Case Study: Amorepacific Headquarters, Seoul

In Numbers: Highest Special-Purpose Spaces

Wind Effects on Permeable Envelopes

Life-Cycle Analysis of Western European Skyscrapers

Using AI to Simulate Vertical Urban Growth
"The future of subcontracting in high-rise projects may leave little room for fragmented, micro-specialized and labor-intensive trades."

Vaz Serra, et al., page 36
Americas

The twists and turns of New York City’s high-rise drama continue to make headlines. The reveals of new supertall projects are beginning to seem as frequent as booms in a fireworks display. The latest entrant was a 440-meter office tower at 350 Park Avenue, in the Midtown East district that had recently been rezoned to allow taller buildings. The design included tapered setbacks and planted terraces on several intermediate levels. Not far away, the gracefully-curving consular facility for the Republic of Turkey, the Turkevi Center, topped out near the United Nations. It, too, features outdoor terraces at height, plus commercial space on the first 15 floors, and 20 apartments for residents and staff, starting on the 20th floor. Downtown, there was considerable umbrage at the prospect of a new jail tower for the city’s Department of Corrections. Part of a plan to replace the sub-functional Riker’s Island prison with facilities closer to borough courthouses, the plan is to demolish the two towers at 124 White Street (13 stories) and 125 White Street (9 stories) and replace them with a 45-story, 118,000 square-meter tower with 1,440 beds. The city had originally planned to shift a portion of the island’s projected 5,000 inmates to a 40-story tower at 80 Centre Street, but that plan fell through in November of 2018.

The 101-meter Martin Tower that had stood on the skyline of Bethlehem, Pennsylvania, and which served as the headquarters of its namesake steel company since 1972, was demolished by implosion in May 2019. A victim of the decline of the US steel industry, the Lehigh Valley landmark had been unoccupied since 2003. Bethlehem’s Lehigh University was the first home of CTBUH, from 1969 until 2005.

Shovels hit the ground April 30 at the site of Victoria sur le Parc, on what could be Montreal’s tallest residential skyscraper. Set to rise 200 meters above the city’s International District, the tower is the latest development by contractor Broccolini on a stretch of Saint-Jacques Street. The project, located at 700 Saint-Jacques, along with a condominium build at 628 Saint-Jacques and construction on the new National Bank Headquarters, total a $1.3 billion investment by the company.

Work is underway at 151 First Avenue South, set to become one of downtown Nashville’s four largest skyscrapers. The Solomon Cordwell Buenz-designed, 40-story tower will contain a five-star hotel and condos. In addition, the project involves a second, slightly shorter tower with apartments, plus retail and restaurant space—consuming the entire city block in “SoBro” (South of Broadway). An adjacent pedestrian bridge spans the Cumberland River.

Miami marked the achievement of the halfway point for Elysee, a 57-story condominium tower under construction in the city’s Edgewater neighborhood. Construction has reached the skyscraper’s 35th floor, with about one full level expected to be completed every week from June until top-off in November. Delivery of the 198-meter-tall building is slated for 2020.

Two milestones were reached for two much-watched towers in Chicago. Ground was broken for One Chicago Square, a two-tower luxury residential and mixed-use complex designed in partnership by Goettsch Partners and Hartshorne Plunkard Architecture. The 76-story, 295-meter main tower will contain 276 apartments and 77 condominiums. The second tower, 49 stories and 175 meters tall and containing 459 apartments, features roof terraces formed by the tower setbacks that provide private outdoor living spaces for residents. The 41-month construction schedule has the complex finishing in 2022. Meanwhile, Vista Tower, planned to become the city’s third-tallest building when complete in 2020, hit its highest point in late April, when construction workers poured concrete to form its 101st and final floor. The program consists of a hotel and condominiums. The building got some extra publicity a few weeks later, when two daredevils were arrested trying to scale its exterior tower crane.

THEY SAID

“You don’t need to be a Nobel physicist to figure the direction California must go to solve its acute housing shortage—up. Stop expanding sideways and become more like New York City—and less like us.”

George Skelton, “Big backyards and pools are California’s past. Apartment buildings are its future.” Los Angeles Times, March 25, 2019.
Just to the north in Milwaukee, a shorter, but significant achievement was taking place. _Ascent_, a 21-story, 201-unit apartment building to be constructed from structural timber, received a grant from the US Forest Service. The grant will allow the developers to seek financing, and would see the building open as early as 2021.

The American West has long been associated with fresh starts. So it was for two tall buildings recently. Revival of the _First National Bank_ tower in Dallas, vacant for almost a decade, is expected to cost almost $450 million. The 52-story landmark skyscraper is undergoing one of the largest urban restoration projects in the US, and the largest ever in Dallas. The building will be turned into a combination of apartments, hotel rooms, retail and office space. It will be known as _The Drever Hotel_ when finished in 2020.

In Las Vegas, the former Fontainebleau Hotel, whose construction had halted during the depths of the financial crisis of 2008, gained a new lease on life when developers who purchased the stalled project in 2017 unveiled a plan to open the building as _The Drew Las Vegas_ by 2022. With new architects Diller Scofidio & Renfro at the helm, the 3,780-room resort will include hotel brands EDITION and JW Marriott, both under the large Marriott umbrella. The Drew Las Vegas is also expected to contain over 500,000 square feet (46,451 square meters) of convention and meeting space.

South of the border, Mexican cities with established and new skylines alike were set to get new additions. Construction began on _SOHL_ in Monterrey, with expected completion by 2022. The complex will consist of 159,859 square meters of space and will be divided into 25,000 square meters of residential area distributed across 24 levels; 28,000 square meters of office space on 27 floors, and a commercial area of 25,000 square meters that includes a linear park and a boutique hotel.

Further south in San Luis Potosi, plans were unveiled for _Comuna Tower_, an extended-stay residential complex. The 25-story tower was set to be just the first in a series of 64 planned around the country by developer Infinite Group, with two in each of 32 states.

Still further south, the Ecuadorian capital of Quito is quickly establishing itself as an epicenter of tall building design in South America. Two residential towers, one by Bjarke Ingels Group (BIG) and one by local firm odD+ Architects, are on the boards. The first, _EPIQ_, comprises two interlocking structures covered in pinkish tiles, as a reference to the hues of the Old City’s salmon pink buildings that date back to the 16th century. Tiles in varying tones will cover different portions of the fragmented building. The second, _Sunflower Tower_, uses interpolating concrete arched forms to both evoke the floral imagery of its namesake, and to support actual flora on their flat tops. The assembly is intended as a shading strategy for the tower.
Case Study: Amorepacific Headquarters, Seoul

From Object to Place: A New, Highly Public Home for a Venerable Company

Abstract
The new headquarters for Amorepacific, South Korea’s largest beauty company, is located in the center of Seoul, on a site which has been occupied by the company since 1956. It is situated next to a former US military zone that is being transformed into the spacious public Yongsan Park and a business district. This was part of a master plan representing the largest high-rise development in South Korea, which substantially altered the urban fabric of the Yongsan district. With its courtyards visible to the exterior, Amorepacific’s openings give scale and allow nature to extend from the adjacent park into all parts of the building. Further, the private office building plays substantial public roles through diverse ground-floor programming.

Keywords: Seoul, Urban Habitat, Office Buildings, Workplace Design, Public Realm

Introduction
By the time the 74-year-old Amorepacific Corporation launched a design competition for a new headquarters in 2009, the company offices were scattered throughout several separate buildings around Seoul. They were too small and no longer viable, and the surrounding neighborhood was undergoing rapid change. The site is located on Hangang-ro, which is an important route leading from the historic city center to the Han River, and is to this day one of the main axes in Seoul. The surrounding Yongsan District is relatively new. Due to its proximity to the river, it had long been reserved for industry and the military, including one of the largest US Army bases in Asia. Current plans stipulate that this base be transformed into a large public park (see Figure 1). When the architects were invited to participate in the competition, their analysis determined that the building would be in immediate vicinity of this new landscaped park, and had the potential to become a gateway to this extensive new inner-city natural space.

A Private Building with Public Functions

Buildings of a scale and function like Amorepacific, in the view of the architect, always carry a public responsibility beyond form, function or the enhancement of a skyline (see Figure 2). Architecture becomes meaningful if it connects and engages with broader issues of the city and the society beyond its specific task, regardless of whether it is a private, commercial or public commission.

Therefore, an essential question to be asked at the beginning of this project was:
How could the new headquarters also engage with the urban energy of Seoul? With Amorepacific, the architect’s and the owner’s vision encompassed similar intentions. In addition to providing offices for 7,000 employees, the owner’s chairman asked for the company’s art collection to be at the heart of the building. His belief was that engagement with art can inspire people, open their minds and perhaps contribute to a better society. During the design process, he even gave up on his initial idea for the ground floor to be completely commercial.

Instead, he proposed vitrine-type art galleries; a public library for art, design and architectural books; a flower shop; a childcare center; a space to exhibit the company’s history; and a number of rooms to enjoy tea ceremonies. He wanted the new building to be more than just a company headquarters, and the commission already implied a public ambition. The intention for the new headquarters was to be a place of connectivity and diversity, both for work and well-being. A local place for public activities, but with a sense of being part of something bigger. And, ultimately, a sustainable place.

The Problem of Context

On the site, a struggle ensued between two opposing urban ideas about how a city should develop, and what type of cities we
Wind Effects on Permeable Tall Building Envelopes: Issues and Potentialities

Abstract

A comprehensive conclusion about the effects of wind on permeable building envelopes (PBEs) remains elusive. The external layer permeability, the gap width, and the internal compartmentations are only a few of the many potential influencing parameters that complicate the study of the fluid-dynamic system that results from creating internal cavities connected to the building exterior. This project sheds light on the aerodynamic behavior of permeable envelopes of tall buildings, focusing on the possible external/internal flow interaction that may strongly influence the overall system. Results from experiments show that a remarkable aerodynamic interaction can occur. This stresses the importance of an iterative dialogue between the experts involved in the design process of such permeable façades and, at the same time, it offers new possibilities related to the control of the complex aerodynamic effects that a PBE can create.

Keywords: Permeable Building Envelope (PBE), Double-Skin Façades, Wind Tunnel Tests

Introduction

The envelope is one of the crucial elements in the design of high-profile buildings. The requirement to achieve high aesthetic and energy-conservation levels makes the building envelope one of the most expensive and risky parts of the building: a façade can constitute up to 25% of the total building cost, and the consequences of windstorms tend to comprise the highest proportion of total insured losses (Overend and Zammit, 2006). Indeed, for such envelopes, the main load is often represented by wind action.

Given the impact of the façade on the overall worth of a tall building project, it seems logical to require that it carry out more than one function. For this reason, permeable building envelopes (PBEs) are widely used. Indeed, a PBE acts as a special layer that protects the building occupants from the external environment in terms of heat, noise and pollution (see Figure 1). Its permeability is the key means to achieve energy efficiency, where internal cavities can be ventilated, so as to dissipate heat and exhaust air. At the same time, the cavities between the external skin and the building face (on which the façade is fixed) must not present a conduit for fire propagation. Moreover, many funding initiatives are focused on energy saving and generation from renewable power sources (e.g., the European Community research and innovation program "Horizon 2020"), pushing the boundaries of façade-technology development. The concept of "smart city" is also becoming popular, requiring increasingly complex features from future buildings. From this perspective, PBEs can be designed not only for energy saving, but also to take advantage of building characteristics to generate energy. Photovoltaic ventilated façades (e.g., Sick and Erge, 1996, Yun et al., 2007) and building-integrated energy harvesting systems (e.g., Sharpe and Proven, 2010, Hassanli et al., 2017) are only few of the many applications that show great potential.

The study of building aerodynamics mainly focuses on the effects caused by wind on the building surfaces. To properly evaluate...
these effects on a specific structure, a combination of influencing elements must be considered, starting from the atmospheric boundary layer (ABL) characteristics—namely, the approaching flow—and culminating in the shape and dynamic properties of the building itself. This approach was formalized in the Alan G. Davenport Wind Loading Chain by the International Association for Wind Engineering (IAWE), named in honor of its creator (IAWE General Assembly, 2011) (see Figure 2). The envelope defines the shape of a building, and therefore plays a fundamental role concerning wind-induced actions. In spite of the small scale of the elements that comprise a façade, previous studies have shown how their features can influence overall building aerodynamics (e.g., Dutton and Isyumov, 1990, Kwok and Bailey, 2006).

The present work considers an additional complication: the fact that a building envelope can create a gap where the air can flow in. In particular, from an aerodynamics point of view, a PBE represents one (or more) additional layer(s) fixed on one (or more) airtight building face(s), at a relatively small distance, which creates one (or more) internal cavity or cavities, which are somehow connected to the exterior. The connection between the internal cavity and the exterior (namely, the permeability of the building envelope) can be represented by openings of a certain size and location, or by porous layers with uniformly diffused openings. The cavities are compartmentalized, depending on the desired internal ventilation and/or fire-safety requirements. However, this work focuses only on the role of external layers and compartmentations with respect to wind effects. Consequently, whether the external additional layer is a glazed skin of a ventilated façade, a rainscreen, a sunshade or a porous metallic layer, the main parameter remains its permeability.

Wind action produces positive or negative pressures on the envelope, which are transferred as forces to the building structure through the supporting systems. The main problem while assessing the wind loads on a PBE is the evaluation of the net pressures—namely, the difference between external and internal pressure distributions. The relatively small dimensions of the cavity compared to the overall building dimensions, and the relation between the size of the building and that of the ABL in which the building is immersed, determine the multi-scale characteristics of the problem (see Figure 3). This feature accounts for the number of

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**Figure 1.** Permeable façade of the Post Tower, Bonn. © Left & Right: Murphy/Jahn; Center: Rainer Viertlboeck

**Figure 2.** The Alan G. Davenport Wind Loading Chain is used to describe the many factors contributing to wind loads. (International Association for Wind Engineering (IAWE)).

**Figure 3.** The definition of wind effects on a permeable building envelope (PBE) involves a wide range of scales. In the sketches, the order of magnitude of the dimensions are shown for: the atmospheric boundary layer (ABL) (left), the building (center) and the façade detail (right). © Courtesy of C. Torsoli
Life Cycle Analysis: Load-Bearing Structures Of High-Rise Buildings in Western Europe

Abstract

The choice of structural system has a big influence on the environmental impact of structural materials in tall building design. This paper provides a comparison of the environmental impact of several structural systems for high-rise buildings. The environmental performance for relatively slender buildings in the range of 150 to 250 meters in Western Europe is analyzed for five different types of structural systems in cast-in-situ concrete, precast concrete, and steel. The cradle-to-gate environmental impact was determined by using environmental cost, an assessment method including 10 impact categories. Compared to tube structures, diagrid structures reduced the impact by 17-33% for the concrete models and 28-41% for the steel models, due to reduction of material use. By using non-conventional structural systems such as diagrids, reductions in environmental impact can be achieved relatively easily.

Keywords: Sustainability, Materials, Life Cycle, Carbon

Introduction

The built environment is a key contributor to global greenhouse gas emissions (Oldfield, 2012), and buildings account for 30-40% of all primary energy used worldwide (UNEP, 2007). Therefore, the industry is researching possible ways to reduce its environmental impact. High-rise buildings have proven to be a potential solution for reducing the environmental impact of construction (Trabucco & Wood, 2016).

Most of the research conducted to date on improving sustainability of buildings has been focused on reducing operational energy (OE), used for heating, cooling, hot water, ventilation, etc. (Oldfield, 2012; Sarkisian, 2016; Trabucco & Wood, 2016). As future buildings will be designed to net-zero energy standards, the impact of embodied energy (EE), used for production, construction, maintenance and demolition of materials, will represent a significantly increasing part of the total impact (Trabucco & Wood, 2016; Webster, 2004; Yohanis & Norton, 2002), possibly increasing up to 100% (Sarkisian, 2016). The biggest part of EE is caused by the predominant structural materials used in tall buildings: concrete and steel (Kaethner & Burridge, 2012; Oldfield, 2012). Figure 1 shows an overview of the life cycle stages of a building with definitions per European standard EN 15804.

Research Objective and Scope

Research into the environmental impact of a wide range of stability systems for high-rise building structures is limited. It is uncertain whether the research by Trabucco et al. (2016) is applicable in Western Europe. First, the average height of high-rise buildings in Europe is typically lower than in North America and Asia. Second, regulations and local conditions are different. For example, a rule regarding daylight penetration in the Netherlands restricts the depth of office floors to approximately 9 meters, resulting in slender buildings. Also, poor soil conditions in many parts of Western Europe result in the average height of high-rise buildings is limited. It is uncertain whether the research by Trabucco et al. (2016) is applicable in Western Europe. First, the average height of high-rise buildings in Europe is typically lower than in North America and Asia. Second, regulations and local conditions are different. For example, a rule regarding daylight penetration in the Netherlands restricts the depth of office floors to approximately 9 meters, resulting in slender buildings. Also, poor soil conditions in many parts of Western Europe result in the average height of high-rise buildings in Western Europe is typically lower than in North America and Asia. Second, regulations and local conditions are different. For example, a rule regarding daylight penetration in the Netherlands restricts the depth of office floors to approximately 9 meters, resulting in slender buildings. Also, poor soil conditions in many parts of Western Europe result in
several structural systems for high-rise buildings in the range of 150-250 meters located in Western Europe. Five different stability systems and three floor systems were designed in cast-in-situ concrete, precast concrete and steel for three fictitious office buildings in Rotterdam. All models contained a concrete core, and the foundation structure was excluded from the study. The environmental impact was calculated and analyzed according to the cradle-to-gate principle (production phase only, A1–A3) for 10 different impact categories, using environmental cost (EC) as the common indicator.

“Differences in daylight penetration standards, soil conditions, material production techniques, and generally lower heights suggest the importance of independently studying European skyscrapers’ environmental impact, beyond prior research conducted on North American and Asian buildings.”
Construction

Implications of Flat-Pack Plumbing Systems For High-Rise Construction Efficiency

Abstract
The concept of design for manufacturing and assembly (DfMA) is gathering momentum in the high-rise construction industry. The construction of tall buildings is well-suited for the adoption of processes that optimize the off-site fabrication of sub-systems. This paper analyzes the reception of DfMA principles in the Australian construction industry and illustrates the specific case of wall-integrated plumbing as an exemplar of the emerging philosophy of “flat-pack” prefabrication in residential high-rise construction. In contrast to the radical off-site manufacturing emphasis that is proposed by prefabricated prefinished volumetric construction (PPVC), flat-pack prefabrication implies off-site manufacturing, combined with the ability to improve, but not discard entirely, processes of erection on-site. These systems can provide the most tangible benefits of productivity and are poised to cause a cultural shift in the way high-rise projects are procured today.

Keywords: DfMA, Flat-Pack, Prefabrication, Modular, Construction

Introduction

Design for Manufacturing and Assembly (DfMA) is a concept developed to improve the efficiency and optimization of industrial processes and products. It has roots in research work started in the late 1970s by merging the two ideas of Design for Manufacture (DFM) and Design for Assembly (DFA) into one framework. Since the 1990s, the concept of DfMA and some of its derived models of application have gathered acceptance in industrial design as a well-established technique for accomplishing significant improvements in productivity (Boothroyd et al. 1994).

At the core of DfMA’s philosophy, there are strategies of labor optimization favoring design solutions that facilitate ease of manufacturing. Common examples of such strategies are the minimizing of part count, the shortening of reticulation and cabling for services, and the avoidance, whenever possible, of unique or non-standard components and products. The application of DfMA principles also purports processes that facilitate part handling and ease of assembly, such as minimizing actions of re-orientation, selecting self-locating or self-fastening parts, avoiding diversity of fasteners and connections, and avoiding the need for adjustments after assembly. Above all, DfMA is a modus operandi that often feeds into industrial production processes that support modular design or semi-modular assembly.

The adoption of DfMA in the disciplines of the built environment has been considered and widely tested, but its principles and applications are not as well established as in the field of industrial design. There is, in fact, abundant academic work concerned with the adoption of DfMA in construction management. Recent studies in this area have highlighted the presence of barriers to its implementation in specific regions (Gao et al. 2018) and considered risks and benefits for particular sub-sectors of the industry (Trinder 2018). A growing area of interest for DfMA applications pertains to high-rise construction, where its value has been manifested in enhanced building productivity (Banks et al. 2018).

Tall DfMA: Modular Trends in Construction

The appeal of DfMA concepts in the high-rise construction industry derives from the likelihood of repetition, which is often an inherent characteristic of tall buildings, and by
the high stakes of economic risk and public safety, which are associated with the timely completion of speculative commercial projects. The idea of applying DfMA strategies in the conception and erection of tall buildings is, therefore, a theme of debate that has gathered interest in the CTBUH community.

Designs conceived with ease of manufacture and assembly in mind can contribute to more efficient tall building construction. This argument is often presented as the justification for high-rise experiments in modular construction. Case studies have been shown where strategies of “partial modularization” have brought tangible benefits of productivity for contractors. One study claimed up to 60% reduction in on-site labor and 30% reduction of program time (McFarlane and Stehle 2014). Moreover, the transfer of DfMA principles from the industrial manufacturing realm to that of construction has an even stronger appeal when applied to three-dimensional modular construction systems, also known as prefabricated prefinished volumetric construction (PPVC). The affinity between the manufacturing of products and the assembly of PPVC modules is almost self-apparent and suggests that there are abundant opportunities for direct transfer of technologies and processes of production from vehicle manufacturing to building construction. Notwithstanding that PPVC may remain as a vital component of the high-rise innovation agenda for years to come, the construction of high-rise buildings with three-dimensional modularization also has significant limitations (Mills et al. 2015; Krulak 2017). It is often suggested that three-dimensional vertical modularization will continue to grow in the future (Wallance et al. 2015), but it is doubtful that PPVC design will be the primary conduit through which DfMA concepts can more effectively penetrate the construction industry.

This paper analyzes the prospects of growth of DfMA in the built environment, by arguing that processes of innovation with flat-pack systems, rather than three-dimensional modularization, can act as an effective catalyst for innovation in tall building projects. The validity and possible repercussions of DfMA for tall buildings are discussed by using the case study of a wall-integrated plumbing system that was developed for the bathrooms of a high-rise apartment tower in Australia. The innovative capacity of flat-pack systems in high-rise projects is considerable, as evidenced by an experimental research project that was carried out by the University of Melbourne in collaboration with Richstone Group, a plumbing contractor based in Melbourne.

Vices and Virtues of the “Pod” Phenomenon

Concepts of DfMA have been already applied successfully, such as in the case of mechanical, electrical and plumbing (MEP) services using prefabricated construction. In modular projects, the components of the buildings are first manufactured in factories and then delivered to the field, where they are hoisted or erected as pre-assembled units that integrate the work of several trades. The benefits of this approach include cost reduction, faster installation and improved quality. Some of the highest environmental and safety hazards associated with construction sites are also significantly mitigated.

A typical application of this kind of prefabrication, which has gathered significant interest in Australia and elsewhere, is the adoption of prefabricated units for bathrooms, also known as “pods” (See Figure 1).

Figure 1. Prefabricated Prefinished Volumetric Construction (PPVC) of bathroom pods in an Australian tall building (left) installed on the floor during construction, with pre-finished interior (right). © G. Marfella
Using AI to Simulate Urban Vertical Growth

Abstract

This research explores the use of artificial intelligence to simulate how cities will grow vertically. By learning how cities have evolved in the recent past, genetic algorithms can successfully simulate vertical urban growth. The research was applied to buildings 130 meters and taller in the Minato Ward of Tokyo in 2015. An evolutionary computer model was built from a standard genetic algorithm, using historical and economic data, which then simulated future growth for the 2016 to 2019 period. The results obtained matched the area of study’s real vertical growth for the study period, with an 85.7% accuracy for the number of buildings, 73.7% for their average heights, and 96.3% for the likelihood of new construction projects happening within a mapped area. By learning how a city evolved in the past, the model replicated the future vertical growth of a city center.

Keywords: Vertical Growth, Genetic Algorithms, Evolutionary Computation, Minato Ward, Tokyo, Skyscrapers

Introduction

Artificial intelligence and machine learning processes have been successfully used in the past to predict how cities will expand over territory. Most of the algorithms used for such purposes were cellular automata models, originally designed to simulate biological growth. This research, however, offers two novel approaches. The first is that it focuses on how densely populated metropolitan centers grow, not horizontally, but vertically. The second is the use of evolutionary computation, specifically genetic algorithms, which are not commonly used for the simulation of urban growth.

Evolutionary Computation

In the early 1950s, Allan Turing (1952) used the term “morphogenesis” to refer to the growth of flowers, and showed mathematically how a complex organism could assemble itself without any master planner. He was particularly concerned about recurring morphological patterns in the growth of living organisms. Further computational studies developed the first cellular automata computer models to be successfully used for the prediction of urban growth. Genetic algorithms were originally developed by Holland (1975 & 1998), as he began to study the logical processes involved in adaptation. Holland was inspired by the studies of cellular automata by Burks (1960) and neural networks by Selfridge (1958), particularly in exploring how simple rules could lead to complex behavior. The concept was further developed by Koza (1989 & 1992), into what he called “genetic programming”, which consisted of breeding computer codes. The algorithms were not originally intended to simulate any biological systems, as their name might suggest, but rather used the logic of genetics, adaptation, evolution and natural selection as a way of finding the most appropriate solutions to a problem.

“Economic stimulus packages by the Japanese government tend to result in an increase of high-rise construction, which materially manifests itself after three years. This produces a clear wave-like pattern.”
Currently, evolutionary computation and artificial neuronal networks are the two branches of machine learning yielding better results, and which have proven to be the most successful. Both disciplines are widely used to solve or simulate various kinds of complex systems, and are inspired by biological processes, but not intended to simulate nature.

This research uses economic and historical data about Tokyo high-rises as a starting point for genetic algorithms, to learn how to simulate a system and find solutions to a problem from the data given to them. Once all the data is gathered and organized, the information is fed into the algorithm, so that it can identify recurring patterns and relations in the data, through which it can later make its own simulations.

One aspect that has led to confusion in the media regarding this research is the difference between prediction and simulation. The evolutionary computation process proposed here doesn’t predict vertical urban growth, but instead simulates likely scenarios thereof. It can simulate very accurately how the city could grow vertically, such as which zones in the urban areas are more likely to host new high-rises, the approximate number of high-rises, and the height patterns that are likely to occur. However, it is unable to accurately predict the exact location, size and height of the new developments, as self-organizing systems respond not only to logical, but also to random patterns.

Urban Growth: Tokyo’s Minato Ward

Many authors, from pioneering studies by Weaver (1958) in the natural sciences to Jacobs (1961), have compared urban growth to biological growth. More recently, authors such as Johnson (2001) and Al-Sayed and Turner (2012) have pointed out how urban growth resembles the growth of biological organisms, and how city growth is governed by a combination of evolutionary and self-organizing processes.

The original research work started in 2015 and was published in 2017 by the *Journal of Urban Planning and Development*. The aim was to use artificial intelligence (AI) to aid planners, policy makers and urban designers in predicting how self-organization processes might produce vertical city growth and, therefore, to be able to react accordingly. For this purpose, a computer model was developed that could estimate the most likely location, height, and number of new skyscrapers that would be built in a determined area of a major city. The research focused on Tokyo and one of its central wards: Minato (see Figure 1). The team fed data to a standard genetic algorithm regarding the historical development of Tokyo, largely based on previous research published by the team in the *Journal of Asian Architecture and Building Engineering* (Pazos, 2014).

Figure 1. Partial view of the Minato Ward skyline in 2015.
Tall Buildings in Numbers

Highest Special-Purpose Spaces

Since humans first began constructing tall buildings, history has been cluttered with claims of all manner of “highest” records. In this study, we examine those claims to unconventional or “special-purpose” spaces that would ordinarily be found in shorter, public buildings closer to street level. Though clearly a spectacular experience is the intended effect of many of these spaces, in many ways these are practical accommodations of the need for diverse amenities spread throughout the vertical dimension, just as they are on the ground.

Unless stated otherwise, all measurements were taken from the highest finished floor surface available within each space.

World’s Highest Restaurant
Restaurant: Any space designed as a publicly accessible dining area. Space must include seating for guests and an adjacent full kitchen.

Guangzhou CTF Finance Centre
Guangzhou, 530 m
Completion: 2016

Restaurant: 495 m
(Name TBD)

#2. International Commerce Centre
Hong Kong, 484 m
Completion: 2010
Ozone: 475 m

#3. Burj Khalifa
Dubai, 828 m
Completion: 2010
At.mosphere: 445 m

#4. Tianjin CTF Finance Centre
Tianjin, 530 m
Completion: 2019
Restaurant: 439 m
(Name TBD)

#5. Changsha IFS Tower T1
Changsha, 452 m
Completion: 2018
Niccolo Kitchen, The Tea Lounge, Bar 93: 432 m

World’s Highest Green Space
Green Space: A space in which a permanent majority of the floor area is devoted to the display and enjoyment of plants.

Guangzhou CTF Finance Centre
Guangzhou, 530 m
Completion: 2016

Terrace 495 m

#2. Vincom Landmark 81
Ho Chi Minh, 461 m
Completion: 2018
Terrace: 382 m

#3. Nanning China Resources Tower
Nanning, 403 m
Completion: 2019
Terrace: 312 m

#4. Yuexiu Fortune Center Tower 1
Wuhan, 330 m
Completion: 2017
Terrace: 305 m

#5. Hon Kwok City Center
Shenzhen, 329 m
Completion: 2017
Terrace: 304 m

At a height of 347 meters, the “BMW Rink 354” is the highest ice skating rink in the world, located on the 91st floor of the OKO - Residential Tower in Moscow, Russia.

According to Dubai’s Islamic Affairs office, due to being situated significantly above the ground-level horizon line, Muslim occupants of Burj Khalifa must delay some prayers by up to 3 minutes to accommodate the later sunset.

The highest pool in the world is located at a 469-meter height on level 118 of International Commerce Centre and is accessible to any hotel, spa, or fitness center guests.
World’s Highest Performance Space
Performance Space: A space that includes tiered/raked levels and fixed seating, for the purpose of observing speakers or performers.

One Shenzhen Bay Tower 7
Shenzhen, 341 m
Completion: 2018

#2. Torre Reforma
Mexico City, 246 m
Completion: 2016
Auditorium: 101 m

#3. Elbphilharmonie
Hamburg, 110 m
Completion: 2016
Concert Hall: 66 m

#4. Daeseong D-Cube City Headquarters
Seoul, 190 m
Completion: 2011
Performance Hall: 56 m

#5. Nakanoshima Festival Tower
Osaka, 199 m
Completion: 2012
Festival Hall: 38 m

Tsinghua University Campus – Z1 Lot
Beijing, 231 m
Completion: 2018

#2. Mode Gakuen Cocoon Tower
Tokyo, 204 m
Completion: 2008
Tokyo Mode Gakuen, HAL Tokyo, and Shuto Ikō: Floor 50 (181 m)

#3. Cathedral of Learning
Pittsburgh, 163 m
Completion: 1936
University of Pittsburgh: Floor 42 (145–155 m)

#4. Cathedral of Learning
Bangkok, 159 m
Completion: 2002
Assumption University of Thailand: Floor 39 (145–155 m)

#5. Mode Gakuen Spiral Towers
Nagoya, 170 m
Completion: 2008
Mode Gakuen, HAL, ISEN: Floor 38 (145 m)

World’s Highest Educational Space
Education Space: A space occupied and operated by a formal academic institution and utilized by students and/or employees of said academic institution. Due to limited data availability, this category has been ranked by the floor number of the highest education space.

Tsinghua University Campus – Z1 Lot
Beijing, 231 m
Completion: 2018

#2. Mode Gakuen Cocoon Tower
Tokyo, 204 m
Completion: 2008
Tokyo Mode Gakuen, HAL Tokyo, and Shuto Ikō: Floor 50 (181 m)

#3. Cathedral of Learning
Pittsburgh, 163 m
Completion: 1936
University of Pittsburgh: Floor 42 (145–155 m)

#4. NBK Tower
Kuwait City, 300 m
Completion: 2019
(Scheduled for October)
Prayer Room: 193 m

#5. Kingdom Centre
Riyadh, 302 m
Completion: 2002
King Abdullah Mosque: 183 m

World’s Highest Religious Space
Religious Space: A space designed and built exclusively for religious purposes (i.e., a refuge floor or break room that may also be used for prayer would not be included).

Makkah Royal Clock Tower Hotel
Mecca, 601 m
Completion: 2012

#2. Burj Khalifa
Dubai, 828 m
Completion: 2010
Prayer Room: 566 m

#3. Great Mosque of Algiers Tower
Algiers, 265 m
Completion: 2019
Minaret Viewing Platform: 224 m

#4. NBK Tower
Kuwait City, 300 m
Completion: 2019
(Scheduled for October)
Prayer Room: 193 m

#5. Kingdom Centre
Riyadh, 302 m
Completion: 2002
King Abdullah Mosque: 183 m

The world’s highest library is inside Tomorrow Square, Shanghai, 228 meters (overall height 285 meters). The world’s tallest library building is the Shanghai Library at 106 meters.

Makkah Royal Clock Tower, Mecca, the world’s third-tallest building, holds top position in three categories, including Highest Astrological Observatory (472 meters), Highest Museum (484 meters), and Highest Religious Space (588 meters).
Talking Tall: Amy De Luca and Julie Foster

Hanging Out With Façade Inspectors

Among the hazards of cities with tall buildings is the prospect of objects falling to the streets below. After a woman was killed by a piece of falling masonry in 1979, the New York City Council enacted Local Law 10, which mandated that buildings taller than six stories be inspected at least once every five years. In 2018, more than 3,300 building exteriors were inspected. An increasing number of these inspections are being done by rope, with inspectors rappelling down the face of the buildings, and a substantial number of the inspectors are women. At Consulting Associates of New York (CANY), eight of the 15 licensed rope-access technicians are women.

CTBUH Editor Daniel Safarik spoke with two of them on a recent visit to New York.

The most obvious question, we’ll get out of the way first: how did you get into this line of work?

Amy DeLuca: I have an architecture background. I found CANY by chance at a job fair. Their brochure had a picture of an inspector rappelling on it, so I was like, “I want to do that!” But I still wanted to do architecture. I didn’t know that the exterior-inspection niche even existed before I came to CANY, and I have fallen in love with it. It’s really interesting. I love historic buildings, restoration and preservation.

Julie Foster: I was an art history major and then did a couple years working in arts development and fundraising. I hated that, went back to school, did a Master’s and a certificate in cultural resource management, and through that, found out about exterior-inspection niche even existed before I came to CANY, and I have fallen in love with it. It’s really interesting. I love historic buildings, restoration and preservation.

Counterintuitive! Neither of you were rock-climbers before this?

DeLuca: No, before I worked here, I think I went to a rock-climbing gym once for fun. Once I started rappelling, I started rock-climbing, but only indoors. It’s a totally different experience with different equipment.

Foster: If you were to have told me that this was going to be my job 10 years ago, I would have told you that you were out of your mind. But now, getting on a ladder to climb up to the first level of a sidewalk bridge is still scarier to me. I would rather rappel off an 80-story building than get on one of those ladders.

“…If you were to have told me that this was going to be my job 10 years ago, I would have told you that you were out of your mind. But now, getting on a ladder to climb up to the first level of a sidewalk bridge is still scarier to me. I would rather rappel off an 80-story building than get on one of those ladders.”

Julie Foster
because I didn’t have my gear, and I wasn’t in my comfort zone.

Let’s talk about gear for a minute. What kind of equipment do you need to stay safe?

DeLuca: We have two ropes that are anchored at the roof and go over the side, and then two running on the ground. It’s kind of like a pulley, and it runs through our harnesses. And as we let ourselves go, a mechanism lets the ropes run through, and when it closes it keeps you where you have stopped (see Figure 1).

Foster: The second rope is for backup only. Once you go past a certain rate of descent, the teeth in the safety catch engage and you stop. It also has a shock absorber spring. It’s funny—when you put on your rope harness for a long time, it feels insufficient. It’s perfectly safe, of course, but you can’t move yourself up and down if the safety catch engages, and the scaffold drops away, you just hang there.

What equipment do you take up with you to do the inspections?

DeLuca: We take very little in terms of electronics, beyond a camera, on the rope. When we’re on scaffolding, we have ultrasound sensors for steel behind the façade. I’ve taken calipers, a card we use for crack measurements, a hammer, and a tape measure.

This is obviously dangerous but also skilled work. Why can’t drones or robots do this?

DeLuca: A drone can take a photo straight on in 3D, but that doesn’t tell the whole story. Something that looks like ordinary bricks is obvious to us as a crack, once you start feeling it and looking from different angles. And you have your own sensors, and there are haptic sensors for robots that can tell if a crack will be obvious to us as a crack, once you start feeling it and looking from different angles.

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What are some things you’ve seen on buildings that you disapprove of, or wish had been done differently?

Foster: My biggest beef is really bad terra-cotta repair. Not necessarily the original architecture itself but when the repair consists of making a new mold and putting the piece of terra cotta back, they just square it off and actually physically sound buildings wrong. And they would come in time. Buildings are rarely the rectangles buildings we’ve seen in magazines and books. As it happens, we use Google Maps and Google Earth all the time. Buildings are rarely the rectangles buildings we’ve seen in magazines and books. As it happens, we use Google Maps and Google Earth all the time.

DeLuca: I hate seeing a cornice being replaced by brick. On older buildings, usually any point or transition, even if it’s not necessarily the original terra-cotta repair, they just square it off and kind of do a flat patch. And that would come in time. Buildings are rarely rectangles, and buildings are rarely rectangles, and buildings are rarely rectangles.

Foster: I love to have a drone! If we can have perfectly 360-degree drone footage before going out, we could determine the best spot to start working.

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About the Council

The Council on Tall Buildings and Urban Habitat (CTBUH) is the world’s leading resource for professionals focused on the inception, design, construction, and operation of tall buildings and future cities. Founded in 1969 and headquartered at Chicago’s historic Monroe Building, the CTBUH is a not-for-profit organization with an Asia Headquarters office at Tongji University, Shanghai, a Research Office at Iuav University, Venice, Italy, and an Academic Office at the Illinois Institute of Technology, Chicago. CTBUH facilitates the exchange of the latest knowledge available on tall buildings around the world through publications, research, events, working groups, web resources, and its extensive network of international representatives. The Council’s research department is spearheading the investigation of the next generation of tall buildings by aiding original research on sustainability and key development issues. The Council’s free database on tall buildings, The Skyscraper Center, is updated daily with detailed information, images, data, and news. The CTBUH also developed the international standards for measuring tall building height and is recognized as the arbiter for bestowing such designations as “The World’s Tallest Building.”