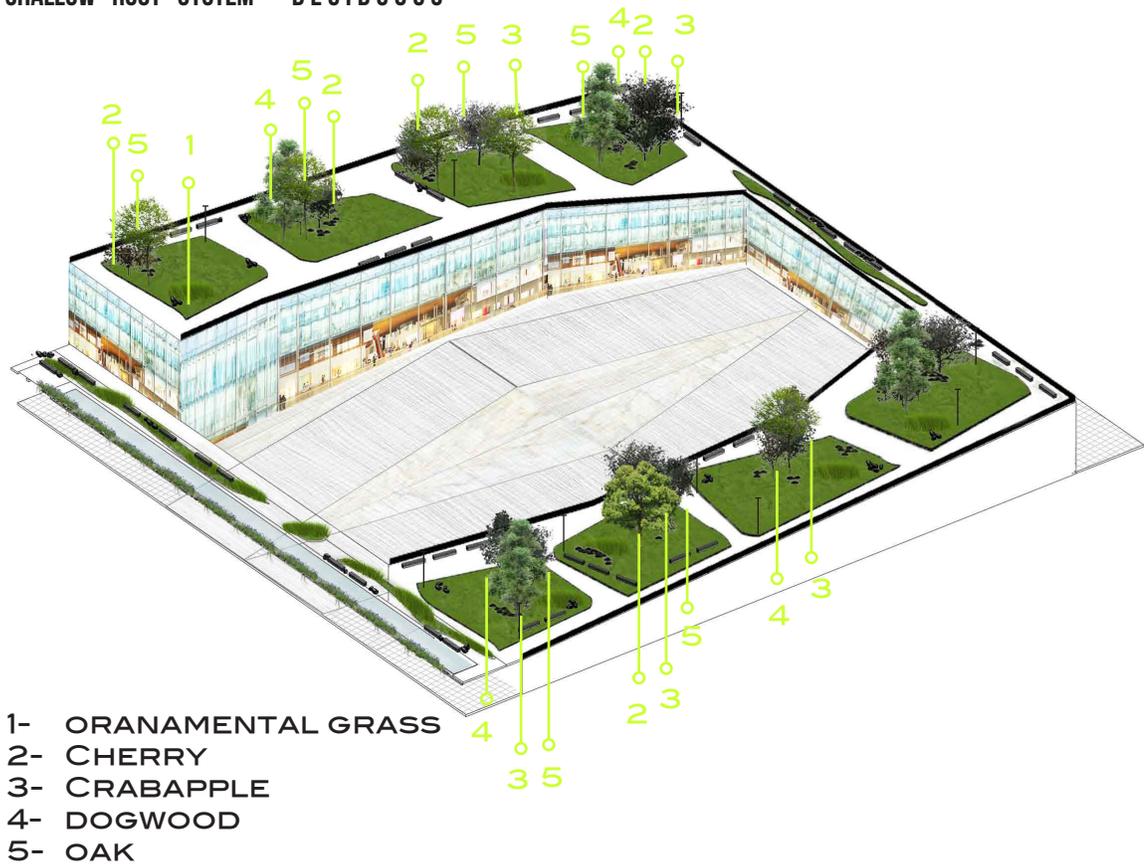
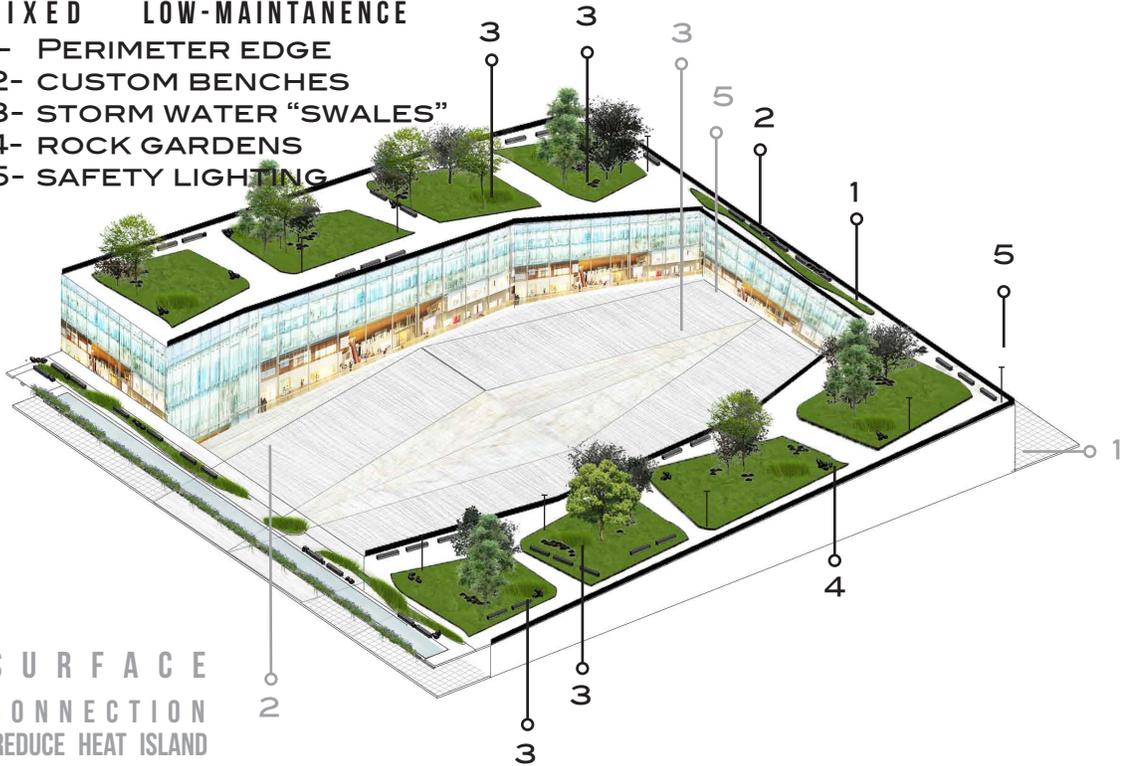


Figure 43: Podium Redesign- Proposed Trees and Grasses

Avenue Viaduct on the second floor and wraps up around the MetLife tower, reaching the sixth floor to escalator access. The urban park is designed so that the user experiences a variety of habitats while ensuring biodiversity. Sloping upwards at a one-to-twelve ratio, garden experiences range from mosslands, tall meadows, wetlands, woodland thickets, mixed perennial meadows, and young woodlands. The extensive green roof is three feet deep and utilizes the structure and drainage system from the ACROS Fukuoka Prefectural International Hall in Fukuoka, Japan (refer to 4.4). The main goals of the urban park is to provide New Yorkers with valuable green space and to encourage wildlife in the city. However, other benefits of creating green roofs include producing oxygen, reducing noise pollution, captures dust particles, releases humidity, acts as an

**INFRASTRUCTURE
FIXED LOW-MAINTENANCE**

- 1- PERIMETER EDGE
- 2- CUSTOM BENCHES
- 3- STORM WATER "SWALES"
- 4- ROCK GARDENS
- 5- SAFETY LIGHTING



**SURFACE
CONNECTION
REDUCE HEAT ISLAND**

- 1- FACADE SUPPORTED GREEN WALL
- 2- LINEAR PLAZA (FARMERS MARKET AREA)
- 3- PLAZA AREA (MOVEABLE CHAIRS)
- 4- GRASSY AREA
- 5- RESTROOMS

Figure 44: Podium Re-design-Proposed-Infrastruture and Surface Design

insulator, and encourages species diversity.



Figure 45: Urban Regeneration View

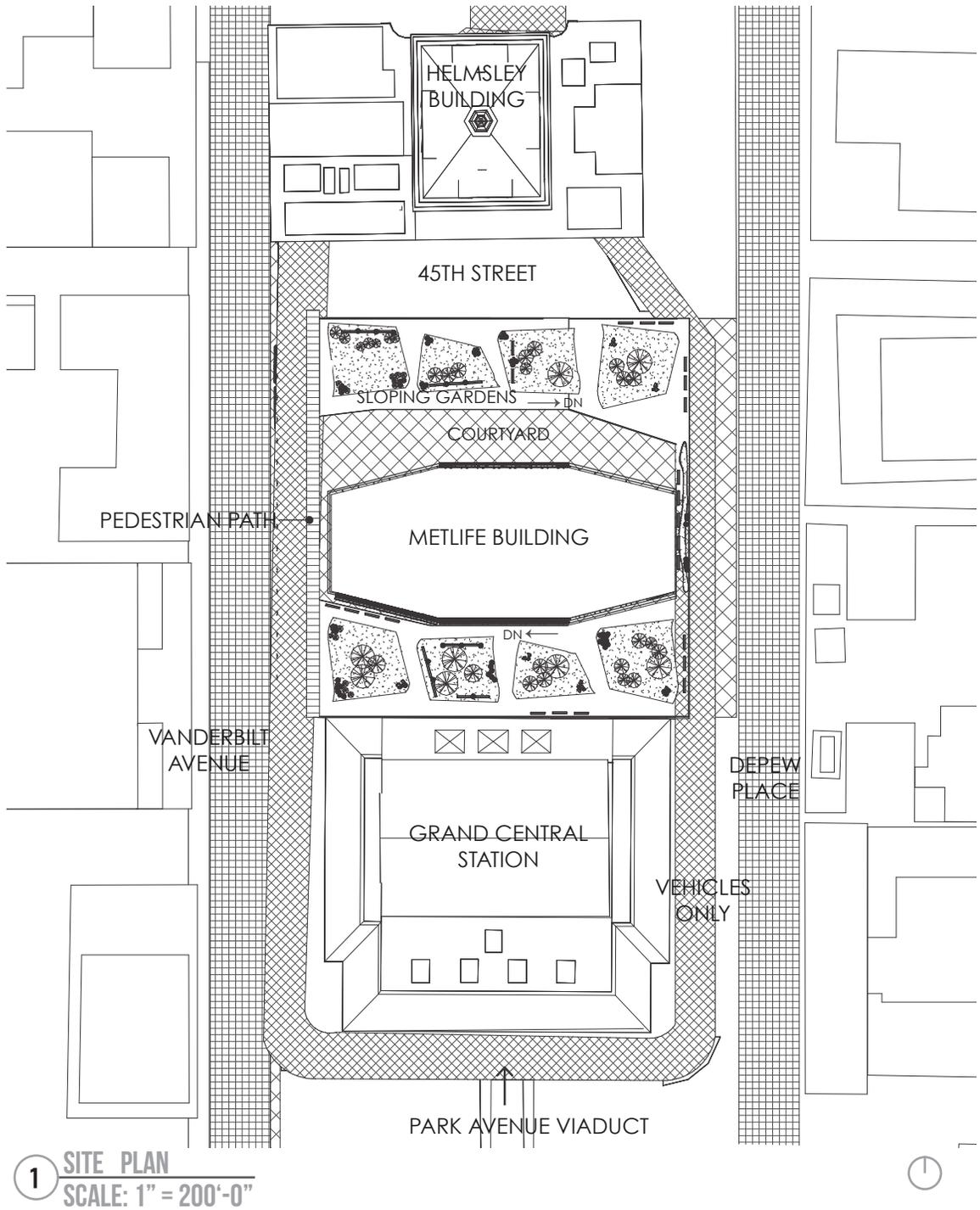


Figure 46: Site Plan

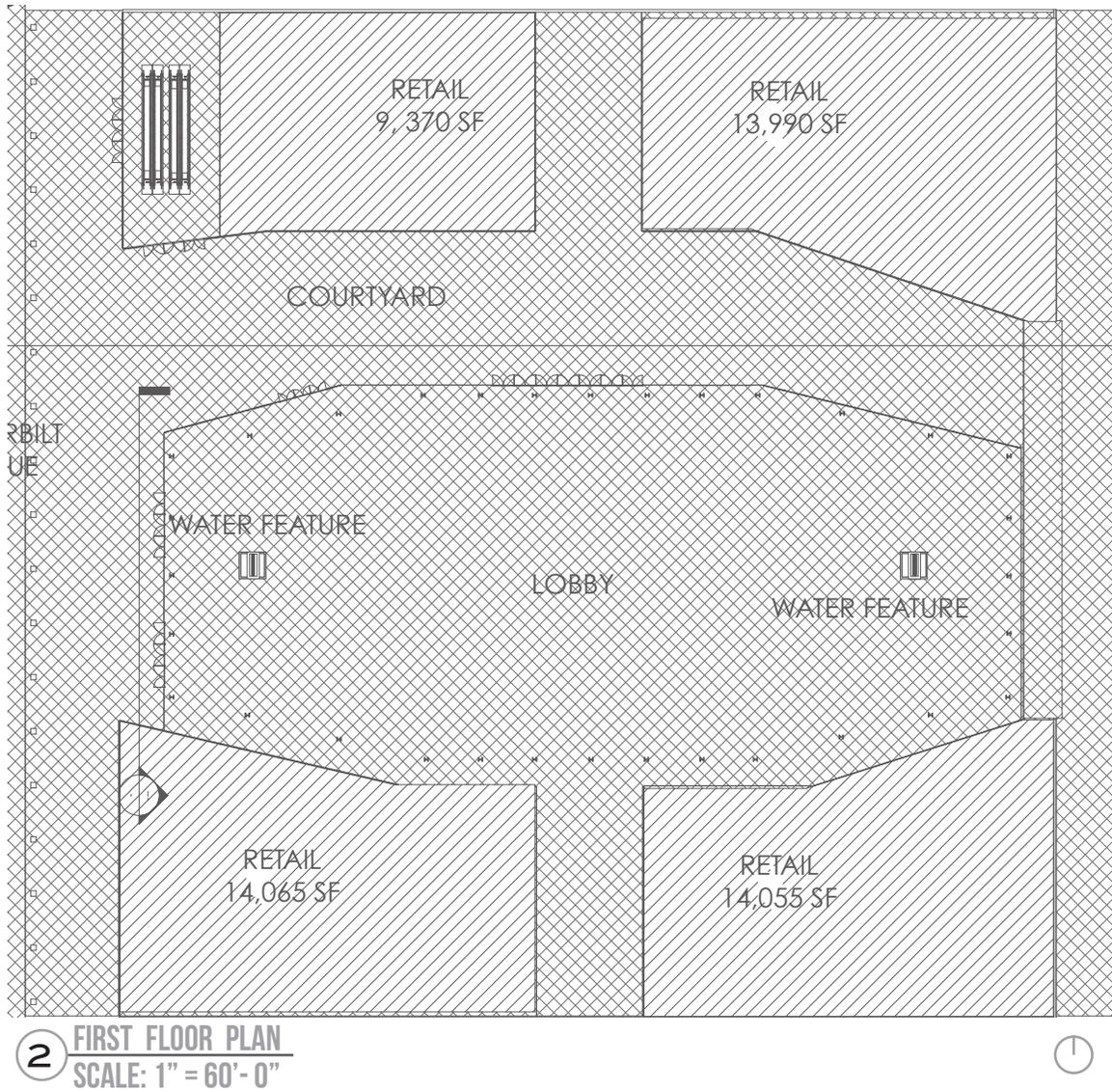
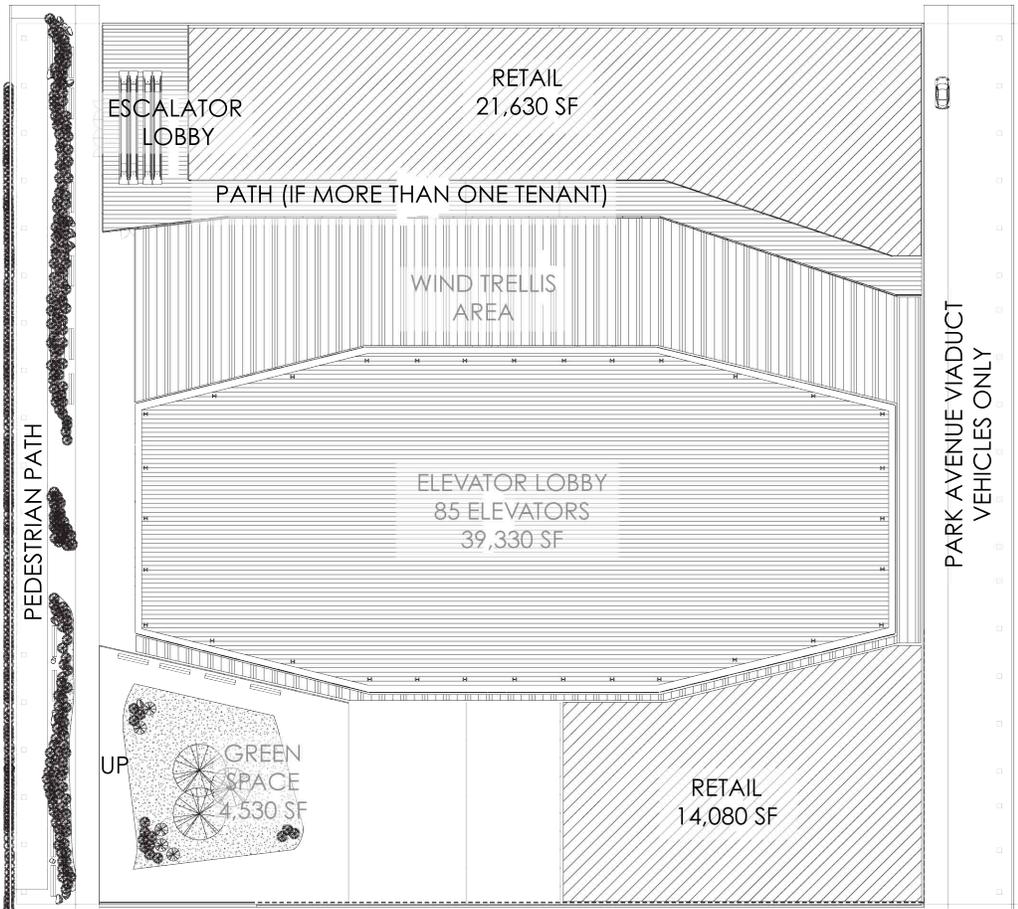
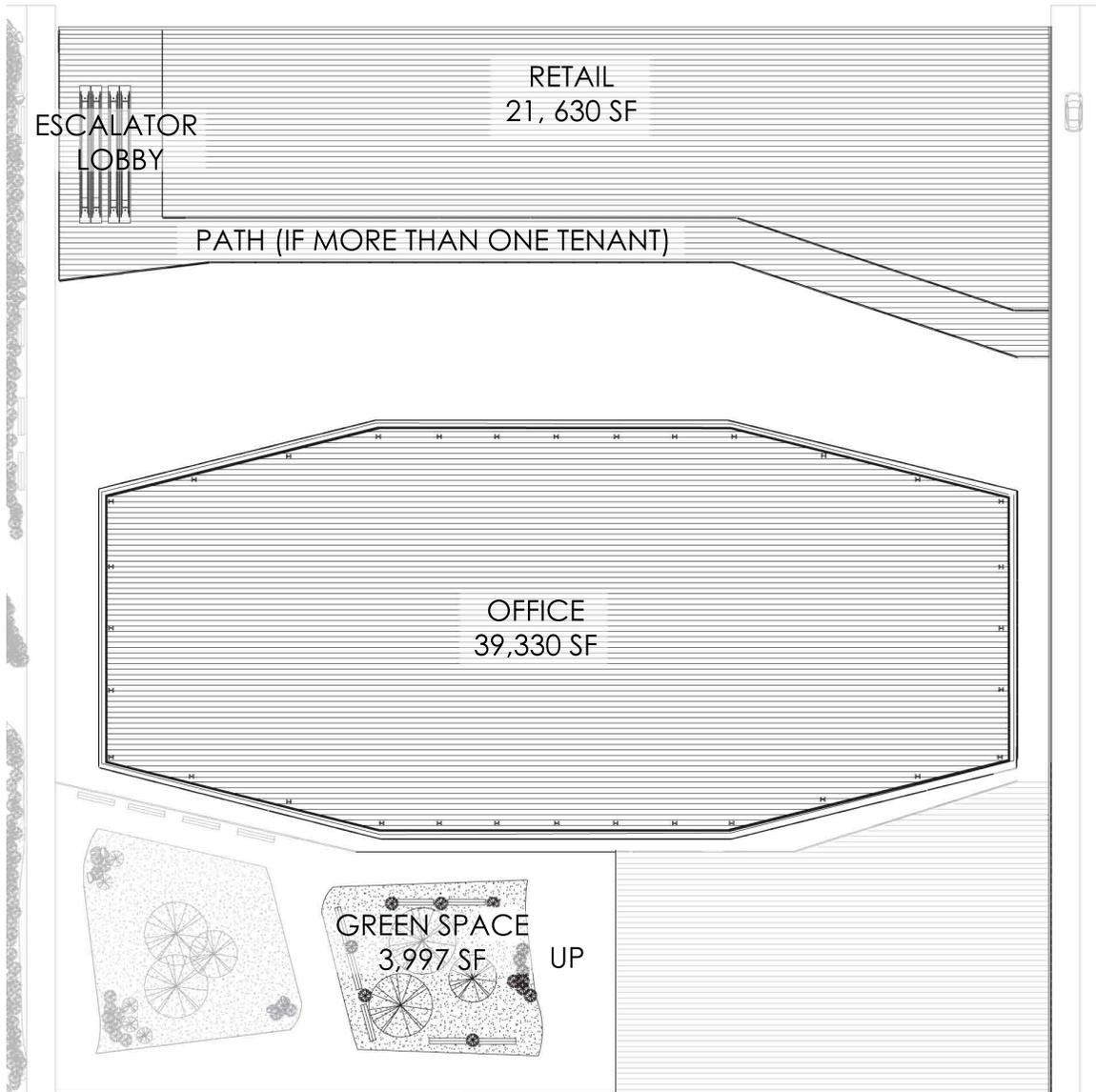


Figure 47: First Floor Plan



3 SECOND FLOOR PLAN
SCALE: 1" = 60'-0"

Figure 48: Second Floor Plan



4 THIRD FLOOR PLAN
SCALE: 1" = 60'-0"

Figure 49: Third Floor Plan

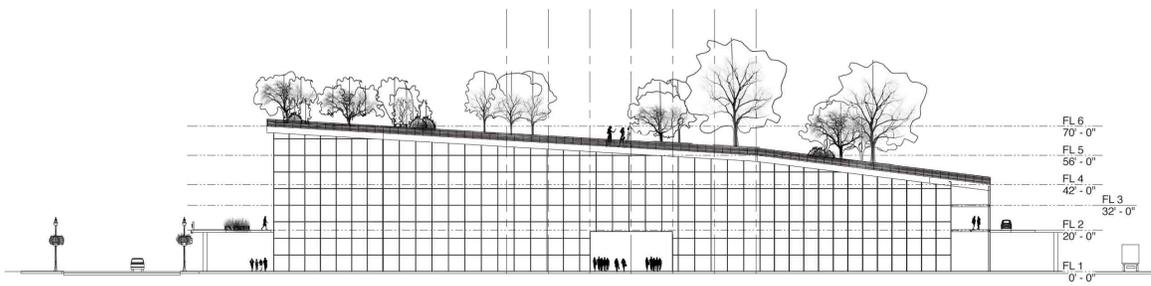


Figure 50: Section- Podium Re-design

The Facade

The redesign of the façade is a mix of new and old. The goal of the façade is to be naturally ventilated, energy producing, and embody elements of the existing façade, creating a ghost of the grid. As a naturally ventilated office tower, the MetLife Building will distinguish itself from other office towers in New York. Naturally ventilated spaces increase productivity from three to eighteen percent.⁹⁶ It provides a healthier and more comfortable environment and reduces the cases of sick building syndrome. Other significant reasons to use natural ventilation is the cost-savings in reduced HVAC use and space savings from a reduction in bulky equipment. Based on New York's climate a mixed-mode strategy would be employed. A mechanical system would supplement the system during winter and summer seasons, which allows for complete natural ventilation in the shoulder seasons. Energy estimates, anticipate at minimum, a fifteen percent decrease in HVAC demands. Utilizing a double-skin façade, which is otherwise too expensive for new buildings to justify; again, the MetLife Building will stand out against other "glass" office towers. The original Mo-Sai panels, which received their names from the manufacturer, went bankrupt during construction. Wolfson averted the problem by purchasing the company to finish the project. However, recreating the Mo-Sai panels today in the event of restoration will result in costly expenses. Therefore, the double skin façade will unify the original vertical Mo-Sai pre-cast panels, deemed in good condition, with the supports of the new façade creating a dynamic aesthetic. The horizontal pre-cast elements will be removed, creating floor to ceiling views.

The vertical pre-cast panels add thermal mass to the facade cavity. The addition of thermal mass adds to success of the double skin facade. The facade cavity also allows for unique access to the original vertical panels. The ghost of the grid is to create an echo of the original facade panels. This is made possible by a vertical and horizontal white fritting pattern added to the exterior layer of the skin. The exterior glazing is bright white to deter bird collisions while maintaining a clean aesthetic similar to the Shard in London (refer to 4.4). The south façade features sloped glass panels allowing for air intake and extract through the bottom of each panel and operable sun shading devices. The north facade

⁹⁶ Wood, Antony, and Ruba Salib. *Natural Ventilation in High-Rise Office Buildings*. CTBUH Technical Guides (New York: Routledge, 2013), 21.

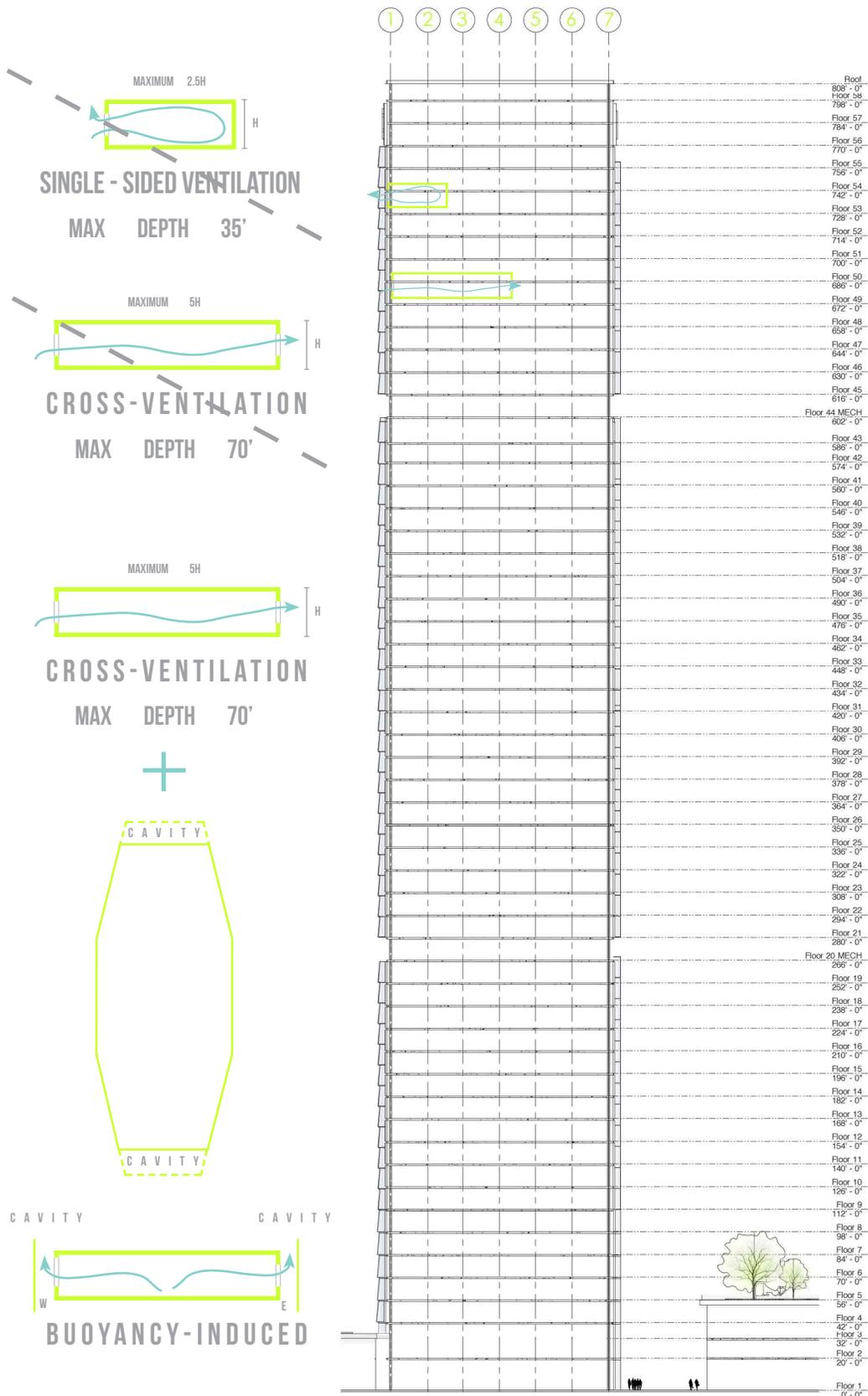
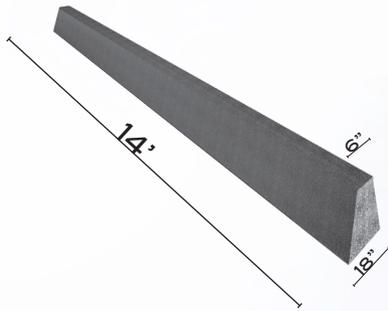


Figure 51: Natural Ventilation Diagram

DOUBLE SKIN FACADE



PRECAST MO-SAI PANELS

* TOP FLOOR MO-SAI PANELS TWICE THE SIZE
 9,000 PRECAST PANEL ELEMENTS
 EACH PANEL WEIGHS 3,500 LBS

- 1- OUTER SINGLE GLAZED SKIN LAMINATED (FRITTED)
- 2- MECHANICAL CABLES
- 3- SUNSHADE
- 4- OPERABLE FLAPS
- 5- VENTS
- 6- ORIGINAL MO-SAI PANELS
- 7- ARGON FILLED DOUBLE PANE GLAZING
- 8- EXTRUDED STAINLESS STEEL SECTIONS
- 9- CANTILEVERING STEEL BRACKETS FROM EXISTING FLOOR PLATE

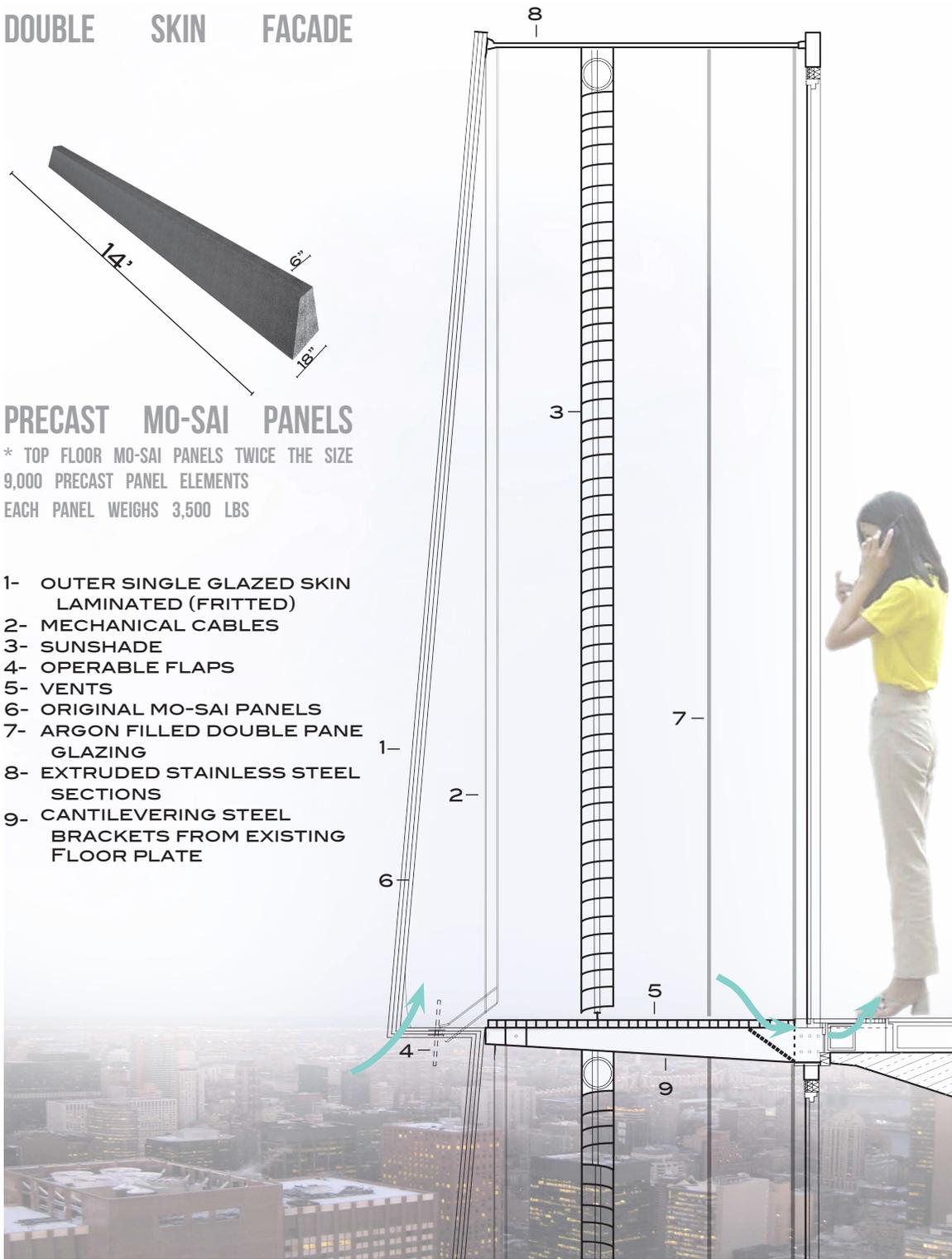


Figure 52: Double Skin Facade-Section

treatment is configured the differently. The north facade cavity is smaller, as less air flow is needed to circulate through the cavity since sun exposure is less and therefore not prone to overheating . The north facade is a smooth surface. The outer skin of the double facade on the east and west sides extends beyond creating an atrium like cavity to induce buoyancy effect. The overall natural veniltation strategy relies on buoyancy and cross-ventilation. The new façade will demonstrate relevance and necessity to positively contribute to the twenty-first century.

The Observatory and the MetLife Sign

“Romance, in the case of the skyscraper, is certainly understandable. Few, purely human achievements can compare with



Figure 53: MetLife Sign

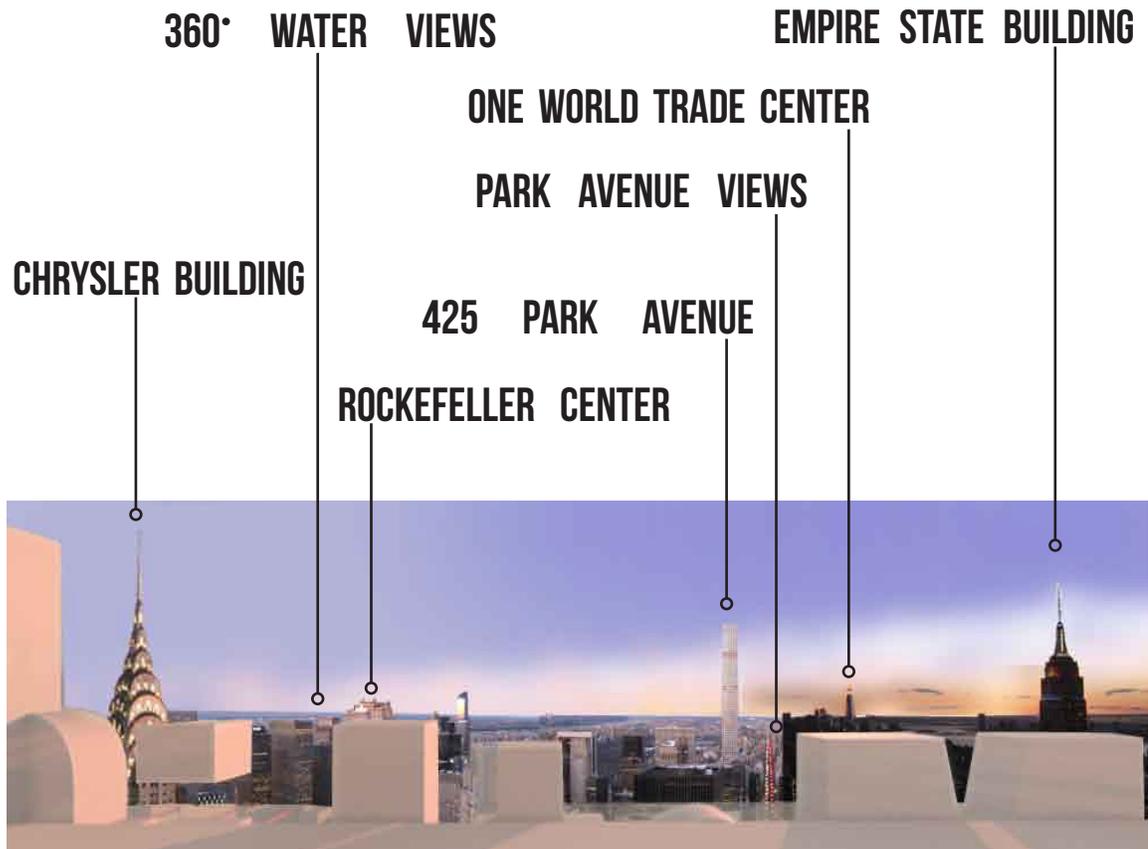


Figure 54: Landmark Skyline, Diagram

it. So the lure of having the company name engraved above a granite arch, topped by six, seven, or eight hundred feet of steel, sculptured stone, and glass is nothing to take lightly."⁹⁷ One should not impede romance— romance in case of the MetLife sign reaches almost eternal heights. New York has accepted the MetLife Building; well at least the press have abstained from publicly hating it and moved on to new subjects. Such is the case with a nearby neighbor, nicknamed the Pencil Tower. 432 Park Avenue is the new detested supertall. Banal love affair or not, the MetLife sign will remain, but will signify a new existence of relevance in, the twenty-first century through an observatory. With the addi-

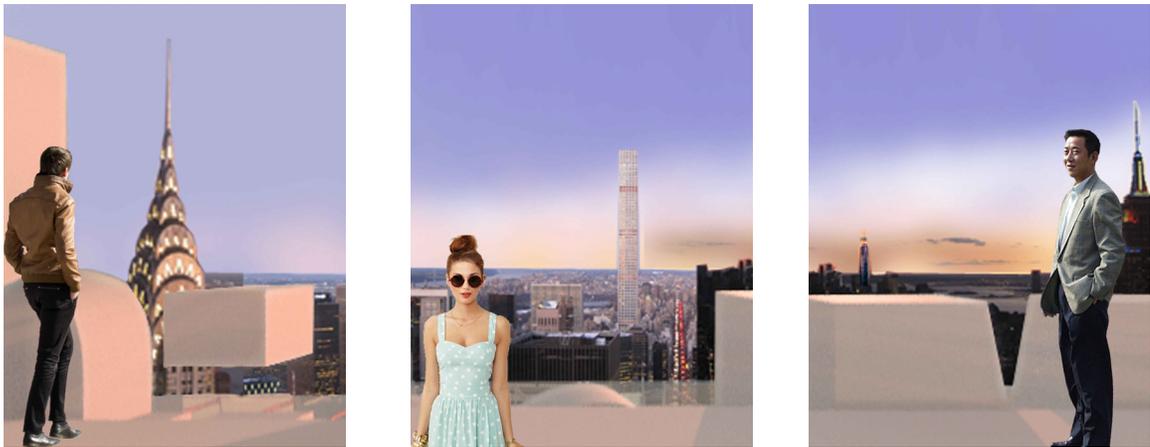


Figure 55: Landmark Skyline View with the MetLife Sign

tion of an observatory, visitors can orient themselves to the skyline through the MetLife letters. Being up close and personal to the sign creates a lasting impression that allows visitors to relate their location to the 805 ft. tower in a human scale way. The observatory utilizes enclosed space on the fifty-eighth floor and the roof top heli-pad. The addition of the observatory integrates the tower's height into the urban fabric of the city, creating sociable spaces that can be shared by all.

97 Hines, Gerald D. "Developing Tall Buildings to Meet Future Needs: Transco Tower Case History." In *Second Century of the Skyscraper*, ed. Lynn S. Beedle (Springer US, 1988), 329.



Figure 56: The View

PART THREE:

ANALYZING TALL BUILDINGS

3.1 Twenty Six Factors of Efficiency

Tall buildings are analyzed in many ways from energy consumption, gross floor area, floor-to-floor ceiling height, and so forth. For office towers, it is even more in depth. This scrutinizing process of number crunching reveals a potential misstep in the design process resulting in a globalized form of monolithic vertical extrusions of an efficient floor plan. The globalized extrusion is potentially devoid of culture and obtrusive to its surroundings. Despite the ramifications of some of the efficiency formulas, this analytical approach is used to create numerical data to examine building elements in office buildings and to better understand the ratios within a tower. The purpose of this investigation is to derive a tangible, quantitative approach to analyzing the efficiency of tall office buildings to be better equipped for applications of renovation.

Using Skidmore, Owings, & Merrill's (SOM) compilation produced in conjunction with Northeastern University, a result of an architectural studio, "genes" of tall office buildings will be showcased through spatial, structural and environmental categories.⁹⁸ Six buildings will be used as a basis for further application: Lever House, National Commercial Bank, 30 St. Mary Axe, Bank of China, Willis Tower, and One World Trade Center.

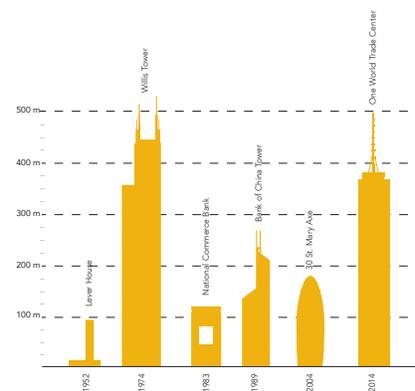


Figure 57: Efficiency Factors Building Chart

⁹⁸ Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 1.

3.1.1 SPATIAL EFFICIENCY

SAMENESS FACTOR

Sameness factor is a gauge of unlikeness between floors. Sameness factor in a building will decrease with abrupt, dramatic changes in floor plates, such as tapering, twisting, or tilting towers (for formalists this is sometimes thought of as torturing). This measurement demonstrates the impact 'changes' have on repetitive building elements, which is extremely crucial over the floors of a tall office tower, a typology in which small changes add up to large quantities.⁹⁹ A ratio of 1.00, as in Lever House means it is a pure extrusion, as the first floor to the top floor plan does not change.

$$\Sigma_R = \frac{R_1 + R_2 + \dots + R_N}{N}$$

$$R = \frac{A_0}{A_C}$$

VARIABLES:

Σ_R - Sameness Factor

A_C - Area Connected

A_0 - Area of Overlap

F_1 - Floor

F_2 - Floor 2 (Above F_1)

R - Ratio per Floor

N - Total Number of Floors

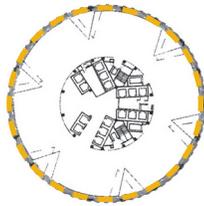
Figure 58: Sameness Factor Formula

⁹⁹ Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 25.

S A M E N E S S F A C T O R

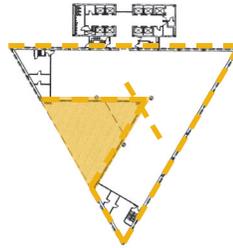
30 ST. MARY AXE.

0.97



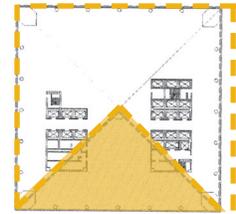
NATIONAL COMM. BANK

0.95



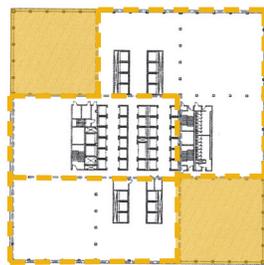
BANK OF CHINA

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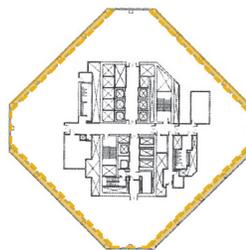
WILLIS TOWER

0.99



ONE WORLD TRADE CENTER

0.99



LEVER HOUSE

1.00

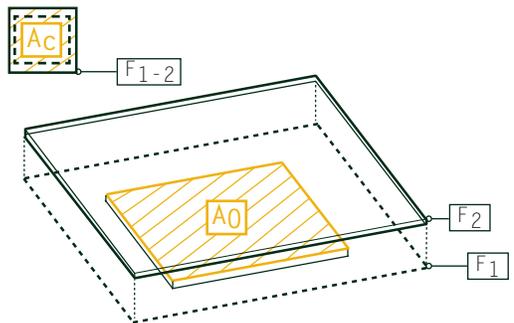
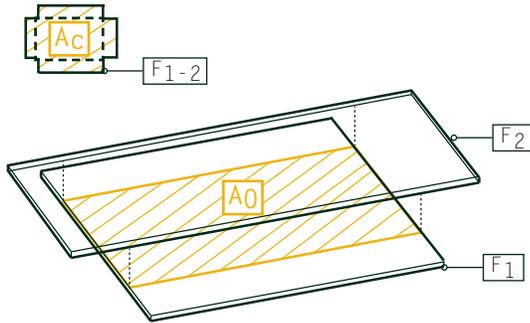
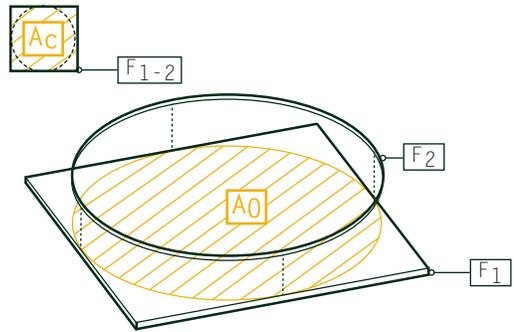
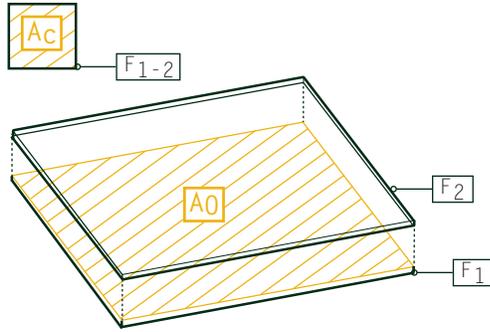
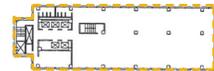


Figure 59: Sameness Factor

(Source: Efficiency: An Analytical Approach to Tall Office Buildings, 25.)
* modified by author.

CONSISTENCY OF LEASE SPAN

Lease span is measured from the face of the building core to the inside face of building enclosure. A consistent span makes it easier to run standard office facilities around a floor adding to functionality of space and the subservient components. The lease span is largely influenced by the “plannable” area of a typical floor, where the “plannable” area exists from the inside face of the enclosure to the perimeter, which is tangent to the building core. A consistent lease span is considered an advantage to a tall office building when allocating its space regularly without much change from floor to floor. Lower consistency is created when core geometry is different than exterior wall geometry. Therefore consistency is related to sameness between building core and exterior wall.¹⁰⁰

$$R = \frac{A_0}{A}$$

VARIABLES:

A - Total Plannable Area

A₀ - Area of Overlap

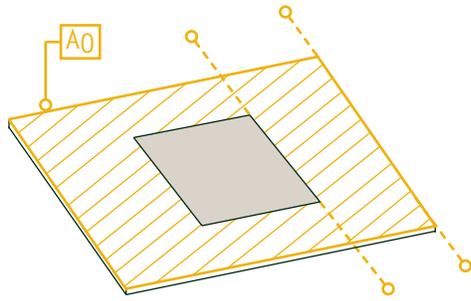
R - Ratio per Floor

Figure 60: Consistency of Lease Span

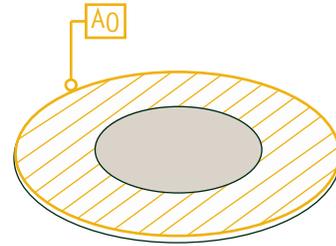
100 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 31.

CONSISTENCY OF LEASE SPAN

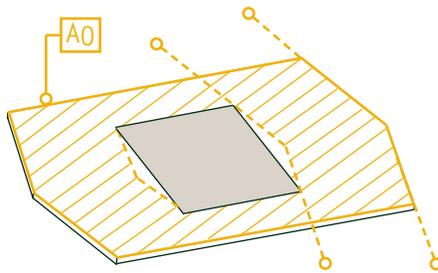
30 ST. MARY AXE.



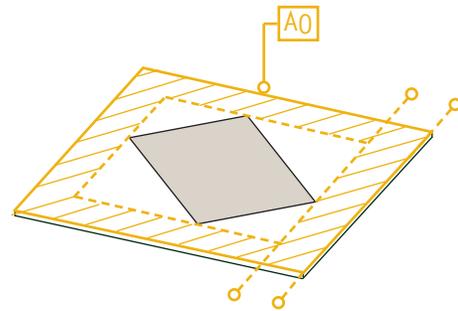
TYPICAL FLOOR PLAN



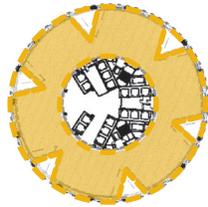
TYPICAL FLOOR PLAN



TYPICAL FLOOR PLAN

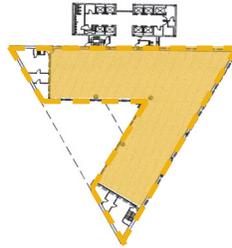


TYPICAL FLOOR PLAN



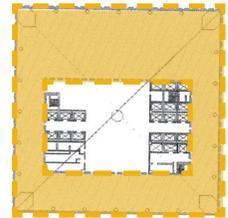
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NATIONAL COMM. BANK



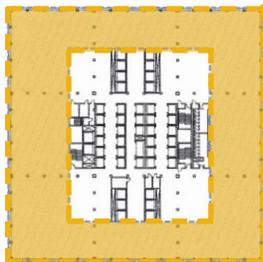
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BANK OF CHINA



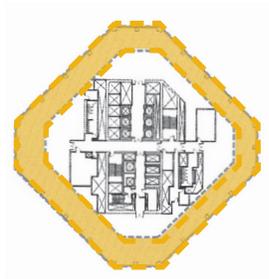
0.99

WILLIS TOWER



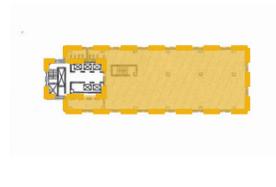
0.77

ONE WORLD TRADE CENTER



0.82

LEVER HOUSE



1.00

Figure 61: Consistency of Lease Span

(Source: Efficiency: An Analytical Approach to Tall Office Buildings, 25.)

* modified by author.

VERTICAL COMMUTE

The vertical commute evaluates how much time a building commute takes up in a person's daily life specifically measuring time in the elevator. Vertical commuters are investigated during their lunch hour, one of the two most heavily traveled time period of the workday, morning arrival being the other. The ratio measures the travel time of an occupant-commuter in a tall office building. The equation assumes the occupant-commuter is traveling to the highest occupiable floor accounting for elevator speed, wait-time, and includes a penalty for transfer floors. While results reveal tallness is an obvious factor, elevator speed is undoubtedly the predominant factor.¹⁰¹

VARIABLES:

$$R = \frac{\left(\frac{\text{HEIGHT}}{\text{E.S.}} \right) + (.5 \times N)}{\text{HEIGHT}}$$

E.S. - ELEVATOR SPEED IS ASSUMED TO BE 20 FT/HR, IF NOT PROVIDED
HEIGHT - MEASURED FROM THE LAST OCCUPIABLE FLOOR TO THE GROUND PLANE (FT.)
N - NUMBER OF WAITS

Notes:

A thirty second wait is added for each transfer floor.

Figure 62: Vertical Commute Formula

¹⁰¹ Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 35.

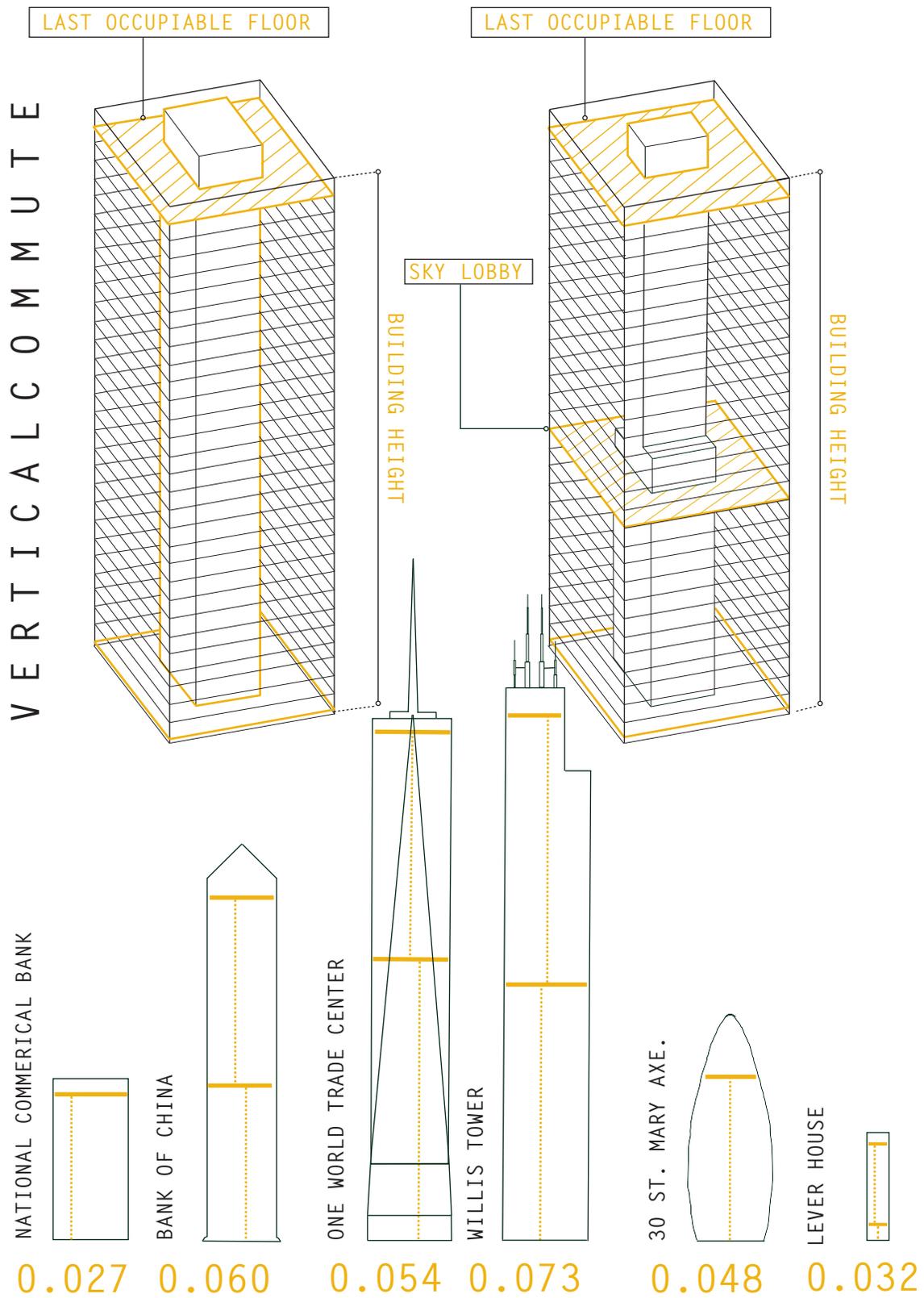


Figure 63: Vertical Commute

(Source: Efficiency: An Analytical Approach to Tall Office Buildings, 33.)
 * modified by author.

FLOOR AREA RATIO

Floor Area Ratio is an industry standard, used beyond that of tall office buildings, defining for the spatial relation of a building's total floor area in relation to the size of the piece of land upon which it is built. Elements such as floor plates can be repeated vertically becoming multipliers used to increase total area.

"Floor area ratios are used as a measure of the density of the site being developed and regulate the amount of constructed square feet in the certain area. In many cases, specific floor area ratios are required (to either limit or encourage density) within the design before building permits will be issued."¹⁰²

$ZFA = A_1 + A_2 + \dots + A_N$ $R = \frac{ZFL}{ZLA}$	<p>VARIABLES:</p> <p>A - AREA OF CORRESPONDING FLOOR</p> <p>ZFA - TOTAL ZONING FLOOR AREA</p>	<p>ZLA - AREA OF THE ZONING LOT</p>
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Notes:

For the purpose of this study, instead of zoning floor area, gross floor area above grade is calculated for the case studies.

Figure 64: Floor Area Ratio Formula

¹⁰² Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 39.

FLOOR AREA RATIO

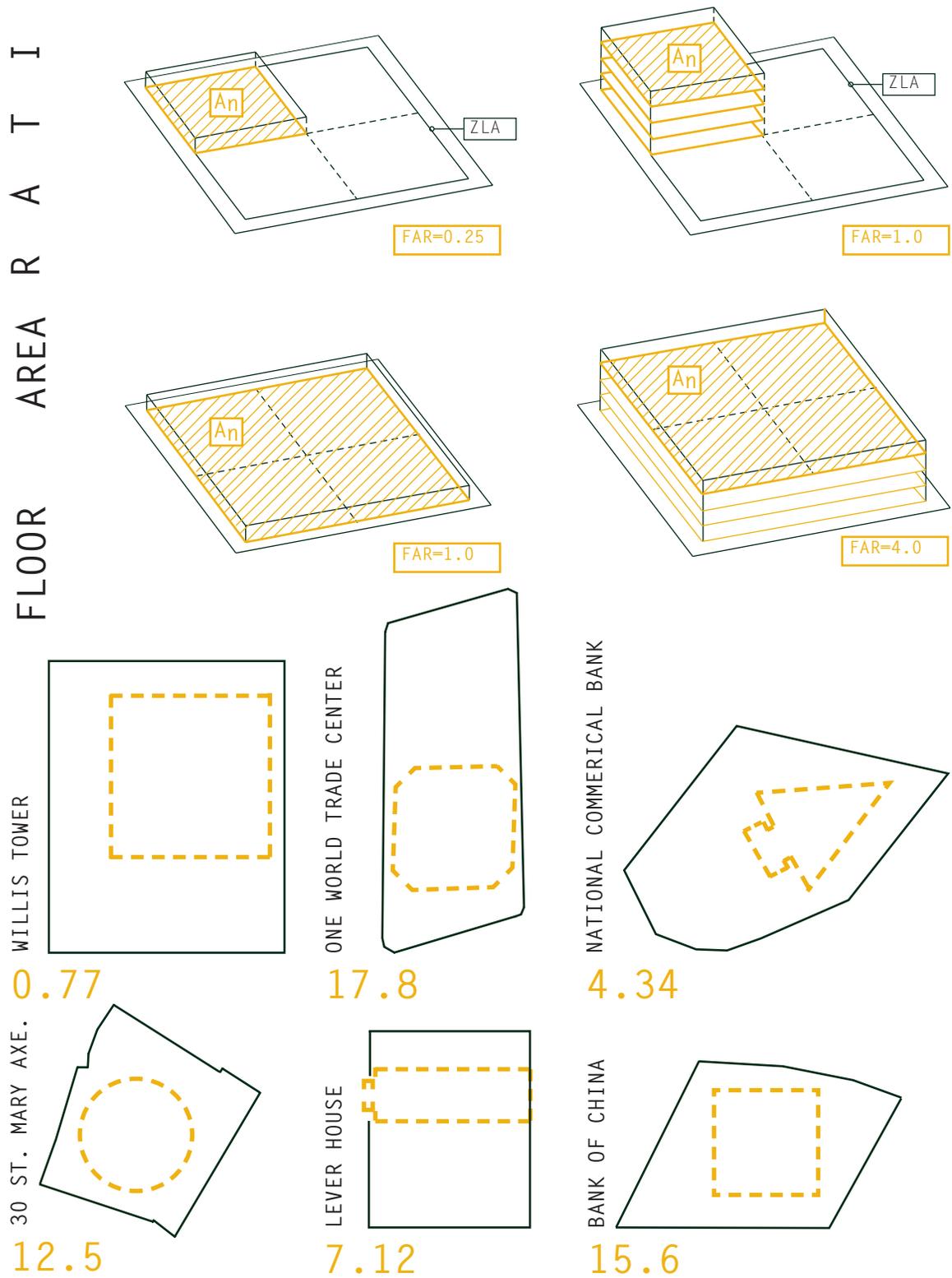


Figure 65: Floor Area Ratio

(Source: Efficiency: An Analytical Approach to Tall Office Buildings, 37.)
 * modified by author.

DENSITY

Density measures the degree of spatial compactness within a given structure, an occupancy ratio. The greater number of people occupying a building, the more "efficient" a building can be considered. The density of a building is a compilation of individuals that are able to occupy a floor measured against the total square footage of that floor. The ratio depicts the fit-ability of people within the structure, which is grossly cultural.¹⁰³

$$A_0 = \text{DENISTY} \times A_1$$

$$R = \frac{A_0}{A_2}$$

VARIABLES:

DENISITY - 1/150 FT²

A₀ - OCCUPANCY

A₁ - TOTAL PLAN-
NABLE AREA OF
TOWER

A₂ - FOOTPRINT OF
TOWER

Notes:

DENISTY MAY BE BASED ON PROGRAM, TYPE OF LAYOUT, BUILDING CLASS, ETC. HOWEVER, FOR STUDY WE ASSUME 1/150 FT² PLANNABLE FOR OFFICE SPACE.

Figure 66: Density Formula

103 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 43.

PLANNABLE AREA

The plannable area of a space is measured in terms of its relationship to gross area. This is used for office planning by providing framework to quantify surface area of an office space within a floor plate.¹⁰⁴ For a multiple tenant configuration, circulation and cores are excluded then measured against gross measured area.

$$R = \frac{\text{PLANNABLE FLOOR AREA}}{\text{GROSS MEASURED AREA}}$$

VARIABLES:

GROSS MEASURED AREA- MEASURED OUTSIDE FACE OF EXTERIOR WALL.

PLANNABLE FLOOR AREA- MEASURED A LEVEL FROM THE INTERIOR FACE OF PERIMETER ENCROACHMENTS SUCH AS MULLIONS, WINDOW SILL, CONVECTORS, BASEBOARD HEATING UNITS, AND RADIATORS TO THE OUTSIDE FACE OF THE CORE ENCLOSURE.

Notes:

Plannable Area includes the area outside of the core where furnishings, departmental functions, and circulation can be accommodated. Plannable ratio is a quantity which measures the relationship of the floor area that the tenant is able to fit out to the interior floor area. This ratio provides an indication of the efficiency of the core, and aids with space planning. Plannable is also referred to as 'carpetable area.'

Figure 67: Plannable Area Formula

104 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 47.

USABLE AREA

The usable area of a space is almost identical to that of plannable areas, except it includes the area of the core serving that floor. The core spaces that are computed includes closets, bathrooms, and equipment rooms, while excluding vertical elements such as elevators, stairs, and airshafts. This calculation helps to understand core efficiency. The useable area of a typical floor is a useful metric for gauging a tower's efficiency with the minimum acceptable range of seventy-five to eighty-five percent efficiency rating, with any percentage over eighty-five considered outstanding. Examining the non-vertical elements on a particular floor reveals how efficiently a tower "stacks."¹⁰⁵

$$R = \frac{\text{USEABLE FLOOR AREA}}{\text{GROSS MEASURED AREA}}$$

VARIABLES:

GROSS MEASURED AREA- MEASURED TO THE OUTSIDE FACE OF EXTERIOR WALL.

USEABLE FLOOR AREA- MEASURED TO THE OUTSIDE SURFACE OF THE BUILDING. THE AREAS EXCLUDED FROM THE UFA ARE ELEMENTS THAT RUN VERTICALLY THROUGH THE ENTIRE BUILDING SUCH AS, ELEVATORS, FIRE STAIRS, VERTICAL SHAFTS, PRIMARY ELECTRICAL AND MECHANICAL CLOSETS.

Figure 68: Useable Area Formula

105 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 51.

COLUMNLESS PLANNABLE FACTOR

This factor is an indicator of how much area columns remove from a plannable area and further suggests the amount of space available for tenant fit out. Columns impact office layout significantly, therefore they are deducted from the plannable floor area. Some spaces are completely column free and thus entirely occupiable. Outboard columns of the enclosure do not affect the lease span and are not counted in this ratio.¹⁰⁶

$$R = \frac{\text{PLA} - \text{COLUMN AREA}}{\text{PLANNABLE FLOOR AREA}}$$

VARIABLES:

PLANNABLE FLOOR AREA (PLA)
- MEASURED AT FLOOR LEVEL FROM THE INTERIOR FACE OF PERIMETER ENCROACHMENT SUCH AS MULLIONS, WINDOW SILLS, CONVECTORS, BASEBOARD HEATING UNITS, AND RADITORS TO THE OUTSIDE FACE OF THE CORE ENCLOSURE.

COLUMN AREA- AREA OF COLUMNS WHICH FALL WITHIN THE PLANNABLE SPACE.

Figure 69: Columnless Plannable Factor Formula

106 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 55.

PERIMETER OFFICE

Typically the most desirable office space in a tall building is the one with the best views and most abundant daylight, the perimeter. Due to the limited amount of perimeter in an office space, it becomes essential to optimize the office plan layout. This ratio exposes the potential strength or weakness of an office plan.¹⁰⁷ In the case of National Commercial Bank the best “perimeter” views are inwardly focused toward the atrium.

$$R = \frac{\text{PERIMETER OFFICE AREA}}{\text{PLANNABLE FLOOR AREA}}$$

VARIABLES:

PLANNABLE FLOOR AREA (PLA) - MEASURED AT FLOOR LEVEL FROM THE INTERIOR FACE OF PERIMETER ENCROACHMENT SUCH AS MULLIONS, WINDOW SILLS, CONVECTORS, BASEBOARD HEATING UNITS, AND RADITORS TO THE OUTSIDE FACE OF THE CORE ENCLOSURE.

Notes:

A typical perimeter office size of 10 ft.. x 15 ft.. can be assumed.

Figure 70: Perimeter Office Formula

107 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 57.

PLANNED ASPECT RATIO

Planned Aspect Ratio measures the amount available daylight in a space. Daylight in an office affects many things including lighting to office layouts, where shallower spaces may have more limits spatially but more comfortable environments. Therefore this assessment identifies the maximum depth sunlight penetrates a space to aid in developing zones of space away from windows. Exterior or offset cores are excluded from this calculation, as it is only central cores that are obstructed. "Plannable aspect ratio expresses the benefit and detriment of a shallow versus deep lease span."¹⁰⁸

$$R = \frac{LS_{MAX}}{H}$$
$$\sum R = \frac{R_1 + R_2 + \dots + R_N}{N}$$

VARIABLES:

LS_{MAX} - MAXIMUM LEASE SPAN PERPENDICULAR TO THE CORE.

H - CEILING HEIGHT, MEASURE FROM FINISHED FLOOR TO CEILING.

N - NUMBER OF FLOORS.

Notes:

Higher .R values for this factor may make it evident of an offset core, or a core that is not greatly impacting your plannable area.

This factor EXCLUDES offset core buildings

Figure 71: Planned Aspect Ratio Formula

108 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 63.

SECTIONAL USABILITY

Sectional Usability highlights the delineation between servant and served type spaces. This factor shows how much space is dedicated to structural or mechanical systems and its influence on usable space. The higher the percentage, the more efficient a floor slab seems within the overall height of the building. Also, this factor exposes the possibility of reworking the measurement of what is sitting above or below the floor. Although this issue is what often plagued earlier buildings, the current tall building market reflects modernity where most buildings feature a ceiling height of at least nine feet.¹⁰⁹

$$R = \frac{H_{FC}}{H_{FF}}$$

VARIABLES:

H_{FC} - FLOOR TO CEILING HEIGHT

H_{FF} - FLOOR TO FLOOR HEIGHT

Notes:

In situations where floor to floor height of an occupiable floor changes, an average will have to be used.

Figure 72: Sectional Useability Formula

109 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 67.

3.1.2 ENVIRONMENTAL EFFICIENCY

CURTAIN WALL UNITS

Curtain Wall Units measures standardization of the façade, taking into consideration the average amount of typical window units per floor of a building. This factor inadvertently addresses enclosure and specifically looks for conditions where the typical curtain wall unit changes. Changes typically occur at the corners where glass dimensions or frame-types change.¹¹⁰ Overall, this factor looks at construction efficiency, playing an important part of building a structure, while providing insight into the predictability of the building's character.

VARIABLES:

A_{TYP} - TOTAL SURFACE AREA COVERED BY THE TYPICAL CURTAIN WALL UNITS

A_0 - OVERALL AREA COVERED

A_u - AREA OF ONE CURTAIN WALL UNIT

N - NUMBER OF FLOORS

Σ_R - OVERALL BUILDING EFFICIENCY OF TYPICAL CURTAIN WALL UNIT COVERAGE

$$R = \frac{A_{TYP}}{A_0}$$

$$\Sigma_R = \frac{R_1 + R_2 + \dots + R_N}{N}$$

Notes:

The difference of unit is determined primarily by dimension.

Figure 73: Curtain Wall Units Formula

110 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 71.

SHADOW AREA

Shadow Area is an important factor with a historical past, pertaining to many laws that protect and prevent new buildings from robbing sunlight and cast shadows on other buildings as well as the urban core itself. The factor identifies a range of time from minimal shading to areas that will be greatly impacted as well as the total area shaded for three hours or more.¹¹¹

$$\text{avg } A_{\text{shadow}} = \frac{A_{9\text{am}} + A_{10\text{am}} + \dots + A_{5\text{pm}}}{9}$$

$$\text{GSF} = A_1 + A_2 + \dots + A_N$$

$$R_{\text{Shadow}} = \frac{\text{avg } A_{\text{shadow}}}{\text{GSF}}$$

VARIABLES:

GSF- TOTAL GROSS AREA ABOVE GRADE

N- NUMBER OF FLOORS

Figure 74: Shadow Area Formula

111 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 75.

SURFACE AREA RATIO

Surface Area Ratio is concerned with identifying excess, illustrating the minimum amount of façade required to enclose the volume versus any additional or subtractive form applied. Return surfaces are included. A ratio of one insinuates an extruded building with all four sides and four ninety-degree corners.¹¹²

VARIABLES:

SAR- SURFACE AREA RATIO

$$R = \frac{\text{ARTICULATED SURFACE AREA}}{\text{BASELINE SURFACE AREA}}$$

A_B- BASELINES SURFACE AREA- MINIMUM FLAT SURFACE OF ENCLOSURE

$$\sum A_0 = A_1 + A_2 + \dots + A_N$$

A₀- ARTICULATED SURFACE AREA - ALL RETURN SURFACES EXTEND BEYOND THE BASELINE SURFACE AREA

Notes:

This measurement does not include additive facade elements such as fins.

Figure 75: Surface Area Ratio Formula

112 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 79.

PERIMETER ENCLOSURE FACTOR

Shape and form are often considered as somewhat of a subjective decision. This factor reveals a cost influence concerned with efficiency of a building's shape and form. Looking for optimal perimeter length, the perimeter enclosure factor is derived by dividing the length of the perimeter of the building by the optimal perimeter length, the circle. The shape/form of a circle is identified as the minimum perimeter required so the final measurement provides an actual versus optimal. Ultimately the ratio that is closest to 1.0, results in cheaper construction cost within the façade system.¹¹³

$$R = \frac{PE_{\text{LENGTH}}}{BE_{\text{CIRC}}}$$

VARIABLES:

PE_{LENGTH} - THE LENGTH OF BUILDING ENCLOSURE

BE_{CIRC} - THE IDEALIZED ENCLOSURE OF THE TYPICAL FLOOR AREA.

R- PERPENDICULAR ENCLOSURE LENGTH TO BASELINE CIRCUMFERENCE OF A TYPICAL FLOOR.

Figure 76: Perimeter Enclosure Formula

113 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 83.

PERCEPTIBLE VOLUME

The perceptible volume measures how much space is perceived when a person is standing in a space. This is important because the building's core, structural components, and mechanical floors take up a substantial amount of space. By measuring gross volume including the amount of space that is taken up by the floors, structure, mechanical areas, dropped ceilings, etc., the space essentially left behind is conceived as perceived space.¹¹⁴

$$R = \frac{\text{OCCUPIABLE VOLUME}}{\text{GROSS VOLUME}}$$

VARIABLES:

OCCUPIABLE VOLUME-	THE TOTAL VOLUME OF SPACE A PERSON CAN PHYSICALLY INHABIT. PLAN-NABLE AREA x FLOOR TO CEILING HEIGHT x # OF FLOORS.
GROSS VOLUME-	THE TOTAL VOLUME OF A BUILDING THAT IS USED FOR STRUCTURAL/MECHANICAL/FLOOR SLABS AND OTHER PHYSICAL BUILDING FUNCTIONAL SPACES.

Figure 77: Perceptible Volume Formula

114 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 85.

USEFUL LUMINANCE

Useful Luminance is used to measure the efficiency of the building configuration in relation to natural lighting given the quantity of daylight that the interior plannable area receives. Illuminance is measured in Lux, a measurement of brightness of light in a particular direction, or the quantity of light over an area (1 lumen by 1 sq. meter). 300 Lux is the minimum benchmark of perceptible light. Further definitions of luminance are as follows: luminous intensity is the measurement of brightness in a particular direction, with the base unit of a Candela (roughly one candle). Luminous flux is the quantity of visible light in a particular direction, with the base unit of a Lumen (1 candela by 1 sq. radian). This ratio will aid in understanding how much space will need artificial lighting.¹¹⁵

VARIABLES:

$$R = \frac{\text{AREA} \geq 300 \text{ LUX}}{\text{PLANNABLE AREA}}$$

PLANNABLE AREA (PLA) - MEASURED AT FLOOR LEVEL FROM THE INTERIOR FACE OF PERIMETER ENCROACHMENT SUCH AS MULLIONS, WINDOW SILLS, CONVECTORS, BASEBOARD HEATING UNITS, AND RADITORS TO THE OUTSIDE FACE OF THE CORE ENCLOSURE.

AREA \geq 300 LUX - THE TOTAL AMOUNT OF AREA RECEIVING 300 LUX OF LIGHT, OR MORE FOR ATLEAST 50% OF THE DAY BETWEEN THE HOURS OF 8AM-6PM.

Notes:

Software such as DIVA for Rhino or ECOTECH is required for this analysis.

Figure 78: Useful Luminance Formula

115 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 91.

ENCLOSURE TRANSPARENCY

Enclosure Transparency identifies a ratio of vision glass, which is high cost and high quality versus the amount of spandrel glass. This concept looks to measure the perceivable transparency of an object based on changing material. The results reveal a tall building's true opacity.¹¹⁶

$$R = \frac{SA_V}{T_{SA}}$$

VARIABLES:

SA_V - TOTAL SURFACE AREA OF VISION GLASS.

T_{SA} - TOTAL AREA OF ENCLOSURE SURFACE

Notes:

The total enclosure area include the surface area of roofs and soffits. It is helpful to consider the tower in terms of simple extruded shape when determining the area. It excludes elements like attached columns, mullions, and louvers.

Figure 79: Enclosure Transparency Formula

116 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 95.

SURFACE AREA TO VOLUME RATIO

The Surface Area to Volume Ratio measures how efficiently the building skin wraps around its volume. This is a three dimensional extrapolation of perimeter to area within the whole tower. This ratio also conveys the amount of surface area exposure. A certain shape will require more surface area, but increases in volume will also bring up the number thus raising cost. However, at a certain point the amount of volume produced more than makes up for the surface area required. Therefore, it becomes more economical to continue building taller. In an abstract way, this ratio focuses on cost.¹¹⁷

VARIABLES:

S- SURFACE AREA OF TOWER

V- VOLUME OF TOWER

R- SURFACE AREA / VOLUME RATIO

$$R = \frac{\text{TOTAL SURFACE AREA}}{\text{VOLUME}}$$

Notes:

This measurement does not include additive facade elements such as fins.

Figure 80: Surface Area to Volume Ratio Formula

117 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 99.

PLANNABLE AREA TO EXTERIOR SURFACE AREA

The Plannable Area to Exterior Surface Area factor integrates many variables into one measurement of efficiency. Exterior finishes are one of the most expensive systems, not only to install but also to maintain. Therefore this ratio reveals the maximum plannable area within the overall volume. This factor amplifies core efficiencies and shows how atrium spaces reduce the plannable area, also showing implications of the floor-to-floor height, and how efficiently plannable areas can be stacked within the same volume. The reasoning for this factor to be included in the environmental category is based on the amount of material and energy needed to condition an area.¹¹⁸

$$R = \frac{\text{TOTAL PLANNABLE AREA}}{\text{TOTAL SURFACE AREA}}$$

VARIABLES:

TOTAL PLAN-MEASURED AT FLOOR
NABLE AREA - LEVEL FROM THE IN-
TERIOR FACE OF PE-
RIMETER ENCROACHMENT
SUCH AS MULLIONS,
WINDOW SILLS, CON-
VECTORS, BASEBOARD
HEATING UNITS, AND
RADITORS TO THE OUT-
SIDE FACE OF THE CORE
ENCLOSURE.

T_{SA} - SURFACE AREA OF TOWER

Notes:

This measurement does not include additive facade elements such as fins.

Figure 81: Plannable Area to Exterior Surface Area Formula

118 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 103.

CARBON FOOTPRINT

The Carbon Footprint factor of a building is calculated by the total plannable area, divided by the carbon emissions. It is well established that tall buildings require large amounts of energy to operate, where energy is expelled in the form of carbon and other harmful gasses. This factor addresses the implications in the amount of floors in a building, the construction material, construction time, and if the building is located within a seismic zone. The Environmental Analysis Tool™ was used to calculate carbon emissions.¹¹⁹

VARIABLES:

TOTAL PLANNABLE AREA - MEASURED AT FLOOR LEVEL FROM THE INTERIOR FACE OF PERIMETER ENCROACHMENT SUCH AS MULLIONS, WINDOW SILLS, CONVECTORS, BASEBOARD HEATING UNITS, AND RADITORS TO THE OUTSIDE FACE OF THE CORE ENCLOSURE.

CARBON EMISSIONS - INFORMATION FOUND BASED ON THE *ENVIRONMENTAL ANALYSIS TOOL™*

$$R = \frac{\text{TOTAL PLANNABLE AREA}}{\text{CARBON EMISSIONS}}$$

Notes:

The *ENVIRONMENTAL ANALYSIS TOOL™* is available at http://www.som.com/news/new_tool_measures_emissions_from_buildings

Figure 82: Carbon Footprint Formula

119 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 107.

3.1.3 STRUCTURAL EFFICIENCY

VOLUME OPTIMIZATION

For structural reasons, in most cases tall towers have a larger base then taper their way up a desired structural form. Volume Optimization sheds light on the overall volume divided by the base area volume.¹²⁰

$$R = \frac{\text{VOLUME}}{A_b \times H}$$

VARIABLES:
VOLUME- TOTAL VOLUME OF ALL TOWER SEGMENTS
 A_b - AREA OF TOWER'S BASE
H - HEIGHT OF TOWER

Figure 83: Volume Optimization Formula

120 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 111.

WEIGHTED ASPECT RATIO

Aspect ratio is an indication of slenderness. The slenderness of a building can be a remarkable aesthetic phenomenon. As towers strive to attain a certain physique, there are huge structural implications. Therefore, this ratio not only speaks to the apparent dimensions of the form, it assesses a structural condition. While the slenderness ratio concept is not uncommon, this factor addresses an additional step by finding the weighted aspect ratio, including set backs and cantilevering forms, generating a smarter metric.¹²¹

$$R = \frac{\text{HEIGHT}}{\text{WIDTH}}$$
$$\sum R = \frac{(H1/W1) \times (H1/(H1+H2))}{(H2/W2) \times (H2/(H1+H2))} +$$

VARIABLES:
HEIGHT- DISTANCE FROM THE BASE OF THE TOWER TO THE TOP OF THE TOWER
WIDTH- THE SHORTEST DISTANCE FROM ONE SIDE OF THE TOWER TO THE OPPOSITE SIDE OF THE TOWER AT BASE

Notes:

Width is measured from the shortest side of the tower. Aspect ratio is an indication of the slenderness of the tower. A setback tower is measured as a weighted average of the aspect ratio of each mass.

Figure 84: Weighted Aspect Ratio Formula

121 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 115.

WEIGHTED CORE ASPECT RATIO

Core Aspect Ratio denotes the slenderness of a tower's core. The core of a building can vary in configuration, ranging from offset to linear. In almost all cases, cores provide structural support, house mechanical systems, elevator cores, as well as many other necessary building functions. Relationship between the core and the structure results in shear walls. Very tall towers (Supertall and Megatall) often have deformed cores due to elevators falling away when they are no longer needed at higher elevations. The core is an integral part of any tall office building, as many structural, environmental, and spatial conditions originate from the configuration of the core.¹²²

$$R = \frac{\text{HEIGHT}}{\text{WIDTH}}$$
$$\Sigma R = \frac{(H1/W1) \times (H1/(H1+H2))}{(H2/W2) \times (H2/(H1+H2))}$$

VARIABLES:
HEIGHT- DISTANCE FROM THE BASE OF THE CORE TO THE TOP OF THE CORE
WIDTH- THE SHORTEST DISTANCE FROM ONE SIDE OF THE CORE TO THE OPPOSITE SIDE OF THE CORE AT BASE

Notes:

Width is measured from the shortest side of the core. Aspect ratio is an indication of the slenderness of the core. A setback core is measured as a weighted average of the aspect ratio of each mass.

Figure 85: Weighted Core Aspect Ratio Formula

122 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 119.

TAPERING FACTOR

The Tapering Factor measures the transformation of a form from its bottom to top. The structural implications of tapering are considerable, as top-heavy objects require more reinforcement at the base. The ratio is created by the distance of D2 to D (building's center as if it were fully extruded) providing the rate of change in its form.¹²³

$$C_x = \frac{fxdV}{V} \quad C_y = \frac{fydV}{V} \quad C_z = \frac{fzdV}{V}$$

$$R = \frac{\text{TOWER CENTROID VERTICAL DISTANCE}}{\text{EXTRUDED FORM CENTROID VERTICAL DISTANCE}}$$

VARIABLES:

C_x -	PERPENDICULAR DISTANCE IN THE x DIRECTION FROM THE yz-PLANE TO THE CENTROID	EXTRUDED FORM CENTROID VERTICAL DISTANCE-
C_y -	PERPENDICULAR DISTANCE IN THE y DIRECTION FROM THE zx-PLANE TO THE CENTROID	VERTICAL DISTANCE MEASURED FROM THE BASE OF THE EXTRUDED FORM TO THE CENTROID OF THE EXTRUDED FORM
C_z -	PERPENDICULAR DISTANCE IN THE z DIRECTION FROM THE xy-PLANE TO THE CENTROID	TOWER CENTROID VERTICAL DISTANCE- VERTICAL DISTANCE MEASURED FROM THE BASE OF THE TOWER TO THE CENTROID OF THE TOWER

Notes:

The tapering factor describes the rate of change in the form. The extruded form is generated by extruding the base of the tower up to the top of the tower. The extruded form provides a neutral state (baseline) to measure against.

Figure 86: Tapering Factor Formula

123 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 123.

SAIL AREA TO THE PERPENDICULAR

The Sail Area to the Perpendicular is a ratio assessing a building's interaction with the wind. "The face of a building obstructs the flow of wind, acting as a sail."¹²⁴ Sail Area is calculated by computing the square footage of the largest projection or broadest face of the building. Wind loads increase as the broadness of the face increases. Looking at sectional slices at every twenty feet of the building to translate forces resisting capacity is found by averaging the square footage of section slices. Resisting forces increase as the depth of the building increases. This factor helps to understand the counterforce coming from the capacity of the structure running perpendicular to the sail. Sail Area to the Perpendicular measures the efficiency of the entire system.¹²⁵

$$A_{AVG} = \frac{A_1 + A_2 + \dots + A_N}{N}$$
$$R = \frac{A_0}{A_{AVG}}$$

VARIABLES:

R - SAIL AREA TO THE AVERAGE RESTING PERPENDICULAR PLANE

A₀ - THE "SAIL" IS THE LARGEST PLANE OF THE BUILDING MOST SUSCEPTIBLE TO DIRECT WIND LOADS

A - THE RESTING PERPENDICULAR PLANE IS THE AREA PERPENDICULAR TO THE MAIN SAIL, RESPONSIBLE FOR RESISTING LATERAL FORCES FROM WIND

Figure 87: Sail Area to the Perpendicular Formula

Summary

Measuring tall building efficiency requires a broad understanding of the relationship of the building's core, floor plates, and exterior. Using an efficiency analysis, the relationship between tall building elements becomes quantifiable and therefore is measurable against environmental and structural factors. This analysis is helpful to the renovation process as it can expose areas of the tall office building that can be improved.

124 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 127.

125 Masters Research Studio 2013-2014 Northeastern University School of Architecture, *Efficiency: An Analytical Approach to Tall Office Buildings*, (Northeastern University, Boston: 2013), 127.

3.2 Building Class Definitions

For the purposes of comparison, office space is grouped into three classes in accordance with one of two alternative bases: metropolitan and international. These classes represent the subjective quality rating of buildings, which indicate the competitive ability of each building to attract similar types of tenants. A combination of factors including rent, building finishes, system standards and efficiency, building amenities, location/accessibility and market perceptions are used as relative measures. The metropolitan base is for use within an office space market and the international base is for use primarily by investors among many metropolitan markets.

Building amenities include services that are helpful to either office workers or office tenants and whose presence is a convenience within a building or building complex. Examples include food facilities, copying services, express mail collection, physical fitness centers and childcare centers. As a rule, amenities are those services provided within a building. The term also includes such issues as the quality of materials used, hardware and finishes, architectural design and detailing, and elevator system performance. Services that are readily available to all buildings in a market, such as access to a subway system or proximity to a park or shopping center affect the quality of the office market, ultimately affecting all buildings. The class of a specific building may be affected by proximity only to the degree that proximity distinguishes the building (favorably or unfavorably) from other buildings in the market.

The purpose of the rating system is to encourage standardization of discussion concerning office markets, including individual buildings and to encourage the reporting of office market conditions that differentiate among the classes. Nevertheless, Building Owners Management Association International does not recommend the publishing of a classification rating for individual properties.

Metropolitan Base Definitions

Class A: Most prestigious buildings competing for premier office users with rents above average for the area. Buildings have high quality standard finishes, state of the art systems, exceptional accessibility and a definite market presence.

Class B: Buildings competing for a wide range of users with rents in the average range for the area. Building finishes are fair to good for the area and systems are adequate, but the building does not compete with Class A at the same price.

Class C: Buildings competing for tenants requiring functional space at rents below the average for the area.

International Base Definitions

Investment

Investment quality properties are those that are unique in their location in that they are in the best metropolitan markets in the world. Also they are unique in their design and construction quality, the stability of the tenants and the tenant markets that they serve and the outstanding building management that is responsible for operating and maintaining them. These properties stand out as leaders not only within their own metropolitan areas but also within the international investment community.

Investment properties usually contain state of the art mechanical, electrical, life safety, elevator and communications systems. Their finishes are of the highest standards and they often provide the occupants with a mix of amenities - in variety and quality - that is exceptional. Often they house a lead tenant for whom the property is named and usually are located in a premier metropolitan area. Investment grade properties need not be considered "trophy" material, but trophy properties are usually investment grade.

Institutional

Institutional grade properties are those of sufficient size and stature that merit attention by large national or international investors, hence the name. These properties are of good design and construction, although are rarely remarkable in design or in use of construction materials. They are typically large and may be located in secondary metropolitan areas, but invariably have a very stable tenant base.

Speculative

Speculative properties usually will conform to popular design conventions (at

the time of construction), but without the use of exceptional materials or construction methods. The design and construction of these properties emphasizes functionality, in contrast with aesthetics, and the design rarely reflects the image of any particular tenant or occupant. To attract national or international attention, speculative properties must be relatively large, although minimum size requirements are lower for properties located in premier office markets. Multiple tenants often occupy them.

PART FOUR:

MOST INFLUENTIAL TALL BUILDINGS

Lessons for the Future

The sheer amount of tall buildings the industry has spawned in a short time is based on replication of the successful buildings. The massive industry of tall buildings has spouted thousands of buildings, but only a few are exemplary. Most are dumbed down copies of the real thing. In the short time span of tall buildings when monumental success is realized, the “success” is then quickly replicated, partially because of zoning laws and building codes of that time, however, mostly because the extreme cost of development makes failure not an option

Society is partially to blame, since there are only a few who protest the rigorous copying. When protests do arise, as in the case of the Pan Am building in the 1950s, more often than not, the buildings are built as they were originally intended. Over time, the city eventually accepts the eyesores of a building and forgets the brutal attack it made against the city and the skyline.

In the history of tall buildings there were missteps, some which still have not been corrected, but instead were replicated. The exemplary tall building that left its mark on history is not without repair, or is it free from progress.

The following case studies address exemplary tall buildings over the generations of which they were built, identifying the influences and the ‘progress’ they made over time on other buildings. The intentions and reasoning clarify their built existence. The featured tall buildings unapologetically continue to shape the rest of the world and because of this, the hand me down copies that are subpar replicas exist in great numbers. Due to the number of replications that exist, focusing renovations based on what we know now is deemed successful and applying these interventions are a fundamental place to start. It will create a lasting effect

of renewal to the cities they inhabit.

4.1 The First Generation: Beginnings to the 1916 Zoning Law

Born from financial ingenuity seeking to maximize returns on a piece of land, tall buildings were conceived out of developments in structural steel framing and the invention of the lift. Soon conceptions of tall buildings spread across America signifying economic growth and prosperity. The first tall building conceived in this fashion is debated, but it is generally agreed that the Home Insurance Building of 1885 was the first building of this generation. Tall buildings of this generation originally demanded little operating energy as air-conditioning and fluorescent lighting were not yet invented.¹²⁶ Artificial lighting levels were between 22 and 43 lux⁵, modestly low. Naturally ventilated through operable windows, the quality and rent-ability of an office space depended on large windows and high ceilings allowing daylight to penetrate as deeply as possible into the interior. Windows of this time occupied 20%-40% of the façade. Overall, façade construction remained heavy and in combination with dense plaster finishes on the interior walls provided thermal mass. This provided some comfort in internal environments maintaining heat during the winter and absorbing excess heat in the summer, making up for the lack of thermal insulation. Tall buildings of the past were only used as offices.

Reliance Building:

126 Oldfield, Philip, Dario Trabucco, Antony Wood. "Five Energy Generations of Tall Buildings: An Historical Analysis of Energy Consumption in High-Rise Buildings." *The Journal of Architecture* 14, no. 5 (October 2009), 592.

32 N. State Street, Chicago, Illinois
Architect: Burnham and Company
Constructed: 1890-1895
Use: Office
Architectural Height: 202 feet / 61 meters



Figure 88: Reliance Building
(Source: Lepik, Andres. Skyscrapers. Rev. ed. Munich; New York: Prestel, 2008, 31).

After the devastating fire of 1871, Chicago experienced a building boom. Investors were demanding high-rises that could be built fast and divided flexibly in order to make expensive sites profitable. Reliance Building is a steel frame construction as a load-bearing framework. The Reliance Building can still be described as the first of Chicago's skyscrapers still in existence that reveals externally the advantages of steel frame construction developed by its predecessors. It clearly anticipated the "dematerialization" of the façade as a load bearing wall, a development that would not take hold for another thirty years. The Reliance Building was converted into 122 hotel rooms, known today as Hotel Burn-

ham.¹²⁷

The Reliance Building showcases the advantages of steel construction for greater transparency. It also proves that the vertical stacking of floors can be profitable, offsetting the costs of expensive real estate in the city, leading to the eventual vertical rise of the city. This relatively small building makes conversion visible showing how tall buildings can be reused differently than how they were originally intended. The Reliance Building is one of the first examples of a success story copied, not only in its original purpose, but also as a conversion project, since many first generation office towers are now hotels. This proves the case that tall buildings live long after their intended use.

Flatiron Building:
175 5th Avenue, New York, NY
Architect: Daniel H. Burnham & Co
Constructed: 1901-1903
Use: Office
Architectural Height: 285 feet / 87 meters
Floors above ground: 21



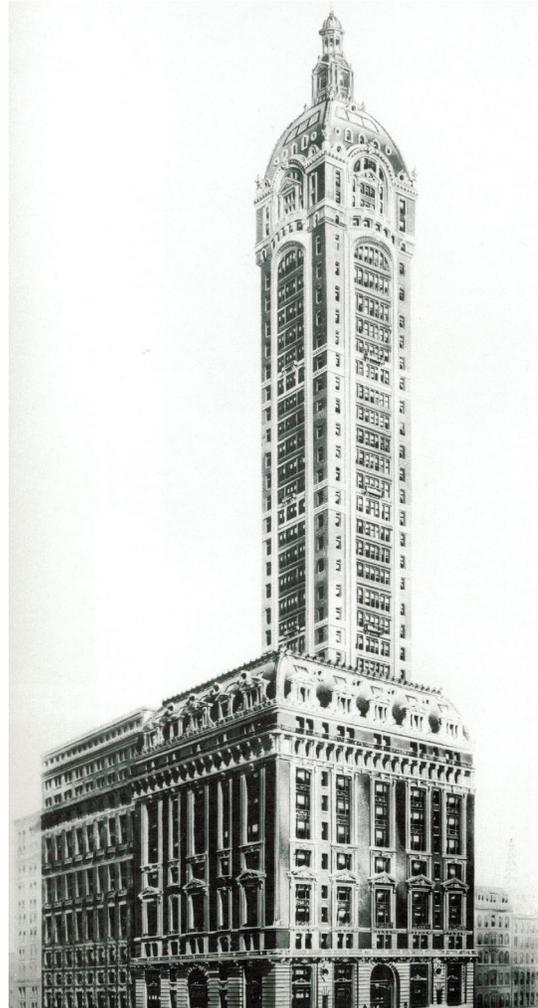
Figure 89: Flatiron Building
(Source: Lepik, Andres. *Skyscrapers*. Rev. ed. Munich; New York: Prestel, 2008, 33).

Built for the Fuller Company, who also later built the Lever House, the Flatiron Building kept its nickname, opposed to its original legal name, Fuller Building. The site is extremely acute angled as the diagonal of Broadway intersects 5th Avenue therefore making the building an unusual shape and soon rose to become one of the landmarks of New York. The narrow and isolated site neces-

127 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 30.

sitated a particularly strong reinforcement of the steel skeleton, in order for it to withstand the high winds encountered at that location. The façade is detailed in the Beaux Arts style.¹²⁸

The Flatiron Building is a testimony to the 'changing of the times' realizing that the effects of efficiency of today's world will not likely conceive another building as acutely shaped. However, The Flatiron Building demonstrates a powerful concept, that tall buildings can be landmarks. Not widely known today, Burnham designed the Flatiron with window shades. As time wore away the evidence, its design intent should remain, skyscrapers should screen themselves from the sun. Remembering this delightful icon should persuade and continue to demonstrate a skyscraper's plasticity, its ability to adapt to any site and any city.



Singer Tower: New York, NY
Architect: Ernest Flagg
Constructed: 1906-1908
Demolished: 1968
Use: Office
Architectural Height: 614 feet / 187 meters

Figure 90: Singer Tower
(Source: Lepik, Andres. *Skyscrapers*. Rev. ed. Munich; New York: Prestel, 2008, 37).

The Singer Tower established a new record height for New York. The slender tower rose out of two fifteen-story buildings. The bedrock of this location was

128 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 33.

91 feet below street level and in between there were clay, sand and other non-loading bearing strata. The Singer Tower became the standard for the zoning law of 1916, because the tower took up only twenty-five percent of the surface of the site. This was established as the basic requirement in the future for all building projects of unlimited height. The Singer Tower held the height record for only a short time. In 1968 when the Singer Tower was demolished, it claimed the record which still stands today as the tallest planned demolition of an office building.¹²⁹

The Singer Tower substantiates the risk involved when only pursuing the quest of height. The Singer Tower's height was due to the success of its foundation, secured in Manhattan's bedrock. Flagg's tower, occupying only a quarter of the site was because of his own beliefs, which later set the stage for zoning laws to protect adjacent buildings from being in constant shadow. More than double the height of the Flatiron building, the Singer Tower ignited yearnings of other corporations to demonstrate their success through building height. Manhattan became the battleground.

Woolworth Building: 233 Broadway, New York, NY

Architect: Cass Gilbert

Constructed: 1910-1913

Use: Office

Architectural Height: 792 feet / 241 meters

Floors Above Ground: 57

Tower GFA: 120,773 m² / 1,299,990 ft²

Elevators: 34 Top Elevator Speed: 3.55m/s



Figure 91:
Woolworth Building
(Source: Lepik, Andres. *Skyscrapers*. Rev. ed. Munich; New York: Prestel, 2008, 38).

The extremely stable steel skeleton was created above a foundation reaching 115 feet to the load-bearing bedrock. A base of thirty stories opened to the

129 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 33.

rear to allow for daylight to enter the offices creating a U-shape, an additional twenty-three-story tower rises from the center of the street façade. Built shortly before the First World War and the zoning laws of 1916, the Woolworth Building became a brilliant conclusion formed from ambitious guidelines becoming the most influential high-rise building for the next twenty years. Architecture became the widely visible symbol of striving for industrial success. The building's success is in its perfect proportion, most advanced technology, traditional decoration, and contemporary comfort as well as its assertive positioning of a building in urban planning. The Woolworth Building lived seventeen years as the world's tallest and underwent recladding in 1977.¹³⁰

It is difficult to separate the success of Woolworth's building from the success of his corporation. Woolworth was motivated and he passed that motivation onto his employees, creating a new social development such as paid vacations and Christmas bonuses. Cass Gilbert was able to translate Woolworth's motivation into a machine for working. The Woolworth Building demonstrated 'success' through maximizing daylight, technology, amenities, and urban planning, all elements designed to make workers more efficient and content. These elements become the guidelines for what is eventually deemed as 'Class A' building standards.

The First Generation of exemplary tall buildings demonstrates that 'tall' has the ability to become a symbol of corporate success, a landmark for the city, a sculpture of its site, a machine for working, and a vehicle for profit.

4.2 The Second Generation: 1916 Zoning Law to 1950

The Second Generation was to be more sensitive than their predecessors. If not wary before about casting shadows as Ernest Flagg was with the Singer Tower, the city was, and New York City authorities made it a law. The Zoning Law of 1916 restricted the bulk of tall buildings, requiring them to allow light and air to penetrate the streets below. Being that New York was at the forefront, setting tall building standards, the zoning law created awareness of the issues of

130 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 39.

light and air, influencing current skyscraper design and beyond. The zoning law led to the 'wedding cake' skyscraper, where 'set-backs' prescribed by the law resembled stacked cakes. The zoning law intended to increase more light to the street by introducing offsets, however this would have inadvertently offset some artificial lighting needs. Despite this, artificial lighting standards increased from the first generation of 86-97 lux to 108-129 lux in the second generation. By the 1930s, experts were suggesting 269 lux.¹³¹ Combining extra lighting needs with the introduction of mechanically conditioned air, the Second Generation of tall buildings used more energy than their predecessors, but still benefitted from thermal mass in their facades. Buildings of the Second Generation are resulting forms of Zoning Laws, showing that law manifests form.



Chicago Tribune Tower:
435 North Michigan Avenue, Chicago, Illinois
Architect: Raymond Hood & John M. Howell
Constructed: 1922-1925
Use: Office
Architectural Height: 463 feet/ 141 meters
Floors Above Ground: 34 Floors Below
Ground: 4
Elevators: 9

Figure 92: Chicago Tribune
(Source: Lepik, Andres. *Skyscrapers*.
Rev. ed. Munich; New York: Prestel,
2008, 33).

The office tower of Chicago Tribune became world famous through its origina-

131 Oldfield, Philip, Dario Trabucco, Antony Wood. "Five Energy Generations of Tall Buildings: An Historical Analysis of Energy Consumption in High-Rise Buildings." *The Journal of Architecture* 14, no. 5 (October 2009), 592.

tion, an international competition with a purse prize of \$100,000. First prize was awarded to the office of Hood and Howells with second place to Finnish architect, Eliel Saarinen. Two hundred and ninety-nine entries were submitted; ninety-five of them arrived late (mostly international entries due to shipping) and were disqualified. It was the European submissions that made the competition legendary. Most American competition entries found inspiration from historic periods of Romanesque, Gothic, or Renaissance. The European entries from Walter Gropius, Adolf Meyer, Thilo Schoder, and Max Taut contained new fundamentals that anticipated further advances in high-rise buildings. A few years later, the Daily News Building in New York modeled the second place design by Eliel Saarinen, a European with new fundamentals. In the end, the Chicago Tribune created a traveling exhibition of all the designs submitted for the public to see.¹³²

The Chicago Tribune showed that despite the skyscraper being an American invention, it was now an international typology. The competition awakened a new age of global advancements suggesting that international hands could better serve the American invention. The international competition served as a great selling tool to public. It was the first time the public was able to view the design advancements through a traveling exhibition. As there were almost four hundred designs, surely someone would be bound to find the one they liked best. Getting the public support and approval for a debatable building typology was a smart move made by the Tribune, and benefited all future skyscrapers in some way. Designs of the time were interchangeable, shown by the Daily News in New York using a Chicago Tribune design for their new building.

132 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 41.

American Radiator Building / Bryant Park
Hotel: 40 W. 40 Street, New York, New York
Architect: Raymond Hood and
J. Andre` Foulihoux
Constructed: 1922-1924
Use: Office / Hotel
Architectural Height: 338 feet / 103 meters
Floors Above Ground: 23
Floors Below Ground: 3
Tower GFA: 11,523 m² / 124,033 ft²
Elevators: 3

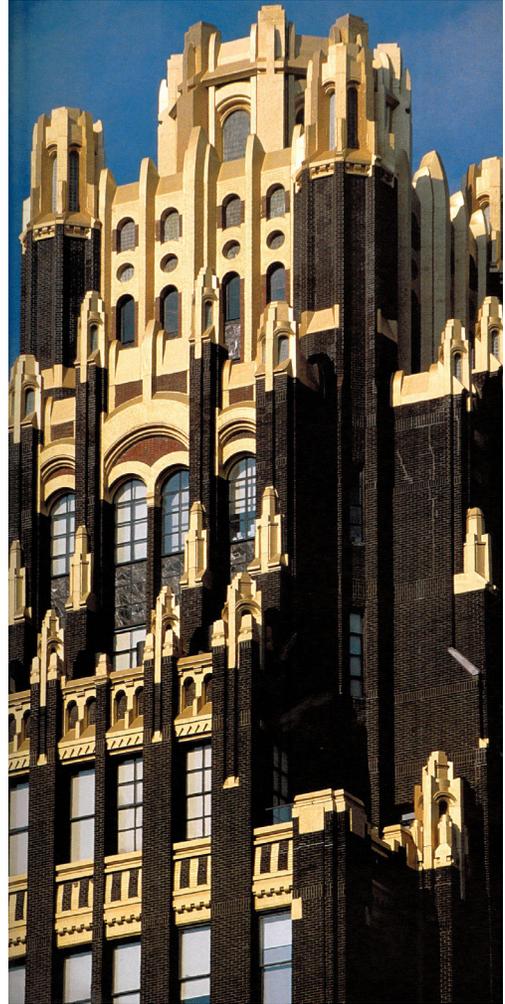


Figure 93: American Radiator Building

(Source: Lepik, Andres. Skyscrapers. Rev. ed. Munich; New York: Prestel, 2008, 45).

Raymond Hood was becoming one of the most-influential architects designing tall buildings. The design for American Radiator Building came one year after winning the Chicago Tribune Tower. The American Radiator Building was the first New York high-rise to conform to the new regulations in zoning laws. The necessary setbacks in the buildings design were varied and dynamic and at the street level the building linked to adjacent shopping on the first and second levels. Hood and Foulihoux used an almost black brick to clad the façade to avoid the windows at daytime from looking like black holes. By nightfall the effect is reversed, when lit from the inside; the building turns into a radiating lantern, a

subtle way to advertise for the American Radiator Company. Hood's American Radiator Building paid tribute to the changing times, adapting Eiel Saarinen's mass distribution seen in his Chicago Tribune Tower entry. The American Radiator Building is known today as the Bryant Park Hotel.¹³³

The American Radiator Building demonstrates how tall building designs can be used as an advertisement. In this case, the design of the building was conceived almost entirely on aesthetics to demonstrate the power of electricity for the client. The American Radiator Building is the first interpretation of branding through architecture of a tall building, a concept later adopted by many tall buildings. Hood's and Foulhoux's understanding and execution of street level programming influenced future designs. This element was included in the redesign of the MetLife Building.

Chrysler Building:
405 Lexington Avenue, New York City, NY
Architect: William van Alen
Constructed: 1928-1930
Use: Office
Architectural Height: 1,046 feet / 319 meters
Floors Above Ground: 77
Tower GFA: 111,201 m² / 1,196,958 ft²
Elevators: 32 Top Elevator Speed: 4.5 m/s



Figure 94: Chrysler Building

(Source: Lepik, Andres. *Skyscrapers*. Rev. ed. Munich; New York: Prestel, 2008, 47).

For only a single year (1930-1931), the Chrysler Building was the tallest building in the world, but remained popular and known as the most beautiful of skyscrap-

133 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 44.

ers, even up to present day. The Chrysler Building was part of a race to new heights, competing against the Bank of Manhattan Company and the Empire State Building. When heights were published, the Chrysler Building was 39 feet (12 meters) short of the Bank of Manhattan's Tower. Therefore a plan for the top was secretly constructed and made of five parts, including a spire totaling 1,046 feet tall. The top of the Chrysler Building was clad in reflective stainless steel making it a star in the skyline giving it a memorable identity; no other building had such a lasting effect. Despite the attractive extension of the top, the upper eleven floors were not rentable due to the division of space. The Empire State Building was redesigned to outreach the Chrysler Building by four feet.¹³⁴

The Chrysler Building is a testimony to the interpretation of branding through architecture. Its shiny top conveys a shiny Chrysler automobile. Although the Chrysler Building has made a lasting impression on the skyline, its unusable top is foretelling of the time. It is no longer financial feasible or responsible to create height for the sake of it if it is not usable. The top of the Chrysler Building presents an interesting opportunity and deserves a second look under today's standards. Perhaps space that was deemed "un-rentable" then can be designed for a different use that is of course without altering its appearance. Due to the significance of the Chrysler Building's top, the MetLife Building's redesign was influenced by its skyline status, ultimately determining any alteration to the MetLife roof could deter from its historic skyline neighbor.

134 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 47- 48.

Empire State Building:
350 5th Avenue, New York, NY
Architect: Shreve, Lamb, and Harmon
Constructed: 1930-1931
Use: Office
Architectural Height: 1,250 feet / 381 meters
Floors Above Ground: 102
Floors Below Ground: 1
Tower GFA: 208,879 m² / 2,248,355 ft²
Elevators: 73 Top Elevator Speed: 7.1 m/s



Figure 95: Empire State Building

(Source: Lepik, Andres. *Skyscrapers*. Rev. ed. Munich; New York: Prestel, 2008, 50).

The Empire State Building's first and foremost goal was to be the tallest tall building in the world and was for forty-one years until the erection of One World Trade Center. Designers succeeded by adding a newly revised mast to the already designed structure, to out do the original four-foot advantage of the Chrysler Building. The Empire State Building's start was only made possible through the demise of the legendary and original Waldorf-Astoria hotel. Upon destruction, the Empire State Building was constructed at record speed with the first sixty floors built in four months between June and September. Over three thousand construction workers were employed and progress resulted in

approximately four and half stories per week.¹³⁵ The Empire State Building is a documented success story of progress, making numerous achievements in planning, logistics, and construction. For construction workers, this innovative planning manifested in cafeterias that would follow them upward. The Empire State Building played a significant role in the movie "King Kong," which may contribute to its super successful observation deck, earning annual revenues of \$92 million, forty percent of total yearly revenue.¹³⁶ The Empire State building had suffered from an increase in vacancy rate over the last decade. Therefore, the building owner invested five hundred million dollars to modernize the building including a major overhaul of its sixty-eight lifts. The overhaul, completed by Otis, modified the cabin's traction control system reduced travel times by twenty to forty percent. A new energy saving system that captures and converts kinetic energy of the moving lift's cabin reduced consumption by seventy percent. The new system allows adjustments for new tenants and increased demands throughout the day.¹³⁷

The Empire State Building is extraordinary, continuing to break records even in the twenty-first century. It demonstrates how an economic machine of a high-rise can continue to renew itself and remain one of the most relevant tall buildings in New York. The Empire State Building is a benchmark building as it is considered to be the most energy efficient tall building as well as the most energy efficient renovated tall building in New York. Even its observation deck is believed to be the most successful in the world. The Empire State Building started its record earning potential by making breakthroughs in construction methods and it still holds the record of having the longest record as the World's tallest.

135 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 50.

136 CTBUH Global News, "Hancock Center Considers Tilting Glass Deck Extension." CTBUH Global News, December 9, 2013, <http://www.ctbuh.org/News/GlobalTallNews/tabid/4810/Article/1022/language/en-US/view.aspx> (accessed February 24, 2015).

137 Trabucco, Dario, Paolo Fava, "Confronting the Question of Demolition or Renovation." CTBUH Journal, Retrofit. no. IV (2013), 41.

Rockefeller Center: New York City, NY
Architect: The Associated Architects: Reinhard & Hofmeister; Corbett, Harrison & McMurray; Hood, Godley & Fouilhoux
Constructed: 1933-1940
Use: Office
Architectural Height: 850 feet / 259 meters



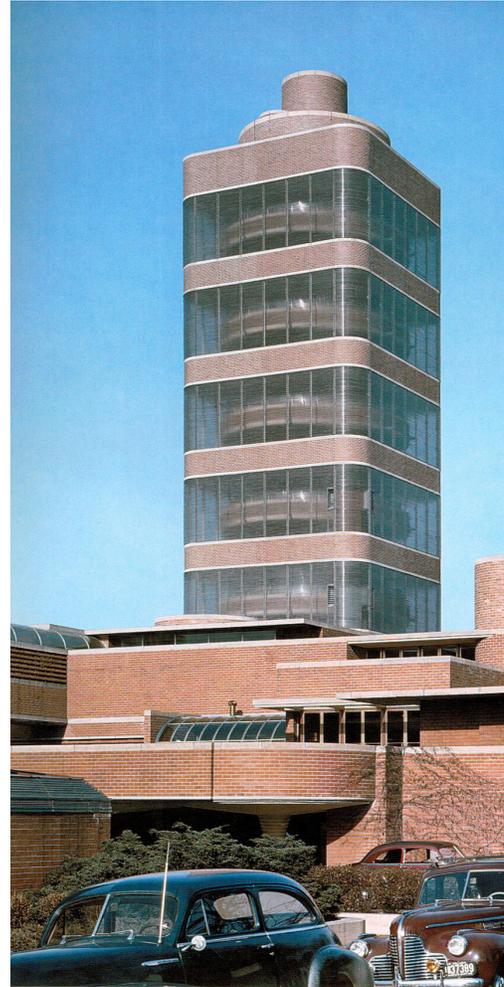
Figure 96: Rockefeller Center
(Source: Lepik, Andres. Skyscrapers. Rev. ed. Munich; New York: Prestel, 2008, 56).

Rockefeller Center was the first of its kind, planned in detail over fifteen acres, a group of tall buildings to stretch for several blocks from 48th and 51st and Fifth and Sixth Avenue. A team of architects was formed called Associated Architects led by Raymond Hood, who defined the project as a “city within a city” right in the heart of Manhattan. The tall buildings were designed for office space intended for RCA and General Electric. The remainders of the buildings were designed as speculative office space with an overall focus on culture. The famous ice-skating rink was originally intended to be a subway entrance and all buildings were to be connected through sky bridges, ideas that never formal-

ized. However, by reclaiming ground space consumed by buildings, rooftop gardens were formed on every tall building, crediting famous architect, Le Corbusier's theories of modernism. The original fourteen buildings expanded since its inception to twenty-one buildings with the tallest still being the most central structure, the original GE building.¹³⁸

Rockefeller Center demonstrates how powerful tall buildings can be when designed as a group. It is not the buildings that make it exemplary; it is the urban planning concepts of making a city within a city that make it exemplary. The massive size of the site precludes it from being replicated. However, the relationship between twenty-one tall buildings is centered around great "public space," making it known for its activities on the site rather than the buildings.

S.C. Johnson Research Tower:
1525 Howe Street, Racine, Wisconsin
Architect: Frank Lloyd Wright
Constructed: 1944-1950
Use: Office
Architectural Height: 151 feet / 46 meters
Floors Above Ground: 14



through the facade

Figure 97: S.C. Johnson Research Tower

(Source: Lepik, Andres. *Skyscrapers*. Rev. ed. Munich; New York: Prestel, 2008, 61).

Ten years after architect Frank Lloyd Wright completed Johnson Wax's administration building known for its inward focus using monumental mushroom-shaped

138 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 57.

columns, he was invited back to design additional space for research laboratories. Using reformulated ideas about workplace design, Wright's fourteen-story tall building was positioned in a closed courtyard alluding to the Japanese temples he had studied. The laboratories were well received according to statements from employees despite the unusual layout of space. The façade was constructed of brick and horizontally stacked Pyrex tubes used in the labs in place of typical glazing. The Pyrex tube façade let light in while screening views, also paralleling Japanese temples. The central core provides structure for the entire building as well as the complex needs of building systems to support laboratory functions. Floors cantilever from the core, and according to CTBUH is "the country's most important examples of cantilevered architecture."¹³⁹ Despite the use of air conditioning, the building was prone to overheating, but the most limiting issue for Johnson Wax was the inability to expand due to the central load-bearing core structure. The limited structure was outgrown within the year.¹⁴⁰ Unfortunately, the facility sat empty for thirty years after S.C. Johnson opened a new research and development center nearby. However, roughly five years ago, a \$30 million renovation was completed and as of spring 2015 free public tours are available.¹⁴¹

Despite Frank Lloyd Wright's infatuation of mile high tower design, he was able to elicit a design with great restraint that explored the central core as the pure form of structure. Within this restraint he was also demonstrating the importance of interior space in relation to the working environment with an inward focus. The S.C. Johnson Research Tower was not copied in its entirety; its structural core was fundamental in exploration of tall building structure seen through tall buildings today.

139 CTBUH Global News, "Tree-Like Wright Tower to Open to the Public." CTBUH Global News, April 23, 2014. <http://www.ctbuh.org/News/GlobalTallNews/tabid/4810/Article/1521/language/en-US/view.aspx>, (accessed March 13, 2015).

140 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 60.

141 CTBUH Global News, "Tree-Like Wright Tower to Open to the Public." CTBUH Global News, April 23, 2014. <http://www.ctbuh.org/News/GlobalTallNews/tabid/4810/Article/1521/language/en-US/view.aspx>, (accessed March 13, 2015)

4.3 The Third Generation: Mid-Century Age of Innocence

The Third Generation of tall buildings (1951 to 1973) was heavily influenced by the glazed curtain wall and mechanical air conditioning. The tall buildings of this generation were hermetically sealed and took complete advantage of inexpensive and readily available energy, hence the term, "age of innocence." Despite high levels of transparency, the deep floor plan of this period resulted in poor daylight penetration. Glazing use increased during this time period to seventy to seventy-five percent of the building envelope, from twenty to forty percent of the previous generation. Glass boxes were "fashionable" in this period leading to an array of colors, but predominately "black" or dark-tinted glazing was the favorite choice. Dark-tinted glazing requires even more mechanical air conditioning. This generation made an important compromise, trading the 1916 Zoning Law for the 1961 Zoning Law that granted a twenty percent density bonus for buildings that created a public plaza on a portion of their plot. Tall buildings built toward the end of the generation on average had an energy requirement twice that of buildings constructed in the early 1950s.¹⁴² This glass movement lasted more than a moment, forever influencing tall buildings and because of this, it is the most duplicated of all the generations.

142 Oldfield, Philip, Dario Trabucco, Antony Wood. "Five Energy Generations of Tall Buildings: An Historical Analysis of Energy Consumption in High-Rise Buildings." *The Journal of Architecture* 14, no. 5 (October 2009), 592.

860 & 880 North Lake Shore Drive,
Chicago, Illinois
Architect: Ludwig Mies van der Rohe
Constructed: 1948-1951
Use: Residential Apartments (95 & 174)
Architectural Height: 269 feet / 82 meters
Floors Above Ground: 26
Elevators: 2

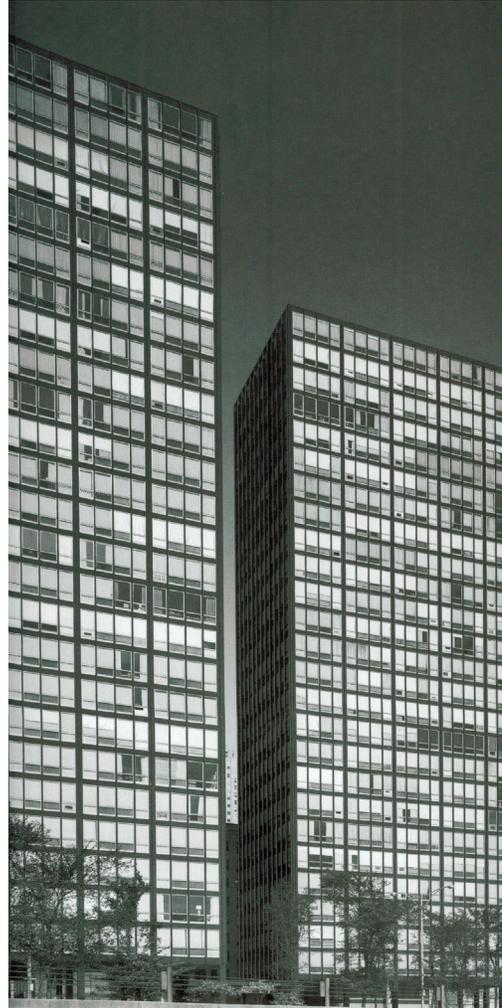


Figure 98: Lake Shore Drive
(Source: Lepik, Andres. Skyscrapers. Rev. ed. Munich; New York: Prestel, 2008, 63).

The Lake Shore Drive Apartments was only Mies van der Rohe's second tall building but this was his first ever curtain façade project, serving as a knowledge base for all his later projects leading up to the famous Seagram House. Made of two towers sitting apart from each other on a ninety-degree angle, the towers were sized to each other in a 6:4 ratio. At the time, his steel construction design was unconventional for residential tall buildings. However, Mies' timing was favorable and the expressed steel frame became visible from the exterior despite the fact that Chicago's building code did not allow construction of multistory buildings using freestanding, non-fireproof materials. Therefore, Mies utilized an

outer skin to encase the load-bearing steel girders, which duplicated their interior structure, the double-T supports/ I-beams. The I-beams on the exterior were a design element that related to the vertical struts.¹⁴³

The Lake Shore Drive Apartments positioned tall building living as affluent. The transparency of the building was perceived as a way to show lifestyle, something only appropriate for the wealthy. The building's view also gave rise to the notion that the best views were reserved for the prosperous. The Lake Shore Drive's steel construction was a new concept for a residential high-rise, but allowed for an aesthetic of expressed steel and transparency that transformed residential tall living.

Lever House:
390 Park Avenue, New York City, NY
Architect: Gordon Bunshaft of Skidmore,
Owings & Merrill
Constructed: 1950-1952
Use: Office
Architectural Height: 302 feet / 92 meters
Floors Above Ground: 21
Tower GFA: 26,967 m² / 290,270 ft²
Elevators: 6



Figure 99: Lever House

(Source: Lepik, Andres. *Skyscrapers*. Rev. ed. Munich; New York: Prestel, 2008, 65).

The Lever House, designed by Gordon Bunshaft at SOM, was designed to make a "clean" looking building for his soap based clients, Lever Brothers. Bunshaft's

143 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 62.

Lever House was to become one of the most influential design ideas in architectural history and was the first ever glass curtain wall façade in New York. There was no tectonic articulation applied to the façade as in Lake Shore Drive Apartments. The Lever House was the modernist's idea of a glass cube. The glass cube did not make any formal reference to its urban context and was realized in a totally logical manner. The building utilized Le Corbusier's Piloti system, standing entirely on supports above its site, creating new public space below while allowing the building's edge from the pedestrians view to disappear. In the center of the ground floor plan lies a garden lit from a large opening in the second floor. The location of the garden was a radical change from the typical centrally located elevator shaft. Careful planning put the slender eighteen-story office building on the north edge of the site. The Lever House was exempt from setbacks at higher levels because it only occupied twenty-five percent of the surface of the site. The Lever House was the first building to use the new zoning provision in this way. Another first for Lever House was the use of inoperable windows; it was the first tall building to be fully air-conditioned. In order to keep the clean look of the Lever House, movable window-cleaning cabins were invented with a running track along the roof, which was later adopted throughout the world.¹⁴⁴ It wasn't just the window-cleaning cabins that were copied. The Lever House became a new benchmark for a sea of plagiarism to follow.

The Lever House is the most influential building type in history in regards to the curtain wall. Its clean façade is also representative of branding through architecture. The Lever House's influence on tall buildings is considered the easiest to see and therefore its duplications can be spotted around the globe despite their differences in climates. However, although the Lever House tower is considered to be exemplary, its public plaza is not.

144 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 6.

Seagram Building:
375 Park Avenue, New York City, NY
Design Architect: Ludwig Mies van der Rohe
Architect of Record: Kahn & Jacobs
Constructed: 1954-1958
Use: Office
Architectural Height: 515 feet / 157 meters
Floors Above Ground: 38
Tower GFA: 59,457 m² / 639,990 ft²



Figure 100: Seagram Building
(Source: Lepik, Andres. Skyscrapers. Rev. ed. Munich; New York: Prestel, 2008, 68).

The Seagram Building is considered one of the most important tall building designs in the history of architecture. Like Gordon Bunshaft's Lever House, the Seagram Building is pushed back from the street leaving the site open for public plazas and two fountains. This was the first time in New York that pedestrians didn't have to cross the street to look up at a tall building. The open space in front of the Seagram Building set a high standard in tall building construction and became a new component of the 1961 zoning laws of New York City. However, since the building only occupied twenty-five percent of the site, Mies was short on rentable office space and height was limited by the number of elevators. Therefore, he had to create a "backbone" made of two additional build-

ings placed on the sides in a “T” fashion. At four and ten stories high, the two additional backbone buildings enlarged the office area by more than one-third. The façade is given an element of relief by using the double-T supports as in Lake Shore Drive Apartments along the vertical window supports and is colored bronze. For the very first time in the history of tall buildings, windows were the same height as the room. The windows were tinted topaz to be in harmony with the bronze frame and gave an impression of closure to the building.¹⁴⁵ The current owner, RFR Holdings purchased the property in 2000 for \$375 million. After failing to resell the building, a \$1 billion loan was taken in order to refinance the landmark tower.¹⁴⁶ In 2014 an announcement was made that the Seagram Building would be getting a new pure white neighbor designed by Foster + Partners, distinguishing itself from Seagram’s dark bronze.¹⁴⁷

The Seagram Tower is an exemplary use of public space. It serves as a great example for the rest of the city and other buildings. The Seagram Tower’s public space layout including the two large water features were instrumental in the redesign of the public space of the MetLife Building.

145 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 69.

146 CTBUH Global News, “Seagram Owners Re-Finance for \$1 Billion.” CTBUH Global News, May 21, 2013, <http://www.ctbuh.org/News/GlobalTallNews/tabid/4810/Article/248/language/en-US/view.aspx> (accessed March 19, 2015).

147 CTBUH Global News, “Seagram Building’s New Neighbor Begins Construction” CTBUH Global News, March 5, 2014, <http://www.ctbuh.org/DesktopModules/DigArticle/Print.aspx?PortalId=0&ModuleId=5721&Article=1327> (accessed March 13, 2015).

Torre Pirelli: Via Fabio Filzi 22, Milan, Italy
Architect: Gio Ponti
Constructed: 1956-1958
Use: Office
Architectural Height: 417 feet / 127 meters
Floors Above Ground: 32 Floors Below
Ground: 2
Elevators: 8

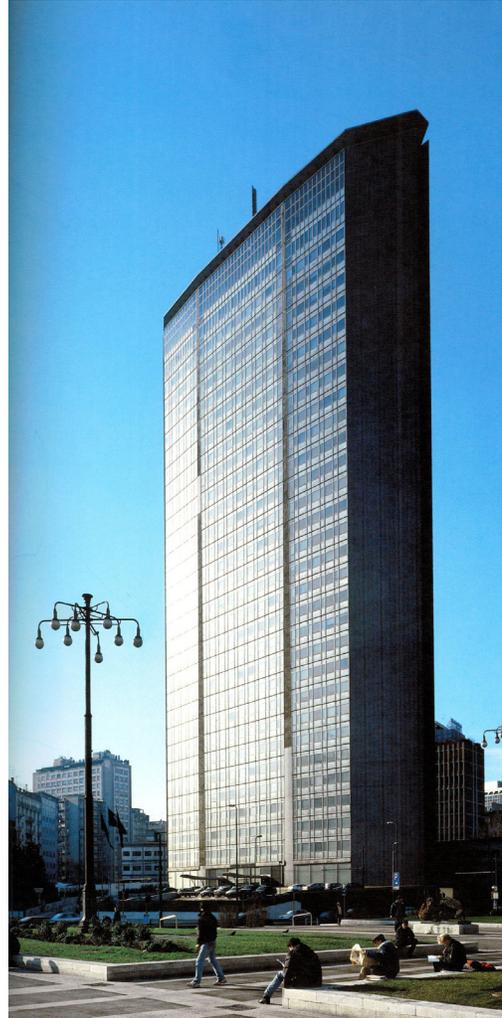


Figure 101: Torre Pirelli

(Source: Lepik, Andres. Skyscrapers. Rev. ed. Munich; New York: Prestel, 2008, 71).

Torre Pirelli was a display of courage on behalf of the client and city by placing an intensified building in the center of the city next to the railway station during the postwar period. Pirelli, an Italian car tire company, was out to prove something to America by securing Gio Ponti, architect, designer and editor of Domus magazine along with Italy's most innovative structural engineer, Pier Luigi Nervi. The poor soil and high wind conditions of the site led to a unique load-bearing structure designed by Nervi, which was made of reinforced concrete that is also visually expressed on the exterior. The building is a polygon, 230 feet (70 meters) long and 61 feet wide (18.5) in the center. The horizontal structural supports are formed into two triangles. On the short ends of the building, two

upward-tapering concrete supports carry the vertical framework without the corners touching. The roof is also unique, as it does not touch the upper edge of the building. The Torre Pirelli design was originally controversial but today is considered among the most successful and elegant high-rises built.¹⁴⁸

Torre Pirelli is an exemplary use of concrete frame construction and design. Many buildings have been influenced by its design. The floating roof is seen repeated in the Pan Am building as well as other buildings. Torre Pirelli was successful in joining Italy into the global tall building craze.

Radisson SAS Royal Hotel: Hammerichsgade 1-5, Copenhagen, Denmark
Architect: Arne Jacobsen
Constructed: 1956-1960
Use: Hotel
Architectural Height: 228 feet / 70 meters
Floors Above Ground: 22 Floors Below Ground: 2
Tower GFA: 267,074 ft² / 24,812 m²
Elevators: 4

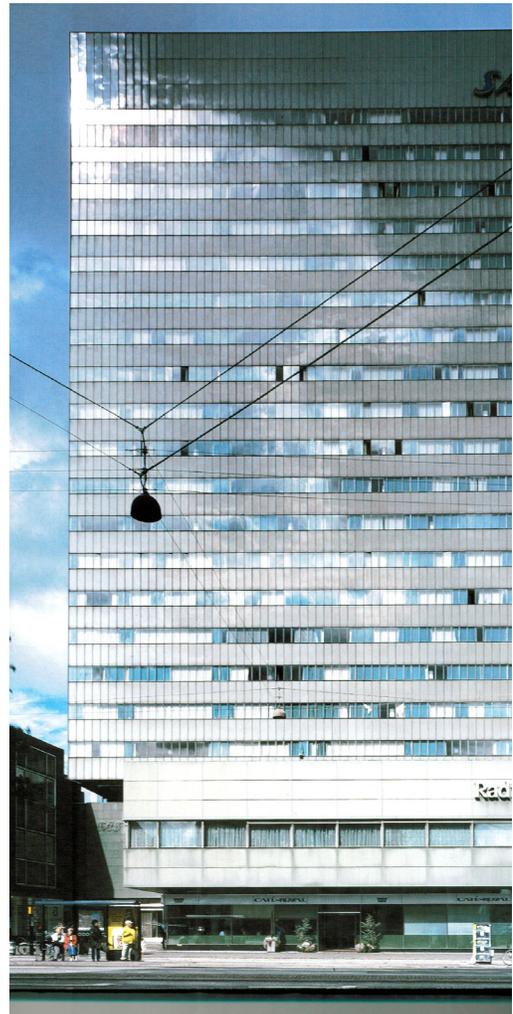


Figure 102: Radisson SAS Royal
(Source: Lepik, Andres. *Skyscrapers*. Rev. ed. Munich; New York: Prestel, 2008, 73).

The Radisson SAS Royal Hotel was designed for Scandinavian Airlines System (SAS) as a central city terminal for their airline passengers arriving by ferry or

148 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 70.

train to have access to a hotel. The hotel included restaurants, saunas, and a bar to make transfer and wait times more pleasant. Like Lever House, SAS Hotel was a closed cube rising from a two-story base, but the SAS is closed at street level and its load-bearing structure is made of concrete not steel. The ground floor has multiple uses including hotel lobby, travel agencies, waiting and transit areas, a restaurant, offices, and conference rooms. The façade is a finely structured curtain facade with grayish-green glass in an aluminum frame to reflect the sky and soften the block-like effect. The windows in the hotel room opens, creating a dynamic façade that is always varied. Arne Jacobsen's commission was for the complete design of the building including all of its details, from furniture to ashtrays. To date only one room, room 606 was preserved with its original furnishings.¹⁴⁹ The Radisson SAS Royal Hotel has 257 rooms.

Radisson SAS Royal Hotel exposed how a cities' transportation can successfully support a private industry through close proximity. It used the cities' infrastructure to service clients and was built for the use of circulation. The architect designed the whole building, down to the detail of its ashtrays. The Radisson SAS demonstrates the importance of proximity to public transport and how that can be successful for the city, its businesses, and its users. This relationship led to the redesign of the MetLife Building because of its proximity to Grand Central Station.

149 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 71.

Thyssenhaus:
August-Thyssen-Straaye
1, Dusseldorf, Germany
Architect: HPP Hentrich-
Petschnigg & Partner
Constructed: 1957-1960
Use: Office
Architectural Height: 311
feet / 95 meters
Floors Above Ground: 26
Floors Below Ground: 2
Tower GFA: 30,300 m² /
326,146 ft²
Elevators: 8



Figure 102: Thyssenhaus

(Source: Lepik, Andres. Skyscrapers. Rev. ed. Munich; New York: Prestel, 2008, 76).

Thyssenhaus also called the “Dreischeibenhochhaus” or “Three Slice High-Rise” was built as an office building for steel firm Phoenix-Rheinrohr AG later Thyssen Krupp AG. In the center of city the sleek slender building stands directly on the main traffic axis. Its longitudinal axis runs north and south with the side views facing east and west completely clad in reflective stainless steel. The south and north side are striped facades of alternating transparent and opaque blue glass in an aluminum frame. The three volumes are staggered in height by one third. By recessing the connection between the buildings, it appears as if they

are separate buildings, when in fact they connect to make an integrated floor plan with the central volume holding the supply core. All office spaces receive natural light along with two corridors that run parallel between the building offices. The entrance lobby ceiling height is over two stories with unblocked views from east to west. Floors above the 22nd floor are designated for the board of directors and an employee-dining hall for the 1,800 staff members. Since Thyssen Krupp AG is a steel company, the structural frame was of course steel with diagonal bracing to stabilize the narrow volumes to protect against enormous wind forces. Thyssenhaus has remained a landmark for the city and a symbol of economic growth for Germany after World War II.¹⁵⁰

Thyssenhaus demonstrates how a high-rise building can show global revitalization, symbolizing economic growth for Germany after WWII. This is a successful example of how a tall building can be integrated as a catalyst for growth when centered on the main traffic axis of the city. This concept influenced choosing the MetLife to be re-designed, affirming that its location is vital to the area and the city as a whole, and therefore deserves revitalization.

150 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 77.

Marina City: 300 North State Street & 301
North Dearborn Street, Chicago, Illinois
Architect: Bertrand Goldberg & Associates
Constructed: 1960-1964
Use: Residential
Architectural Height: 562 feet / 171 meters
Floors Above Ground: 61
Floors Below Ground: 1
Elevators: 5



Figure 103: Marina City

(Source: Lepik, Andres. Skyscrapers. Rev. ed. Munich; New York: Prestel, 2008, 78).

Bertrand Goldberg's research was focused on functional utilization of spaces and Marina City was designed as a "micro city" with varied living concepts to increase populations in the city center. The total complex includes two apartment towers with a mix of uses such as a high-rise office tower, theater, a private landing strip on the Chicago River, green spaces, and an ice skating rink. The Marina City towers are the tallest reinforced concrete buildings to date. Optimization between the exterior and interior space of the floor plan was realized in a sixteen incremental division, producing a circular effect. At sixty-one stories tall, the lower twenty-five stories formed the spiraling car park. The service area completely occupies the whole twenty-fifth floor with the remaining thirty-six

are floors dedicated to apartments. The façade of two towers are reminiscent of corncobs and break the city's dominance of right angles. Their aerodynamic shapes are ideal forms for wind protection, being well suited for the Windy City. Marina City is significant for setting a new direction in theory of form, building, and urban planning.¹⁵¹

Marina City established a new height for tall residential living while demonstrating a new floor plan. Marina City set a new standard of "outdoor" living giving every residence their own lanai/patio space, although this tower can serve as an example of creating isolation between inhabitants and the city. The concept of outdoor space combined with green space of Marina City is revitalized into the redesign of the MetLife Building's podium and courtyard spaces.



Economist Building:
25 St. James Street, London, UK
Architect: Alison and Peter Smithson
Constructed: 1959-1964
Use: Office / Residential
Architectural Height: 174 feet / 53 meters
Floors Above Ground: 17

Figure 104: Economist Building

(Source: Lepik, Andres. *Skyscrapers*. Rev. ed. Munich; New York: Prestel, 2008, 80).

Economist Newspaper Group was ready for a new building with an attached economic research organization. The building authorities specified the site as

151 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 78.

mixed use with a 5:1 ratio of office to residential. Upon winning a competition, Alison and Peter Smithson put their three spatially separated buildings around the center block with an inner plaza. The buildings comprised of a four-story bank on the front corner of St. James's Street in front of an office tower of seventeen stories, and a seven-story apartment. All three buildings were constructed uniformly as steel skeleton structures. A 10.5 x 10.5 ft. module was used for both the bank and office towers, the residential module was cut in half. The façade is made of fossil rich Portland Stone known as "roach" with great porosity and texture. The Economist Building complex showed another way of progression in modest measures, showing consideration for its historic environment and its urban solution integrating work and life. Architects Skidmore, Owings & Merrill renovated the Economist Building Complex in 1990, receiving Grade II status.¹⁵²

The careful integration of mixed uses into an historic context proves that sensitive designs can address diversity of the city. The Smithson's sensitivity and restraint is paralleled into the redesign of the MetLife Building's facade and diversity of uses.

152 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 81.

Lake Point Tower: 505 North Lake Shore Drive, Chicago, Illinois
Design Architect:
Schipporeit-Heinrich Associates
Architect of Record: Graham, Anderson, Probst & White
Constructed: 1965-1968
Use: Residential
Architectural Height: 645 feet / 197 meters
Floors Above Ground: 70
Tower GFA: 1,299,990 ft² / 120,773 m²
Elevators: 9



Figure 104: Lake Point Tower
(Source: Lepik, Andres. Skyscrapers. Rev. ed. Munich; New York: Prestel, 2008, 84).

Lake Point Tower is comprised of approximately 900 apartments with views of Lake Michigan and Chicago's skyline. The design inspiration came from Mies van der Rohe's famous idea of a glass high rise from 1922 where light is reflected on a curved façade made of entirely transparent glass. The idea was transformed into Lake Point Tower. The shape resembles a cloverleaf and stands on a two story rectangular base to accommodate retail stores and 700 vehicles. The roof of the base is landscaped with ponds and playgrounds. The structure is reinforced concrete. The core is triangular and is 59 feet in length with nine elevators, three stairwells and an installation shaft to service sixty-five residential floors. The three-arm design makes it so residents cannot see into other apart-

ments. Short corridors lead to a maximum of six apartments. Water, power, and other supply connections were placed in a way so they could be easily changed or moved. The façade is made of bronze-colored sun-resistant glass in dark aluminum frames. Private outdoor space could not be realized due to high-winds, but each unit has its own self-regulated air conditioner placed between the façade and structural skeleton and is capable of capturing natural ventilation through its slits. Lake Point Tower completely isolates itself from the urban context and presents itself as a hermetically sealed sculpture open exclusively to its residents.¹⁵³

Lake Point Tower's expansive green roof with ponds and playgrounds was instrumental in the redesign of MetLife Building's podium roof design. Special attention was made not to isolate the park space, as is the case with Lake Point Tower, by creating multiple access points and vistas around the MetLife tower.

John Hancock Center: 875 North Michigan Avenue, Chicago, Illinois
Architect: SOM Skidmore, Owings & Merrill
Constructed: 1965-1969
Use: Residential / Office
Architectural Height: 1,217 feet / 344 meters
Floors Above Ground: 100
Tower GFA: 2,799,973 ft² / 260,126 m²
Elevators: 50 Top Elevator Speed: 9.2 m/s



Figure 105: John Hancock Center

(Source: Lepik, Andres. *Skyscrapers*. Rev. ed. Munich; New York: Prestel, 2008, 88).

The John Hancock Center made numerous contributions to tall building progress. SOM's engineer Fazlur Khan who made a break through at the time, dis-

153 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 84.

missing the non-load-bearing façade that had become the standard, instead developing a steel tube load-bearing framework system. The new load-bearing framework forms a very stable and visible structure allowing for increased heights using less steel. For example, a one-hundred-story building could be produced at a cost similar to a forty-five-story building. This economic breakthrough instilled worldwide interest in the topic and quest for height once again. The upward tapering obelisk shaped tower reaches one hundred stories. The windows are placed in the center of the steel load-bearing structure expressing the façade. The design architect from SOM, Bruce Graham, said, "It was essential to us to expose the structure of this mammoth as it is to perceive the structure of the Eiffel Tower." In the Chicago tradition of mixed use structures, John Hancock Center follows tradition with its first five stories dedicated to retail, topped with a six-story garage, and with twenty-nine stories above for office space. On top of the offices there is a hotel, followed by forty-eight stories of residential apartments. The 94th floor contains an observation deck, and the 95th and 96th floors have a restaurant and bar. John Hancock Center is "city within a city," a concept originated by Raymond Hood, with a supermarket, post office and swimming pool. The John Hancock Center is exceptionally planned, however its urban integration is not. The sunken plaza in front does not create any relationship between the mammoth building or its surroundings.¹⁵⁴ In 2014, the tower added "Tilt," a window that actually tilts out over the streets ninety-four floors below, providing visitors a new way to experience the tower's height and boost observatory revenues from the current \$10 million.¹⁵⁵

The John Hancock Center's lack of urban integration impacted the redesign of the MetLife Building's first floor. Although the MetLife Building does not have a sunken plaza, its redesign focused on elevating streetlife by creating an extension of the first floor into a ramping urban park on its roof. The John Hancock Center was also instrumental in implementing a public observatory into the MetLife Building as a way to integrate users into the skyline while creating an additional social and economic platform.

154 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 88.

155 CTBUH Global News, "Hancock Center Considers Tilting Glass Deck Extension." CTBUH Global News, December 9, 2013, <http://www.ctbuh.org/News/GlobalTallNews/tabid/4810/Article/1022/language/en-US/view.aspx> (accessed February 24, 2015).

Nakagin Capsule Tower:
6-10-8 Ginza, Chuo-ku, Tokyo, Japan
Architect:
Kisho Kurokawa Architects & Associates
Constructed: 1970-1972
Use: Hotel
Architectural Height: 177 feet / 54 meters
Floors Above Ground: 13
Floors Below Ground: 1
Tower GFA: 33,271 ft² / 3,091 m²



Figure 106: Nagakin Capsule
(Source: Lepik, Andres. Skyscrapers.
Rev. ed. Munich; New York: Prestel,
2008, 91).

Circa 1960, a group of young Japanese architects formed, calling themselves the, Metabolists, responding to the increasing density of Japan's big cities. Their foundation developed concepts that created architectural solutions that could adapt to individuals, society, and cities without hierarchy in organization. The Nagakin Capsule Tower was only one of a few projects that were built. The capsule towers fulfilled two main concepts through two identical towers varying in height, a durable primary structure, and a secondary flexible structure. The primary structures were constructed with concrete and contained the cores. The secondary structures, the cells, were made of prefabricated steel frames with

sheet metal.¹⁵⁶ The residential cells, the living capsules, “plug in” to the cores. The cells were fully furnished with a bed, bath, seating, storage space, television, air-conditioning, and one circular window, all fitting into three hundred square feet. The original vision of Kurokawa was to own a capsule, allowing you to keep all of your belongings intact and simply move your capsule to a new location within the city. And when needed, owners could purchase a new capsule. However, the actual cost to build the capsule proved to be too expensive causing Kurokawa’s vision to come to a stand still. The building is in disrepair facing the threat of demolition since 2007.¹⁵⁷

4.4 The Fourth Generation: 1973 Energy Crisis, The Age of Consciousness

The Fourth Generation of tall buildings benefited from a widespread switch to double-glazing and increased technological development in curtain wall façades. Most buildings constructed today are still considered to be of the “fourth generation,” demonstrating a compact shape and with high levels of glazing and reliance on air-conditioning.¹⁵⁸

156 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 90.

157 CTBUH Global News, “Tokyo’s Futuristic Capsule Threatened With Demolition.” CTBUH Global News, October 3, 2014, <http://www.ctbuh.org/News/GlobalTallNews/tabid/4810/Article/2115/language/en-US/view.aspx> (accessed March 19, 2015).

158 Oldfield, Philip, Dario Trabucco, Antony Wood. “Five Energy Generations of Tall Buildings: An Historical Analysis of Energy Consumption in High-Rise Buildings.” *The Journal of Architecture* 14, no. 5 (October 2009), 592..

Willis Tower (Sears Tower): 233 South Wacker Drive, Chicago, Illinois
Architect: Bruce Graham of SOM Skidmore, Owings & Merrill
Constructed: 1970-1974
Use: Office
Architectural Height: 1,451 feet / 442 meters
Floors Above Ground: 108 Floors Below Ground: 3
Tower GFA: 4,477,787 ft² / 416,000 m²
Elevators: 104 Top Elevator Speed: 8.1 m/s



Figure 107: Willis Tower

(Source: Lepik, Andres. Skyscrapers. Rev. ed. Munich; New York: Prestel, 2008, 97).

Sears, Roebuck & Co. designed a tower with 4.4 million square feet (410,000 square meters) of usable floor space for 10,000 Sears's employees and 6,000 tenants with one hundred and eight floors. At the time, it was the tallest building in the world with the second largest surface area in the world next to The Pentagon. Fazlur Khan, engineer of SOM, who was responsible for John Hancock Center in Chicago, devised a new construction approach to achieve new

heights with moderate costs. The static structure consisted of nine square tubes 75 feet long divided into five sections. The bundling of load bearing structural tubes was apparent in the form, allowing the upper half of the one hundred and nine eight floors to have a sculptural effect. However, the bottom half of the building appeared massive and closed off. The façade is black with black colored aluminum and black tinted windows, a black giant that was considered even more disconnected to the city than the World Trade Centers at the time. The Sear Towers was the tallest tower in the world for twenty-three years, but it was hardly regarded or accepted by the city.¹⁵⁹ It was rumored that the New York based owners put the tower on the market in 2015 with brokerage firm *Eastdil Secured*. If sold, the tower could fetch \$1.5 billion.¹⁶⁰

The public sentiment towards the Willis Tower is similar to that of the MetLife Building. The MetLife Building is also described as massive and closed off while blocking view of Park Avenue. This element played an important part in the MetLife's redesign of the podium allowing for maximum permeability from all sides of the street into and up the tower.

Citicorp Center:
153 East 53rd Street, New York City, NY
Architect: The Stubbins Associates with



Figure 108: Citicorp Center
(Source: Lepik, Andres. *Skyscrapers*. Rev. ed. Munich; New York: Prestel, 2008, 99).

159 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 97.

160 CTBUH Global News, "Chicago's Willis Tower Said Put Up For Sale." CTBUH Global News, March 4, 2015, <http://www.ctbuh.org/News/GlobalTallNews/tabid/4810/Article/2583/language/en-US/view.aspx> (accessed March 18, 2015).

Emery Roth & Sons

Constructed: 1974-1977

Use: Office

Architectural Height: 915 feet / 279 meters

Floors Above Ground: 59 Floors Below Ground: 3

Tower GFA: 1,578,883 ft² / 146,683 m²

Elevators: 38 Top Elevator Speed: 7.1 m/s

The Citicorp Group, acquired almost the entire block of 53rd and 54th Avenue on Lexington Avenue in New York. The site had been the possession of the Lutheran Parrish of St. Peter's for more than 100 years. The Parrish had agreed to allow a new high-rise to be built as long as there was nothing but free sky overhead; therefore it had to be positioned on the opposite edge of the site from the church. The tall building stands on gigantic supports almost 115 feet high allowing light to wash the ground below, which supports numerous retail shops and outdoor spaces. The Citicorp Center load-bearing structure consisted of diagonal tubes using very little steel. The load-bearing diagonal tubes hide behind the façade of aluminum and reflective blue glass. Citicorp Center's tower was the first to utilize a tuned-mass damper to counteract high winds and violent movement, a 400 - ton concrete block on top of an oil film that moves horizontally, activated by sensors to move the block in opposition, cutting oscillation in half. This invention was utilized in many other tall buildings after. In addition to the dampening, Citicorp was the first to create an unusual triangular roof. Although its form was intended for solar collecting, it was never realized, yet it continued a dialogue of individuality shown through the tops of tall buildings.¹⁶¹

The success of Citicorp's sun washed plaza supporting retail shops and outdoor spaces was instrumental in the redesign of the MetLife Building's first floor and podium. The redesign features a central outdoor courtyard space.

161 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 98.

National Commercial Bank: King Abdulaziz Street, Balad Area, 3555, Jeddah, Saudi Arabia
Architect:
Gordon Bunshaft, Skidmore, Owings & Merrill
Constructed: 1981-1983
Use: Office
Architectural Height: 413 feet / 126 meters
Floors Above Ground: 27
Tower GFA: 765,992 ft² / 71,163 m²
Elevators: 11

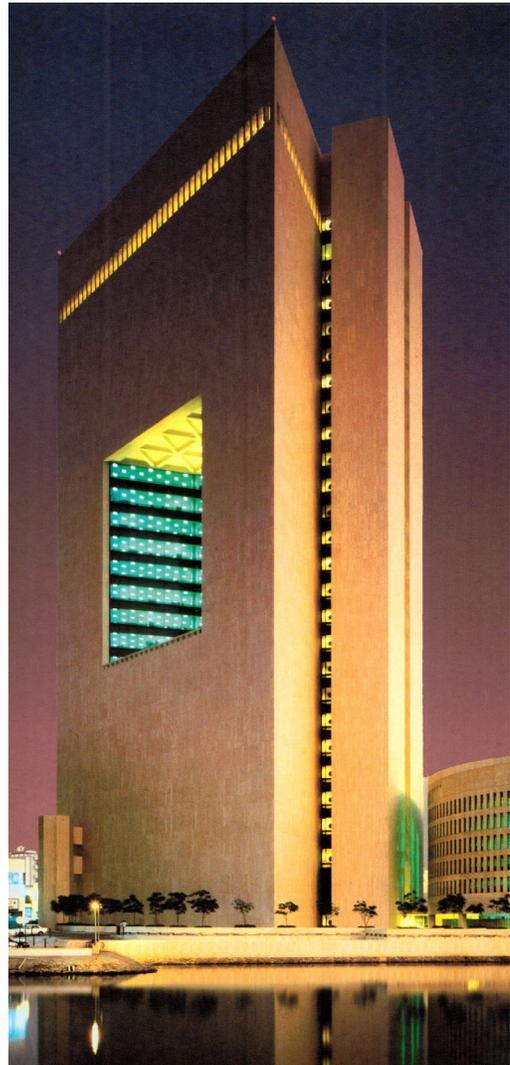


Figure 109:
National Commercial Bank
(Source: Lepik, Andres. Skyscrapers. Rev. ed. Munich; New York: Prestel, 2008, 101).

The National Commercial Bank, the largest merchant bank in the Middle East at the time, commissioned SOM to build a new “impressive and trend setting structure which would link the latest technologies of high-rise construction with the special climatic conditions and building traditions of the country.” Gordon Bunshaft delivered an equilateral triangular base tower with a windowless exterior where the building is orientated entirely toward the interior due to the extreme desert heat. The façade, clad in light-colored roman travertine, reflects

the light, while two inner courtyards overlap to create an opening with views of the old city to one side and the Red Sea to the other. The courtyard provides natural ventilation and light to the building. The supply core, with elevators and staircases, is located on the side without openings to help shade the building. Access is provided through two covered entries, the main entrance is through a circular car park configured to hold six hundred and fifty vehicles or through the green terrace of an auditorium, café, and a lounge.¹⁶² National Commercial Bank is a combination of traditional Arab architecture and modern building form. Gordon Bunshaft proved how adaptable the tall building can be even in a culturally varied context.

The National Commercial Bank inward focus is a result of its climatic context, serving to protect its inhabitant from harsh climate elements while providing great courtyard views. The MetLife Building, although charged as bisecting Park Avenue and disrupting city views is designed to with sun orientation in mind, minimizing sun exposure on its east and west sides allowing for its broad sides to face north and south.

162 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 100.

Hong Kong and Shanghai Bank (HSBC): 1
Queen's Road Central, Hong Kong, China
Architect: Foster + Partners
Constructed: 1983-1986
Use: Office
Architectural Height: 587 feet / 179 meters
Floors Above Ground: 43 Floors Below
Ground: 4
Tower GFA: 1,067,468 ft² / 99,171 m²
Elevators: 28

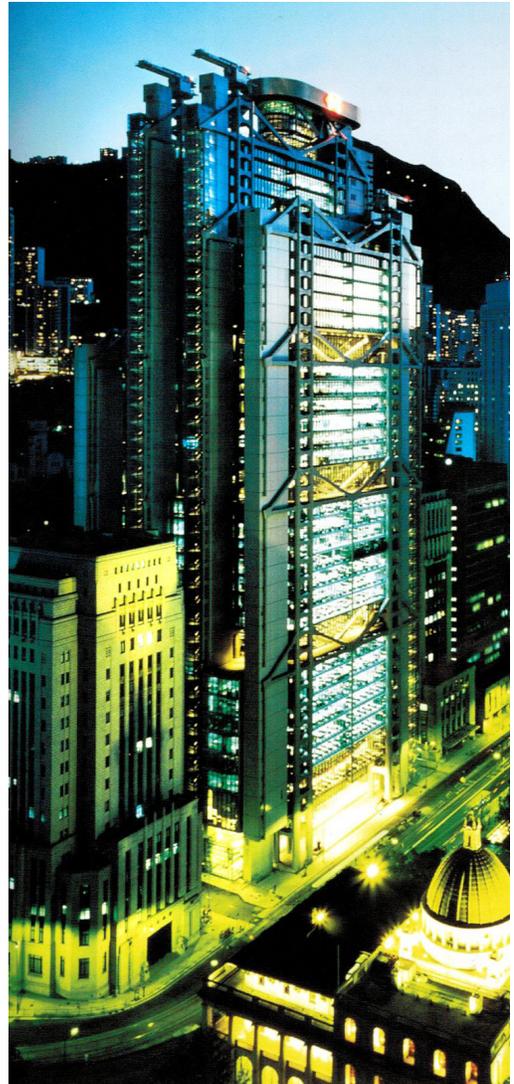


Figure 110: Hong Kong and Shanghai Bank Headquarters
(Source: Lepik, Andres. Skyscrapers. Rev. ed. Munich; New York: Prestel, 2008, 107).

Norman Foster won the design competition for Hong Kong and Shanghai Bank with a phased redesign of the current building, rather than demolishing the existing building. After receiving the project, Foster was forced to give up his original idea and design a brand new tower. However, Foster was able to use one of his original ideas for the new tower, the now iconic, bridge-like structure. To divert the weight of the structure into the foundation, a total of eight masts were used. The masts each consist of four steel tubes linked to each other by

square supports. Then a carrying framework two stories high is attached to the masts, which in turn hold the individual stories. This unique division of load allows for unlimited floor plan designs. The supporting structure is strikingly evident inside and out. The building does not have a traditional façade, because the steel framework is placed in front of the recessed glass facades, as if to overtake it. Where the traditional dark core would lie, an open and transparent central banking hall covers over ten floors supplied with natural light by way of computerized mirrors and reflectors. Foster was noted with numerous inventions for this building including work place lighting and air-conditioning by way of cooled seawater. Circulation zones are connected by escalators, a different but efficient idea, combined with a helicopter-landing pad, are examples of Foster's ability to rethink the space within a tower. The Hong Kong and Shanghai Bank Headquarters was Foster's first realized high-rise but in doing so established a new set of standards. Never before had a tall building appeared so powerful and self-confident in the fabric of a city, and yet remained so sensitively linked to its surroundings.¹⁶³ It also signified anticipations about ecological advances and globalization of tall building, since being designed by a British architect and composed of prefabricated parts from all over of the world. The Hong Kong and Shanghai Bank is an example of global architecture at its best.

The Hong Kong and Shanghai Bank use of escalators, and heli-pad serves as a reinforcement to the MetLife Building's original design utilizing both forms of circulation. Since escalators are an easy way to move people fast, the original escalators connecting Grand Central to the MetLife Building are kept along with implement a series of new escalators on the northwest corner of the site to serve the new retail and park space. Despite the closure of the MetLife Building's heli-pad, the space remains unchanged in the redesign and is still operable. It can still function for air travel or the future use of drones. However, the heli-pad makes a great platform for viewing the city.

163 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 106.

The Bank of China Tower:
1 Garden Road, Central, Hong Kong, China
Design Architect: I.M. Pei & Partners
Architect of Record:
Sherman Kung & Associates Architects
Constructed: 1985-1989
Use: Office
Architectural Height: 1,205 feet / 367 meters
Floors Above Ground: 72 Floors Below
Ground: 4
Tower GFA: 1,453,128 ft² / 135,000 m²
Elevators: 49

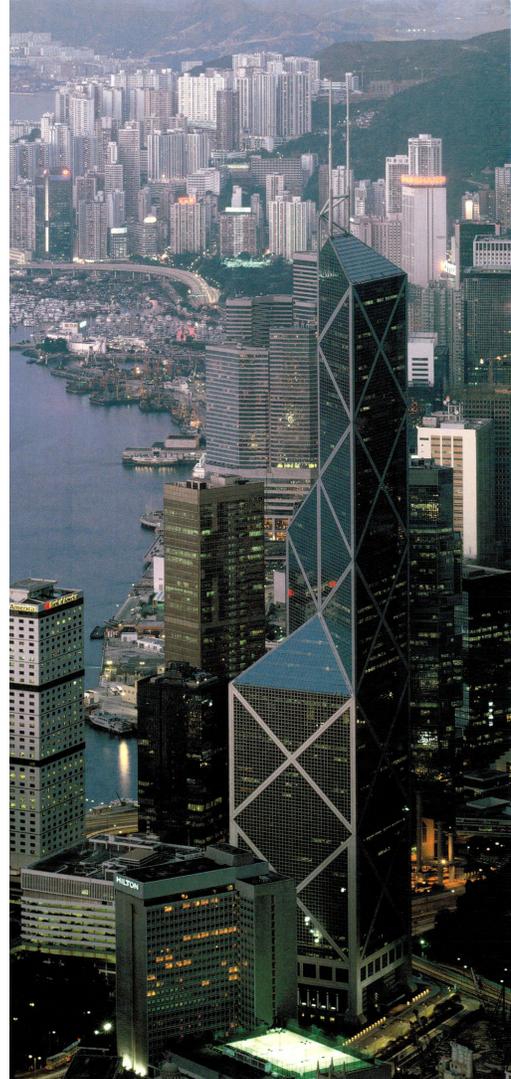


Figure 111:
Bank of China Tower
(Source: Lepik, Andres. Skyscrapers.
Rev. ed. Munich; New York: Prestel,
2008, 113).

The Bank of China building was to become a conspicuous symbol for the future of the city and its fate laid in the hands of Loeh Ming, I.M. Pei's father, who was asked for permission to commission his son. Pei's father let it be his son's decision and Pei accepted. Pei's design is unpretentious, geometrically simple but at the same time carries elegant proportions. The tower grows out of a square, which is then divided into four triangles. The triangles become the vertical static tubes that support the structure. As the tower grows, the triangles stagger in a diagonal sloping direction with set backs at the 25th, 38th, 51st with the glass

following, leaving only one triangle left at the top. The three-dimensional interplay resembles a tangram toy. In order to withstand typhoons, a tall building's stability needs to be twice that of New York's standards. The triangular structure Pei designed was just for that reason as the vertical forces are redirected by the diagonals to the four main structural supports at the base and also at a central core. Pei also achieved excellence in costs as well as greater height and usable floor space. After calculating costs, Bank of China was only one fifth of the cost of HSBC tower. However, there were set backs as the innovative design did not allow for a central core with vertical accesses, and feng shui principles were not considered in the original design. Despite these challenges, Pei overcame and fell in line with his personal fulfillment of achieving an elegantly fashioned tall building for his clients who wanted to symbolize the economic awakening of China while marking an architectural high point for the twentieth century.¹⁶⁴

Tokyo Metropolitan Government Building:
 2-8-1 Nishi Shinjuku, Tokyo, Japan
 Architect: Tange Associates
 Constructed: 1988-1991
 Use: Office
 Architectural Height: 799 feet / 243 meters
 Floors Above Ground: 48 Floors Below
 Ground: 3
 Tower GFA: 2,109,726 ft² / 196,000 m
 Top Elevator Speed: 9 m/s



Figure 112:
 New Tokyo City Hall
 (Source: Lepik, Andres. *Skyscrapers*.
 Rev. ed. Munich; New York: Prestel,
 2008, 117).

Thirty years after designing Tokyo City Hall in 1957, Kenzo Tange was commis-

164 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 110.

sioned again to design the New Tokyo City Hall as the building had become too small to serve the city of over one million people. The new hall was to be outside the old center in Shinjuku where several tall buildings already existed. Tange received approval after winning a limited national competition of nine entries for a double tower, as well as an adjacent tower that is staggered and connected to the towers. In front of the towers is an additional seven-story conference center that is connected to the two main towers by colonnaded footbridges. The footbridges cross over an expressway and link to a semi-circular plaza for public events— in a classical theater kind-of-way sloping downward to the stage. Although the main City Hall buildings are reminiscent of general forms seen in previous double-tower facades, Tange separated the broad structure at a high level to avoid disproportionate massiveness as they rose to forty-eight stories tall. The upper structures, now separate, rotate 45 degrees to appear lighter and counteract rigidity. Tange is noted as playing with the similarity between the towers and electronic microchips, therefore emphasizing this aspect through the façade made of Swedish and Spanish granite according to Japanese methods.¹⁶⁵ The New Tokyo City Hall is a severe high-rise building with references to American, European, and Asian influences. Nevertheless, its general approach to urban planning connects this large structure to the dense urban fabric of the city, making it truly exemplary.

Kenzo Tange's use of footbridges at multiple levels connecting people to public space is a design element carried over to the MetLife Building. Seen as an urban regeneration project converting part of the Park Avenue Viaduct, to a second level pedestrian and cyclist pathway, similar to a footbridge, connects people to a rooftop park above the MetLife Building's podium.

165 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 116.

Menara Mesiniaga: 1, Jalan SS 16/1, SS
16, 47500, Subang Jaya, Malaysia
Architect: TR Hamzah & Ken Yeang
Constructed: 1989-1992
Use: Office
Architectural Height: 207 feet / 63 meters
Floors Above Ground: 15 Floors Below
Ground: 1
Tower GFA: 132,891 ft² / 12,346 m²



Figure 113: Menara Mesiniaga
(Source: Lepik, Andres. Skyscrapers.
Rev. ed. Munich; New York: Prestel,
2008, 119).

IBM Corporation commissioned Ken Yeang for his bioclimatic high-rise research to reveal progressive technological aspects making them visible from the outside and at a distance. Ken Yeang delivered a fifteen story tall building giving the impression of a great machine carried by eight supports with the façade opening and closing in sections arranged around the tower. The exterior loading bearing structure is made of steel, aluminum, and glass. Topping the tower is a super-structure planned as a support for solar cells. Climatic considerations formed the interior and exterior structure, resulting in a massive exterior core containing stairs. Elevators face east to shade the building from morning to midday sun.

The south is protected by deep incisions and suspended aluminum sunscreens. The majority of office space faces west and north. Taking root from the wrap-around sloping gardens at the base, the gardens extend into the tower spiraling up in terraces. The terrace gardens become an extension of the building, visibly bringing the natural environment into the built environment; that can be used as relaxation areas.¹⁶⁶ The top of the building is a sun deck and swimming pool. Ken Yeang, through the Menara Mesiniaga, present an early model for the physical translation of ecological principles into high-rise architecture.

Ken Yeang's ecological principles are vital to the redesign of the MetLife Building, with particular focus to sloping rooftop gardens starting at the base of the podium spiraling up to the sixth floor. The gardens are meant to be natural with a wide range of plant species. The rooftop gardens have many benefits such as Menara Mesiniaga's, but also serves the purpose of aiding in noise reduction, insulation, air pollution, reducing heat island effect, and providing New Yorkers with valuable open, green space.

ACROS Fukuoka Prefectural International Hall: Fukuoka, Japan

Architect: Emilio Ambasz & Associates

Use: Office / Museum and Exhibition

Constructed: 1993-1995

Architectural Height: 197 feet / 60 meters

Floors Above Ground: 14

Floors Below Ground: 4

Tower GFA: 1,000,000 ft² / 92,903 m²



Figure 114: ACROS Fukuoka Prefectural Hall

(Source: Wood, Antony, Payam Bahrami, and Daniel Safarik. *Green Walls in High-Rise Buildings*. CTBUH Technical Guides. New York: Routledge, 2014, 43.)

ACROS Fukuoka Prefectural International Hall is an exemplary synthesis of urban

166 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 118.

and park forms. The north façade resembles a typical urban office façade facing the most prestigious street in Fukuoka's financial district. The south façade is comprised entirely of stepped terraced gardens connecting to Tenjin Central Park, the only green space in the area. Sitting at the edge of the park, the building steps up, floor by floor, creating stratifying layers of low landscaped terraces. Each terraced floor is a vertical extension of the park creating an array of gardens for meditation and relaxation from the congestion of the city. In addition to the greenery in vertical and roof gardens, a series of reflecting ponds steps down the building. Fed by ladder-like upward spraying jets of water, reflecting ponds receive water in a waterfall like way masking the surrounding noise of the city. At the top terraces is an open-side gallery providing magnificent views of the city's harbor.

Originally, the vegetated terraces (four meters high) included thirty seven thousand plants from seventy-six plant species. Over the last ten years the plant species has grown naturally to fifty thousand plants and more than one hundred and twenty plant species. Sprinklers and water filters supplement the natural ecosystem that has been created over time. Primarily watered by rainwater similar to natural systems in the mountains, rainwater flows into the soil at the top and flows through water paths cascading down the soil layer. The use of foam in place of soil in the flattened horizontal areas at the bottom of each terrace offsets the massive weight of soil. Additionally, soil in this area was substituted for an "artificial, inorganic lightweight soil made of perlite, a naturally occurring amorphous volcanic glass, containing mainly silicon dioxide, aluminum, potassium, and sodium dioxides." This soil provided high water retention and great drainage capacity when saturated. Extra reinforcement of the structure was based on saturated conditions with additional waterproofing systems. Waterproofing systems incorporated an underlying drainage system made of plastic. The incorporation of these systems included top-down layers of filtering mats, water drainage, retaining layer, roof mat, perlite, polyethylene sheet, and a waterproof membrane over major I-beam sized at 700 x 300 and minor beams at 400 x 200.

Performance data was gathered in five years after completion verify the significant role of the greenery by reducing building energy consumption, mitigating heat island effect, and cooling surrounding areas. The surrounding area account-

ed for a difference of up to fifteen-degrees Celsius cooler between green areas and adjacent concrete. The ACROS is one of the largest buildings in the world to have its surface covered in greenery. The design successfully gives back public space it would have taken away allowing for a major urban structure to exist symbiotically giving invaluable resource of open public space.¹⁶⁷

ACROS rooftop's design layers is a precedent for the redesign of the MetLife Building's podium green roof. Although the roof does not terrace like ACROS, its slope allows for the same drainage principles aiding in a natural watering system. This design element will contribute to the success of a rooftop garden lessening the amount of watering and maintenance.

Commerzbank: Kaiserplatz 1, Frankfurt
Main, Germany
Architect: Foster + Partners
Constructed: 1994-1997
Use: Office
Architectural Height: 850 feet / 259 meters
Floors Above Ground: 56
Floors Below Ground: 2
Tower GFA: 1,162,502 ft²/ 108,000 m²
Elevators: 25



Figure 115: Commerzbank
(Source: Lepik, Andres. *Skyscrapers*. Rev. ed. Munich; New York: Prestel, 2008, 120).

167 Wood, Antony, Payam Bahrami, and Daniel Safarik. *Green Walls in High-Rise Buildings*. CTBUH Technical Guides (New York: Routledge, 2014), 44-51.

The Commerzbank designed by Norman Foster was the first ecological office tower in the world and the tallest tower in the Europe, at that time. Twelve years after completing the Hong Kong and Shanghai Bank tower, Foster was achieving new breakthroughs in high-rise construction. Commerzbank wished to build the first naturally ventilated and naturally lit high-rise, all of which is now a regulated requirement in Germany. Commerzbank needed their new tower to be integrated into the same site as the old office tower from 1970. The new tower was based on a triangular ground plan curving slightly outward with an open atrium. The corners of the atrium are defined by the structural columns with transport, supply, and waste water disposal facilities. The structural frame is comprised of steel tubes making it extremely stable and weighing only 132,000 tons, which is similar to the weight of the neighboring office tower but considerably taller. Offices are located between columns in each wing with a garden on the third side. At every four stories there is a sky garden that turns into "hanging gardens" as the floor plan twists 120 degrees making the gardens spiral upwards. Foster also integrated nine winter gardens to ensure that enough daylight reached inner offices while providing great views of the city. The naturally ventilated air conditioner was resolved by an intelligent air-conditioning system that used external air from slits between the inner and outer façade. Other energy saving techniques such as heat recovery was utilized reducing Commerzbank energy consumption to far less than traditional tall buildings.¹⁶⁸ Combined with its exceptional spatial qualities, Commerzbank set new standards for the development of tall buildings.

The realization of a naturally ventilated office tower for a Class A tenant was instrumental in the redesign of the MetLife Building's facade. Besides the energy savings benefit, naturally ventilated tall office buildings are increasing in duration due health benefits they provide. Although sky gardens were considered in the redesign, they were not implemented due to the need for leasable space.

168 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 121-22.

Petronas Towers:
Jalan Ampang, Kuala Lumpur, Malaysia
Architect: Cesar Pelli & Associates
Constructed: 1992-1998
Use: Office
Architectural Height: 1,483 feet / 452 meters
Floors Above Ground: 88
Floors Below Ground: 5
Tower GFA: 2,125,872 ft² / 197,500 m² per tower
Elevators: 39 Top Elevator Speed: 7 m/s

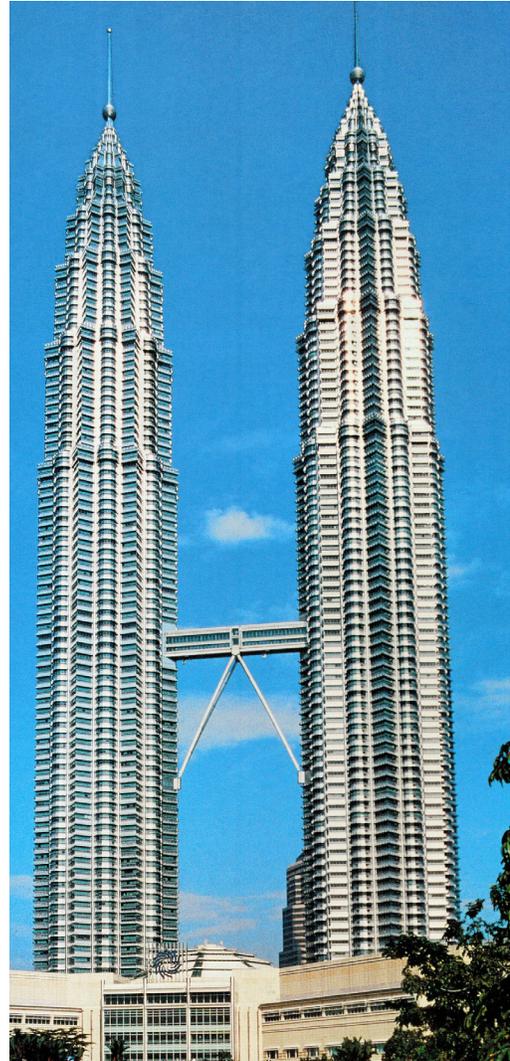


Figure 116: Petronas Towers
(Source: Lepik, Andres. Skyscrapers. Rev. ed. Munich; New York: Prestel, 2008, 125).

Malaysia's state petroleum company decided to join tall building territory with a bit of a different outlook. Not only were the towers going to be very tall, they were going to be part of a large complex for a variety of public and commercial uses in a new district, the Golden Triangle. To conceive of something monumental, eight international firms were invited to partake in a competition to make a significant form but also a symbolic connection to the country. Cesar Pelli, known for his extension to the Museum of Modern Art in New York at the time, won with designing precisely symmetrical double towers to be perceived as a gate to the city. A two-story sky bridge links the towers at 525 feet (160

meters) at the 41st and 42nd floors and is structurally independent of the varying movement of the towers. The structure of Petronas Towers is comprised of a reinforced concrete frame combined with “outrigger” structures to increase rigidity. Pelli borrowed from Islamic patterns creating the form from superimposed squares at 45 - degree angles to form an eight-pointed star. By adding eight semicircles at the point of intersection Pelli creates a sixteen-leaved form. There are sixteen concrete supports in the outer ring that link to the inner concrete core, which is an extremely stable construction method. The façade of the towers is also structurally independent, consisting of glass and polished steel elements to reflect the surrounding elements. While Pelli’s double tower does not set new standards in tall buildings, they did break the record for tallest high-rise in the world ending Sears Tower’s thirty-three year reign, and becoming the tallest building in the world outside North America, signifying the reach and influence tall buildings had spread across the globe. The Petronas Towers have become landmark buildings for Kuala Lumpur.¹⁶⁹

The Petronas Towers are typical of the fourth generation, where the focus is toward structural design of the supertall. They are also representative of the global interchange of tall buildings. In this case, the Petronas Towers demonstrate how elements of tall building design are exponentially duplicated.

Jin Mao Tower: No. 88 Century Avenue, Pudong New Area, Shanghai, China
Design Architect: Adrian Smith of SOM Skidmore, Owings & Merrill
Architect of Record: ECADI
Constructed: 1994-1999
Use: Hotel / Office
Architectural Height: 1,380 feet / 421 meters
Floors Above Ground: 88 Floors Below Ground: 3
Tower GFA: 3,116,152 ft² / 289,500 m²
Elevators: 61 Top Elevator Speed: 9 m/s

Jin Mao Tower marks a new wave of extremely tall buildings. In Pudong province outside of Shanghai, the Jin Moa Tower rises up in a new office district, eighty-eight stories tall. The number eight is significant to the design and is

169 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 124.

considered a lucky number in China. According to Smith, it was on the eighth month of 1988, Deng Xiaoping, the eighty-eight year old Chinese leader stood at the very site declaring it would become the new financial center for China. Later at a restaurant, the client's chairman, Mr. Zhang opened his fortune cookie to discover a fortune of numbers, 8, 16, 24, 32, and 40. After sharing this good fortune with the group, Smith realized there were eight people around the lunch table and the date was March 24: $3 \times 8 = 24$. The number eight became significant to the client and influenced design decisions, especially the client's demands of the building becoming eighty-eight stories tall.¹⁷⁰

Adrian Smith's past experience understanding the relationship between a supertall's exterior form and wind resistance led him to develop a methodology that mitigates the acceleration of movement caused by wind vortices through building form. The wind resistance methodology is designed to mitigate the tower's movement and improve occupant comfort. The method confuses the wind by manipulating the building's form. It is testable in early stages of design and is now widely emulated within the profession aiding in designing the eighty-eight-story building.¹⁷¹



Figure 117: Jin Mao
(Source: Lepik, Andres. *Skyscrapers*. Rev. ed. Munich; New York: Prestel, 2008, 127).

The center contains a static core in octagonal form, representative of the number eight. At sixteen stories the base shrinks by 0.8 meters or (2.6 feet) and this gradual decrease continues upwards until a section comprises only eight floors, where each floor shrinks by 0.8 meters. The tower is mixed use with the first lower fifty stories designed for office use. The top thirty-eight are designed for hotel use with an observation deck. At the fifty-third floor, the hotel contains an

170 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 121-22.

171 Smith, Adrian. "From Jin Mao to Kingdom: Search for an Asian Supertall Vernacular." In *Asia Ascending: Age of the Sustainable Skyscraper City*, (Shanghai: CTBUH, 2012), 34.

open atrium that extends to the top. This is considered one of the most spectacular inner spaces of present day.¹⁷²

The Jin Moa frame is similar to Petronas Towers, as both are comprised of concrete and steel. The structure needed extra stability due to the foundation not being rested on bedrock resulting in two-story high outrigger trusses with mega supports placed behind the façade. This method ensures an extremely high vertical rigidity and weight-bearing capacity. The suspended façade is made of granite, steel, glass, and aluminum. Fire escape methods of China ensured that every fifteen floors contained exit escape spaces which also dual as conference rooms. A current issue in regards to elevator access for hotel guests exists as they try to reach the observation deck on the eighty-eighth-floor, because the elevator banks go from 1 to 54, 54 to 85 and 85 to 87.

Jin Mao Tower has become a new architectural symbol of China, but is recognized in its aesthetics and construction as a typical product of an American architectural firm specializing in skyscrapers. Also a significant awareness is expressed in the changing role of the developer and the influence they carry over the architects' design and process.¹⁷³

172 Smith, Adrian. "From Jin Mao to Kingdom: Search for an Asian Supertall Vernacular." In *Asia Ascending: Age of the Sustainable Skyscraper City*, (Shanghai: CTBUH, 2012), 33.

173 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 126.

Burj al Arab Hotel: Jumeirah Beach Road,
Dubai, United Arab Emirates
Architect: Tom Wright of W.S. Atkins & Partners
Constructed: 1994-1999
Use: Hotel
Architectural Height: 1,053 feet / 321 meters
Floors Above Ground: 26
Floors Below Ground: 3
Tower GFA: 2,152,782 ft² / 200,000 m²
Elevators: 18 Top Elevator Speed: 7 m/s



Figure 118: Burj al Arab Hotel
(Source: Lepik, Andres. Skyscrapers.
Rev. ed. Munich; New York: Prestel,
2008, 129).

W.S. Atkins was commissioned by the reigning sheikh, Muhammad bin Rashid al Maktoum, to create an internationally recognized architectural landmark. The landmark was to be a luxury hotel setting new standards of sensation in every aspect. From furnishings, design, size, and site, the unique luxury hotel was to be an "Arabian Tower." 984 feet (300 meters) from shore, The Burj al Arab hotel became its own island giving hotel guests, unobstructed views of the Arabian Gulf. The hotel was designed to resemble an enormous sail pointing its way to the city. The sail is suspended from a steel load-bearing skeleton with a straight mast at the top and two bent supports. The hotel rooms are located in two

wings with an open-air atrium 590 feet (180 meters) high between. This open side represents the sail made of a double membrane fiberglass fabric strengthened with Teflon. The membrane allows for natural lighting throughout the day and then used as a light projection screen at night. Two hundred fifty reinforced concrete piles were driven over 130 feet deep into the sand to form the base of the foundation. As a seven star rated hotel, it is no surprise at the opulence present, making it the most luxurious hotel in the world. The 202 duplex suites range in size from 1,830 and 7,621 square feet.¹⁷⁴ The building also contains a helicopter-landing pad reinforcing the idea of access by air. Despite Burj al Arab's luxurious offerings, the all too evident symbolism places the building in category of themed architecture with a Las Vegas type feeling. The Burj al Arab Hotel is a display of exuberance and exclusivity showing endless capabilities of architectural significance when financial limitations are not an issue.

4.5 The Fifth Generation: Rising Up Tall 2000 - 2015

This generation of building associates an end period to it, but in fact buildings of this generation are still rare. There are two categories, the "sensitive" and the "supertall." The sensitive are characterized as energy conservative, having a mixed mode system using natural ventilation and exploring on-site energy generation from low- and zero-carbon sources. The supertalls are primarily focused on building height.¹⁷⁵

174 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 128.

175 Oldfield, Philip, Dario Trabucco, Antony Wood. "Five Energy Generations of Tall Buildings: An Historical Analysis of Energy Consumption in High-Rise Buildings." *The Journal of Architecture* 14, no. 5 (October 2009), 592.

Post Tower: Charles-de-Gaulle-Strayye 20,
Bonn, Germany
Design Architect: Murphy Jahn Architects
Architect of Record:
Heinle, Wischer und Parner
Constructed: 2000-2002
Use: Office
Architectural Height: 533 feet / 163 meters
Floors Above Ground: 42
Floors Below Ground: 5
Tower GFA: 1,151,738 ft² / 107,000 m²
Elevators: 19



Figure 119: Post Tower
(Source: Wood, Antony and Ruba Salib, *Natural Ventilation in High-Rise Office Buildings*. CT-BUH Technical Guides (New York: Routledge, 2013),75.)

Each office floor is cross ventilated by drawing fresh air in from the double-skin facade and exhausting it into the central atrium sky gardens through vents in the raised floor system since the sky gardens are separated from the corridors with glazing. Additionally vents at the bottom of each sky garden facade add cool air to aid the stack effect within the nine-story space and vents at the top of each

sky garden facade exhaust the air from the building.¹⁷⁶

The Post Tower is a precedent design for the redesigning of the MetLife Building's facade. Wind studies show the Post Tower and the MetLife Building have similar wind conditions.

30 St. Mary Axe, London, UK
Architect: Foster + Partners
Constructed: 2000-2004
Use: Office
Architectural Height: 590 feet / 180 meters
Floors Above Ground: 40
Floors Below Ground: 1
Tower GFA: 693,949 ft² / 64,470 m²
Elevators: 24 Top Elevator Speed: 6 m/s



Figure 120: 30 St. Mary Axe
(Source: Lepik, Andres. *Skyscrapers*. Rev. ed. Munich; New York: Prestel, 2008, 132).

At the turn of the millennium attitudes changed, allowing new tall buildings to be developed in the inner city of London. For twenty years London sat without any new towers until 30 St. Mary Axe, the Swiss Re Building. According to Jonathan Massey and Andrew Weigand on their piece titled *Risk Design Analytical Drawing*, "To build a new tower, developers and architects convinced planning officers that the buildings would help the City manage threats to its economy and future posed by climate change, terrorism, and the global competition

176 Wood, Antony and Ruba Salib, *Natural Ventilation in High-Rise Office Buildings*. CTBUH Technical Guides (New York: Routledge, 2013), 74-83.

among cities for investment. They did so by designing a building that translated risk into opportunity.” The Swiss Re was designed to have more public street space than its predecessor, the Old Baltic Exchange Building, demolished in 1992 after the Bishopsgate bombing.

Originally, Norman Foster designed a ninety-eight-story Millennium Tower 1,265 feet (386 meters) tall, but was not approved, leading Swiss Re to buy the site and commission Foster to design a smaller high-rise. The form, uniquely giving it many nicknames, most common “The Gherkin,” is designed around aerodynamic experiments informed by wind technologies lowering the resistance to wind. This results in diminishing demands on the load-bearing structure and strong katabatic (downward) winds in the area around the building, fitting into a natural ventilation strategy by using both cross-ventilation and stack effect. “As wind flows around the tower it accelerates, increasing the pressure differentials between the windward and leeward sides for more effective cross-ventilation while reducing downdrafts and causing less turbulence at street level.”¹⁷⁷ Office spaces are traditionally around a central core with elevators, stairs, toilets, service risers, and fire escapes. The load bearing structure is a diagonally braced steel diagrid, a net-like steel construction that lies directly behind the glass façade. This allows column free spaces right up to the core. Spiraling upwards over the whole height of the building is a new element, triangular shaped light wells/atria. Cutting away six triangular forms from each floor plate, maximizes the natural light and fresh air through light wells/atria. Rising up, each floor plate light wells/atria are rotated 5 degrees. Fresh air enters from the windward aria and is dispelled out the leeward atria using inducing cross ventilation.¹⁷⁸ Darker tinted glass placed in these areas creates a striking pattern in the façade. To combat noise and drafts, the light wells/atria are interrupted every six floors by an intermediate floor. The intermediate floors create informal breakout spaces that spiral up over several stories.¹⁷⁹ The spiraling atria utilize stack effect taking advantage of the high and low-pressure zones of the façade created by wind currents flowing around the aerodynamic tower. The outer

177 Wood, Antony and Ruba Salib, *Natural Ventilation in High-Rise Office Buildings*. CTBUH Technical Guides (New York: Routledge, 2013), 87.

178 Wood, Antony and Ruba Salib, *Natural Ventilation in High-Rise Office Buildings*. CTBUH Technical Guides (New York: Routledge, 2013), 84-91.

179 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 132.

façade of the atria contains motorized, open-able triangular windows in groups of four. Although naturally ventilated, forty percent of the year, 30 St. Mary Axe operates on a mixed-mode strategy, utilizing mechanical and natural ventilation to operate concurrently. The building is equipped with a building management system (BMS) that monitors external weather conditions and controls the operation of window openings. The size of the floor plates range from the first floor being fifty meters in diameter, then widening at the seventeenth story to fifty-seven meters, then each floor plates decreases in size until they reach the apex.¹⁸⁰ At the very top, under the suspended glass dome is a restaurant, function room, and a bar, however not open to the public. Originally designed for the single tenant, reinsurer Swiss Re, the building now is rented to twenty different tenants and is also used as a wedding venue.

For London, “The Gerkin” is one of the most sought after addresses and commands the most expensive rents. However, this iconic building, so successfully branded as the future of London, is up for sale. The German property firm IVG Immobilien and co-owner London-based Evans Randall Ltd. are looking to sell the property for £600 m (US \$1 billion) to £650 m (US\$1.1 billion).¹⁸¹ 30 St. Mary Axe is a significant form representing successful development of a European type tall building, paving the way for more urban planning breakthroughs.

The “Gerkin’s” natural ventilation strategy greatly influenced the redesign of the MetLife Building’s facade, integrating multiple methods for ultimate success.

180 Wood, Antony and Ruba Salib, *Natural Ventilation in High-Rise Office Buildings*. CTBUH Technical Guides (New York: Routledge, 2013), 85.

181 CTBUH Global News, “London’s Gherkin Put on the Market.” CTBUH Global News, July 29, 2014. Accessed March 18, 2015 <http://www.skyscrapercenter.com/building/30-st-mary-axe/2369>

Shanghai World Financial Center: No. 100, Century Avenue, Pudong New Area, Shanghai, China
Design Architect:
Kohn Pederson Fox Association,
Irie Miyake Architects and Engineers
Architect of Record: ECADI, Shanghai
Modern Architectural Design Company
Constructed: 1995-2008
Use: Office / Hotel
Architectural Height: 1,614 feet / 492 meters
Floors Above Ground: 101
Floors Below Ground: 3
Tower GFA: 4,107,508 ft² / 381,600 m²
Elevators: 91 Top Elevator Speed: 10 m/s



Figure 121: Shanghai World Financial Center

(Source: Lepik, Andres. Skyscrapers. Rev. ed. Munich; New York: 132).

The Shanghai World Financial Center is a lesson in endurance. Construction started in the 1990's and by 1995 more than two hundred concrete-filled steel friction piles were driven seventy-eight meters into the ground. By 1997, the investor group of thirty-six international firms and banks due to Asia's financial crisis put the project on hold until 1999. The \$625 million tower resumed but the developer needed it to be one hundred and five feet taller than the originally designed 1,509 feet (460 meters) and the "moon gate" circular top that

resembled a Japanese flag's rising sun, needed to be redesigned.¹⁸² The structural engineer determined that the existing foundation could be used for a taller building if the weight was decreased by ten percent and the loads to the piling were redistributed to accept the increased lateral loads from winds and earthquakes. A reduction was made to the concrete shear walls of the service core and the weight was decreased. Another weight reduction was found through the addition of outrigger trusses coupled to the columns of the mega-structure. Despite the decreases in structural design, the Shanghai World Financial Center is complete with robustness and redundancy as the structural system is designed to accept the simultaneous loss of a multitude of structural elements, an awareness that came from the 9/11 attacks. According to Paul Katz, FAIA at KPF and Leslie E. Robertson principle structural engineer of Leslie E. Robertson, "the structural system went through a four-phased program of wind tunnel testing that included:

- Force balance test for structural loads and dynamic response (structure strength and human comfort respectively);
- Pressure test of dynamic pressures and suctions for façade design;
- Environmental test for windiness in the public spaces such as streets and courtyards;
- Aeroelastic test for structural loads and dynamic response."¹⁸³

The structure is comprised of mega-columns of reinforced concrete and structural steel, mega-diagonals of welded steel boxes of structural steel in-filled with concrete, embedded core perimeter trusses, belt-trusses and outrigger trusses. Every thirteen floors of the structure, the mechanical system and exterior envelope are integrated for optimization. Despite the original design's top featuring a hole, referred to as "Moon Gate" or also described as a formal gestural allusion to the two large spheres on the nearby Oriental Pearl television tower, the primary purpose is to reduce wind pressure on the façade. The hole was later revised to a 164 foot-wide parallelogram, a bold feature resembling a "bottle opener" in the skyline. Completed in August 2008, Shanghai World Financial Center was the tallest building in the world and symbolized more commerce.

182 "Vertically Challenged." *Fortune* 139, no. 11 (June 7, 1999): 144–46.

183 Katz, Paul, Leslie Robertson, and SawTeen See, "Shanghai World Financial Center: Without Compromise..." (Dubai: CTBUH Journal, 2008), 13.

The mixed-use building is comprised of one hundred and one floors with the bottom sixty-two floors designated for offices, conference facilities, urban retail, and dining spaces. Above the offices from the seventy-ninth to ninety-third floors is the five star Park Hyatt Hotel, and at the ninety-fourth to one hundredth floor is a visitor square and observatory.¹⁸⁴ The Shanghai World Financial Center revolutionizes structural design while showcasing that the delirium of dedication to tall still exists and can triumph all.¹⁸⁵

Manitoba Hydro Place:
360 Portage Avenue, Winnipeg, Canada
Design Architect: Kuwabara Payne McKenna Blumberg Architects
Architect of Record:
Smith Carter Architects and Engineers
Constructed: 2005-20008
Use: Office
Architectural Height: 377 feet / 115 meters
Floors Above Ground: 22
Floors Below Ground: 1
Tower GFA: 694,993 ft² / 64,567 m²



Figure 122: Manitoba Hydro Place

(Source: Wood, Antony and Ruba Salib, *Natural Ventilation in High-Rise Office Buildings*. CTBUH Technical Guides (New York: Routledge, 2013), 75.)

Manitoba Hydro Place was viewed as an opportunity to develop downtown Winnipeg while supporting a local transit system bringing new vitality to the

184 Wood, Antony, ed. *Best Tall Buildings 2008: CTBUH International Award Winning Projects*. 1 ed. Burlington, MA (Chicago: Architectural Press, 2008), 34-39.

185 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 132.

city. Deliberate studies were done prior to relocating their new headquarters, including a public transport proximity study for its one thousand eight hundred employees. Before relocating, ninety-five percent of the employees drove to work. After relocating, sixty-eight percent of the employees use public transport to and from work. The city is now benefiting from one thousand eight hundred new patrons frequenting local restaurants and shops and the tower's public three story light-filled galleria.

Despite Winnipeg's extreme variations in climate with temperature changes ranging from negative thirty-five degrees Celsius and thirty-five degrees Celsius, Manitoba Hydro Place supplies one-hundred percent fresh air regardless of outside temperatures. The layout consists of two eighteen-story office wings connected to the service core. Each office wing is met and supported by a three-story podium. The form and structure is informed by solar orientation, wind conditions, and other unique climatic conditions specific to Winnipeg. The building plan is an "A" shape, opening up to the south atrium capturing winter sunlight and consistent southern winds. "Fresh air is drawn in through the south atrium. The air then passes into the raised floor distribution plenum and is distributed along the building perimeter. During the shoulder season, supplemental natural ventilation can be provided through the west and northeast double-skin façades. The air is then drawn through glass louvers to the north atrium where stack effect in the solar chimney pulls air from the north atrium and exhausts the building."¹⁸⁶ Design strategies included double-skin facades, segmented atria and sky gardens acting as thermal buffer zones, and a three hundred seventy-seven foot tall (115 meters) solar chimney that extends beyond the building. The double skin façade features operable exterior glazing panels and motorized blinds in a 1.3 - meter cavity.

Other special features include an atrium and a solar chimney. The south atrium has a sixty-foot, floor-to-ceiling water feature that humidifies the incoming air. In the summer months the water can be chilled to the point where it can dehumidify fresh air entering the atria. The solar chimney utilizes stack effect, where in the summer and shoulder months it draws used air up and exhausts it out of

186 Wood, Antony and Ruba Salib, *Natural Ventilation in High-Rise Office Buildings*. CTBUH Technical Guides (New York: Routledge, 2013), 115.

the building. In winter, the solar chimney closes and fans draw warm air down, the air is then re-circulated to warm the parking garage where heat exchangers re-capture the heat and return it to south winter gardens, preheating the incoming air.

In addition to the tangible design strategies, the building uses a geothermal system comprised of two hundred and eighty boreholes one hundred and twenty-five meters deep. The boreholes draw in excess hot or cold air stored within the soil to condition the building. Manitoba Hydro Place is an exemplary example of purpose driven functional design, recording an energy savings associated to heating and cooling of seventy-three percent compared to a fully air-conditioned Manitoba office building with typical annual energy consumption of heating and cooling at 39 kWh/m². This office building serves as a successful model for a naturally ventilated tall building in an extremely cold, dry winter climate with a relatively high amount of sun-hours.¹⁸⁷

CCTV Headquarters: 32 Dongsanhuan Zhonglu, Chaoyang District, Beijing, China

Design Architect: OMA Office for Metropolitan Architecture

Architect of Record: ECADI

Constructed: 2004-2012

Use: Office

Architectural Height: 768 feet / 234 meters

Floors Above Ground: 54

Floors Below Ground: 3

Tower GFA: 5,091,330 ft² / 473,000 m²

Elevators: 75 Top Elevator Speed: 7 m/s

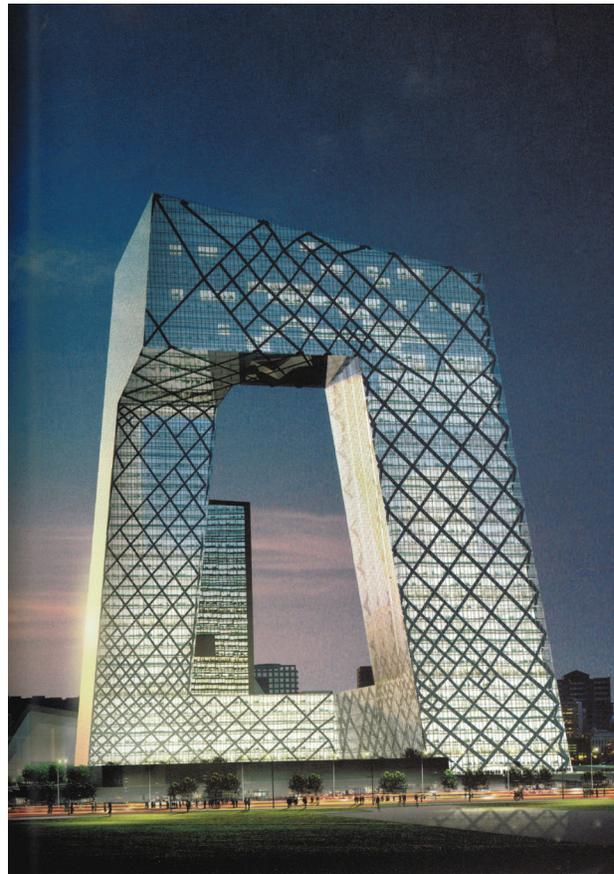


Figure 123: CCTV Headquarters

(Source: Nordenson, Guy, and Terence Riley. *Tall Buildings*. New York: Museum of Modern Art, 2003.)

187 Wood, Antony and Ruba Salib, *Natural Ventilation in High-Rise Office Buildings*. CTBUH Technical Guides (New York: Routledge, 2013), 110-121.

Central China Television Headquarters (CCTV) commissioned Dutch architect, Rem Koolhaas of Office for Metropolitan Architecture (OMA) to contribute to the Beijing skyline for the 2008 Olympic Games in an untypical way. Concerned with spatial and static concepts of tall buildings, Koolhaas choose between two invitations in 2002, Ground Zero in New York and CCTV in Beijing; deciding on the latter. The decision resulted in a winning commission becoming OMA's largest building project at the time in his career.

The six million square foot (558,000 square meters) building bridges production, administration, news stations, and broadcasting into one building. Rising from the same platform, two slanted towers merge at the thirty-seventh floor leaving a deliberately empty center.¹⁸⁸ The structure is comprised of continuous steel tubular columns linked together while closing in on themselves. China's building codes allow for a maximum height two hundred and sixty meters, leaving the two hundred and thirty-four-meter tower well within the limit. However, its geometry was insufficient. The Seismic Administration Office of Beijing Municipal Government arranged a twelve member expert panel to closely examine the structural design concentrating on seismic resistance, seismic structural damage and control, and life safety. "The approval process requires three physical tests in order to verify analytical calculations:

1. Joint Test (butterfly plate): Beijing's Tsinghua University tested a 1:5 scale model of the column-brace joint. This test looks for performance under cyclical loading and specifically the requirements that failure takes place by yielding of the element rather than at the connection.
2. Composite Column: Tongji University in Shanghai tested 1:5 scale models of the project's non-standard steel reinforced columns. These tests came underway because of concerns of reduced ductility from a high structural steel ratio.
3. Shaking Table Test: China Academy of Building Research (CABR) in Beijing tested a seven-meter tall model, in 1:35 scale of the entire building. The test simulated several seismic events including a severe level three earthquake to test structural performance."¹⁸⁹

188 Lepik, Andres, *Skyscrapers*, rev. ed. Munich, (New York: Prestel, 2008), 144-147.

189 Carroll, et al., "CTBUH Journal: Case Study, CCTV Building." CTBUH Journal, no. 3 (2008), 14-24.

The façade interacts with the structure illuminating it with images as a way to reflect the television companies' identity. This design element while not directly relatable to the redesign of the MetLife Building, influences the treatment of the MetLife sign and the design of the facade. The new facade showcases the sign while keeping the original design's intent.

The Shard:
32 London Bridge Street, London, UK
Design Architect: RPBW Renzo Piano
Building Workshop
Architect of Record: Adamson Associates
Constructed: 2009-2013
Use: Residential/Hotel/Office
Architectural Height: 1,004 feet / 306 meters
Floors Above Ground: 73
Floors Below Ground: 3
Tower GFA: 1,372,280 ft² / 127,489 m²
Elevators: 44 Top Elevator Speed: 6 m/s



Figure 124: The Shard

(Source: Nordenson, Guy, and Terence Riley. *Tall Buildings*. New York: Museum of Modern Art, 2003.)

The Shard, also known as the London Bridge Tower, is a mixed-use tower located beside the London Bridge Station on the south bank of the Thames. The Shard is an urban vision responding to London's Mayor, Ken Livingstone and his policy to encourage high-density development at prime transportation hubs in London. "This sort of sustainable urban extension relies on the proximity of public transportation, discourages car use and helps to reduce traffic congestion

in the city.” Residential, office and retail uses keep the tall building in use twenty-four hours a day. The pyramidal form is in response to the floor plate sizes needed for each use— large floor plates at the bottom for offices, restaurants and public space— middle floor plates fit for hotel use providing views for each room— and private apartments at the top are appropriate for occupying one or more floors per tenant. The final floors allow for a public viewing gallery, two hundred forty meters above street level. The overall form is in response to the arrangement of use while tapering off and disappearing into the sky, a significant detail of the Renzo Piano Building Workshop. The “shards” refer to the eight sloping glass facades that define the shape and visual quality of the tower. The extra-white glass façade creates lightness and sensitivity to the surrounding area especially to the skyline. A double skin façade is employed to allow for natural ventilation using internal blinds that automatically respond to changes in light levels— blinds are very effective in mitigating solar gain and are protected inside the double skin façade. Part of the project addresses a section of the London Bridge Station’s concourse that was also re-developed simultaneously becoming a stimulus for regeneration of the surrounding area.¹⁹⁰

The structural frame is mixed using steel framing at the lower floors where longer spans are needed and post-tensioned concrete towards the top where the spans are shorter. The heavier concrete frame at the upper levels replaced the need for structure dampening, freeing up space of two floors, money and weight. The eight-sided building form is a direct response to the historic site and ancient streets. The site did not allow for any “lay-down” space at ground level for construction. For this reason the tower’s spire was prefabricated into modules for easy crane-installation.¹⁹¹

The Shard’s facade design impacted the redesign of the MetLife Building’s facade, implementing elements such as blinds in the facade cavity for sunshading, bright white glazing to minimize bird collisions, and the overall reinvigoration of the design reinforces high density built around the city’s public transportation hubs.

190 Moazami, Kamran and Ron Slade, “Engineering Tall in Historic Cities: The Shard.” CTBUH Journal Issue II (2013), 44-49.

191 Moazami, Kamran and Ron Slade, “Engineering Tall in Historic Cities: The Shard.” CTBUH Journal Issue II (2013), 44-49.

Bosco Verticale Torre D & E: Via De Castilla & Via Confalonieri, Porta Nova 1-20100, Milan, Italy
Architect: Stefano Boeri
Constructed: 2010-2014
Use: Residential
Architectural Height: 279 feet / 85 meters & 382 feet / 116.5 meters
Floors Above Ground: 18 & 27
Floors Below Ground: 3
Tower GFA: 126,939 ft² / 11,793 m² & 201,468 ft² / 18,717 m²
Elevators: 3 Top Elevator Speed: 2 m/s



Figure 125: Bosco Verticale Torre

(Source: Wood, Antony and Ruba Salib, *Natural Ventilation in High-Rise Office Buildings*. CT-BUH Technical Guides (New York: Routledge, 2013),75.)

Bosco Verticale is part of a large urban redevelopment project, Porta Nuova by Hines Italia. The two residential towers 18 and 27 stories tall are all born around the concept of the “vertical forest.” Bosco Verticale meaning “Vertical forest” is described by Stefano Boeri as an experiment of urbanization for the 21st century, based on the premise that the city is still the most appropriate place to live, opposed to sprawl that has left cities without quality and identity.

Boeri served as the architect, green wall designer, and landscape architect. Aligned with Milan's current transformation that has reduced heat island effect and an in-city industrial sector now results in the haze-free skyline, Bosco Verticale's design intent is to increase biodiversity and help establish an urban ecosystem. Projecting balconies, on each floor and on each face contain tree planters with bushes and plants. The objective was to reproduce the equivalent of one hectare of forest vertically providing noise and pollution reduction, shade for cooling, and aesthetic enhancement for tenants. However, this design also positively affects non-human users, attracting birds and insects to re-colonize the city through vegetation and animal life. Plant diversity includes trees, shrubs, and herbs with a rich assortment of fruit, seeds, and flowers.

Cantilevering three meters from the façade, the balconies outer edges vary in width from nine hundred millimeters to one and a half meters and 1.1 meters in height. The overall green coverage of both towers totals to ten thousand one hundred and forty-two meters squared or about forty-two percent of the entire vertical surface area. A new urban ecosystem is achieved by using ninety different plant species. This includes seven hundred trees up to six meters high. The total specimen count is over thirteen thousand plant specimens.

The process and construction techniques are well documented by the Council for Tall Buildings and Urban Habitat through a research seed fund sponsored by Arup, serving as a public interface to the urbanization experiment. The structure is made entirely of concrete. The columns are reinforced concrete and the floors are post-tensioned. Performance tests were utilized to define the dynamic loads using pressure sensors at the base of trees, air permeability of selected species, wind tunnel tests specific to façade, and a full-scale wind tunnel test at Florida International University. This essential knowledge led to safe and efficient solutions that were also mindful of botanical and architectural demands. While it will take several years to form a true quantitative analysis of its success, as the trees still need time to mature, Bosco Verticale is a unique addition to Milan's skyline. Its contributions to maintenance, safety, irrigation systems, plant integrated structural design, plant selection and placement make Bosco Verticale an unprecedented-

ed contribution to tall buildings “representing a different idea of sustainability.”¹⁹² Bosco Verticale gives unprecedented research on process and design integration of trees on tall buildings. This well documented design serves as inspiration to the redesign of the MetLife Building, bolstering the range of tree species now possible to live on rooftops.

One World Trade Center:
1 World Trade Center, New York City, NY
Architect: David Childs of SOM
Skidmore, Owings & Merrill
Constructed: 2006-2014
Use: Office
Architectural Height: 1,776 feet / 541 meters
Floors Above Ground: 94 Floors Below
Ground: 5
Tower GFA: 3,501,274 ft² / 325,279 m²
Elevators: 73 Top Elevator Speed: 10.16 m/s



Figure 126: One World Trade Center
(Source: Lewis, Kenneth, and Nicholas Holt, “One World Trade Center.” CTBUH Journal, Tall Buildings: designs, construction, and operation, no. 3 (2011), 15.)

One World Trade Center is a symbol of innovation in architecture, structure, urban design, safety, and sustainability. Following the nine-eleven attacks, One World Trade Center was faced with unprecedented challenges for a building of its size and location on such a difficult site. Reconstruction started soon after the cleanup finished, underground and out of site. The supertall building includes a transportation hub connecting two hundred and fifty thousand pedestrians every day to its site. The tower’s structure is designed around a massive, redundant steel moment frame consisting of beam and columns. The structural system is a hybrid of high strength concrete and structural steel. The shear walls are made of 14,000 psi concrete compared to the current standard of 8,000 psi. The geometrical shape of the tower reduces exposure to wind loads while creating a kaleidoscope of ever-changing displays of refracted light. The office tower is topped with a rooftop observation deck at one thousand three hun-

192 Giacomello, Elena. “A New Urban Forest Rises in Milan.” CTBUH Journal, Case Study: Bosco Verticale, no. 1 (2015), 12–18.

dred and sixty-two feet from the street level. A glass parapet extends beyond the observation deck floor and stops at the original height of the Twin Towers, one thousand three hundred and sixty-eight feet. At the top, a spire performing multiple functions raises the total building height to one thousand seven hundred and seventy-six feet, symbolizing the year 1776 when America earned independence. Functioning as a broadcasting and digital communication tool, the spire uses Morse code to beacon the letter N, for New York, just as ships did in ports centuries ago. The building looks to have a twenty-five percent reduction in energy consumption, being partially powered by twelve hydrogen fuel cells expected to generate 4.8 megawatts of power for One World and other surrounding buildings. The \$3.2 billion tower has many staggering numbers, two hundred thousand cubic feet of concrete, forty-five thousand tons of structural steel, one million square feet of exterior glazing, and 2.6 million square feet of office space. One World Trade Center serves to be a preeminent business center, and a memorable landmark for the city and the nation.¹⁹³

The quantity and quality, although subjective, of the buildings studied provides a glimpse of what the second century of tall buildings has to offer: urban experiments, technology and one-upmanship. Although the majority of tall buildings do not aim to become a symbol of global economic power, there is still iconic awareness towards aesthetic significance and ethical values combined with human experience. But looming over is the 'two percent' of tall buildings that are

193 Lewis, Kenneth, and Nicholas Holt, "One World Trade Center." *CTBUH Journal, Tall Buildings: designs, construction, and operation*, no. 3 (2011), 14–19.

still striving to be over two hundred plus meters and aim to claim the world's tallest. At the present time it seems technology has no limit, exchanging hands, crossing borders, synthesizing the built world, constructing nature, and informing cultures. Never before have our cities had such interconnectedness. Yet, at the same time the authority remains aligned with power, resulting in duplications of architects, developers, and owners across the globe. Despite this, tall buildings are advancing from technology and one - upmanship even if they are tracing back to passive strategies seen in the first century, evidence that awareness of our on-doings is driving us forward.

4.6 Future of Tall Buildings: Collective Intelligence

As technology and one - upmanship drive us forward, where will it take tall buildings in the next generation? It has already been recorded that 2020 will deliver an era defined by the CTBUH as megatall.¹⁹⁴ Others proclaim, "The age of skyscrapers is at an end. It must now be considered an experimental building typology that has failed. With the arrival of the global economic slump in 2007-2008, so began the end of the age of tall buildings."¹⁹⁵ With what we know now, the age of tall buildings is not over or is sight of its end in view. The tall building typology has truly been an experiment leaving many tall buildings inept and out dated. It is argued that altering tall buildings of the past jeopardizes historical references and robs the city of cultural character and identity, leaving functional obsolete tall buildings untouched in the urban environment, and could effect economic vitality and encourage urban sprawl. In spite of this argument, historic low-rise buildings may provide marketing appeal for some tenants who are willing to ignore inefficient floors plans or environmental comforts for social benefit

194 Hollister, Nathaniel. "The Tallest 20 in 2020: Entering the Era of the Megatall." Press Release. Chicago, December 8, 2011.

195 Leung, Luke, Stephen D. Ray, "Low-Energy Tall Buildings? Room for Improvement as Demonstrated by New York City Energy Benchmarking Data." *International Journal of High-Rise Buildings* 2, no. 4 (December 2013), 285.

of the business. Consequently, this does not translate easily to tall buildings. In a competitive market, the headquarters of a large firm or bank are required to meet very high standards and working conditions to retain their employees, the tenants and its end-users. The standard is even higher for hotel towers, where poor comfort condition may result in non-returning customers.¹⁹⁶ Therefore, it is vital for urban agglomerations of past experiments to be reexamined under the “collective intelligence” from the second century of tall buildings.

If the skyscraper and the twentieth century are synonymous, leaving a legacy of tall buildings, it is up to the current century to become synonymous for transmitting twenty-first century knowledge to that legacy of tall buildings.

196 Trabucco, Dario and Paolo Fava, “Confronting the Question of Demolition or Renovation.” CTBUH Journal, Retrofit. no. IV (2013), 38.

Despite twenty-first century developments, existing tall buildings remain in their original state using excessive energy, impeding street life, and furthering ecological imbalance. An integrated design approach in a renovation can transform existing tall buildings making our cities capable of renewal without having to demolish or build new. A case study analysis demonstrates how a modification of the MetLife Building can impact energy use, street life, and the ecosystem even in the densest, most traveled part of the city.

TALL GLOSSARY

Architect of Record- Usually takes on the balance of the architectural effort not executed by the "Design Architect," typically responsible for the construction documents, conforming to local codes, etc. May often be referred to as "Executive," "Associate," or "Local" Architect, however, for consistency "Architect of Record" is used exclusively.

Building Function- A single-function tall building is defined as one where 85% or more of its usable floor area is dedicated to a single usage. Thus a building with 90% office floor area would be said to be an "office" building, irrespective of other minor functions it may also contain.

Mixed-Use- A mixed-use tall building contains two or more functions (or uses), where each of the functions occupies a significant proportion of the tower's total space. Support areas such as car parks and mechanical plant space do not constitute mixed-use functions. Functions are denoted in descending order, e.g., "hotel/office" indicates hotel function above office function.

City Ranking- The project's height ranking against completed buildings in the same city (according to architectural height). Buildings are only compared against other buildings while telecommunications towers are compared against both other towers and buildings.

Co-joined Building- A building complex is considered to be a single, co-joined building (as opposed to two separate buildings connected by sky bridges or other elements) when 50% or more of the total building height is connected. Exceptions to this 50% rule can be made in cases where the form of the building creates a coherent arch, creating a singular architectural expression and thus a co-joined building.

Collaborative Architect- The Collaborative Architect is an additional organization that is brought in, usually at the request of either the client or the main design architect, to collaborate on the design of the building.

Completion- A building is considered to be "Complete" (and officially added

to the CTBUH Tallest Buildings lists) if it fulfills all of the following three criteria:

- 1) Topped out architecturally¹
- 2) Fully-clad²
- 3) Open for business, or at least partially capable of occupancy

¹ The topping out architecturally of a building implies that ALL structural and finished architectural elements are in place.

² The omission of a small number of cladding panels to allow fixing of a construction hoist while interior fit-out of some building areas is continuing does not affect the status of "fully clad."

Complex- A complex is a group of buildings designed and built as pieces of a greater development.

Demolished- The building has been destroyed by controlled end-of-life demolition, fire, natural catastrophe, war, terrorist attack, or through other means intended or unintended.

Design Architect- Usually involved in the front end design, with a "typical" condition being that of a leadership role through either Schematic Design or Design Development, and then a monitoring role through the CD and CA phases.

Design Engineer- Usually a 1:1 match with the "Design Architect's" efforts for the front-end design, with the "typical" condition being a leadership role through either Schematic Design or Design Development, and then a monitoring role through the CD and CA phases.

Development Gross Floor Area (GFA)- Development GFA refers to the total gross floor area within the entire development in which the tower exists, and may therefore be at times the total sum of several towers and related low-rise buildings.

Engineer of Record- Usually a 1:1 match with the definition of the "Architect of Record's" role. It is the balance of the effort not executed by the "Design Engineer."

Façade Consultant- These are firms that consult on the design of a building's

façade. May often be referred to as “Cladding,” “Envelope,” “Exterior Wall,” or “Curtain Wall” Consultant, however, for consistency “Façade Consultant” is used exclusively.

Floors Above Ground- The number of floors above ground should include the ground floor level and be the number of main floors above ground, including any significant mezzanine floors and major mechanical plant floors. Mechanical mezzanines should not be included if they have a significantly smaller floor area than the major floors below. Similarly, mechanical penthouses or plant rooms protruding above the general roof area should not be counted. Note: floor counts may differ from published accounts, as it is common in some regions of the world for certain floor levels not to be included (e.g., the level 4, 14, 24, etc. in Hong Kong).

Global Ranking- The project’s height ranking against all completed buildings globally (according to architectural height). Buildings are only compared against other buildings; towers are excluded.

Height: Architectural- Height is measured from the level of the lowest, significant, open-air, pedestrian entrance to the architectural top of the building, including spires, but not including antennae, signage, flag poles or other functional-technical equipment. This measurement is the most widely utilized.

Height: Observatory- Height measure from the level of the lowest, significant, open-air, pedestrian entrance to the building’s public observatory, which may be either internal or external.

Height: Occupied Floor- Height is measured from the level of the lowest, significant, open-air, pedestrian entrance to the highest occupied floor within the building.

Height: To Tip- Height is measured from the level of the lowest, significant, open-air, pedestrian entrance to the highest point of the building, irrespective of material or function of the highest element (i.e., including antennae, flagpoles, signage and other functional-technical equipment).

Interior Fit-Out- the installation of ceilings, floors, furnishings, and partitions of a building, as well as the installation of all required building services.

Level- Level refers to finished floor level at threshold of the lowest entrance door.

Main Contractor- The main contractor is the supervisory contractor of all construction work on a project, management of sub-contractors and vendors, etc. May be referred to as "Construction Manager," however, for consistency "Main Contractor" is used exclusively.

National Ranking- The project's height ranking against completed buildings in the same country (according to architectural height). Buildings are only compared against other buildings while telecommunications towers are compared against both other towers and buildings.

Never Completed- Construction works had begun, but work on-site was halted and never resumed. The site may go on to accommodate a new building, different to the original design, that may or may not retain the original construction.

On Hold- Construction works had begun, but work on-site has been halted indefinitely. However there is still intent to complete the construction to the original design at a future date.

Open-air- A open-air entrance must be located directly off of an external space at that level that is open to air.

Other Consultant- Other Consultant refers to other organizations that provided significant consultation services for a building project (e.g. wind consultants, environmental consultants, fire and life safety consultants, etc.)

Pedestrian Entrance- Is an entrance that is available to common building users or occupants and is intended to exclude service, ancillary, or similar areas.

Peer Review Engineer- Usually is not driving a part of the design, such as the "Design Engineer". This role is traditionally to comment on the information pro-

duced by the other party, and to render second opinions, but not to initiate what the design looks like from the start.

Proposed- A building is considered to be 'Proposed' (i.e., a real proposal) when it fulfills all of the following criteria:

- 1) Has a specific site with ownership interests within the building development team
- 2) Has a full professional design team progressing the design beyond the conceptual stage
- 3) Has obtained, or is in the process of obtaining, formal planning consent/legal permission for construction
- 4) Has a full intention to progress the building to construction and completion

Only buildings that have been announced publicly by the client and fulfill all the above criteria are included in the CTBUH "proposed" building listings. The source of the announcement must also be credible. Due to the changing nature of early stage designs and client information restrictions, some height data may be unconfirmed.

Recladding- A building is said to have undergone a recladding when a significant architectural alteration has been made to the façade of the building.

Renovation- is any renovation of a building where (a) the total cost of the renovation related to the building envelope or the technical building systems is higher than 25 % of the value of the building, excluding the value of the land upon which the building is situated, or (b) more than 25 % of the surface of the building envelope undergoes renovation.

Significant Entrance- A significant entrance is an entrance which is predominantly above existing or pre-existing grade and permits access to one or more primary uses in the building via elevators, as opposed to ground floor retail or other uses which solely relate/connect to the immediately adjacent external environment. Thus entrances via below-grade sunken plazas or similar are not generally recognized. Also note that access to car park and/or ancillary/support areas are not considered significant entrances.

Structural Material- A steel tall building is defined as a building where the main vertical and lateral structural elements and floor systems are constructed from steel.

A concrete tall building is defined as one where the main vertical and lateral structural elements and floor systems are constructed from concrete.

A composite tall building utilizes a combination of both steel and concrete acting compositely in the main structural elements, thus including a steel building with a concrete core.

A mixed-structure tall building is any building that utilizes distinct steel and concrete systems above or below each other. There are two main types of mixed structural systems: A steel/concrete tall building indicates a steel structural system located above a concrete structural system, with the opposite true of a concrete/steel building.

Additional Notes:

- 1) If a tall building is of steel construction with a floor system of concrete planks on steel beams, it is considered a steel tall building.
- 2) If a tall building is of steel construction with a floor system of a concrete slab on steel beams, it is considered a steel tall building.
- 3) If a tall building has steel columns plus a floor system of concrete beams, it is considered a composite tall building.

Topped Out- The building is under construction and has reached its full height both structurally and architecturally (e.g., including its spires, parapets, etc.).

Tower Gross Floor Area (GFA)- Tower GFA refers to the total gross floor area within the tower footprint, not including adjoining podiums, connected buildings or other towers within the development.

Vision- A building is considered to be a 'Vision' when it either:

- 1) Is in the early stages of inception and does not yet fulfill the criteria under the "proposal" category, or
- 2) Was a proposal that never advanced to the construction stages, or
- 3) Was a theoretical proposition

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