FRAMEWORK FOR DESIGN: THE STUDY OF PARAMETRICS FOR CONTEXTUALLY RESPONSIVE HIGH RISE DESIGN

by

Nicholas Caron

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for the degree of Master of Architecture

at

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Supervisor: ______________________

Reader: ______________________

Reader: ______________________

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ABSTRACT

The following thesis investigates parametric thinking and evolutionary solving principles in the creation of a framework for residential high rise design. Site specific parameters such as site access (pedestrian and vehicular), views, acknowledgement of neighbours, or climatic, such as natural day lighting and ventilation, should be used to inform the design. Parametric software is used as a tool to generate designs dynamically. With the help of an evolutionary solver component, the design potential is augmented by generating multiple iterations which are analyzed for their success or failure in an effort to provide an appropriate response within the context of the site. The framework is tested on a site located at the corner of Duplex Avenue and Eglinton Avenue West in Toronto, Canada.

ACKNOWLEDGEMENTS

Foremost, I would like to express my sincere gratitude to my advisor Roland Hudson for the continuous support of my study and research, for his patience, motivation, enthusiasm, and immense knowledge. This thesis would not be what it is without his guidance and motivation. I could not have imagined having a better advisor and mentor.

Besides my advisor, I would like to thank Steven Mannell for his encouragement, insightful comments, and hard questions.

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CHAPTER 1: INTRODUCTION

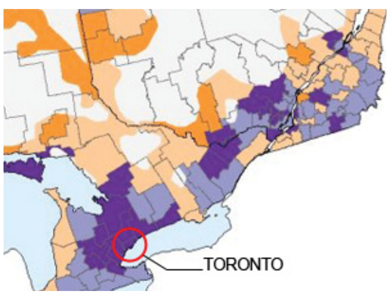
1.1. Thesis Question

How might parametric thinking and evolutionary solving principles be applied within a design framework to aid the architect in the development of a contextually responsive residential high rise?

1.2. Existing Context of Toronto

A portrait of the history and current context of Toronto can be drawn from studying the data contained in the 2006 Canadian Census. The following section contains a resume of this data. (Canadian Census, 2006)

1.2.1. Population Growth

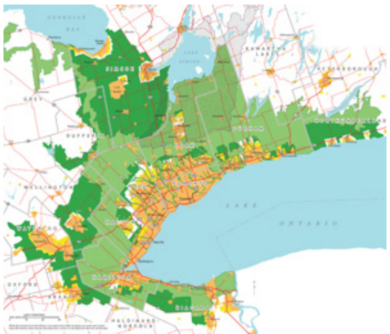


Southern Ontario population change
Dark purple: >=4%
Map by Statistics Canada

Amongst all the G8 countries, Canada has experienced the largest growth in population between 2001 and 2006 (last tabulated census year). Moreover, the province of Ontario, which has seen a constant population growth rate since 1991, accounts for half of this population growth. Since urban population surpassed rural in 1931, the urbanization rate has been rising almost without a break in Canada. New employment opportunities generated by the development of the manufacturing sector and the service industry contributed to the rapid growth of the country's urban population. The high concentration of new immigrants in the country's largest cities was also an important population growth factor.

Since 2001, the population of Canada's census metropolitan areas grew by 1.4 million, which represents nearly 90% of the 1.6 million increase in the country's total population over that period. By 2006, nearly 25 million people, more than 80% of Canadians, were living in urban areas.

Extending along the western end of Lake Ontario, the Greater Golden Horseshoe is both the most populous and the most heavily urbanized region in Canada. It is home to 8.1 million people, two-thirds of Ontarians and one-quarter of all Canadians. Between 2001 and 2006, the Greater Golden Horseshoe accounted for 84% of Ontario's population increase and 39% of the total national increase.



Greater Golden Horseshoe and Green Belt
Map by the Ontario Greenbelt Alliance

Toronto, the most populous city in Canada, is a city located within the Greater Golden Horseshoe along Lake Ontario. With a population of over 2.5 million and growing, 38% live in apartment towers of five storeys or more. The number of dwellings built in Toronto between 1986 and 2006 representing 23% of all dwellings in the city. The biggest population is of Chinese origins followed by Canadian, Italian, and East Indian respectively. This is shown evidently with the presence of neighbourhoods such as Chinatown, Little Italy, and Little India.

1.2.2. City Portrait

The city is divided East/West by Yonge Street, the main commercial artery, and North/South by Bloor Street, which is at the edge of downtown and intersects Yonge Street. The extensive public transportation system makes most areas of the city easily accessible. Entrances to the subway are located at major intersections or at specific points of interest (commercial, entertainment, or community).

The city consists of a mix of dense high-rise buildings sur-

Section through Yonge Street

rounded by medium and low-rise buildings intermingled with residential neighbourhoods. Most tall buildings are located in nodes following the main arteries. By drawing a section along Yonge Street for example, nodes are noticeable at the downtown core, at the Bloor Street intersection, at the St-Clair Avenue intersection and at the Eglinton Street intersection.

To try and slow the process of suburbanization and protect its green areas (which are numerous), the Government of Ontario passed a bill (Greenbelt Act, 2005) which created and protects a green band on the northern outer edge of the city called the greenbelt. This protected land area along with the cities surrounding it prevents Toronto (as separate from the GTA – Greater Toronto Area) from gaining any more land area. Not unlike many other cities with a lack of buildable land area, one solution is to go up. Due to the enormous amount of people living in the city, most of the construction undertaken since 2006 has been of residential programming; most notably mixed-use base buildings topped with a tower of residential condominium units. Concentrated around the waterfront, these projects have slowly made their way along the main arteries, deeper into the urban fabric of the city.

1.3. Area of Study

This thesis is focused on two parts: the study of high rise design and associated living environments and the study of parametric thinking and how it can inform the design of high rises based on site specific parameters.

1.3.1. High Rise Building Design

At the turn of the 20th century, rapid urbanization of cities and lack of available area for building saw the emergence of the high rise building type. Although, people started moving from cities to suburbia in the years following the Second World War, we are now realizing the potentials of the city.

> [This] drive to suburbanization deprived us of [the] advantages of urban living. The realization of this loss, in tandem with recent concerns about energy scarcity and global warming, has made us see cities with fresh eyes and a growing understanding that they can provide us with an unparalleled measure of sustainability (Greenberg 2001, 10).

With more people moving back to the city as depicted by Statistics Canada, there is a resurgence in residential high rise buildings as typology:

> they do more things on those smaller footprints with fewer resources and can repurpose those resources as new needs emerge (Greenberg 2001, 79).

However, more often than not, high rises are conceived as simple extrusions of the ground planes they occupy in an effort to maximize profit (maximum rentable floor area). With this intent, there is little concern regarding both the livable environment inside and outside these towers.

> The desire for engineering expediency in the skyscraper's design and construction has undermined the potential for the diversity and richness of urban life in the building (Yeang 2002, 59).

1.3.2. Parametric Design

An architecture project begins with the collection and analysis of information of various types and is later synthesized into a design. In traditional computer aided design, architects formulate an idea and then use the computer to represent the idea. Whether, physical or digital, a design process should entail several iterations as the designer works through design concepts towards a solution. However, the design process often results in the study of only a few options.

When working through a design process heavily loaded with information, the computer can aid in processing information for assessing multiple solutions. Whereas the computer is used as a tool to represent a design in a manual design process, parametric thinking employs the capability of computers to make quantitative decisions that would influence the design process. Thus, the creation of a family of parts and modifications can be performed much more quickly in comparison to the redrawing of components required by traditional CAD. Parametric thinking allows for adjustability and efficiency through a design process.

In a parametric design process, information is gathered and organized as various inputs to generate unique forms.

> The sheer scale of the high rise building typology indicates several multidisciplinary concerns, such as, economics, ecology, sociology, environment, psychology, technology, urban geography, cultural theory and real estate. (Yeang 2002, 14)

The results are then analyzed by the designer according to specific quantitative and qualitative criterias in the development of a responsive solution. Parametric design offers a flexible set of components to manipulate, which leads to an infinite amount of variation. The larger the scale of the project the more pronounced is parametricism's superior capacity to articulate programmatic complexity.

CHAPTER 2: APPROACHES TO HIGH RISE LIVING

2.1. Variety

It seems most residential towers in Toronto are built to cater to a certain demographic. The square footage of condominium units contributes to restricting occupants to singles, couples, or young families with a maximum of two children.

> Compact, walkable, transit-oriented, dense, for all ages, mixed-use (Greenberg 2001, 16)

These are keywords that should be considered when designing for urban areas. Although many of these attributes have been incorporated in Toronto towers (see Appendix A), "for all ages" seems to be lacking.

> With no requirements for affordable housing, what developer would bother to include such units in their plans? There are significant segments of the population that the private real-estate market just does not reach - despite the recent and ongoing condominium boom in many North American cities (Greenberg 2001, 100).

Greenberg's observation is on point. The case studies on towers in Toronto (Appendix A) are proof: no consideration is given to providing habitat for everyone; moreover, towers are designed to provide habitat for the well off.

Jane Jacobs states that,

> diversity among adjacent uses, and hence diversity among users and their schedules results in lively areas (Jacobs 1992, 97).

Brunswick Centre, built in London in the 1960's, is a mixed use complex consisting of apartments, restaurants, shops and a cinema (see Appendix A). The complex provides variety and thus diversity of users, fostering a social atmosphere. Providing a wide variety of unit options, not just in terms of unit size, but also unit type, at the podium level and throughout the whole height of the tower, would have a positive effect on the overall livable environment of the tower.

2.2. Form As A Response To Context

The examples of towers in Toronto (see Appendix A) illustrate little importance on orientation and building shape to take advantage of natural processes: sun, wind, and rain. The floors of most towers are configured around a central core, requiring the units to rely on mechanical ventilation as there is no option for passive ventilation. The Menara UMNO in Malaysia (see Appendix A) is an example of a tower that was designed in response to site and climate. All office floors of the Menara UMNO can be naturally ventilated. The design of wind wing-walls to direct wind to special balcony zones for natural ventilation inside the building are the main feature of the project. Air is continuously replaced by the force of wind alone, reducing the building's energy use by half. All elevator lobbies, as well as stairways and washrooms, are naturally ventilated and illuminated.

2.3. Access To Public Spaces

Tower podiums are, more often than not, extrusions of the site's footprint to maximize rentable floor area. Previous publicly accessible ground space is replaced by private accessibility in the form of a landscaped roof. Effort to maintain publicly available spaces at ground level should be made by incorporating public access in the design. The two residential towers that comprise the Minto

Midtown in Toronto (see Appendix A), are separated at their base by a landscaped public plaza. The plaza also serves as an entry point to each tower's lobby. The Menara Mesiniaga in Malaysia (see Appendix A), incorporates sky courts that serve as public spaces for inhabitants to enjoy the outdoors within the tower. Although unbuilt, the Editt Tower (see Appendix A), in essence, is a proposal to spatially continue street-level activities to the upper floors of the high rise tower. In London, the Brunswick Centre (see Appendix A) is built above an elevated publicly accessible courtyard, which serves as an outdoor market during the hot summer months.

2.4. Strengthening The Hubs

By locating these projects at important hubs (where amenities are concentrated), developers and city officials not only provide an opportunity for monetary success, but also improved urban living environments:

> cities at their best provide much of what we seek in a place to call home: community, places of culture and business that we can walk to, mass transit and a wealth of amenities that couldn't be supported without a city's density (Greenberg 2001, 10.)

By fortifying these hubs within a dense environment, we

> combat the degradation of other irreplaceable environments that are suffering from the encroachment of human settlements (Greenberg 2001, 74).

The Aura in Toronto (see Appendix A), not only incorporates extensive retail and office space in it's podium, but also connects to the city's extensive underground transportation system.

2.5. Summary

This thesis is a project that attempts to redefine the process by which the high rise building typology is conceived. Thus it relies on the critiques of many; most notably the theories of Ken Yeang. In his book, Reinventing the Skyscraper, Yeang advocates a vertical theory for urban design, where the design and planning of tall buildings

> are perceived as a form of urban design which takes precedence over its architectural form-making (Yeang 2002, 7).

Although the various projects studied in Appendix A employ some principles, such as, mixed use, passive ventilation, and access to public space, none are successful at reaching full potential for urban-connectivity.

Yeang argues for a reversal of the standardization and universality of spaces within the skyscraper in order to create environments that mimic those fulfilling aspects of our life on the ground (Yeang 2002, 12).

> The design endeavor would certainly require careful attention in order to integrate the skyscraper's design within the context of the existing urban fabric and circulation linkages, in order to link with the existing urban networks and systems surrounding the site, to create new public realms and urban places within the overall plan, and to attend to many of the usual social and physical considerations inherent in any urban planning and design situation (Yeang 2002, 25).

Whereas current high rises, such as those recently built in Toronto (see Appendix A), are vertically zoned with little integration into the existing urban fabric, Yeang proposes a shift in the thinking where the high rise is:

> a spatially continuous realm that starts from the ground upwards within the three-dimensional planning matrix (Yeang 2002, 83).

The combination of variety of choice and public areas to be used and enjoyed by all city residents is something that should be present in urban design;

> the city [should be] seen as something to enjoy, not a place to escape from (Greenberg 2001, 20).

A vast amount of information is required to design a high rise building. To manage a project of such scale in three-dimensional space increases the amount of variables to consider and complexity, thus lending itself to parametric thinking principles.

CHAPTER 3: PARAMETRICS

3.1. What is Parametrics?

With parametric thinking, designers use parameters to inform their design.

> A parameter is a variable to which other variables are related, all of which can be obtained via parametric equations. (Szalapaj 2001)

Design parameters for an architecture project are defined by specific site characteristics. To identify all aspects of the site's carrying capacity, a thorough analysis of the site's context is required. A location's neighbours, access points (pedestrian and vehicular), circulation on and around the site, views to and from, as well as climate and seasonal variations, are relatively constant features that serve as a legitimate starting point for architectural expression. The analysis of these parameters and their responses, in turn, can be optimized in terms of design to provide healthy, livable spaces.

> Conceptual design is a challenging part of the design

> process as it requires reconciling the design with a complex set of goals and constraints such as program requirements, construction cost, environmental performance, and more abstract notions such as aesthetics and usability. (Gane/Haymaker 2007, 1)

With the use of parametric thinking, in conjunction with parametric modelling software, designers can define and manipulate parameters to reach these goals. By generating multiple options, as opposed to traditional methods where fewer options are considered, can arrive at a more responsive resolution to the problem.

Robert Aish describes:

> design involves both exploration and the resolution of ambiguity. Therefore, it is not sufficient [to] model [a few solutions] to this problem, but [instead] design rules that can be used to explore alternative solutions. (Hensel 2006,14)

To think parametrically means to think in terms of relationships between parameters and how rules can be applied to generate multiple solutions which are then analyzed according to their response to specific goals.

> Parametric methods are very useful for subjecting uncertain situations to the rigors of a predefined and proven mathematical model. They can usefully embody a great deal of prior experience and are less biased than human thought processes alone. (Seer)

Furthermore, by using parametric thinking in tandem with parametric modelling software, the values and relationships between these parameters can be dynamically modified and automatically updated. Compared to traditional ways of design, with parametric design, we

> now have all possibilities of computational geometries as well as managing huge amount of data, numbers and calculations. Here the argument is to not limit the design in any predefined experiment, and explore infinite potentials; there are always alternative ways to set up design algorithms. (Khabazi 2010, 168)

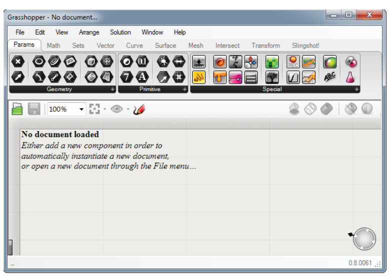
More importantly, as architectural design is a very dynamic process, using static representation with traditional computer aided design can be but detrimental,

> [a] solution [to] this situation can be [achieved] by radical change in the viewpoint: the architecture and urban form not to be conceived as a static system of predetermined ideal forms but rather as a dynamic system of changes that will generate a complex result. (Stavric/ Marina 2011, 10)

3.2. Parametric CAD Software

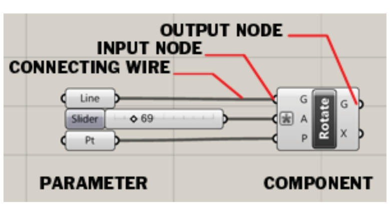
In recent years, multiple different parametric CAD software options have appeared on the market; each with their own advantages and inconveniences. Grasshopper3D, a parametric plugin for Rhinoceros3D's modelling software, is the software used for this thesis.

3.2.1. Grasshopper3D



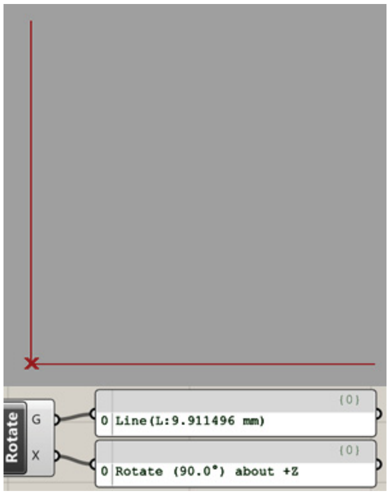
Grasshopper3D
Main Interface

Grasshopper3D is increasingly gaining in popularity. Its user friendly interface enables its users with the ability of creating generative algorithms visually using parameters and components. Parameters consist of data while components act on these parameters. The relationship between these are used to draw elements, generate new data streams or solve mathematical equations.



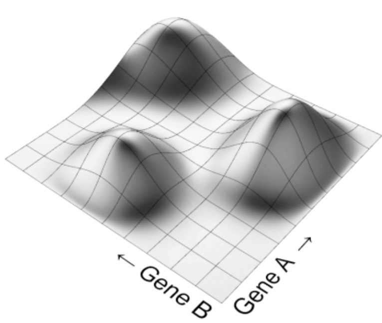
Grasshopper3D
Parameters and Components

An algorithm is defined by connecting a parameter to a component's input node via connecting wires. The component processes this data and it transfers it to its output node. In the image on the left, a line parameter is input into a rotation component. A slider parameter is used to define the rotation angle. Finally a point parameter is used to define the centre of rotation. The line is thus rotated by modifying the value of the angle using the slider. The component outputs are the rotated line and



Grasshopper3D
Modified Geometry

DesignResearchLab Pavilion
Photograph by Michael G. Mc-Cune



Genes Within a Landscape
Image by David Rutten

the transformation data; which in this case is a rotation of 90 degrees around the "Z" axis.

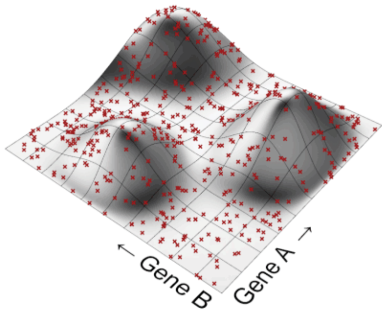
In this example, the line parameter is parametrically modified using the slider component. As the value on the slider changes, the line is rotated accordingly. This assembly of parameters and components create a generative algorithm. By using this process, multiple lines can be generated. Furthermore, by simply changing the location of the rotation centre, a whole new set of lines can be generated. The same principles applies to more complex systems, enabling the design of involved elements, such as the pavilion built by the DesignResearchLab on the image to the left.

3.2.2 Evolutionary Solver

Grasshopper3D comes bundled with an evolutionary solving component: Galapagos. An evolutionary solver applies the principles of evolution as a way to reach a specific goal. However, without setting a time constraint or stopping the process manually, the solver will try and find different solutions as it tries to reach this goal indefinitely. The advantage of Galapagos is the opportunity to revisit each solution and select the one that best fit the purpose at hand.

3.2.2.1. Galapagos, How Does It Work?

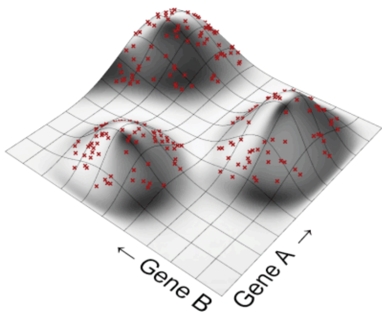
With the help of David Rutten's explanation of "Evolutionary Principles applied to Problem Solving using Galapagos" from the Grasshopper3D website (Evolutionary Principles), the following is a description of how Galapagos works.



Populated Landscape
Image by David Rutten

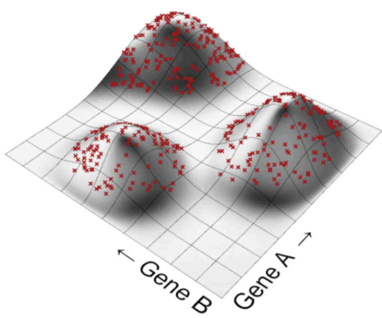
Two genes (A and B) are allowed to change within a landscape. The combination of gene A and B results in individuals within a population. If the goal is to find the highest peak within this landscape, each of the individual would correspond to a better or worse solution, or fitness.

When the solver first starts the evolutionary process with the goal of finding the highest peak, it has no idea what the landscape looks like. As a result, it populates it with a number of individuals or genomes. The solver evaluates the fitness of each genomes and sorts them from fittest to lamest (or better to worse), which in this case would be the highest elevation value to the lowest, with the lamest being discarded.



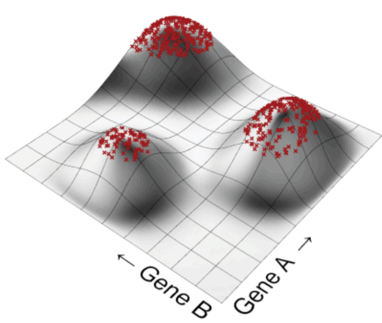
Discarded Genomes
Image by David Rutten

As the initial genome were populated at random, it is unlikely that the fittest genome actually represents the highest peak within this landscape. Considering that the highest peak is in the proximity of these fittest genome, their breeding (generation 0) will populate the resulting offspring (generation 1) within proximity. This new population is no longer random and are clustering around in fitness peaks.



Offspring Population
Image by David Rutten

By running the process again and removing the lamest genomes at each generation, the solver has a better opportunity of finding a solution to the desired goal as the generated populations gets more fit.



Cluster of Fit Genomes
Image by David Rutten

3.4. Summary

The complexity that comes with developing a high rise lends itself to parametrics and generative design as it simplifies the complexities associated with such a project. The parameters used to define the design algorithm are linked to each other by rules and goals. When one is modified, the others respond accordingly in real time; the coordination between these relationships is done automatically. The breadth of the design exploration is augmented by generating multiple options, rather quickly, with a high level of control and precision.

This thesis aims to explore parametric thinking with such tools as Grasshopper3D's generative design and its evolutionary solver Galapagos, on a specific site, by the creation of an algorithm for high rise design. The algorithm is developed by using site specific parameters and assigning relationships and rules governing them. By generating multiple iterations and evaluating them according to specific goals, a contextually responsive high rise will be designed.

CHAPTER 4: DESIGN

4.1. Site Selection

The site at the intersection of Duplex Avenue and Eglinton Avenue West was chosen for its location and characteristics:

- Is situated at a prominent intersection (Yonge and Eglinton).
- The site is adjacent to a major transportation hub (Eglinton subway terminal on the Yonge-University line, Eglinton Bus terminal, Yonge Street and Eglinton Avenue are major vehicular traffic arteries).
- The site is located within a 30 minutes travel time of most areas of interest.
- Yonge Street and Eglinton Avenue are major commercial arteries.
- Green areas and multiple different amenities are within a 15 minutes walk (1km) radius.
- The site's zoning permits high rise buildings while being at a transition point between low rise single dwellings and high rise office and condominium towers (the site itself is surrounded by buildings of various heights).
- Key landmarks (CN Tower, the downtown skyline, the Beaches and Exhibition Place) are visible from the site.

4.2. Program Development

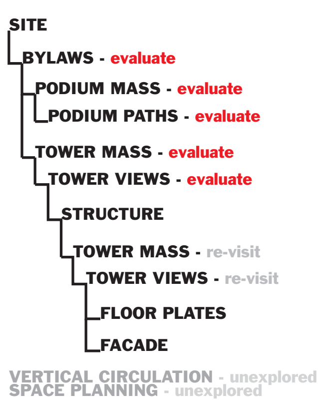
With population levels increasing continuously within urban centre, and the question of how to house them, a residential program has been selected for the high rise. The case studies of high rises in Toronto, Ken Yeang's theories and Utopian living projects, has resulted in the identification of certain goals to be achieved with the design of such a building: provide variety, form as a response to context, access to public spaces and the strengthening of hubs.

4.3. Design

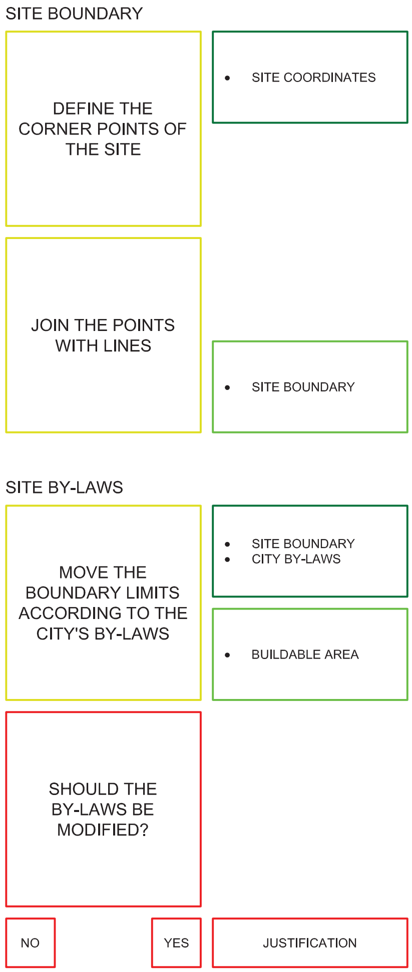
Using the design goals, along with digital tools, a design framework for the development of a residential tower is created. The framework algorithm is divided into sub parts: site, bylaws, podium mass and paths, tower mass and views, structure, floor plates and facade; vertical cores and space planning were left out due to time constraints. A more in detailed look into these is provided in the following pages.

The relationships between the different algorithms used within the framework enabled an iterative process as opposed to a hierarchical manner. On the left is the route (one of many possible) followed through this thesis.

The site boundary and bylaws are the main algorithms from which all others derive. Once these were created, the other algorithms could be defined and revisited as needed according to changes brought upon them by other algorithms.



Algorithm Process
One of Many Possible Routes



LEGEND
- ACTION
- PARAMETER INPUT
- PARAMETER OUTPUT
- EVALUATION

Process Diagram - Site and Bylaws

PODIUM MASSING

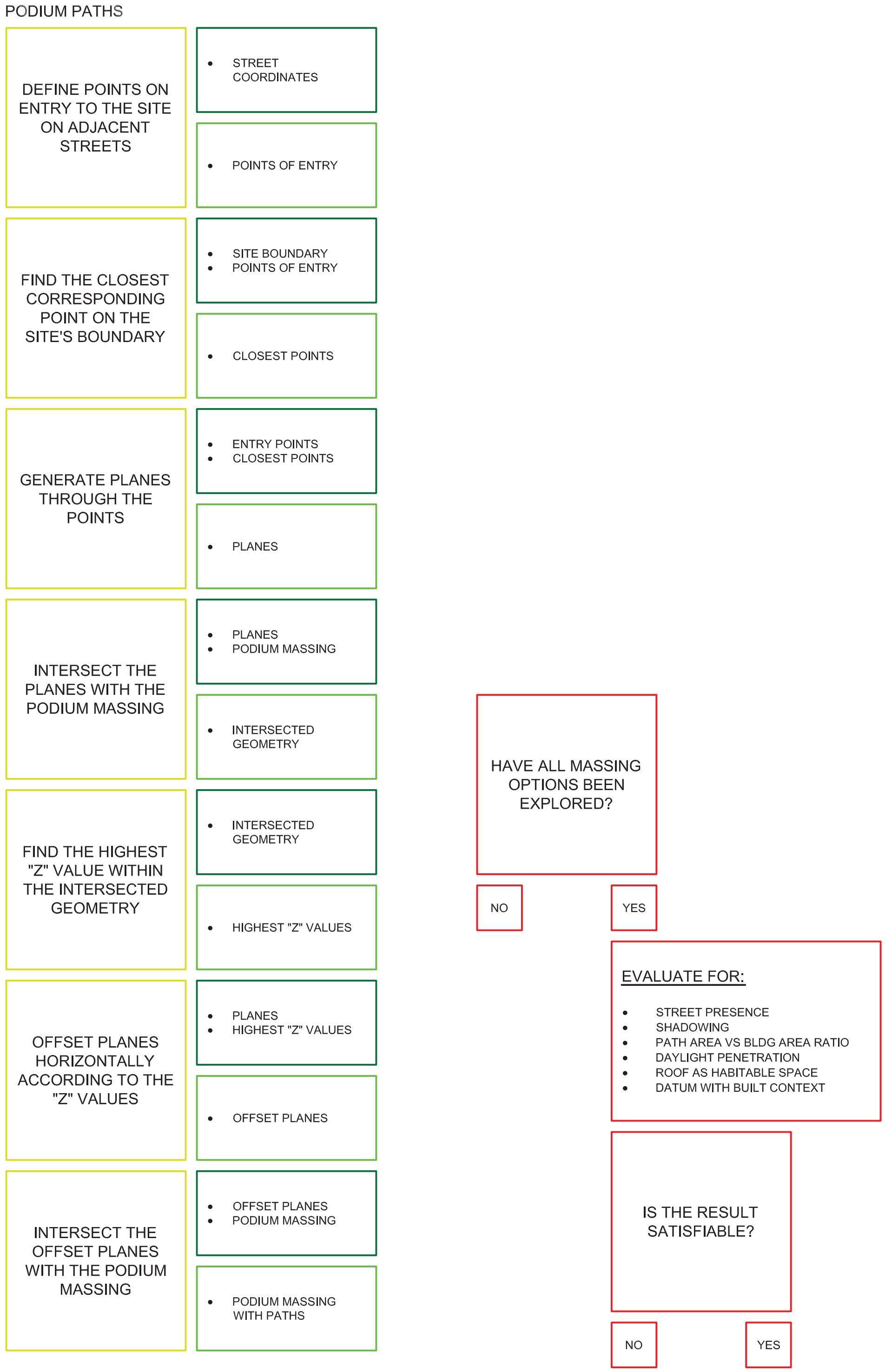
Action	Parameter Input	Parameter Output
DEFINE THE CORNER POINTS OF ADJACENT BUILDINGS ON THE SITE'S NORTH BOUNDARY	• NEIGHBOUR COORDINATES	• NEIGHBOUR POINTS
FIND THE CLOSEST CORRESPONDING POINT ON THE SITE'S BOUNDARY	• SITE BOUNDARY • NEIGHBOUR POINTS	• CLOSEST POINTS
MOVE THE POINTS UPWARDS ACCORDING TO THE DISTANCE BETWEEN THEM (1:1 RATIO DISTANCE/HEIGHT)	• DISTANCE • NEIGHBOUR POINTS • CLOSEST POINTS	• CLOSEST POINTS
GENERATE A CURVE THROUGH THE POINTS	• CLOSEST POINTS	• CURVE
EXTRUDE THE CURVE ALONG THE SITE BOUNDARY	• CURVE • SITE BOUNDARY	• EXTRUDED CURVE
EXTRUDE THE BUILDABLE AREA	• BUILDABLE AREA	• EXTRUDED BUILDABLE AREA
INTERSECT BOTH GEOMETRY	• EXTRUDED CURVE • EXTRUDED BUILDABLE AREA	• PODIUM MASSING

HAVE ALL CURVATURE DEGREES BEEN EXPLORED?

NO | YES

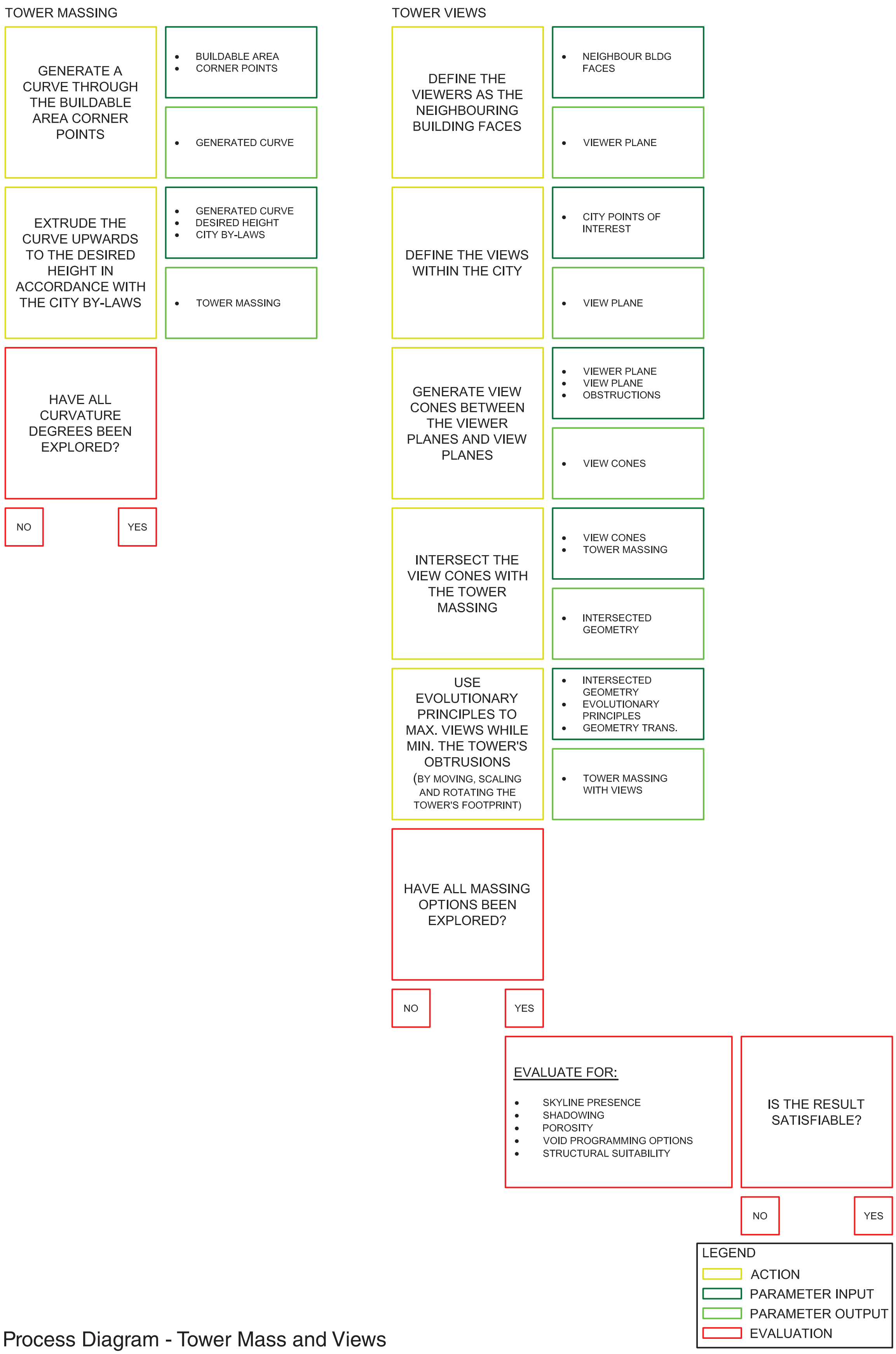
LEGEND
- ACTION
- PARAMETER INPUT
- PARAMETER OUTPUT
- EVALUATION

Process Diagram - Podium Mass



LEGEND
- ACTION
- PARAMETER INPUT
- PARAMETER OUTPUT
- EVALUATION

Process Diagram - Podium Paths



Process Diagram - Tower Mass and Views

STRUCTURE

DEFINE THE FOOTPRINT SURFACE
- FOOTPRINT SURFACE
- DEFINED FOOTPRINT SURFACE

DIVIDE THE SURFACE INTO A GRID WITH THE DESIRED SPAN
- DEFINED FOOTPRINT SURFACE
- STRUCTURAL SPAN
- STRUCTURAL GRID

POSITION STRUCTURAL SECTION AT GRID INTERSECTIONS
- STRUCTURAL GRID
- STRUCTURAL SECTION
- POSITIONED STRUCTURAL GEOMETRIES

EXTRUDE THE GEOMETRIES ACCORDING TO THE HEIGHT REQUIRED
- POSITIONED STRUCTURAL GEOMETRIES
- HEIGHT
- STRUCTURE MASSING

EVALUATE FOR:
- SENSIBLE SPACE PLANNING
- SPAN VERSUS STRUCTURAL SECTION
- VIEW CUT OBSTRUCTION

IS THE RESULT SATISFIABLE?

NO | YES

FLOOR PLATES

DIVIDE THE OVERALL HEIGHT BY THE DESIRED FLOOR TO FLOOR HEIGHT
- OVERALL HEIGHT
- FLOOR TO FLOOR HEIGHT
- DIVISION POINTS

GENERATE INTERSECTING PLANES AT THE DIVISION POINTS
- DIVISION POINTS
- MASSING
- INTERSECTING PLANES
- FLOOR CURVES

EXTRUDE THE FLOOR CURVES BY THE DESIRED SLAB THICKNESS
- FLOOR CURVES
- SLAB THICKNESS
- FLOOR PLATES

EVALUATE FOR:
- USABLE FLOOR AREA
- VARIETY PROVIDED BY PLANS
- DEPTH OF FLOOR PLATE

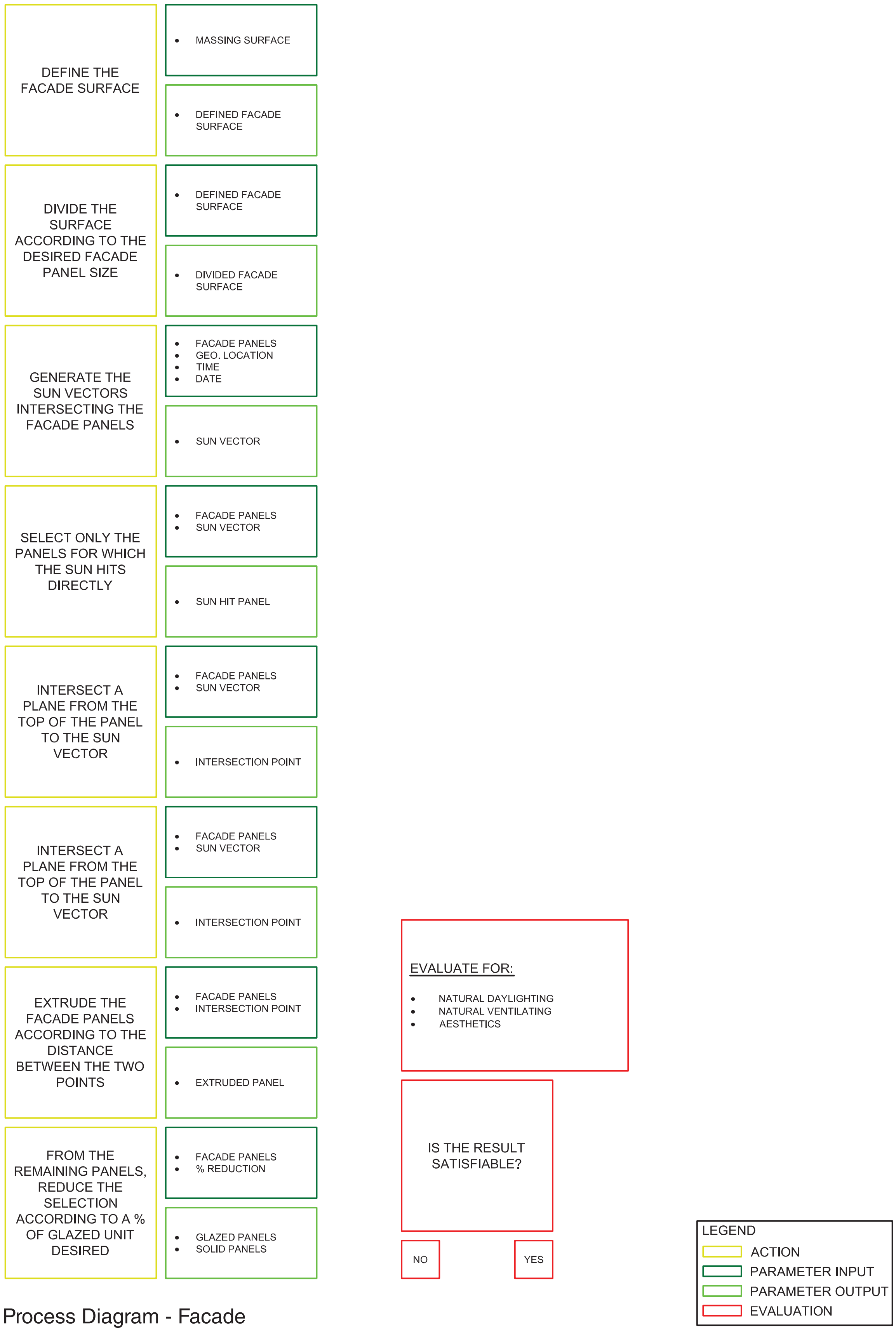
IS THE RESULT SATISFIABLE?

NO | YES

LEGEND
- ACTION
- PARAMETER INPUT
- PARAMETER OUTPUT
- EVALUATION

Process Diagram - Structure and Floor Plates

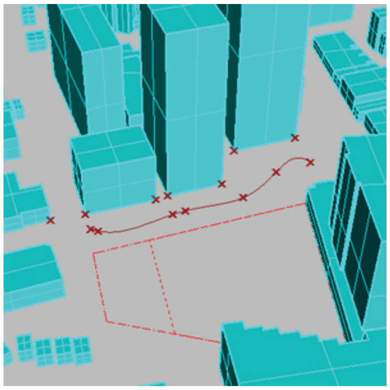
FACADE



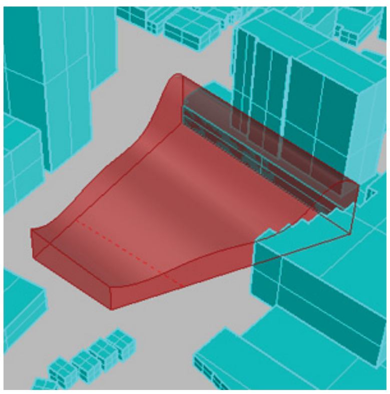
Process Diagram - Facade

4.3.1. Podium

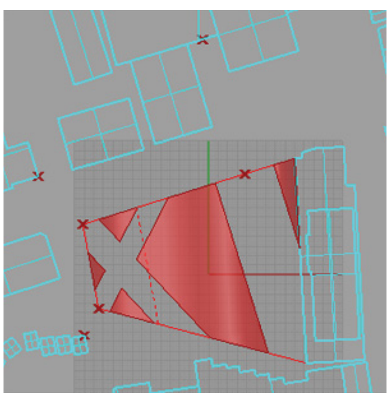
4.3.1.1. Massing



Guiding Curve Generated From Neighbour Building Coordinates



Podium Massing



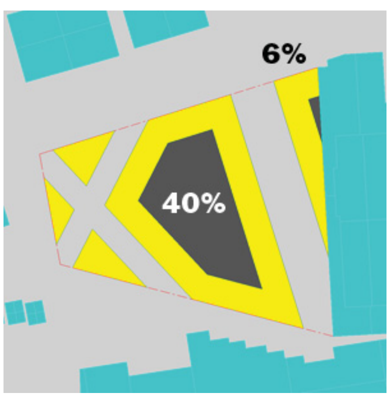
Pathways Generated From Entry Points

Theoretically, by keeping a 45 degree angle between the opposite street neighbours ground floor and the top of the podium's roof, daylight will be provided to these neighbours' ground floor throughout the year. Using this as a starting point, the neighbours' building corner points are selected. These coordinates are then positioned onto the site's boundary following the 45 degree angle; their z-value being dictated by their distance to the site's boundary. By generating a guiding curve through these points and intersecting it with an extrusion of the site's boundary curve, a podium mass is thus generated. The guiding curve's degree (amount of attraction from the curve's control points) can be modified rendering a curve that is either straight lines or curvilinear. The guiding curve's height is also adjustable by multiplying its control points z-values by a factor ranging from 0.00 to 1.00, where 1.00 represent the height limit based on the 45 degree angle.

Due to the site's size and in an effort to provide more street frontage to ground floor programming, pathways are created through the site. Point of entry to the site are defined and then positioned on the site's boundary according to the shortest distance between them. A plane generated by these two points intersect the podium mass. Using the 45 degree principle to allow daylight penetration explained above, the plane is offset according to the maximum z-value of the intersection between the plane and the mass. The relationship between height of podium and pathways width is as such established: by modifying the podium's height, the pathways width is adjusted accordingly.

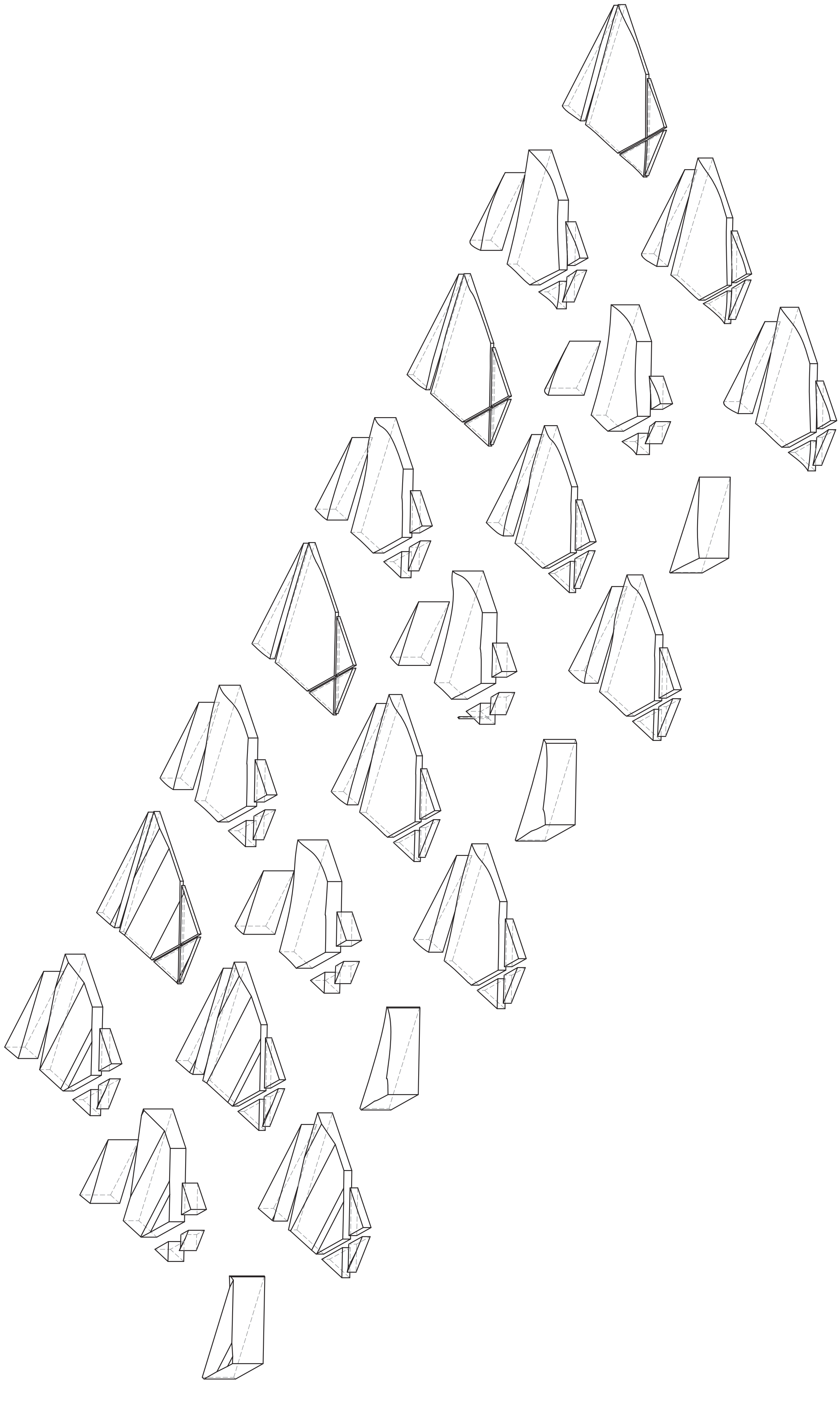
4.3.1.2. Massing Evaluation

The combination of guiding curve degree and height generated 24 potential options for podium massing (see drawing on the following page). As a result, it is the designers task to eliminate the ones that are outside the range of evaluation criterias. In this case, quantitative criterias (daylight access, street storefront perimeter and building height requirements) are used to quickly reduce the number of options which are then reduced further more using qualitative criterias (street presence and programming opportunities). Although looked into only after the options were generated, the quantitative criterias could be built directly into the algorithm by preventing the podium mass of being generated if x or y criteria is not satisfied.



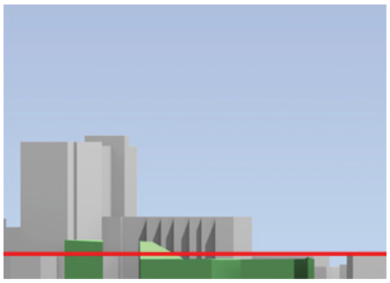
Area Without Proper Daylight

It is considered that a maximum of 11 metres are provided daylight in a glazing to core condition and 13 metres in a glazing to glazing condition. (Yeang 2000,15) Using Grasshopper, each massing's perimeter curve is offset according to the shortest distance (glazing to core condition) as by using this number, both conditions are satisfied. By dividing the offset area by the footprint area, a ratio of improper day lit area if provided. Considering circulation and servicing areas to usually account for 30% of the total floor area, an improper day lit ratio of 30% or less is considered acceptable.



Podium massing options

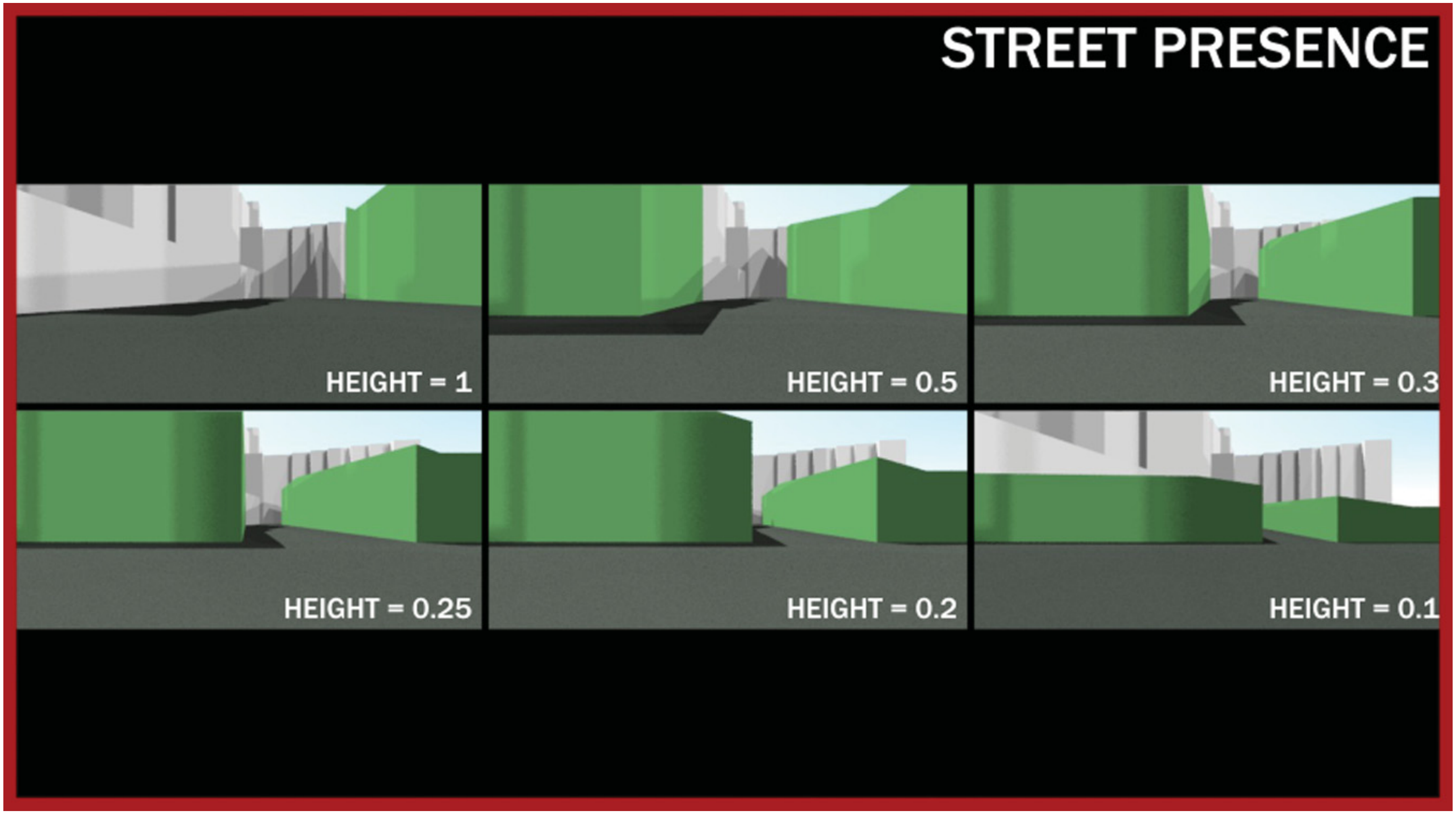
A visual inspection is enough to realize which of the podium options has the largest street storefront perimeter. But, this happens at the detriment of the pathways width.



3 Storey Datum

Toronto's Tall Building Criterias document specifies that podium height should be a minimum of 11 metres (or 3 storeys) in height. (HOK 2006, 33) As the buildings adjacent to the site (on the corners of Yonge Street and Duplex Avenue) are themselves 3 storeys in height, they are used as a datum line to evaluate the podium options' heights. The mass should also be at an appropriate scale (City Plan 2009,3-8). The height of the different massings creating the podium are different and as a result, a mix and match of different massing options might provide a better solution.

In an effort to evaluate the options in a qualitative manner, an animation is created to simulate a walk by looking at the site in elevation (see still on following page). Although interesting to look at, the success of this process is limited. Not in so much as a failure of the process but more so in the limited amount of qualitative information that can be gathered from a massing element. Another process is created (see still on following page) by combining an elevation view along with key street views (Yonge-Eglinton north-east corner, Rio-Can plaza, Duplex and Eglinton north-west corner). Again, due to the limited amount of qualitative information that can be gathered from a massing element, the success is limited.

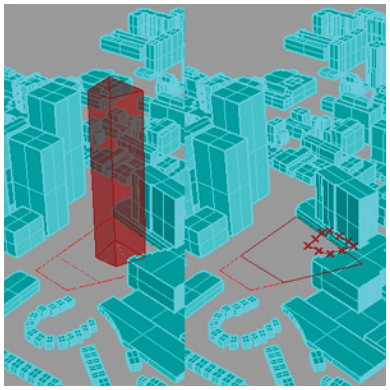


Still From Evaluation Animation

Still From Evaluation Animation

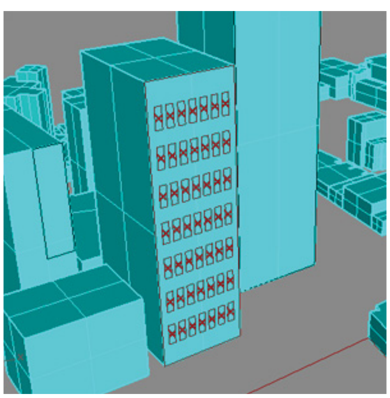
4.3.2. Tower

4.3.2.1. Massing



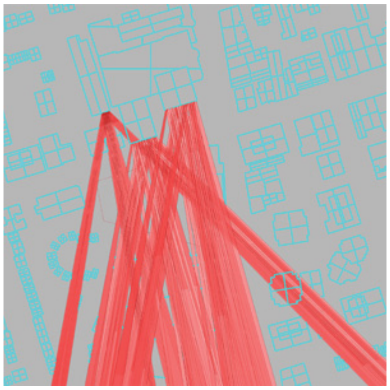
The Tower Isn't Extruded If Not Completely Inside The Buildable Area Boundary

The city's bylaws state that a 20 metres setback should be implement for tall buildings adjacent to low rise residential zoning. As such, the site's boundary is adjusted accordingly to create a buildable area boundary. The tower's footprint curve is generated using this new boundary. Its degree (amount of attraction from the curve's control points), position, scale, rotation and extrusion height parameters can all be adjusted using number sliders. These paramete. The tower is set to an extruded height of 180 metres, which is 25 metres higher than its highest neighbour, Quantum Tower North, at 156 metres tall. In an effort to prevent the tower from mistakenly being placed outside of the buildable area, a rule has been implemented where the tower will not extrude if its footprint exceeds that boundary. This is achieved by dividing the footprint into a number of point and evaluating if these points are located within the buildable area or not.

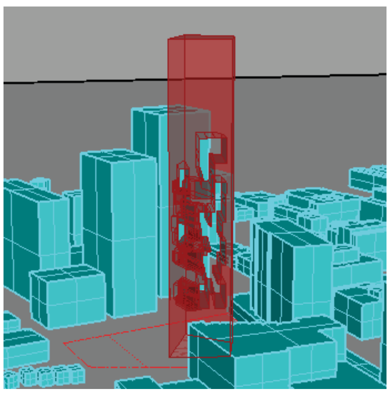


Viewer Plane Subdivision

Regular development seldom acknowledge their immediate context. One way to remedy to this situation is to respect the neighbours' right to views. To achieve this, view cones are generated from adjacent neighbours to key landmarks within the city. The view cones are created by selecting a viewer plane (neighbour) and a view plane (landmark). The view planes are then divided into a number of smaller planes representing windows. The number of divisions and their width and height parameters are also adjustable using number sliders. Cones are generated between the viewer and view plane using these subdivided surfaces.



View Cones Between Neighbours And Landmarks



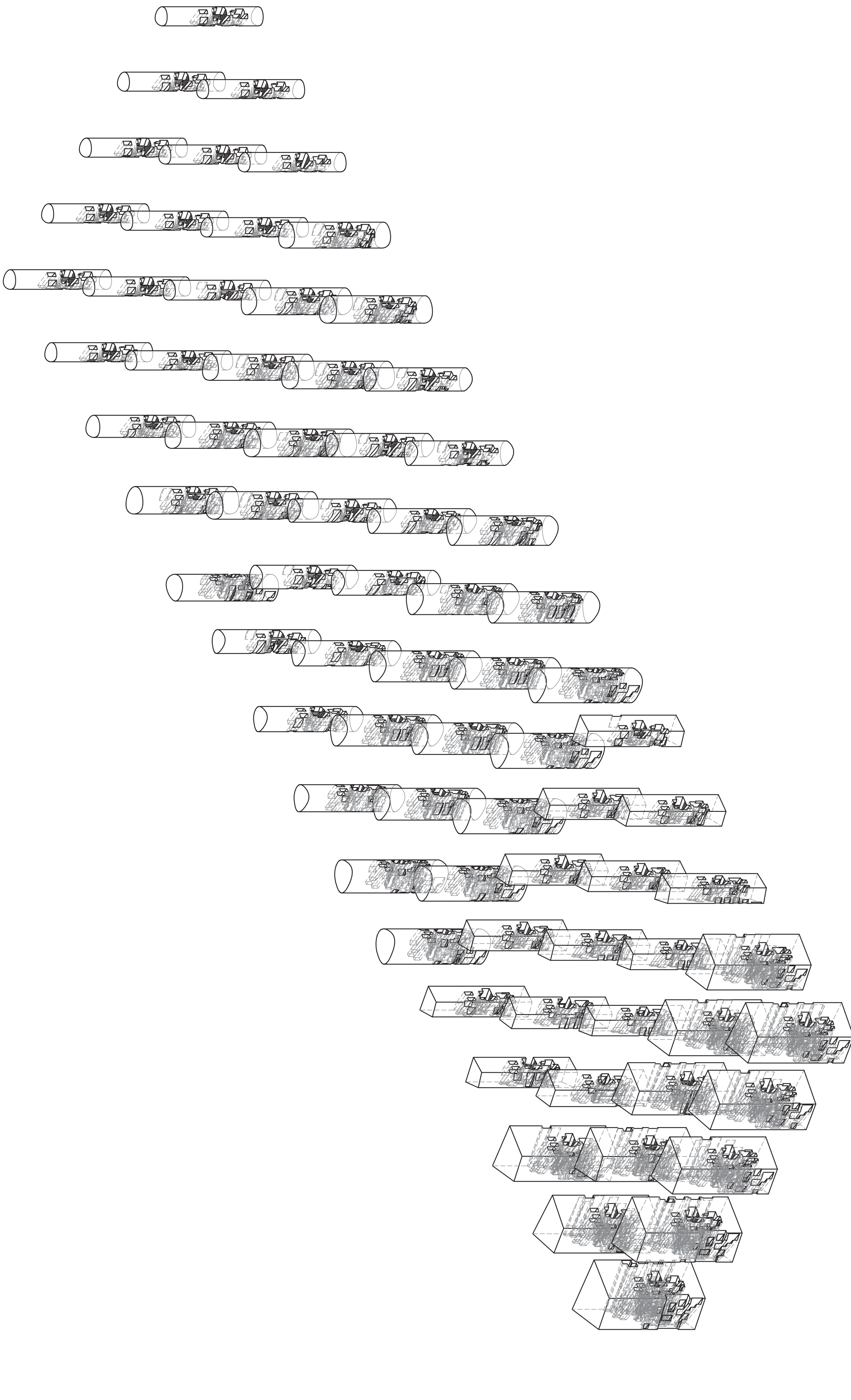
View Cones Are Removed From The Tower's Mass

Obviously, not all the cones have direct and complete view to the landmarks. Thus by defining obstructing building within the view cones and removing the cones that are obstructed, the result is the remaining viewers with complete unobstructed views. For further control over these view cones, a randomizing reducing component connected to a number slider representing a percentage of reduction allows for a varied viewing pattern.

Using Grasshopper3d's evolutionary solving component, Galapagos, and a view cone reduction ratio of 75%, the tower's position, scale and rotation are optimized to minimize the amount of view cone intersection through the tower, thus maximizing the amount of views to landmarks available to the neighbours. These are the tower's driving parameters and, along with the tower's height, represent the genome used by the evolutionary solver in the optimization process. The intersecting view cones' volume are removed from the tower's extruded volume to provide even more views to the landmarks, create a wide variety in floor plate configurations (variety design goal - see chapter 2), an opportunity for passive ventilation and daylight entry deep into the building.

4.3.2.2. Massing Evaluation

To reach a satisfiable level of tower optimization, the generative process is left to run for multiple generations; where the first generation is populated with 100 genomes and 50 offsprings for each of the following ones. The fittest genome is kept at every 5th generation. The optimization process is run for each of the tower's footprint curve degree. In the end, a total of 75 different tower options are generated (see drawing on following page).

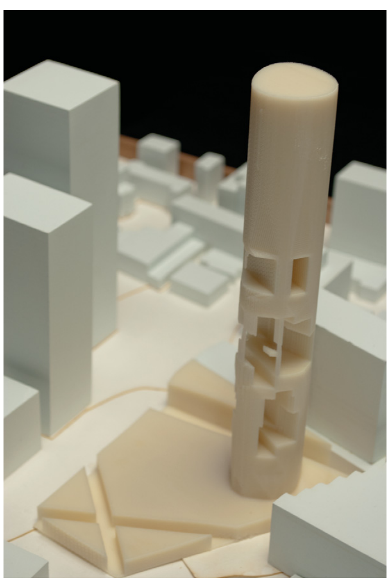


Tower massing options

Here again, quantitative (comparison of the amount of shade in a specific area at a specific time, floor plate rentable area) and qualitative (view cut pattern, skyline presence, interior programming, structural possibilities) evaluation criterias are used to reduce the number of potential options for this particular site.

Common sense is enough to know that the slender towers will create the least amount of shadowing on site. But by creating an outline of that shadow and calculating its area, a definitive answer is provided; the 25th genome of each footprint curve degree provides the least amount of shadowing on site.

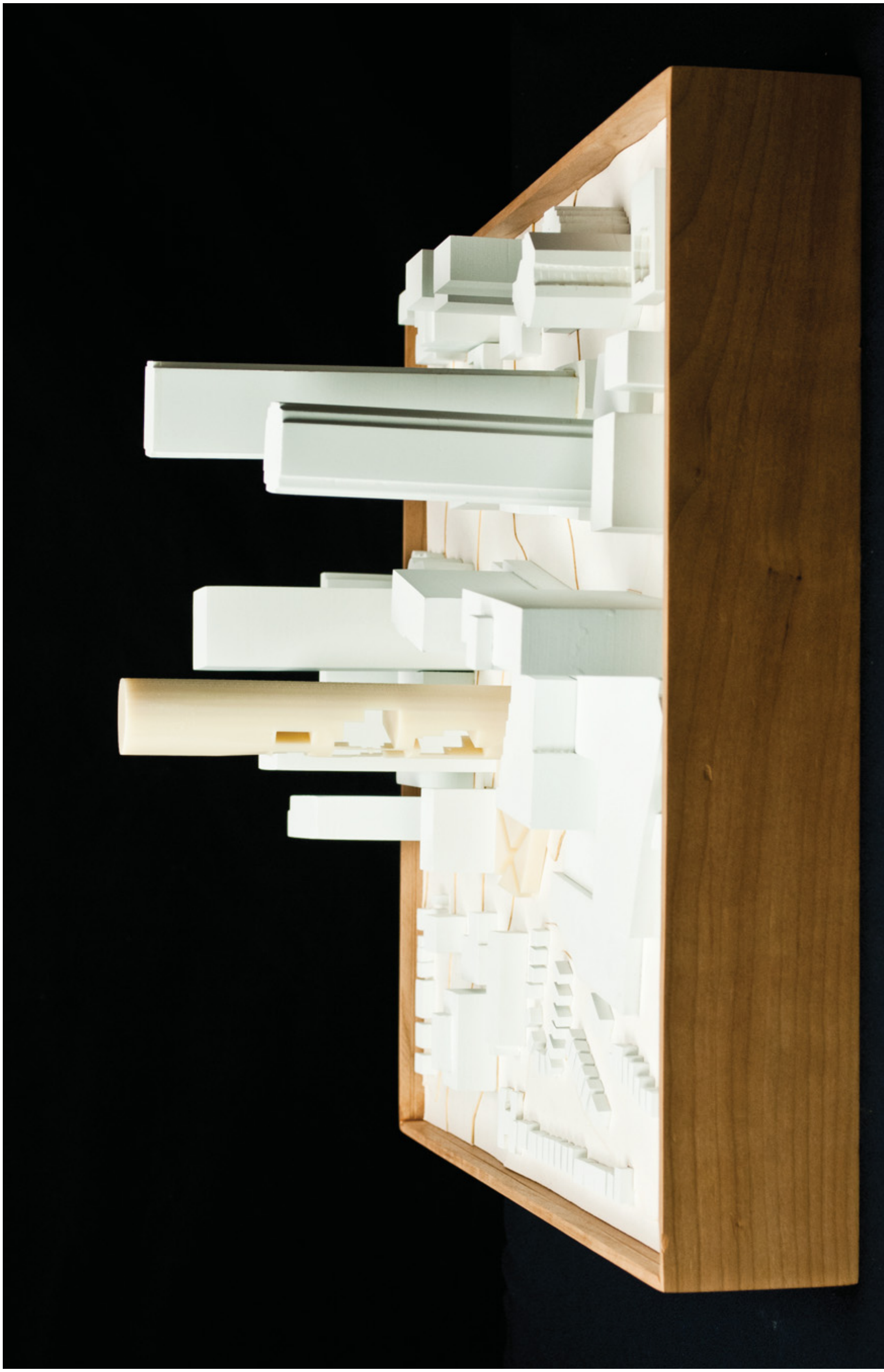
In the same way, the maximum floor plate rentable area is provided by the earlier genomes (their footprint is larger) but their large floor area is conflicting with the ability to create sensible living quarters with natural daylight and passive ventilation opportunities.



3D Print of a Podium And Tower Option

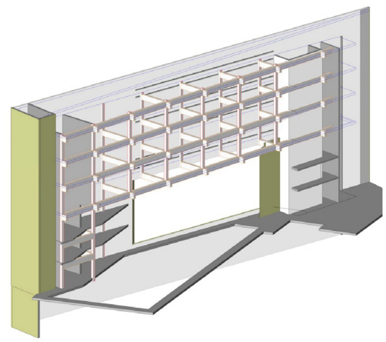
As the view cones used to create the view cuts are the same for every tower option, the view cut pattern manifest itself in the amount of void versus solid. In these terms, a slender tower looks very airy, as a larger footprint tower seems to support a very heavy mass on very little structure where the voids are. Along the same lines, the skyline presence is very subjective and here again, very little information can be gained from a massing element.

The use of 3D printing and physical site model is also used in an effort to visualize the massing component within its environment along with a podium element in terms of form and scale.



Site Model and Tower

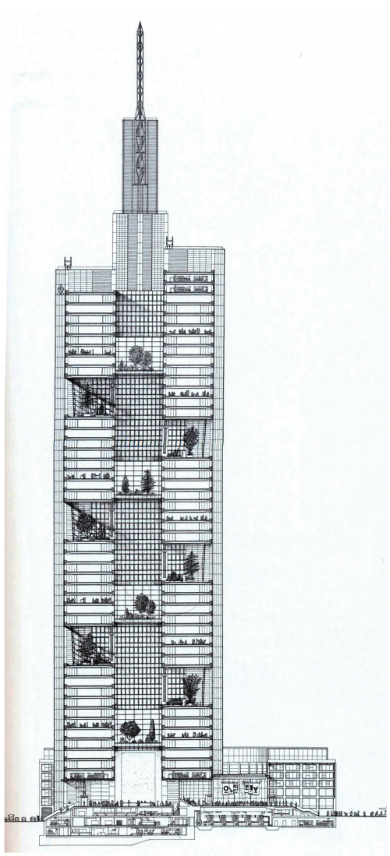
4.3.3. Structure



Vierendeel Frame System
Image by Karrick

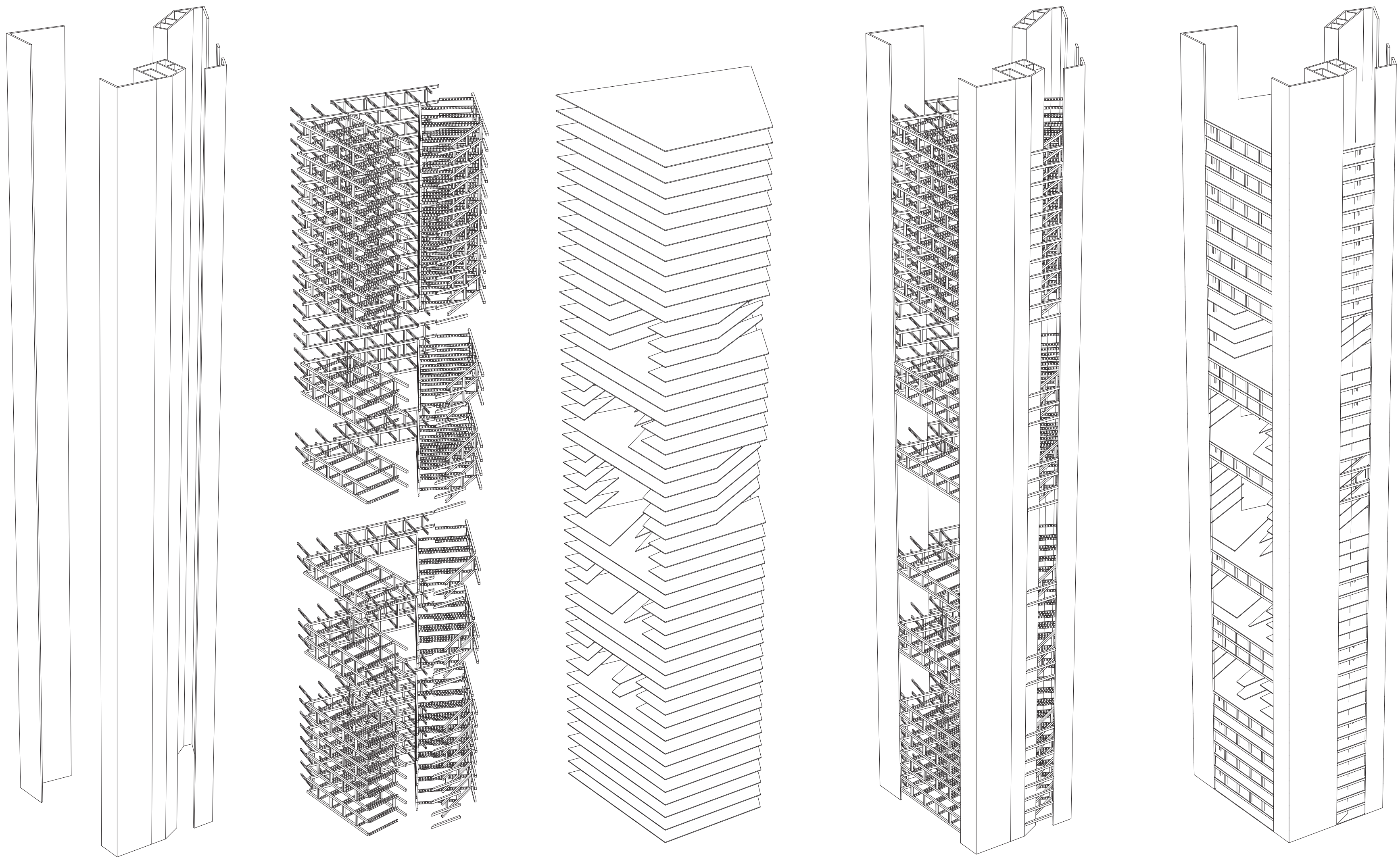
Where it becomes evident that another process is needed to analyze the tower massing is when looking at possible structural systems. Using a standard grid of columns would inadvertently block out some of the view cuts with structural members, rendering them purposeless in providing more view for the neighbours as well as from within the building itself. A diagrid system runs into the same issues although at the facade boundary only.

One option is to create vierendeel frames spanning between vertical structural supports. Vierendeel frames are composed of Vierendeel trusses joined together by perpendicular beams (see image on the top left). This system allows a maximum unobstructed volume for the view cuts. A similar system used for Norman Forster's Commerzbank Tower in Frankfurt was the inspiration for this implementation. The following page shows the Vierendeel system applied to the thesis tower, along with the vertical structure supporting it.

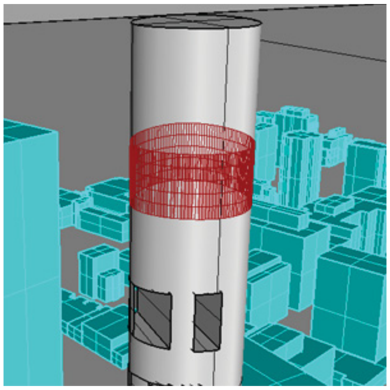


Commerzbank Tower
Section Through Tower
Image from OpenBuildings

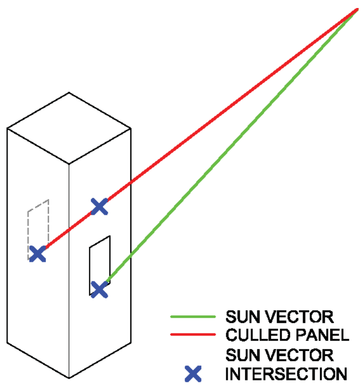
To generate options where vierendeel trusses can be used, the tower optimization process is revisited. This time, core areas are added at the corners of the footprint's curve which are in direct relation to the curves parameters (position, scale, rotation). The optimization process is run in a way that the tower is positioned, scaled and rotated to minimize the amount of view cones intersecting the core areas. Again, 25 different options are generated by keeping the fittest genome at every 5th generation for each of the footprint's curve degree (75 overall).



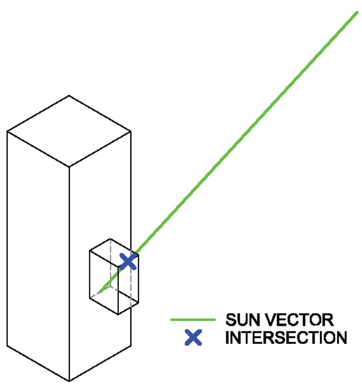
Structural Diagram



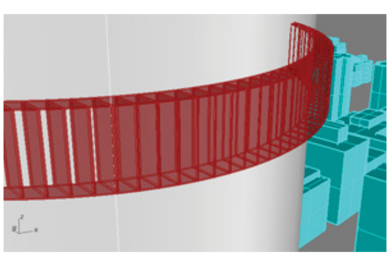
The Subdivided Facade



Sun Vector vs Intersections



Extruding the Panels



Extruded Units

4.3.4. Facade

Using Ted N'Gai's incident solar/current time algorithm (N'Gai, 2009) facade panels are generated that reduces heat gain in the summer month but allows it during the winter months due to the sun's angle.

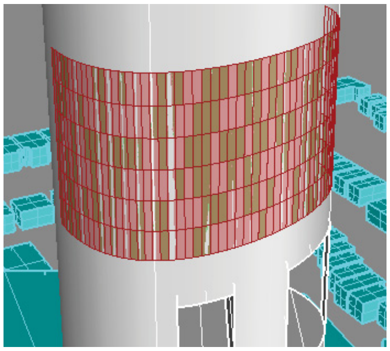
The panels are defined by dividing the facade's surface into smaller sub-surfaces. These are dimensioned using number sliders according to the desired width and height.

To allow greater control over facade and allow them to respond to it's context (design goal - see chapter 2), the panels can be selected to allow work on a single or a range of floors at a time.

The depth of the panel units correlates to the angle of the sun at the summer solstice. The summer solstice is used as reference as to avoid unwanted heat gain during the hot summer months. The panels' depth create a shading device that prevents direct sunlight from hitting the facade.

The panels are created by generating a vector from the sun to the panel's bottom edge. The panels are then extruded according to the distance between the top edge of the unit and the vector. This distance is the minimum dimension that provides the shading needed to block direct sunlight on the facade.

To prevent panels which do not receive direct sunlight from being extruded, Roland Hudson's intersection component is introduced. This component counts the number of intersections that occur between the sun vector and the massing. If the count is two or more, the panel



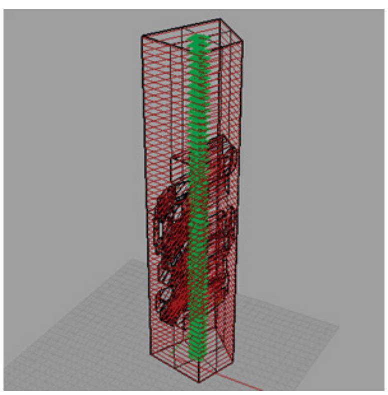
Glazing (red) vs Spandrel (green)

being evaluated does not get direct sunlight. These panels are removed from the list.

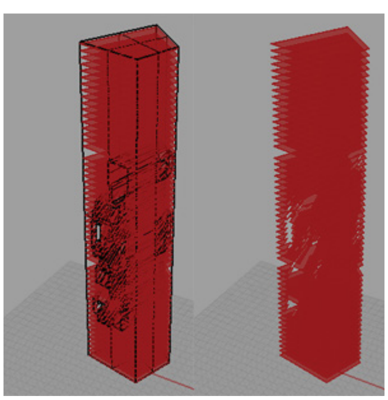
For facades that do not require shading, a random reducer component is used to create a pattern of solid and void, or glazed and spandrel panels units. This provides opportunity for indirect daylight to come through but also provides options for privacy.

4.3.5. Design Development

As the focus of this thesis is on the exploration of parametrics in the creation of a design framework for high rise design, further exploration of the podium is halted to the benefit of the tower element.



Intersecting the Mass with Planes

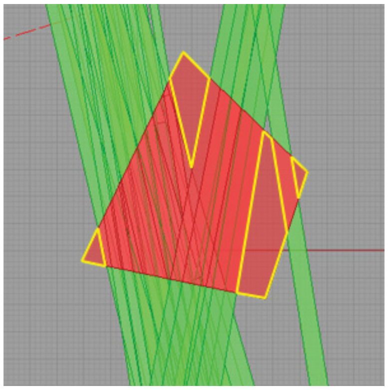


Extruded Floor Plates

Only a portion of the tower has been selected to develop further into an architectural response. The portion chosen has been selected for its containment of most of the building characteristics found elsewhere within the tower: view cuts, vierendeel frames, punctual structural elements and various floor plate forms.

The first step is to create the floor plates. This is done by intersecting the tower's mass with planes positioned at the desired slab to slab dimension. The resulting intersecting curves are then extruded to the desired slab thickness.

Looking at the resulting tower from the structural optimizing process, zones without any intercepting view cones are defined. These zones become areas where structural elements such as vertical circulation and edge supports for the vierendeel frames can be positioned.

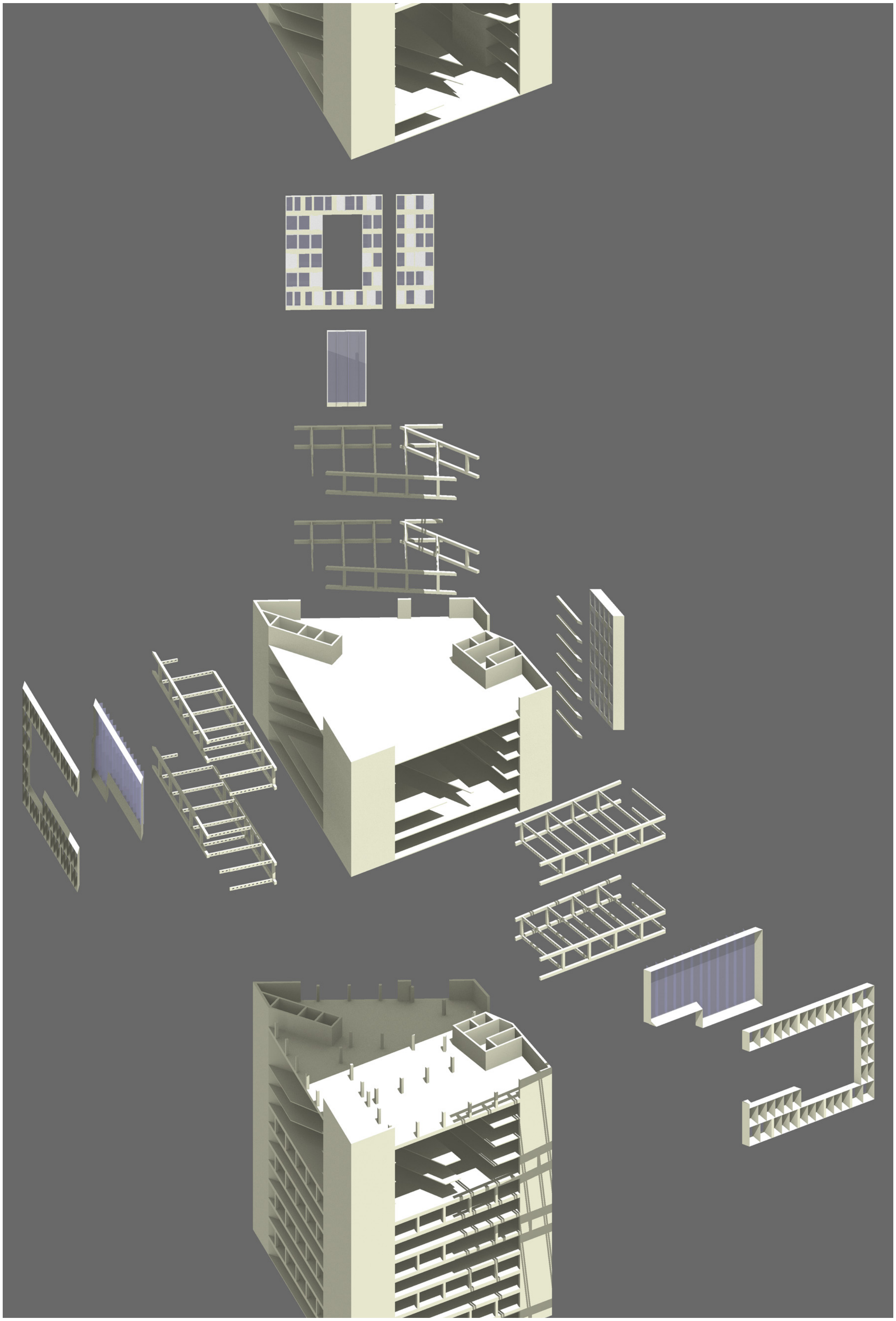


Structural Zones Shown in Yellow Outline

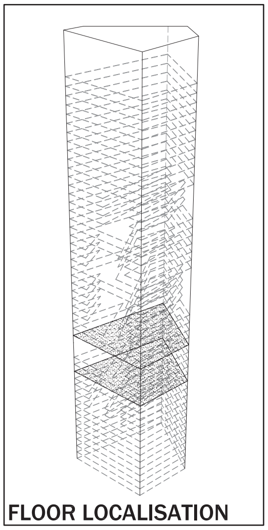
Switching between 2D and 3D environments is necessary to fully understand how floor plates and vertical circulation can work together in the configuration provided by the view cuts. Adjustments, addition and removal to the floor plates are applied to create comprehensive and structurally sound horizontal elements.

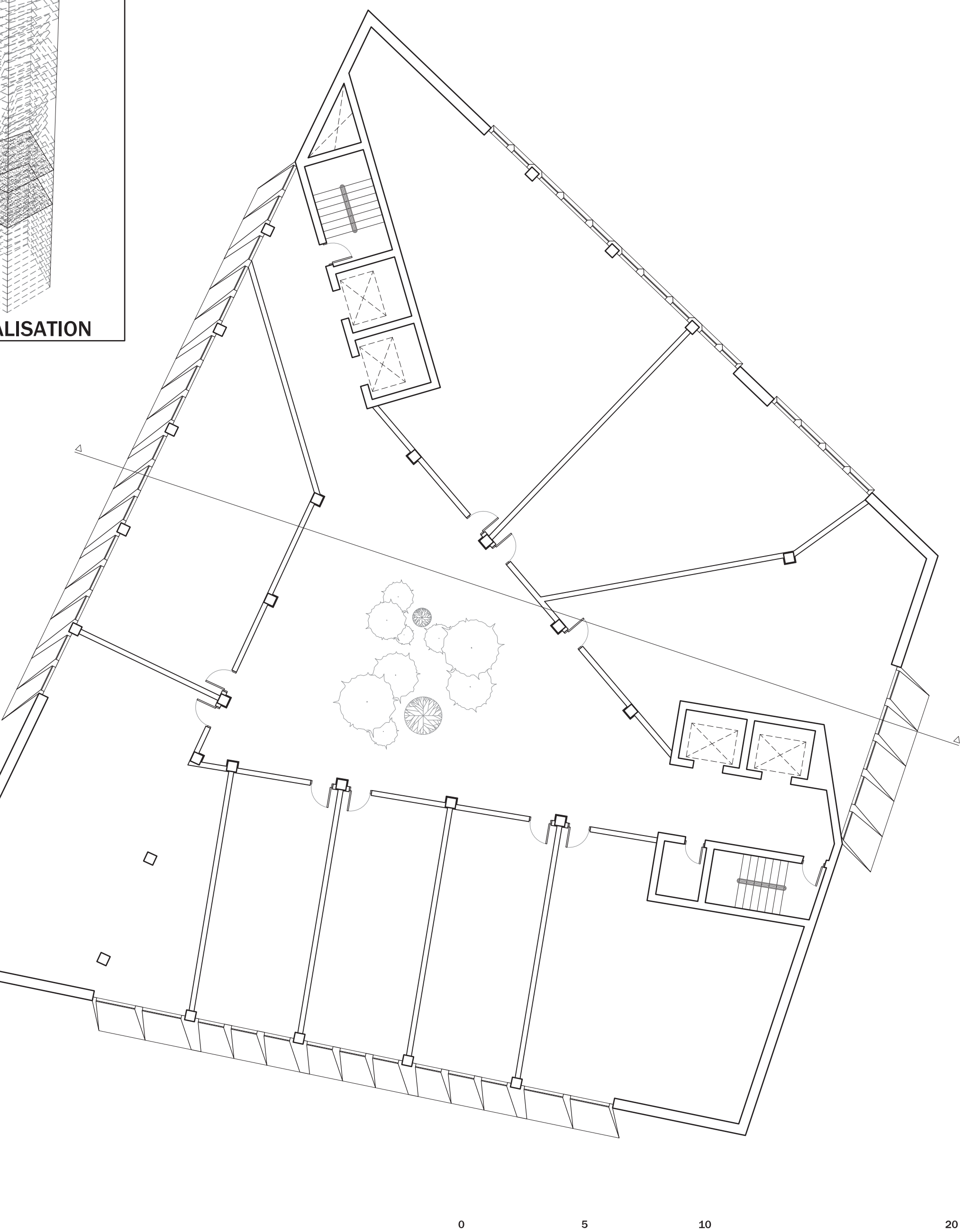
Having the main structural element in place, the vierendeel frame can be generated (see drawing on page 36). Working in plan view, a horizontal grid between the main structural elements is defined. These grid lines are then divided into a fixed spacing number, the resulting points being where a vertical member will be located. The horizontal and vertical members are extruded and populated across the tower according to their necessity to support floor plates. The advantage of the vierendeel frame is that it not only enables the view cuts to be unobstructed by structural elements, it also enable the clearance of structural elements on every second floor enabling variety in subdivision opportunities throughout the tower.

Floor plans are generated from the digital model and further developed in 2D. The floors are subdivided into apartment units and public areas using the cores and structural members as defining elements. The zone studied is comprised of four different levels, in terms of floor plate form, within a view cut sandwiched between two typical floor slabs.

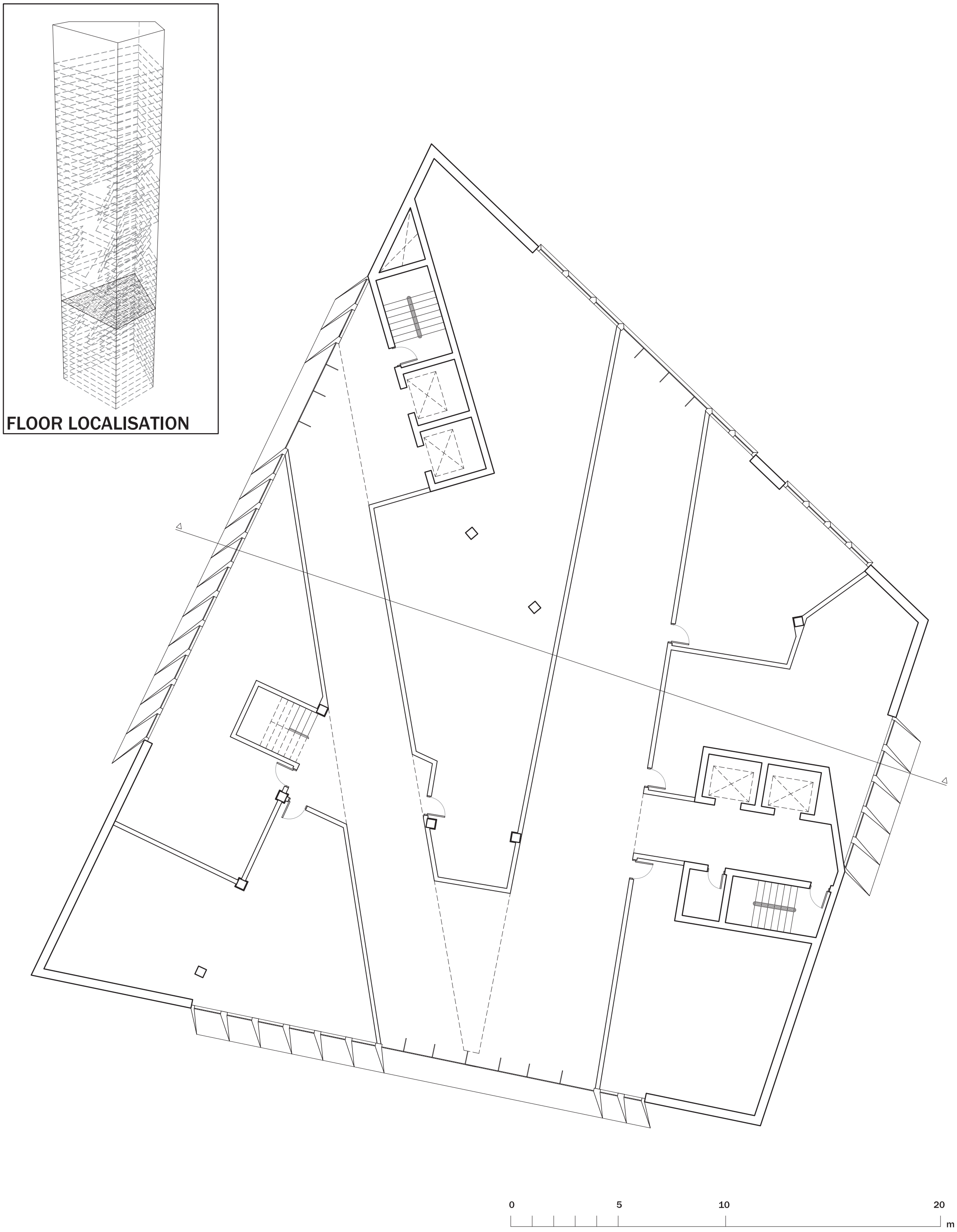


Exploded View of Studied Zone Components

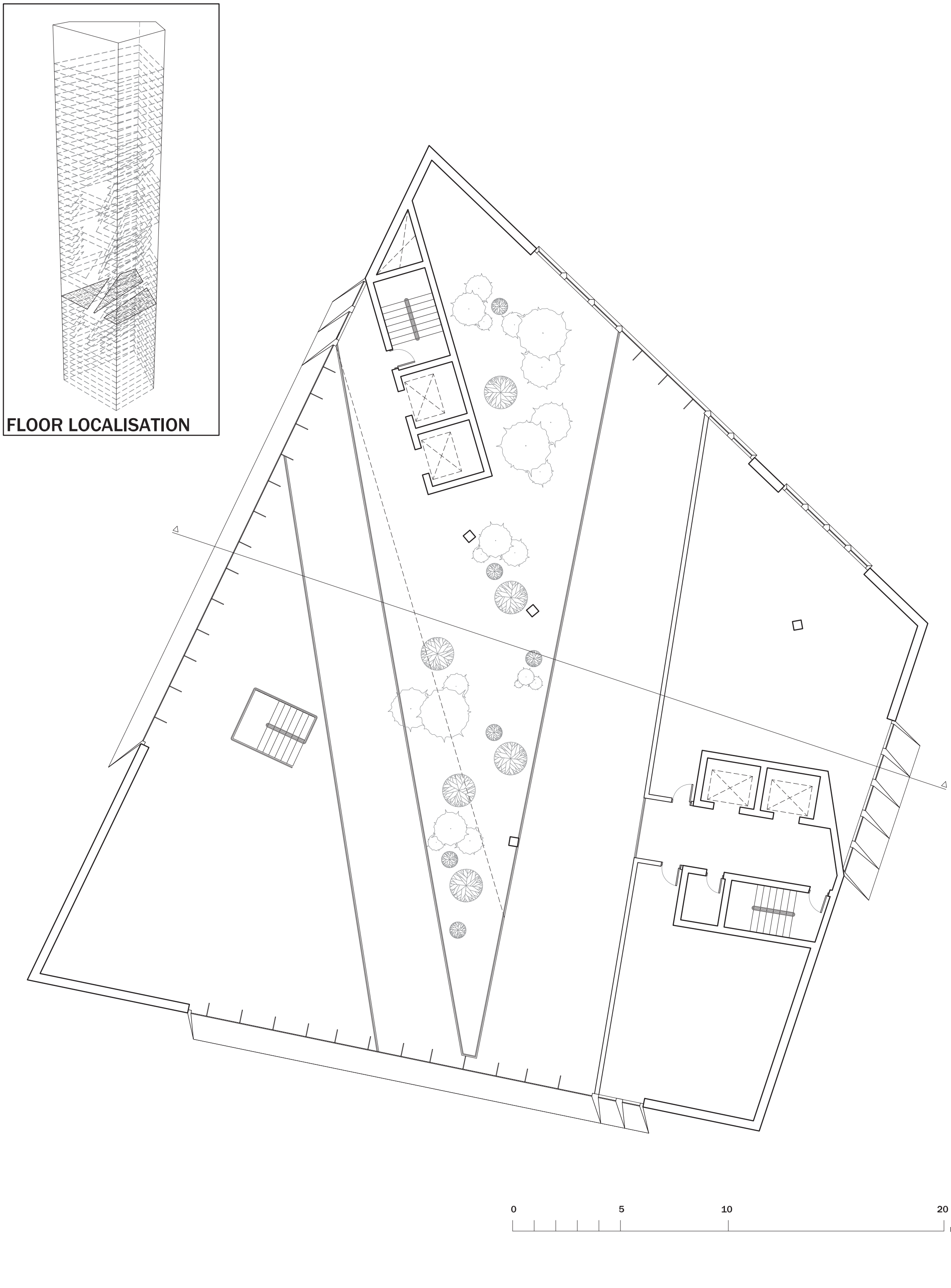




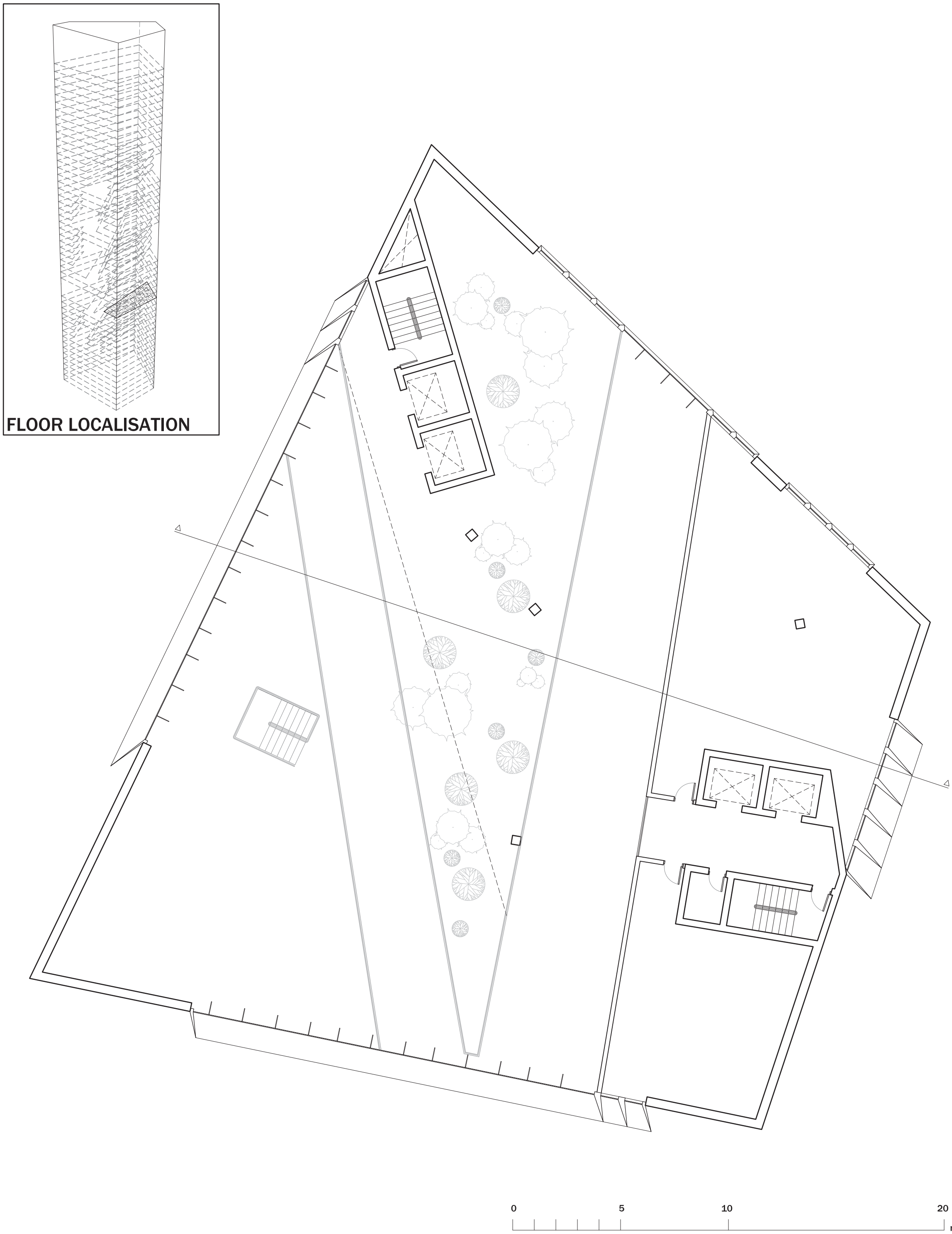
Typical Floor Plan



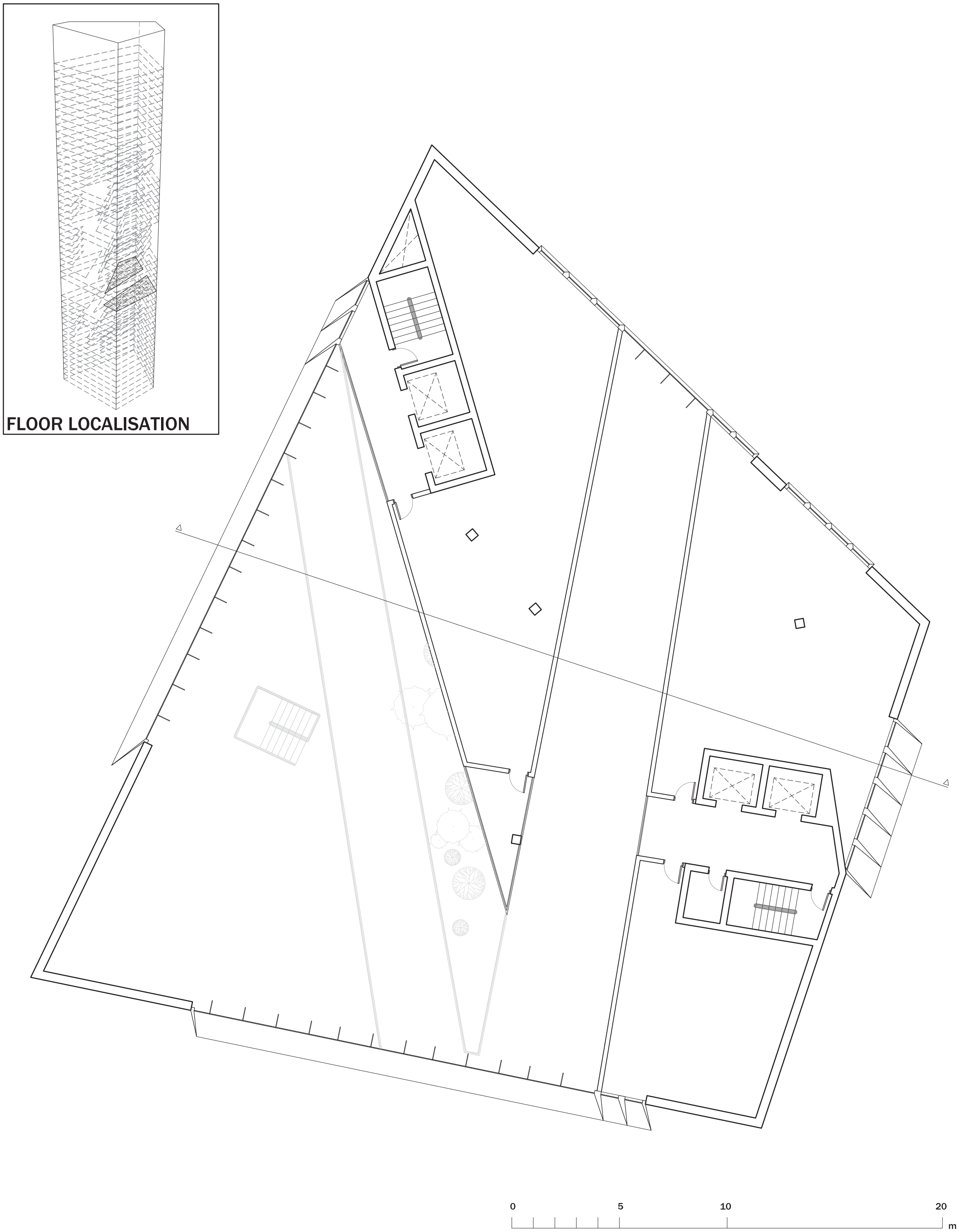
Level 15 Floor Plan



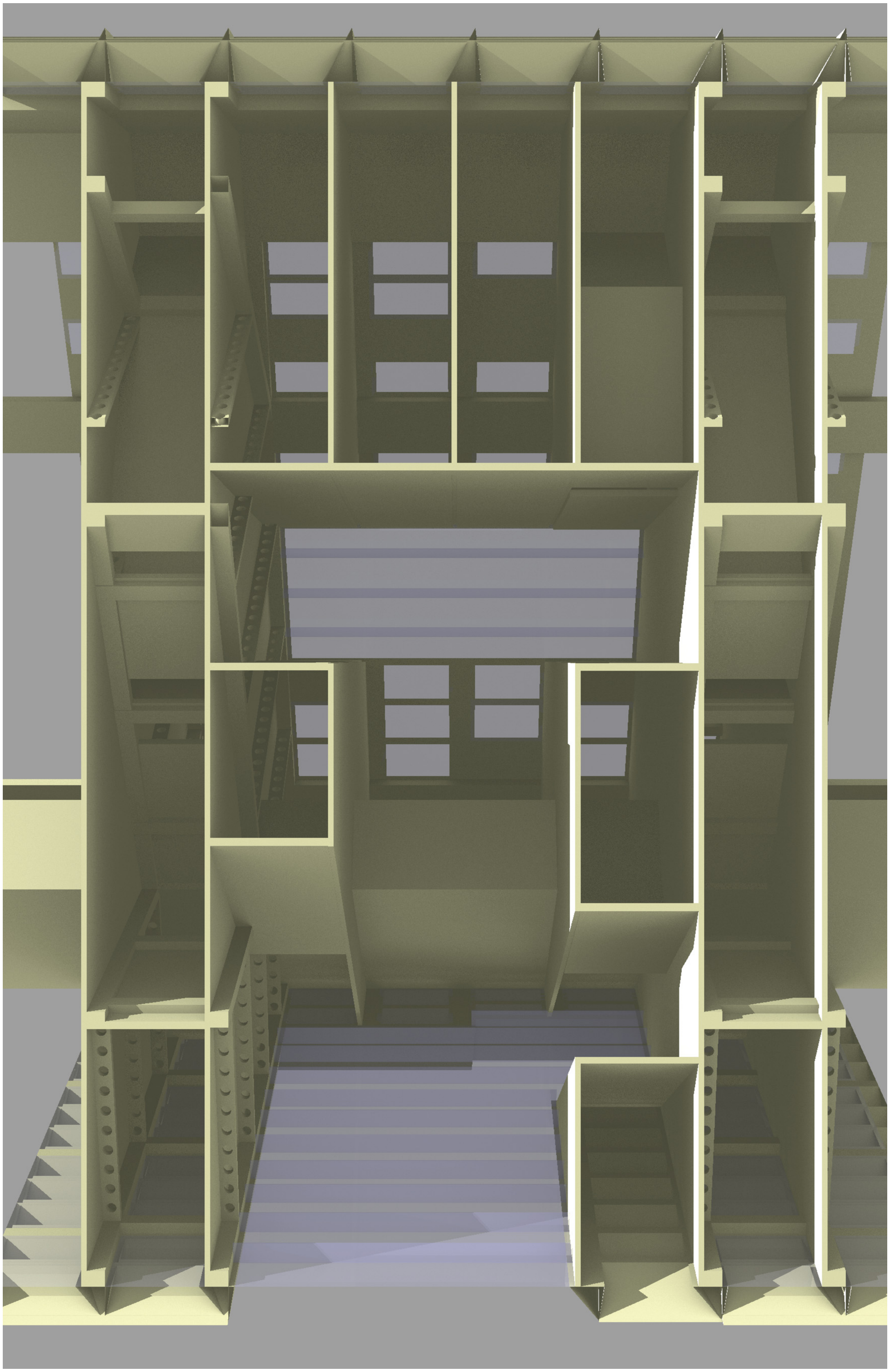
Level 16 Floor Plan



Level 17 Floor Plan



Level 18 Floor Plan



Rendered Section Through Building

CHAPTER 5: CONCLUSION

Throughout this exploration, parametric thinking and evolutionary principles have been applied to the development of a potential algorithm for the design of a residential high rise.

The parameters and rules are derived from a critique of current building trends in Toronto, drawing inspiration from the theories of Jane Jacobs and Ken Greenberg, as well as the works of Ken Yeang and Utopian residential projects. The framework of the parametric project is created in an effort to generate a tower form that responds to its context, provides variety in its environments, gives back to the public realm (accessible public spaces throughout the tower) and creates a high-density hub.

The design algorithm provided in Chapter 4 and explained in Chapter 4, was used to design the high rise. Site specific parameters were used to shape the massing of the tower podium. The combination of the various parameters generated 24 different options which needed to be analyzed critically. The challenge was to provide adequate and constructive evaluation criteria to successfully reduce the number of options; this was something easier said than done.

The tower was also generated using site specific parameters. By evaluating the view cones from neighbouring buildings, the tower was positioned using evolutionary principles. The intention was to minimize the amount of view cones that intersected with the tower. This process led to the creation of 75 different options. Again, critical analysis would be required to reduce this number.

A second optimization was needed to define structural zones within the tower. Time and effort would have been spared by starting with a structural algorithm to position and shape the tower.

By cutting view cones through the tower, it enabled the creation of very different floor plate forms throughout the tower. As a result, various unit configurations were developed according to size and type. Furthermore, the relationships between various programming elements, private versus public, are enhanced through the zones created by these cuts. By having the “ground” floor of these zones act as sky lobbies, interactions opportunities between the occupants is augmented.

By applying parametric thinking and evolutionary principles with the use of computer software, multiple variations of possible solutions were generated in a considerably short amount of time. The advantage of generating multiple options is to maximize the exploration of design possibilities. Evaluating these possibilities in a quantitative manner quickly reduced the number of satisfiable options that could be explored further. If the differentiation between the options is minimal, it becomes very difficult to define one option as being better than another. Clear goals and critical analysis is definitely required.

Another advantage is seeing the relationships between the parameters in real time. Because the digital models are based on parameters, algorithms can be developed individually and reference each other, eliminating the need for a central file where only one person can work on at a time.

But these advantages also come at a price. Parametric modelling requires and incredible amount of time, patience and rigour, as the resulting possibilities from this process seem endless.

Although parametric thinking is not a new subject, applying it to architectural design is. As such, definitive research still needs to be done.

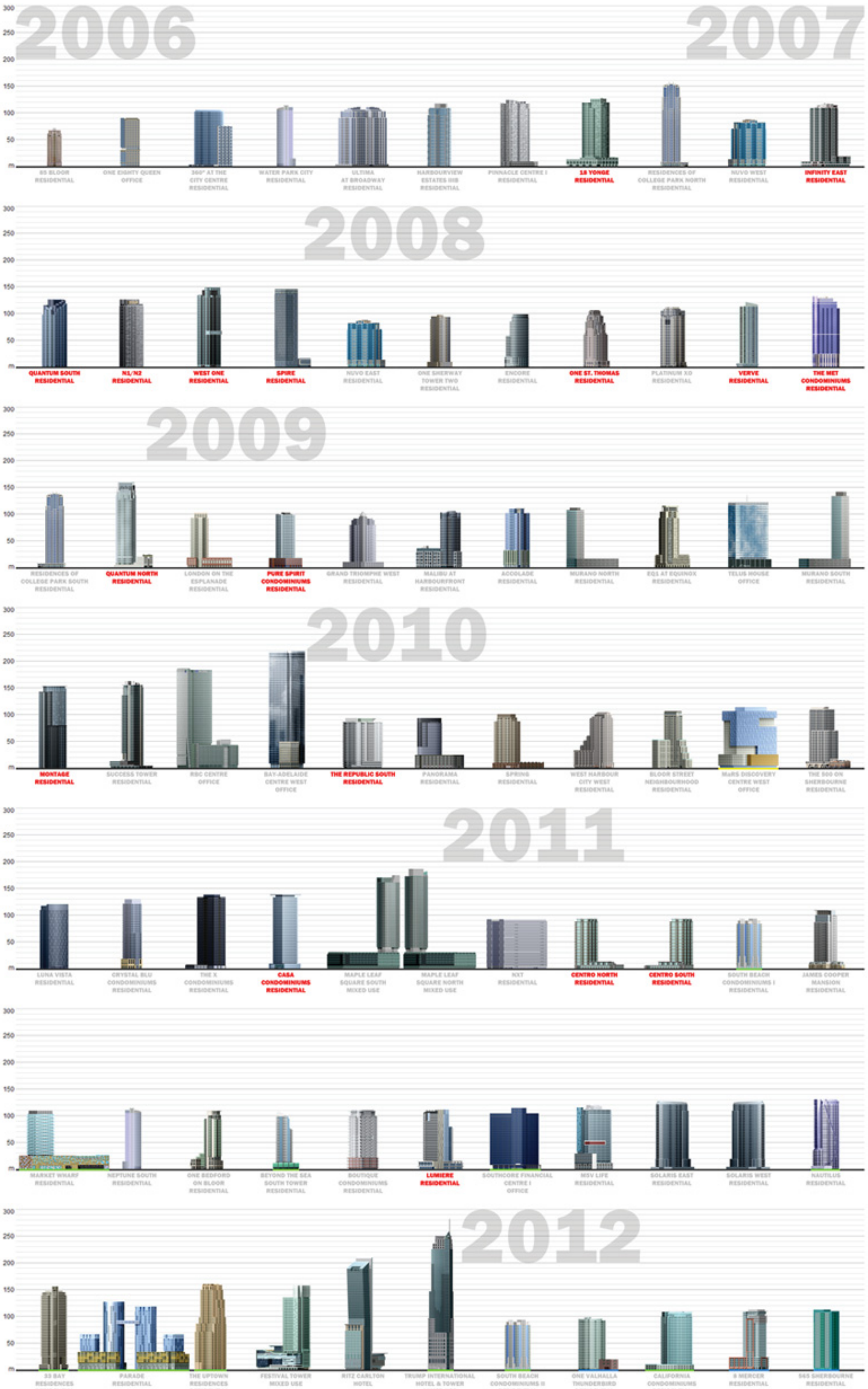
In retrospect, the goal of providing a parametric algorithm for high rise design was achieved on some level. An algorithm was created, but the elements explored left me pondering different approaches and possibilities for this project:

Would starting with a structural exploration have lead me to a different approach in terms of providing views to the neighbours?

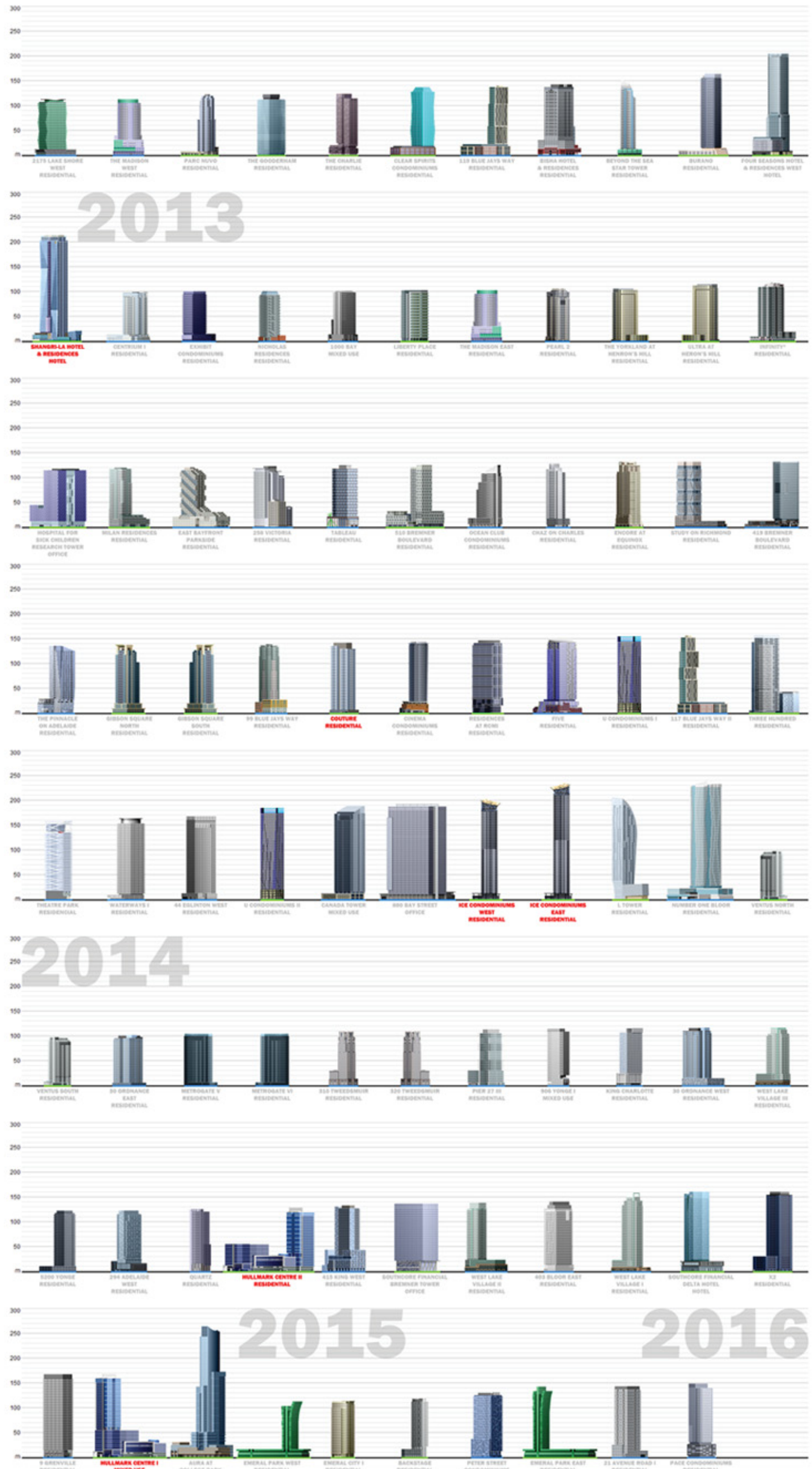
How would an algorithm to divide the floor plates into coherent living quarters be implemented?

More interestingly, how could I use meteorological data to inform the tower's form?

APPENDIX A: CASE STUDIES



Representation of Toronto's built and proposed since 2006



Representation of Toronto’s built and proposed since 2006 (continued)

18 Yonge Street

18 Yonge Street
Yonge Street elevation
Photograph from Real Estate Brothers

Designed by Page+Steele and completed in 2006, 18 Yonge Street is a condominium tower on a commercial unit podium. Located at the foot of Yonge Street, it occupies an infill lot between the railway and the Gardener Expressway, within walking distance of downtown and the waterfront.

The podium's street facade is treated the same along its entire length while its treatment above - large multi-level glazing - gives the podium a commercial appearance. The roof is landscaped on the north side which is self shaded by the tower itself during the hot summer months.

With its north/south orientation, the apartments face east and west which allows daylight entry. Balconies provide shading, but the residual amount of unprotected glass is considerable enough to indicate that the spaces would be affected by heat gain. The orientation and rounded northwest facade should subdue the dominent winter wind.

18 Yonge Street
Typical residential floor plan

The residential units themselves are organized around a double loaded corridor with a central, vertical circulation core. This configuration requires electrical lighting and mechanical ventilation within the circulation areas. Furthermore, the units, having access to the exterior on one side only, limits the opportunity to create a naturally ventilated environment.

One St. Thomas

One St.Thomas
View from Charles Street
Photograph from TO Built

One St. Thomas, designed by Robert A.M. Stern Architects and completed in 2008, is a 29-storey condominium tower with adjoining townhouses. Sited at the intersection with Charles Street, it is located a block away from Bay Street, one of the major office arteries in Toronto. Although the tower is quite small (70 units on 29 floors), the units themselves are very spacious; the smallest unit having a floor area of just under 186 sq.m.

The tower steps back as it goes up giving definition to its base, middle and top. The base of the tower is related to the scale of the adjoining townhouses. The greyish white colour of the facade reflects sun rays and thus reduces heat gain to some extent. The windows bring in plenty of daylight but they also allow heat gain within the spaces on the sunny facades.

One St.Thomas
Residential unit example

The residential units are arranged around a central core which requires electrical lighting and mechanical ventilation. The configuration allows access to views along the whole periphery. All units, except for the penthouse, are corner units which provides them with an opportunity for natural ventilation.

In an effort to blend with the historic neighbourhood where it is located, the tower is decorated with bay windows, stone pilasters, cornices, and balconies. The top penthouses are equipped with open terraces.

Pure Spirit

Pure Spirit
View at the intersection of Mill and Parliament Street
Photograh by Rod Taylor

Pure Spirit
Typical residential floor plan

Designed by architectsAlliance and built in 2009, Pure Spirit is a 34 storey glass and steel condominium tower positioned off centered from a five storey red brick podium. It is located in the historic Distillery district just east of downtown Toronto. It's within walking distance of downtown and public transport is available in the form of streetcars and buses. The district contains many art related functions, such as theatres and art galleries. Amenities such as, shops and dining options, are close by as well.

The podium, a flatiron configuration, is cladded with red brick, replicating the surrounding historic buildings in the area, and glazed storefront facades. The remaining four floors of the five storey podium contains lofts and terraced units. The podium is topped with a landscaped rooftop accessible to the residents.

All facades are treated the same way with floor to ceiling glass enabling daylight entry at the expense of heat gain. The floor is configured around a central core which requires electric lighting, mechanical ventialtion and provides unit access to views along the whole periphery. With multiple units per side, only the corner units have an opportunity for passive ventilation. Each unit has access to outdoor space in the form of a balcony, which does provides shading to counteract heat gain on sun affected facades. The units range between 50 sq.m. (one bedroom) to 100 sq.m. (two bedrooms) in size.

Quantum North and South (Minto Midtown)

Minto Midtown
View from Yonge Street
Photograph from DCN News services

Designed by SOM, Minto Midtown was completed in two phases: the south tower completed in 2007 and the north tower in 2009. The complex features two residential towers (south at 37 and north at 54 storey tall) atop commercial podiums. It is located at the intersection of Eglinton Avenue and Yonge Street, two major commercial arteries.

The towers are separated at their base by a public plaza which is landscaped with vegetation, seating areas, and art sculptures. The plaza also serves as an entry point to each tower's lobby.

The towers' facades are all treated the same with glass curtain walls and balconies. The balconies are recessed creating pockets of shade. The residual unprotected glazing are prone to heat gains on the sun affected facades. The residential units are arranged around a central circulation core providing access to views around the periphery and passive ventilation opportunities to the corner units.

One Bloor East

One Bloor East
Artist rendering
Image from Urban Toronto

One Bloor East
Typical residential floor plan

One Bloor East is located at the south east intersection of Bloor Street and Yonge Street; two of the major arteries in Toronto. Designed by Hariri Pontarini Architects the mixed use tower is to be composed of a multi- storey podium housing retail and office spaces, topped with 687 residential units within a 65 storey tower. It is estimated for completion in late 2013. It is located in an area of high accessibility within the city: major arteries, subway intersection hub, minutes to downtown.

The residential units will be organized around a central circulation core. This allows access to views along the periphery and passive ventilation opportunities for the corner units. The curved balconies are said to bring a certain level of control on daylight and heat gain while also generating a contrast between the facades. They also serve to increase the size of the corner units. The size of the units will range from 50 sq.m. to just under 180 sq.m.

Aura at College Park

Aura at College Park
Artist rendering
Image from Urban Toronto

Aura at College Park
Typical residential floor plan

The final of a series of condominiums near College Park in Toronto, this tower, designed by Graziani + Corazza Architects, is set to be the tallest condominium in Canada (over 243m tall), and fourth overall, when it is completed in late 2014. Set atop a 3 storey mixed use podium will be a 75 storey residential tower. Located at the intersection of Yonge and Gerard Street, entertainment, education, public transport, and green spaces are all a short walk away.

With a plan to connect the tower to Toronto's extensive underground (the P.A.T.H. system), residents will have access to the subway and shopping without ever having to step foot outside.

The podium will contain just under 3,000 sq.m. of retail space at street level for over 100 merchants. The upper two levels will contain office space. The podium's roof is to be landscaped and accessible to residents.

The residential units are organized around a central core providing access to views around the periphery. The units will vary, aside from the penthouses, between 50 sq.m. (one bedroom) and 120 sq.m. (two bedrooms).

Menara Mesiniaga

Menara Mesiniaga
Photograph from MIT Library

Menara Mesiniaga, built in 1992, is a 15 storey office tower located in Subang Jaya, Malaysia. It incorporates several passive low-energy features. All east and west facing windows (the hot sides of the building) have external louvres to reduce solar heat gain into internal spaces. The north and south sides have unshielded curtain-walled glazing to maximize natural lighting and views. The façade is designed to be porous, not hermetically sealed as with most common high rises. This is possible as the project is located in a tropical climate.

All elevator lobbies, as well as, stairways and washrooms, are naturally ventilated and illuminated. Of all the bio climatic features employed in the project, vertical landscaping and the sky courts are most prevalent. The vegetation provides cooling for the building, while the sky courts serve as potential expansion zones and opportunities for inhabitants to have contact with the outside environment.

For Yeang, this tower

> heralds the arrival of an original, new type of skyscraper, the form of which is derived from the application of ecological principles. (Powell 1999, 47)

Menara UMNO
Photograph from AE WorldMap

Menara UMNO

Menara UMNO, built in 1998, is a 21 storey office tower located on the island of Penang, Malaysia. It doesn't limit itself to office as the tower contains two banking halls and an auditorium. (Powell 1999, 83) As in many of Yeang's project, UMNO's geometry is a marriage between site and climate.

The façades are equipped with louvers that control sunlight penetration throughout the year. To maximize access to daylight for the workers, no desk location is further than 6 metres from a window. Furthermore, these windows are operable. (Powell 1999, 89)

All office floors of the Menara UMNO can be naturally ventilated. The design of wind wing-walls to direct wind to special balcony zones for natural ventilation inside the building are the main feature of the project. Air is continuously replaced by the force of wind alone, reducing the building's energy use by half. All elevator lobbies, as well as, stairways and washrooms, are naturally ventilated and illuminated.

The tropical climate in which UMNO is located allows for the design of sky-courts and roof-top spaces which allows workers access to an outdoor environment.

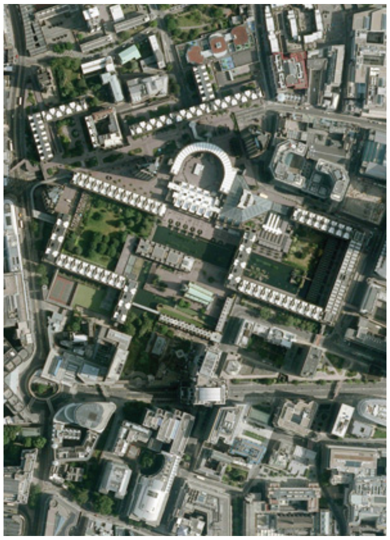
Editt Tower

EDITT Tower
Artist rendering
Image from World Architecture News

Designed for a site in Singapore, but currently unbuilt, the Editt Tower is an exhibition tower with retail, exhibition spaces, and auditorium uses. The design employs several principles applied in Yeang's previous projects, with greater attention paid to the habitability of spaces due to the programmatic requirements of the project.

The Editt Tower addresses the poor spatial continuity between street-level activities with those spaces at the upper floors of high rise towers (due to the physical compartmentation of floors inherent in the skyscraper typology). The design attempts to bring 'street-life' to the upper floors through wide landscaped-ramps upwards from street-level. The ramps are lined with street-activities: stalls, shops, cafes, performance spaces, viewing-decks etc. The ramp serves as an extension of the street, providing a continuous spatial flow from the public to less public spaces of the tower. Bridge-linkages on the upper floors connect to neighbouring buildings for greater urban-connectivity.

As an added bonus, the life span of the project was also considered, thus the tower was designed to facilitate future reuse.



Barbican Estate
Aerial View
Photograph from Google Maps

Barbican Estate

The Barbican Estate in London, designed by architects Chamberlin, Powell and Bon (CP&B), never lived up to its ideas of utopian living, although all elements are present. CP&B mentioned in the Barbican Redevelopment publication (Heathcote 2004, 26)

> The intention underlying our design is to create a coherent residential precinct in which people can live both conveniently and with pleasure. [...] the buildings and the space between them are composed in such a way as to create a clear sense of order without monotony. Uninterrupted by road traffic, which is kept separate from pedestrian circulation through and about the neighbourhood, a quiet precinct will be created in which people will be able to move about freely enjoying constantly changing perspectives or terraces, lawns, trees and flowers seen against the background or the new buildings or reflected in the ornamental lake.

Barbican Estate
View inside the courtyard
Photograph by Alex Cox

While within the estate, this separation between vehicles and pedestrian with a change in elevation and surrounding nature accentuates the feeling of being outside of the city within the city.

Comprised of over 2,000 apartments and houses, the Barbican is built around a publicly accessible green space and lake. The attached Barbican Arts Centre is an attractor point for residents outside of the estate. Enveloping the green space are 13 terraced blocks. Rising higher above and offering city views are three, 42 storey, residential high-rises. Elevated walkways connect buildings and are carefully landscaped, putting an emphasis on creating a unique living environment:

> wherever you stand there are interesting and unexpected lines and angles [...] everywhere there are juxtapositions between walkways and towers which are very pleasing to the eye. (Barrets Solicitors)

Barbican Estate
Terraced block overlapping an articificial lake
Photograph by EZTD

Brunswick Centre

Brunswick Centre
Aerial view
From Google maps

Brunswick Centre
View inside the courtyard with tiered terrace above
Photograph by Mark Moxon

Brunswick Centre in London, by Patrick Hodgkinson, is a mixed use complex in London, England. Built in the 1960s, it consists of apartments, restaurants, shops and a cinema. It had been left to itself for a number of years until it was renovated in 2006.

An elevated, concrete paved, central public courtyard, landscaped with benches, trees and a water feature, is surrounded by shops. During the warmer months, the courtyard is transformed into an outdoor market, while chairs and tables outside the various eateries fill up quickly. Above the shops, tiered terraced apartment units provide daylight to the shopping plaza below, but also ensure plenty of daylight to the apartment themselves. They are however separated from the courtyard. As the entry to the apartment units are on the street side from elevated walkways, the residents interaction with the courtyard is as outsiders. To further this disconnect, residents of each block enter from opposing streets. Without entering the courtyard, residents from opposing blocks have little interactions between each other.

But, despite this and high end store brands taking home at the Brunswick Centre, the complex, with its mix of sheltered (elderly with limited on site services), council (social) and privately owned housing is

> a unique place – you have all races, all ages, all classes living together in harmony. There's a sense of community and everyone talks when they pass each other on a bridge or meet in the hallways. (Davis 2006)

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