Encouraging Interaction: Neighbourhood-Specific Computational Design

by

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Contents

Abstract

Most high-density urban housing, while successful in meeting escalating population and financial demands, fails to sustain the local identity and community that make cities desirable. While high density typologies tend to isolate their residents, established neighbourhoods encourage the interactions necessary to allow a distinct identity and community to emerge. Formal patterns on the urban, building, and inhabitation scales are observed in these typologies to help or hinder interactions with the physical and social contexts. The thesis creates a custom computational tool that allows the architect to aggregate these neighbourhood-specific patterns in response to real time visual and data feedback, simultaneously evaluating qualitative and quantitative targets. A proof-of-concept design is carried out in the North End neighbourhood of Halifax, NS, resulting in an engaging and realistic residential development while contributing to thought on using computation to design for the human experience.

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Chapter 1: Introduction

This chapter discusses the two trends brought together in this thesis; the escalating use of isolating housing typologies, and the continued adoption of computation in the architecture, engineering, and construction industry. Can a custom computational tool be used to help architects design simultaneously for the qualitative human experience and quantitative targets? Readings of key influences, including Jan Gehl, Herman Hertzberger, Christopher Alexander, and Kostas Terzidis, are discussed in this context. Finally, the outline of the thesis is presented, breaking the argument down into chapters.

The Four Sisters, an architectural landmark in North End Halifax which displays the local identity.

Two Trends

The architecture, engineering and construction industry is facing two well-established trends regarding the future of urban housing. First, escalating financial and population pressures have made isolating high-density typologies common among infill projects in existing urban fabric, disregarding lessons from their engaging context (Farha, 2017; Gehl 1987). This isolation prevents the interactions necessary for local identity and community to continue emerging, eroding the aspects that make cities desirable in the first place (Hertzberger, 2015). Second, the ongoing adoption of computation can offer more than value engineering (Terzidis, 2006). Architects have a rich history of making custom design tools to help manifest their intentions, and computation presents an opportunity to create custom design tools to help architects manifest a rich and connected human experience (Kotnik, 2010). Can architects use computation to intervene in the busy housing industry, encouraging the interactions necessary for local identity and community to emerge while maintaining a population density that satisfies financial and urban growth pressures?

Imagining new residential development as the backdrop for many spontaneous relationships, rich lives, and other adventures.

Summary

Our cities are facing a dilemma. They need to meet escalating financial pressures and demand for urban living, but the typical typologies used to house these new residents often isolate people from their physical and social context. This isolation erodes the casual interactions that have made cities unique places by allowing local culture and community to emerge and diminishing the aspects that made cities desirable in the first place (Gehl, 1987). As cities densify using isolating typologies, they are destroying the opportunities for interaction that made cities the epicentres of human culture and community. How can architects intervene to improve the lives of urban dwellers?

This thesis looks specifically at high-density typologies that are built within an established urban fabric. These existing neighbourhoods engage the human mind with their cultural, social and physical surroundings. Therefore, developments are opportunities to reinforce established neighbourhoods, which already encourage interaction, by weaving more population density into their fabric. However in common practice, developments tend to instill isolation and emphasize splits in the urban fabric. Is it possible for cities to densify an area using lessons learned from the surrounding established neighbourhoods?

Architects are able to codify lessons learned as formal patterns that shape the human experience of a neighbourhood (Alexander, 1977). These patterns can hold the local identity (Hertzberger, 2015), and are especially useful to help design the structured variety

that offers a gradient for inhabitation and more stimuli for the inhabitants (Gehl, 1987). A custom computational design tool was made to interact various patterns. This more closely learns from the emergent nature of established neighbourhoods, which were built over a period of time with many human-scaled interactions and decisions relating to form, site, neighbours, culture, society, bylaws, and other influences (Ball, 2011).

Like other custom architectural tools, the tool created in this thesis responds in real-time to formal generators that the architect manipulates to provide visual and data feedback. This allows the architect to understand the impact of design moves, both qualitatively and quantitatively. This builds their intuition, allowing a more thorough design investigation.

This approach is applied as a case study to the North End neighbourhood in Halifax, NS. Typologies surrounding the study area were analyzed to find beneficial formal patterns, modified to provide more community space and population density, and applied to the study area. This resulted in a design that is effectively as dense as the isolating high-rise typologies, but arose from its context to provide a much more engaging human experience that allows local identity and community to continue emerging.

Outline

Chapter 2 establishes the impact of residential built form on the human experience. It first delves into the financial and growth pressures new residential developments are facing, and the isolating typologies that have emerged. The theories of Gehl (soft edges, stimuli) and Hertzberger (identity, variety, globalization) are used to understand the how the built form can foster either engaging or isolating human experiences. Inspired by Christopher Alexander's *A Pattern Language*, the chapter segues by discussing the opportunity provided to architects to design with formal patterns, and how understanding patterns as algorithms allows the architect to harness the power of computation.

Chapter 3 establishes the impact of design tools on the built form, as there is a tendency to adapt problems to tools, rather than adapting tools to the problem at hand (Tomkins, 1963). Opening with examples from recent development, the chapter then discusses the history of architects adapting tools to the specific design problem. The chapter closes by discussing the powerful opportunity to simultaneously evaluate the qualitative and quantitative results of design changes through the architect/tool feedback loop (Terzidis, 2006) established by the custom design tool created for this thesis project.

Chapter 4 is a case study of the methodology, applying it to the study area in North End Halifax. Neighbourhood-specific patterns are documented and combined into a hybrid typology which offers the high population density of isolating typologies while retaining the engagement observed in the surrounding established neighbourhood. The use of the custom design tool is well documented, showing the graphic, metadata, and numeric inputs. Tool operation is shown aggregating patterns at the urban, building, and inhabitation scales, before closing with the final design.

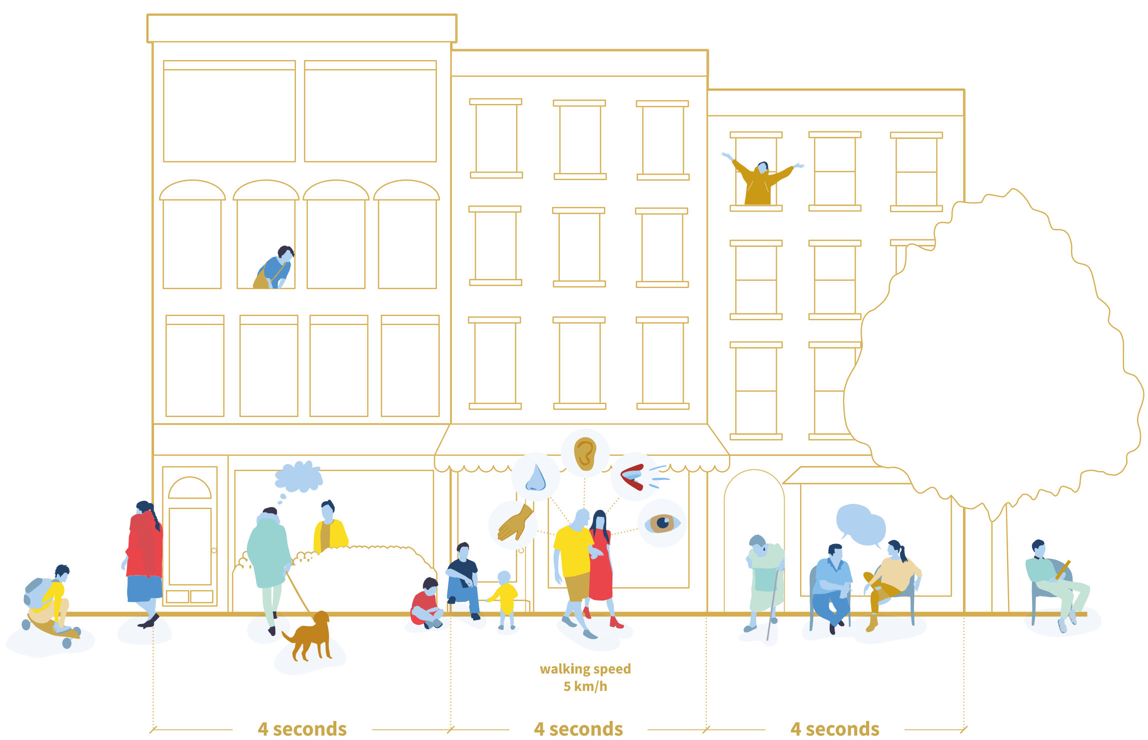
Chapter 2: Impact of Form on the Human Experience

This chapter will discuss the pressures that are encouraging typologies that isolate their residents instead of encouraging them to interact with their surroundings. It will then observe the role that the built form plays in the shaping of human experience, particularly in Jan Gehl's idea of a soft edge that offers a gradient of inhabitation and Hertzberger's ideas of variety and identity. Finally, it will discuss the opportunity to design new residential developments with formal patterns derived from the desired human experience to allow architects to create meaningful variety on a neighbourhood scale.

Desired human experience.

Desired Human Experience

Humans are innately curious beings. Starting at birth we learn about the world by engaging with it, an instinct that remains with us for the rest of our life (Chiarotto, 2011). Stimuli for engagement can take various forms; cultural signifiers, social interactions, the presence of nature, etc. Being engaged in our cultural, social, and physical surroundings allows us to satisfy the basic human need to understand how we relate to the world, and allows us to build our identity. This instinct is why the human brain needs a thousand stimulations per hour to be content (Gehl, 1987). The need for stimuli is further corroborated by environmental psychology studies, which have determined a correlation between complexity in urban scenes and perceptions of pleasantness and arousal (Hanyu, 2000; Dosen, 2016).



Guideline to provide a change in stimuli every 4 seconds, or roughly every 6 metres to sustain engagement. (Gehl, 2018)

Once we have this self-knowledge, we want to express it back to the world that shaped us to influence other people's lives. A reciprocal relationship arises: "Behaviour, thoughts and feelings of each person are affected by his environment, and vice versa everyone affects his surroundings with his behaviour, thoughts and feelings" (Glaser, 2012, 219).

This thesis aims to manifest this reciprocal relationship: to design a human experience for pedestrians and residents that is rich in meaningful stimuli, providing opportunities to influence people's identity (Alexander, 1979). The residents can then express their identity, thus adding to the available stimuli. This experience exists in the world today, in the established neighbourhoods of many cities.

An engaging historic neighbourhood provides stimuli for inhabitants to be curious about in North End Halifax.

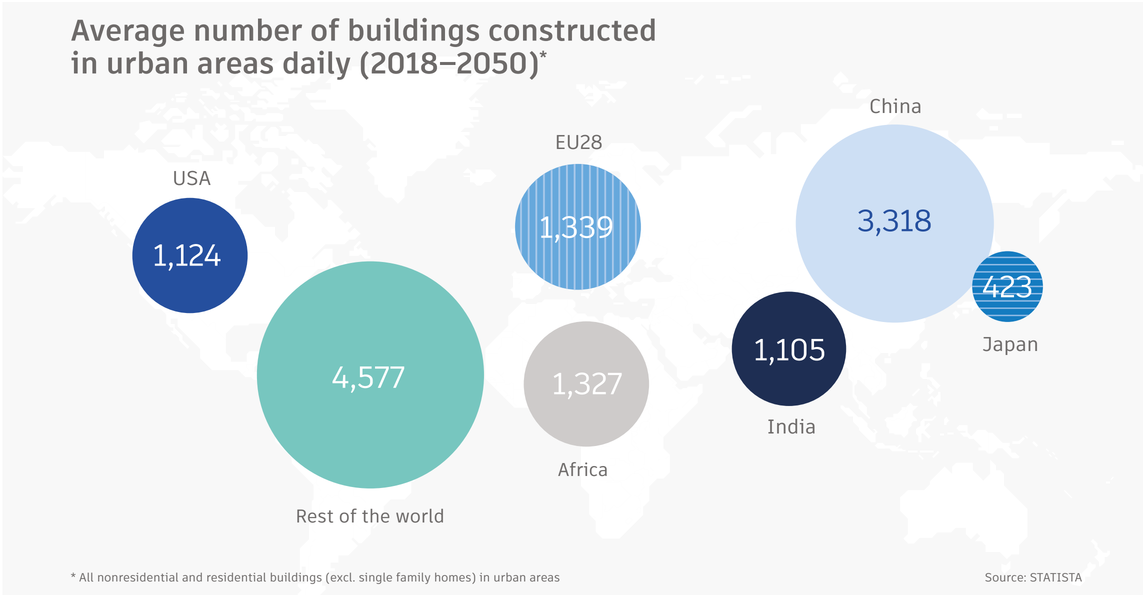
Isolating Typologies

Yet all too often new residential developments do not allow situations for this engagement, and so ferment feelings of anxiety, isolation and banality. The pedestrian gets the distinct feeling they are inhabiting an afterthought, as the monotonous facade provides no indicators of common identity nor windows into people's lives (Hertzberger, 2015). The residents cannot express themselves to the public realm nor observe it, being either too far away or having no nooks to safely appropriate. The experience of this built environment insidiously makes both pedestrians and inhabitants quite miserable. One quickly notices there are differences in the architectural expression, suggesting that architecture is influencing people's well-being (Ricci, 2017).

A new development just blocks from the previous photo separates the public and private realms, and the concrete retaining wall provides no stimuli.

The built form can encourage interaction, which allows local identity and community to emerge over time through responding to the local context (Alexander, 1979). The opposite of encouraging interaction is instilling isolation, which is exactly what most of the high-density typologies we are filling our cities with do (Hertzberger, 2015). Living in a neighbourhood with a distinct community and identity that reflects how you see yourself is a much more fulfilling way to live, however the built form of many new urban developments does not allow for the necessary interactions.

Isolating typologies have become the standard response in urban areas seeking to grow their population. The demand for urban housing is high, with 200,000 people moving into urban areas every day (Kinver, 2016). This demand is also growing fast, as the global urban population is expected to rise by two billion in the next twenty years (Farha, 2017). The architecture, engineering, and construction industry is being called on to provide housing for these people. While the industry already builds 11,000 new urban buildings every day to sustain current demand, this number must rise to 14,600 by 2050 as demand rises (Bertollini, 2018). With such a high volume of construction, many of these new homes are designed for efficiency, with little attention given to the inhabitation.



Global distribution of urban buildings built to meet the demand of urban population growth (Bertollini, 2018).

This is indicative of the financializaton of residential real estate, or the fundamental shift of residential architecture from a lived-in and well-loved home to an instrument of wealth accumulation (Wainwright, 2019). According to the UN Human Rights Council, this financializaton "disconnects housing from its social function of providing a place to live in security and dignity and hence undermines the realization of housing as a human right. It refers to the way housing and financial markets are oblivious to people and communities, and the role housing plays in their well-being" (Farha, 2017, 3). In this way, isolating typologies do respond to their context - but it is a context of the financial system, not of human inhabitation. Some governments have introduced policy changes to reduce the strain placed on cities by the financialization of housing, such as Vancouver's Empty Homes Tax which changes property owners a 1% tax on assessed value when the home is empty for more than 6 months of the year (The Canadian Press, 2019).

Prioritizing sheer population density, and therefore monetary return, over an empathy for the residents and an understanding of inhabitation contributes to the construction of many homes in high-density typologies that inadvertently isolate their residents from the world around them.

The typology employed in downtown Vancouver leads to many isolating towers being built, providing for the financial system instead of for the human experience of those inhabiting the city (Lawreszuk, 2018).

Isolation instilled by the form of our homes has negative impacts on the physical and mental health of both inhabitants and those occupying the public space outside (Fanning, 1967). In fact, chronic isolation can be as bad as smoking 15 cigarettes a day (Morin, 2018). These isolating typologies not only impact personal well-being, but they also drain the health of the city.

A commonly cited example of isolating built form degrading the health of a city is the Pruitt-Igoe housing development in St. Louis, Missouri. Here, the human-scaled tenements were demolished and replaced with isolating towers. The high-rise typology removed the casual presence of families in the neighbourhood streets, contributing to the litany of serious issues that led to the development's decline and its demolition just 16 years after construction (Bauman et al., 2000).

Implosion of building C-15 at the failed Pruitt-Igoe housing development in St. Louis (U.S. Department of Housing and Urban Development, 1972).

Cities are special places in humanity. Their density of population and casual interactions allow distinct local identities and communities emerge through people's engagement with their particular context (Hertzberger, 2015). Cities are the epicentres of human culture and achievements, partially because they allow many casual interactions between people who would otherwise not meet. Cities have developed a human-scale urban fabric, with formal patterns that encourage these interactions. New developments offer an opportunity to strengthen this established fabric and integrate more people and more opportunities for interaction, but in reality new developments are often isolating and disrupt the established fabric. With fewer interactions with the context, local community and identity are unable to continue emerging and the city scape becomes homogenized, globalized (Hertzberger, 2015).

Another example of a disengaging development in North End Halifax that uses globalized materials and prevents local identity from emerging.

All this to say: economic and population pressures have led to housing typologies that instill isolation, in stark contrast to established neighbourhood typologies that encourage interaction and allow local community and identity to emerge. In the words of Jan Gehl, we have high density, but we need *better* density. These pressures are well-established design constraints that must be accounted for by the architect to receive commissions to design residential developments. How can architects intervene within the constraints of this busy system to enable more engaging housing to be built? Is it possible for architects to apply lessons learned from established neighbourhoods to a higher-density typology?

Soft Edge & Personal Touch

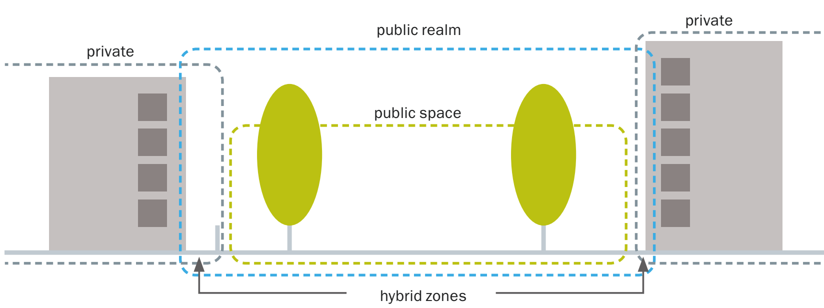
> The more emphasis placed on expressing the identity of users and functions, the more pronounced the differences become and the more differences there are, the greater the diversity and this is what everyone wants. (Hertzberger, 2015, 161)

A soft edge providing a gradient between the public sidewalk and private stoop, allowing the resident to create the exact inhabitation they desire.

Beneficial neighbourhoods comprised of human-scaled vernacular buildings fulfill much of Maslow's hierarchy of needs by providing stimuli to foster feelings of security, belongingness, and curiosity. The pedestrian is engaged by facades that express the local architectural language and provide windows into people's lives (Gehl, 2010). The resident is given the window as an opportunity to express themselves to the public realm, and to observe life as it goes by on the street. Both the pedestrian and resident are engaged, either indirectly through objects of self-expression or directly with each other, allowing them to learn more about the world and express their identity (Hertzberger, 2015). This established a gradient in the environment, within which a person can establish the exact inhabitation that suits their needs in that particular time.

The residential facade emerges as the architectural element best suited to provide opportunities for engagement. Jan Gehl suggests that the best way to do this is to establish ‘soft edges’ which provide a gradient of inhabitation, instead of a binary of two choices. This gives people the agency to appropriate the space and change it to suit their needs, deciding how far the public realm can visually penetrate into their private domain. In doing so, they express their personal touch, which adds to the stimuli and variety that make established neighbourhoods so engaging.

The public realm can be thought of as the volume between facades (Glaser, 2012), meaning that facades define the majority of a pedestrian’s experience and act as the membrane between the public realm and the resident’s private domain. If the resident is to have the opportunity to use their home as a method to express themselves, the facade must allow it. This suggests that the public realm extends past the facade into the private domain, and that the private domain extends past the facade into the public realm (Glaser, 2012).



The hybrid zone as a volume between residential facades (Glaser, 2012).

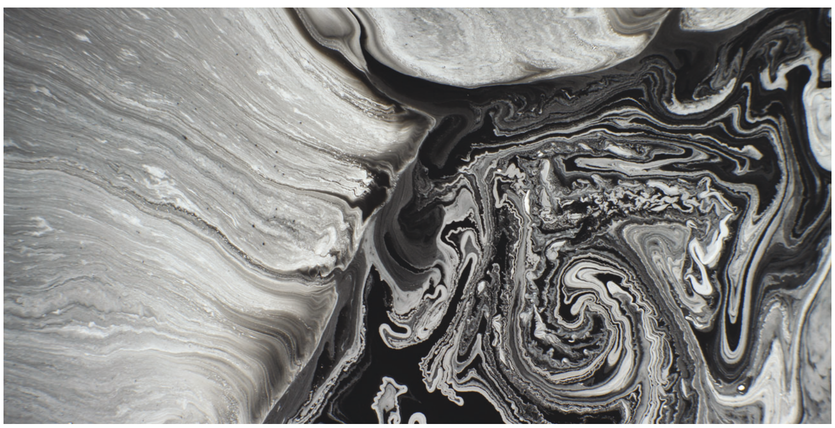
Jan Gehl explains that these colourful streets are engaging because their street wall has a soft edge, or what others call a hybrid zone. An engaging street wall allows a gradation of experience instead of a stark binary. Humans yearn for these engaging experiences because interacting with stimuli in their social, cultural, and physical surroundings helps us shape and express our own identity. In the photo at the start of this section, the sidewalk is private, and the stairs to the door are private, and the space where these two meet is semi-private. The gradation between extremes of a spectrum allows the resident to create the exact inhabitation they desire, and through this express themselves to the world with personal touches (Hertzberger, 2015). In the photo at the start of this section you can see flower pots, a choice of paint colours, and the placement of a table and chairs to allow the resident to just be in the world. Personal touches enrich the pedestrian's experience by providing stimuli that can sustain an empathetic connection.

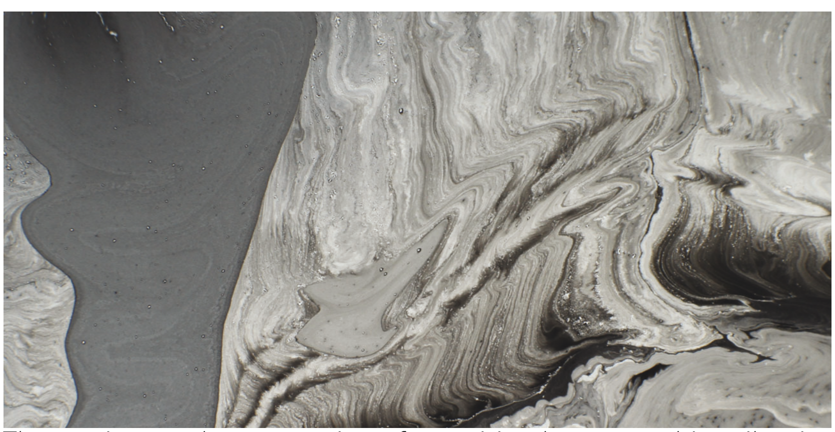
The resident expressing their values to the world with a planter, paint colours, and a young child's poster proclaiming "in case of rising gas prices, BREAK GLASS" to access a bicycle.

Disengaging form offers a clear binary of two often unideal choices. They do not offer a soft edge at all, contributing to deep seated feelings of anxiety and isolation. In the next photo you can see there is no gradation between the fully private and a fully public realm. They are far from each other, and the space in between is an uncomfortable no-mans land that nobody quite feels comfortable inhabiting. Further lacking a personal touch, this concrete street wall is for the pedestrian to hurry past. Thus, providing a hybrid zone with meaningful opportunities for self-expression and community building has a significant impact on the quality of life for both residents and pedestrians.

A clear binary of private or public is established by the built from. The fully private building is set back 50' from the fully public sidewalk, further buffered by deep bushes by and an 8' retaining wall. This establishes an awkward no-mans between the two extremes.

This transition zone bears striking resemblance to the discussion of boundaries provided by Addington and Schodek in Smart Materials and Technologies. Traditionally a boundary demarcates two different states, meaning that the area of interaction is two-dimensional, static, and uniform. They argue that boundaries should instead be understood as regions of transition between environments of different energy levels, meaning the volume of interaction is three-dimensional, dynamic, and eccentric. Boundaries are therefore active zones of mediation rather than lines of delineation. The architect can therefore understand the volume surrounding the facade as an active boundary zone that transitions between the public realm and private domain.





The top image shows a region of transition between white oil paint and black india ink, providing many interesting details that leave hints of how they formed. The bottom image is a mundane delineation.

Local Identity & Structured Variety

> Stiny and Gips (1972) argue that aesthetic objects will often feature 'a high [level of] visual complexity which does not totally obscure an underlying simplicity.' (Dosen, 2016, 219)

The Haligonian box responds to local materials, labour, and culture.

Structured variety emerges from the activity in a soft edge as a volume of active transition that transcends the facade and allows interaction between public and private, instead of a line delineating inside from outside. The variation is present in all scales, from the material itself, to types of ornamental filigrees, to changes in the building's massing (Gehl, 1987). This variation also defines the distinct local identity of a city (Hertzberger, 2015). Parisian Haussmann blocks, Brooklyn walk-ups, Glasgow tenements, and Haligonian boxes define the majority of the city's urban fabric, and therefore of a person's daily life in these cities. The typologies emerged in response to local materials, labour, and culture, resulting in form that is neither unstructured chaos, nor simple repetition. Therefore, variety in the facade can be thought of as affecting two interconnected areas: the expression of an enduring common identity, and the expression of transient individual identities (Hertzberger, 2015).

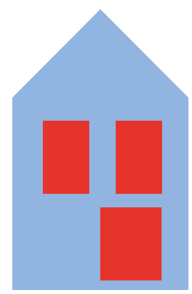
Structured variety emerges in the Haligonian box typology as each home responds to its site, neighbours, and desired inhabitation. The facade provides a common neighbourhood identity, while providing windows into the transient identity of their occupants.

The common identity stems from the language of local vernacular architecture that emerged in response to local materials, conditions, and desires. It can be understood as a defined set of elements (massings, facade layouts, fenestration, entry ways, ornamentation) that are aggregated according to simple rules (Alexander, 1964). These elements are signified to the region, as they arose before the globalizing pressures invoked by the Industrial Revolution (Hertzberger, 2015). This means that the vernacular architecture creates part of the cultural surroundings available for people to engage

The shingles used as external cladding respond to the abundance of trees in the area for building supplies. The shingles also bear traces of their manufacturing in the sawmill marks, and traces of their installation in their imprecise size and placement, contributing to structured variety.

with. The variation also gives depth to the facade through protrusions like bay windows and stoops, allowing interaction with the social context through individual self-expression.

A resident's use of their home as an avenue for self-expression stems from their ability to control how deeply into their private domain they invite the visual connection from the public realm (Hertzberger, 2015). This allows the resident to create vignettes of their life for the pedestrian to observe. The variation found in the expression of the common identity facilitates the expression of individual identity by providing a range of situations to inhabit, allowing the resident to establish a relationship with the public realm that suits their desire for prospect or refuge. This range of situations allows for a range of sightlines, which gives the inhabitant agency to control the extent to which views from the public realm are invited to various areas of their realm at any particular time.



Common identity (blue) and individual expression (red)

A bow window accommodating a vignette from the resident to the word.

Newer developments without this variation provide a stark contrast. The common identity is not local and does not engender an emotional connection. These apartment blocks could be placed in any major city as they belong to the global, ”identity-denying” international style made possible through advances in production and transportation after the Industrial Revolution, “As everything in a global economy is available everywhere, it all tends to look the same” (Hertzberger, 2015, 149). The facade is often a veil of flat curtain wall that extends high into the sky, denying meaningful interaction between public and private by collapsing the hybrid zone into a delineating line.

Flattening the hybrid zone to nonexistence.

The following few pages contain studies that show the huge difference in the human experience of simple repetition and meaningful variety. Each iteration of the new development is a simple replication, where as the established neighbourhood offers meaningful variety in each iteration. This variety is meaningful because it responds to the local site, culture, materials, construction methods, and other aspects. Meaningful variety offers stimuli that allow people to connect with their social, cultural, and physical context.

The difference between simple repetition in new development s (blue) and meaningful variety in established neighbourhoods (red) is seen. The retreating from of the new development does not encourage a soft edge, nor a personal touch.

The following composite images collage these facades together, retaining distinct visual elements and colours. These collages are used to express the beneficial impact of meaningful variety on the human experience.

Composite of the facades from the new development. Small gestures of personal touch are seen, but otherwise each facade is identical, as seen by the high degree of overlap. The experience of these facades can be described as dull, lifeless, boring, impersonal, sterile.

Composite of the facades with meaningful variety, offering a flurry of stimuli to engage those in the public realm. Variety in entry condition, cladding material, colours, and significant personal touch are clearly visible, offering many stimuli to engage with.

New development on Gladstone Street, again exemplifying the similarity of each facade with only token gestures to variety.

Just a block away from Gladstone St., the meaningful variety on Willow St. offers a wide range of stimuli to engage with.

Close inspection of established neighbourhoods reveal that their variation is neither unstructured chaos, nor banal repetition, as both these extremes create an uncomfortable human experience. A shared language is apparent between the houses, but there is no simple pattern of repetition present. Instead, the neighbourhood attained a structured variation in the same way nature builds patterns: emergent processes (Ball, 2011). An emergent process aggregates simple elements according to simple rules in order to reduce the external forces acting on the process, per Le Chatelier's principle (Alexander, 1964).

Formal Patterns & Algorithms

As the established neighbourhoods emerged over time as the interaction of simple forms according to simple rules to satisfy inhabitation needs, is it possible to discover patterns in the resulting neighbourhoods and use them to design new developments? This would allow new housing to be empathetic to the needs of human inhabitation, in addition to responding to the realities of the financial system.

Patterns emerge in all facets of life, shaping what feels right - even if people are not aware their comfort is shaped by distinct patterns (Ricci, 2017). For example, you may have had a '**big** red cart' in your childhood, but you certainly did not have a 'red **big** cart' for this phrase plainly sounds incorrect to the native English speaker.

What shapes this guttural reaction? Linguists have theories, but more importantly they are able to describe explicitly in a pattern what all English speakers understand implicitly through feelings of comfort and beauty or the impulse to cringe. This is a pattern of what order adjectives must be said, namely: opinion, size, age, shape, colour, origin, material, purpose (Forsyth, 2016).

This specific pattern emerged over time as the English language developed and has become so ingrained in native English speakers that they can tell a new English speaker 'the green old small cricket' is fully and totally unacceptable, but are stumped when explained why it sounds so wrong. That is why a professional noticed the dissonant effect, studied it, and discovered a quantifiable pattern.

Architects can be thought of as the professionals that discover these hidden patterns in the built environment that shape what feels 'right' to people through subconscious, often unrecognized, feelings of comfort and beauty or discomfort and alienation. Christopher Alexander codified many of these patterns in A Pattern Language. Architects use their understanding of these patterns in order to design built space congruent to people's expectations, allowing architects to achieve their ultimate goal as this author sees it: to improve the quality of life of as many people as possible.

This understanding of underlying patterns is often limited to an experienced designer's intuition, preventing the architect from effectively building on their own knowledge (Alexander, 1964). This imprecise methodology helps frame architecture as an artistic "aesthetic bonus" instead of a major influence on people's well-being (Ricci, 2017, 2). Designing explicit patterns allows architects to instead directly build on previous design effort or to alter it to new conditions, releasing knowledge from the confines of 'intuition'.

Expanding this internal use to its logical, if ambitious conclusion, explicit patterns could be used as a shared language to create a common repository of knowledge for all to access. This follows the collaborative example set in the scientific community, and would bring much needed clarity to architectural research (Kotnik, 2010). This would allow future generations of architects to 'build on the shoulders of giants' of contemporary architects. It would also provide a forum to codify the patterns found in the origins of underlying patterns: vernacular architecture.

These patterns are codified as ordered sets of instructions, or simple algorithms. An example of the simplest algorithm could be to create a stair by extruding the stair line up 7" and then in 11". These algorithms are ordered by simple logic (if the entry stair is next to another entry stair align their starting points, then repeat the stair algorithm enough time times to create a staircase that reaches the ground). This algorithmic approach allows the designer to make changes that would otherwise mean a return to the drawing board, such as changing the rise to run ratio for external stairs, or moving the lot line setback one metre out. The tool is also flexible enough to allow manual control in desired areas of the project. Further, the tool can be used on other sites to apply the patterns in their neighbourhood. This reflects the shift in the scientific community that Kotnik sees paralleled in the design community, away from reductionism and towards complexity.

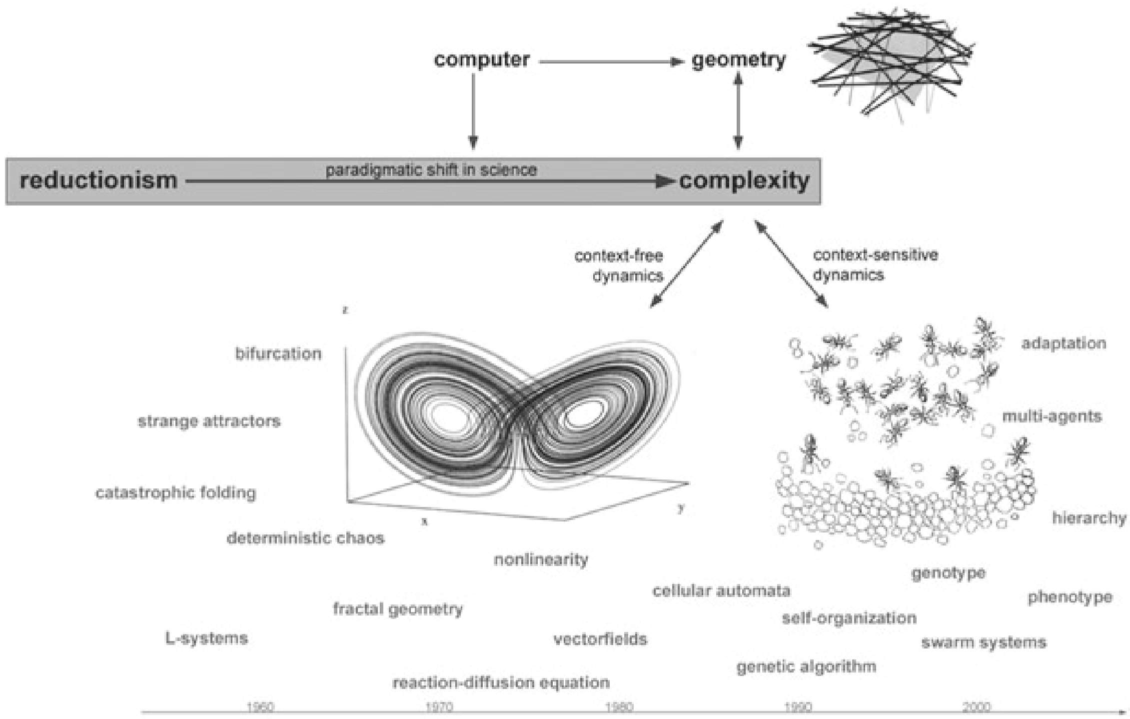


Diagram showing the shift in the scientific and design communities away from reductionism toward complexity (Kotnik, 2010).

In short, by designing with patterns the architect is able to design the meaningful variation they learned is important to the engaging nature of historic housing. Instead of a simple copy/paste aggregation found in suburbs or monotonous apartment blocks, these tools allow the architect to design rules that guide how forms are aggregated by responding to other elements and to the external influences of the site (Ball, 2011). This allows the architect to effectively satisfy the basic human need to be engaged with their surroundings, as well as contemporary density, environmental and code requirements. The effectiveness of this design will allow the architect to expand the reach of their design effort, meaning that more people can live in a designed home and by reducing the amount of developments optimized solely for the owner's financial profits. This thesis proposes a methodology that democratizes design by extending the reach of an architect's design effort through aggregation at the neighbourhood scale, improving as many lives as possible. Computation is uniquely suited to create the custom design tool necessary to design with these patterns and rules.

Computation Opportunity

Standard design tools are unable to model the interactions necessary for emergent process. This thesis will utilize shape grammar, which is a tool that can allow the architect to design these simple elements and their rules of interaction (Stiny, 2006). This tool can be augmented by specific analytical tools that can analyze in real-time if a design intention is being met, such as population density or sightlines between public and private domains. Using emergent tools is crucial to replicating the desired experience. After all, the historic neighbourhood has had over a hundred years to accrue stimuli, and was built in a time that allowed locally signified, human-scaled building. New developments are designed, built, and occupied in a space of eighteen months. These design tools will allow the architect to leverage the power of emergent processes.

The meaningful variety made possible by emergent processes over time (top) and the attempt at capturing this quality in a new development, constrained by available tools (bottom).

The goal of this thesis is to create a series of computational tools that help design the human experience in a new residential development that learn from and engage with beneficial neighbourhoods surrounding a development opportunity. While this methodology can be applied in any city, the thesis was spurred by an interest in discovering why some historic neighbourhoods felt engaging and comfortable to the author, while many new residential developments induce feelings of anxiety and isolation, and applying these lessons to denser residential forms that are able to sustain urban growth. Architects can design an engaging residential development by using patterns of structured variation found in historic neighbourhoods, offering opportunities to build self-expression and community.

The approach is influenced by three statements:

• More people should live in well-designed housing that improve their quality of life.

• The design methodology this thesis develops revolves around noticing, understanding, and applying patterns.

• Computation allows patterns to be aggregated into housing at the urban, building and inhabitation scale, aiding in the design of meaningful variety.

Residents to add their personal touch to the meaningful variety.

Chapter 3: Impact of Design Tools on the Built Form

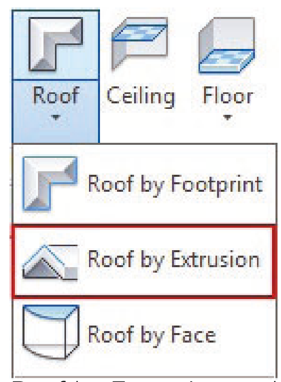
Design tools impact the final built form of a project, as there is a tendency to adapt the job to the tool than the tool to the job (Tomkins, 1963). There is however a rich history of architects creating custom tools to manifest their intention, and some of these tools were made with the human experience as their driving motivation. These custom tools respond in real-time to manipulations of formal generators by the architect, providing discrete feedback for the architect to make further manipulations and establishing a human/tool feedback loop (Kotnik, 2010).

Can custom tools help us design a residential development acts as a successful framework for inhabitation?

Impact of Design Tools

Before discussing computation and the custom tool created for this thesis, we will establish the impact that design tools have on the built form. This impact can be boiled down to the old adage, if all you have is a hammer, everything looks like a nail. Academically, Tomkins discusses “the tendency of jobs to be adapted to tools, rather than adapting tools to jobs” (Tomkins, 1963, 445). This means that the tools architects use impact how they think about design problems, and the forms creates to solve these problems. This can be seen in recent developments that had their approach to form and materiality influenced by Revit and Sketchup.

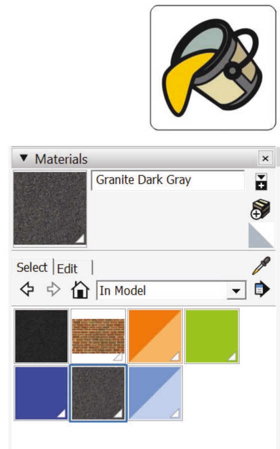
The roof design of this recent development was clearly influenced by the Roof by Extrusion tool in Revit (Google, 2019).



Roof by Extrusion tool in Revit.

In this first example, users of Revit will recognize that this roof was designed with the ‘roof by extrusion’ tool. This clearly shows that the tools used by architects guide them towards certain physical forms to manifest their intentions. In all design, the tools available can manifest approximations of the original intention - there is a balance between adapting the intention to the available tools, and manipulating the tools to approximate the intention more closely.


The approach to materiality in this recent development retained the aesthetic of dropping swatches onto a massing with the paint bucket tool in Sketchup (Google, 2019).



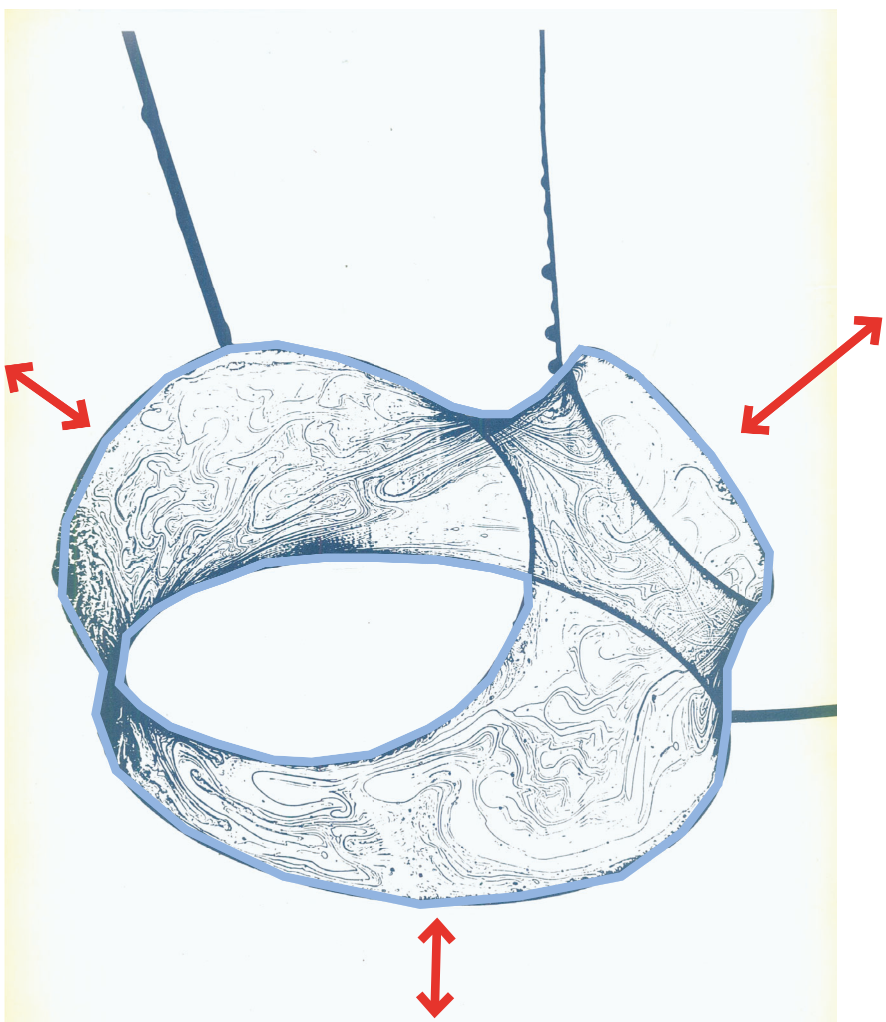
Paint bucket tool in Sketchup.

This example shows how a tool can alter how an architect thinks about materiality, adapting the job of choosing materials to the tool at hand. This recent development, designed in Sketchup, does not consider the human experience of its materiality. Instead, it appears that materials were thought of as textures or colours applied to inert planes in a massing model, creating a rather confusing experience for the passer-by.

These current tools do not allow architects to design using patterns and rules to create meaningful variety, but there is a tradition of architects being stubborn and making their own tools to manifest their intentions.

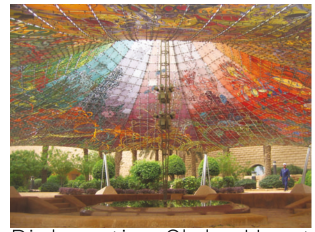
History of Stubborn Architects

Many architects have created their own tools to manifest their intentions when existing tools limited their abilities. From Gaudi to Gehry to WeWork to Gramazio & Kohler, each entity has used computation to make a custom tool to manifest their intentions.



Analog computational design tool by Frei Otto. The formal generators are manipulated by the architect (red) to receive a surface of minimal surface area (blue) in real time (Dean, 2010).

To understand the relationship between input and output of a custom design tool, Frei Otto's soap film studies are a good example as they display the immediate feedback to manipulations of formal generators. The formal generators are the shape, number, and relative position of the wires. The transformation is computed by a soap film, to find the surface with the minimum area that connects the formal generators. This computation occurs in real time, allowing the architect to explore how changing the formal generators impact the resulting massing. The shape of the final desired soap film is then photographed with a grid in the background, and computed by hand into a structural system. A similar analog computation model was created by Gaudi to explore the structural system of his Sagrada Familia masterpiece. These systems allow an architect to manipulate various inputs, have an analog process compute interactions between the inputs, and evaluate in real time the impacts on the resulting massing.

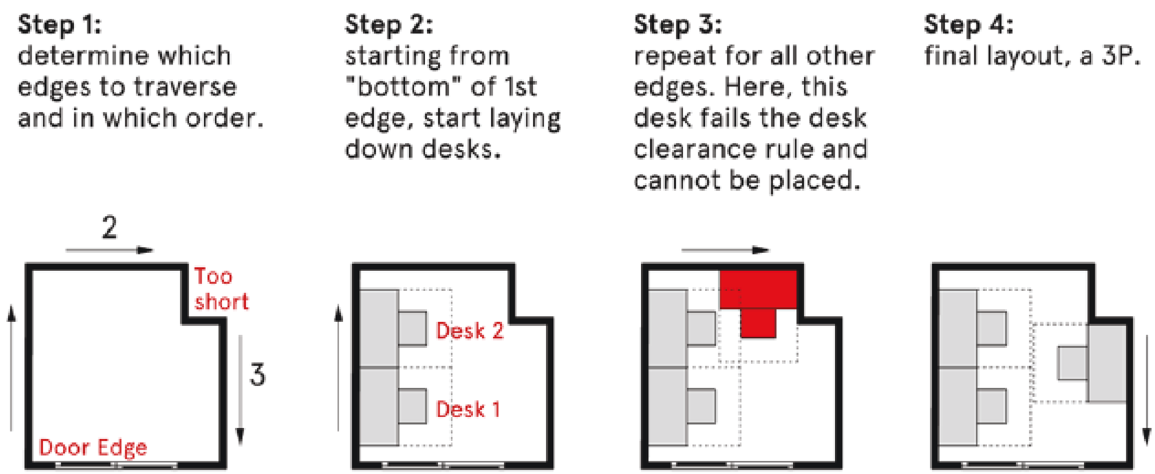

Diplomatic Club Heart Tent by Frei Otto, 1980 (Rosenfield, 2015).

CATIA, the aerospace program that helped Gehry design the Guggenheim Museum Bilbao (Chang, 2015).


Lou Ruvo Center for Brain Health by Frank Ghery, 2010 (Basulto, 2010).

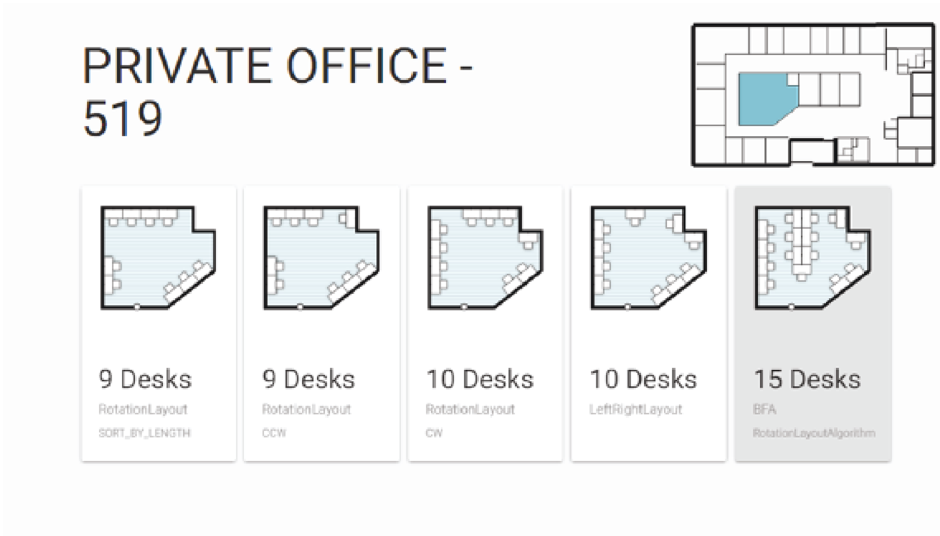
Creating a digital tool allows the architect to control the transformations applied to the inputs. Most people think of the work of Zaha Hadid or Frank Gehry when 'computational architecture' or 'parametric architecture' is mentioned. These architects created digital computational tools that are able to work with abstract formal generators, such as numerically inputting angles and counts. By using a digital process instead of an analog process, the architects are now able to take control over the transformations that the tool applies to the formal generators. This control is applied through a logic tree, that selects the optimal algorithm to apply given the particular inputs. Both the logic tree and the algorithms are provided by the architect. This opens up a universe of possibilities, as the transformations are no longer reliant on natural forces such as surface tension or gravity - the architect is able to control the forces applied to the tool system. This aligns with Kotnik's idea of design as the exploration of computable functions (Kotnik, 2010). In the case of Gehry and Hadid, their tools allow them to generate structural drawings of their swoopy, sculptural intentions.

A clear example of the transformations that can be applied to an input through a digital computation tool is by automating repetitive, well-defined tasks. For example, the author has seen a tool that takes as inputs the outline of a concrete floor slab and information about loads on the floor and concrete performance, and is able to output the construction drawings for where the rebar is to be placed. This process is well-defined by engineering standards, and works as a series of if-then statements for what rebar to place where in the slab. This tool codifies information in a way that it can be computed and drawn by the tool, instead of by a structural engineer, who calculates rebar needs and draws them by hand on the plan for an assistant to input back into a BIM program. Instead of this menial labour, the engineer is now able to spend their time and talent working on design tasks that require human intuition to accomplish.



An algorithm that human designers followed by intuition, codified to allow a computer to carry out this ordered list of instructions (Anderson et al., 2018).

Another example of codifying this information is the ‘augmented design tool’ that was funded by WeWork, an international company that provides co-working offices. This tool codifies the process that office designers took to place desks in private offices, providing a number of choices for the designer to choose from (Anderson, 2018). The tool was optimized to provide the largest number of desks, and it is up to the designer to decide which that layout, even though they all meet minimum requirements, is acceptable to inhabit.



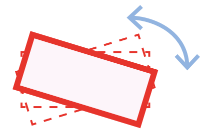
Choices offered to the human designer by the custom tool created for WeWork (Anderson et al., 2018).

These tools were created by entities because existing tools did not allow them to manifest their intentions effectively. The intentions range from exploring structural systems, exploring how to make sculptural buildings, and how to be more efficient. But can the human experience be the intention that drives the development of a new tool? And can this tool also help meet unit count goals, to ensure the proposed design is feasible?

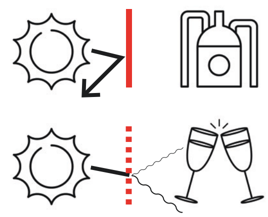
An example of a tool that allows the designer to consider human inhabitation alongside other constraints was created by Gramazio & Kohler to create the facade for the Gantenbein Winery. The facade was made of bricks, but each brick was rotated according to inputs from the architects. This rotation allows different amounts of light to be reflected and let into the structure, establishing each brick as a pixel when seen from the exterior and the whole facade as a light screen for the interior perception. The tool allowed the architects to express a pictorial sense of place when seen from a distance, control ventilation, and control the lighting to meet programmatic needs to create lighting effects for the inhabitants.

The facade of the Gantenbein Winery uses a formal pattern that responds to programmatic and experiential intentions to create a human experience (Gramazio Kohler Architects, 2018).

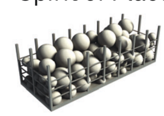
Formal Pattern
Brick Rotation



Use Pattern
Sunlight x Program



Spirit of Place



Patterns of form and use at the Winery Gantenbein.

The custom tools investigated in this thesis ingest inputs, apply transformations, and output a discrete result. The architect has control over both the inputs and transformations, and alters them in response to the real-time results computed by the tool. This means that the tool is not a magical black box, it is for the architect to engage with directly through coding it (Terzidis, 2006). The results can be visual, such as a massing, and/or statistical, such as FAR, unit counts, lot coverage, etc. This allows the architect to evaluate qualitative elements in the design, using their knowledge and intuition to read the massing, as well as quantitative elements to understand the impact of design moves on the feasibility of the project. This feedback allows the architect to better reach both qualitative and quantitative goals by shortening the feedback loop on exploring a design idea.

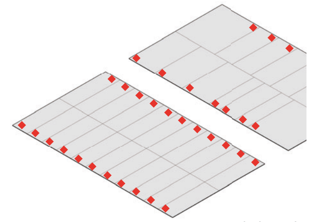
Custom Computational Design Tools

As seen in the previous case studies, computational tools take an input, alter it with specific lists of ordered instructions according to a logic tree, and output an altered element (Kotnik, 2010). This tool can aggregate simple elements according to simple rules responding to inhabitation and site to create the meaningful variety that makes established neighbourhoods engaging. These rules can be thought of as algorithms, or ordered lists of instructions. Computation is uniquely well suited to execute these instructions quickly, accurately, and without complaint, according to the architect's instructions (Terzidis, 2006).

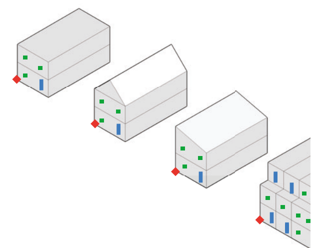
This feedback loop establishes a human/tool partnership that builds on the strength of both parties (Terzidis, 20006). The architect is able to use their intuition to explore design ideas, and the computer is able to compute through the many steps needed to provide feedback to the architect to evaluate the impact of their design changes. While many computational approaches focus on offering dozens, if not hundreds or thousands of options for the architect to sift through, the approach taken here is to offer one discrete solution at a time. This allows the back and forth of the design process, albeit with more information informing each design decision.

Inspired by A Pattern Language, a shape grammar will be the basis of this methodology, allowing forms to be aggregated according to specific rules. This shape grammar will be augmented by specialized analytical tools that can provide real-time feedback, allowing the designer to ensure their intentions are expressed.

The shape grammar will be provided with a street plan, a set of massings with population and bedroom count metadata, and rules for placing the massings on the block. It will output a potential massing of the block visually, as well as providing the population and count of bedrooms possible with this massing. The architect can then alter any of these elements to change the massings to achieve the desired population and bedroom mix. The shape grammar allows the architect to apply their design effort not on one building, but on a whole neighbourhood in a sophisticated manner, avoiding the simple cookie cutter repetition of suburbia. By designing rules instead of individual dwellings, variation permeates the neighbourhood instead of replication.

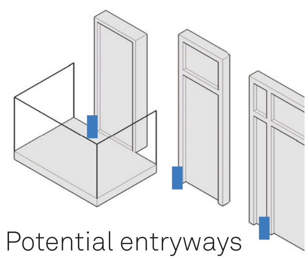


Insertion points on block for potential massings

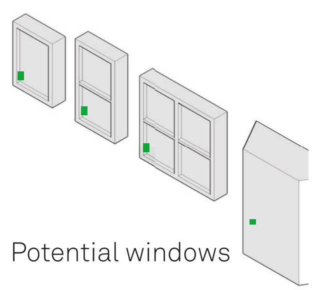


Insertion points on massings for windows and entryways

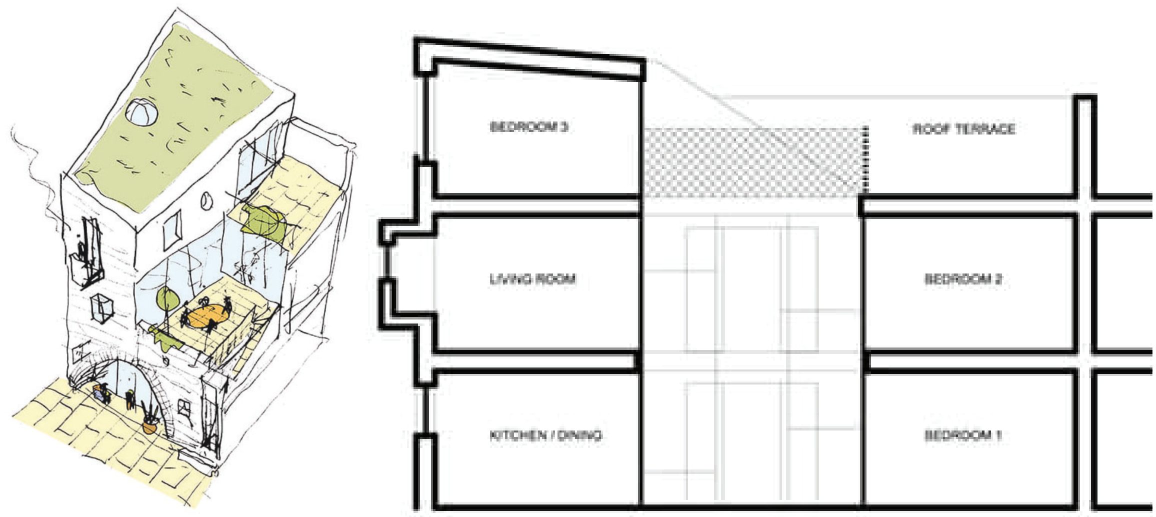
The accepted massing is the inputted into the next shape grammar, which also takes in a set of facade elements designed by the architect, and rules for placing them on the facade. The shape grammar tool aggregates these forms into a potential facade. The architect can alter the elements of the facade shape grammar, or the massing shape grammar, to achieve desired results, as the output of the first tool creates part of the input for the next tool. This is where the architect retains their agency as the design decision maker. The architect is able to explore typologies, modernizing them to suit modern needs.



Potential entryways



Potential windows

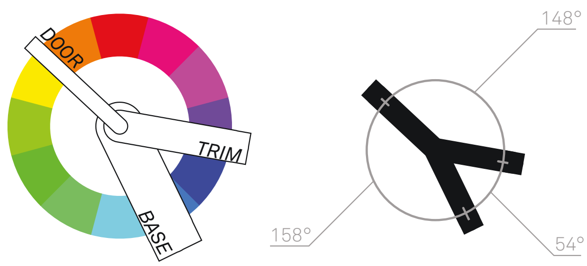


Two projects by Peter Barber, showing his adaption of Victorian working-class housing typologies to suit modern desires (Barber, 2018).

Using custom tools, architects can reduce the amount of poorly designed housing being constructed by designing with patterns of structured variation discovered in historic neighbourhoods, increasing their design reach to more residential developments and allowing more people to live in a home that has situations to help build self-expression and community.

human
tool

1. Identify
element carrying spirit of place



2. Abstract
pattern of variation

3. Codify
relationships & desired range

```
1/ h = userInput OR
1/ h = randomNumber(between .3 and .6)
...
4/ fill [baseGeo] with colour (h, s, b)
5/ fill [trimGeo] with colour (h+.1, s-.2, b+.3)
6/ fill [doorGeo] with colour  (h+.6, s+.4, b+.2)
```

4. Visualize
formal generator

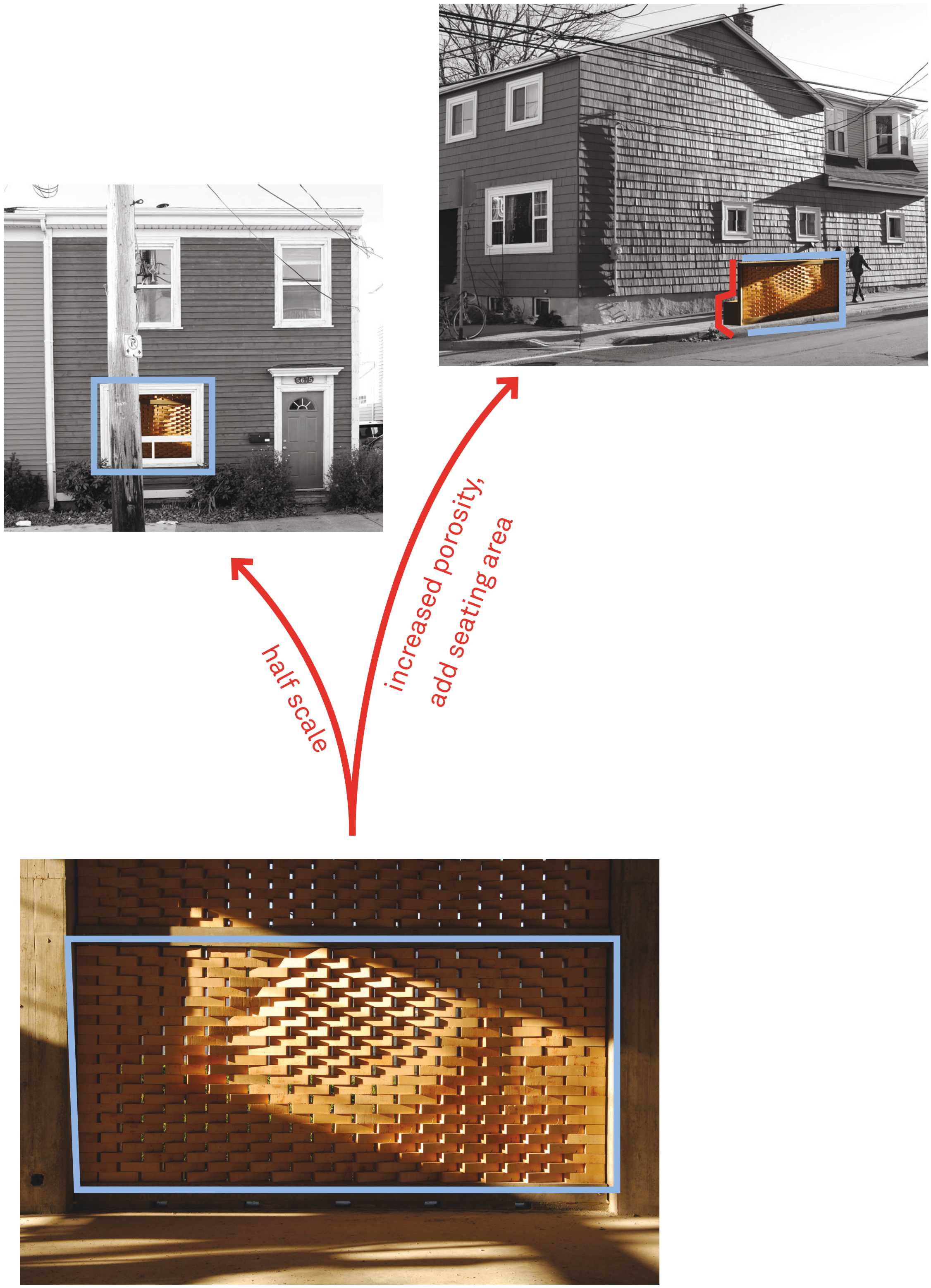
5. Evaluate
meets intentions?

? YES → pattern block created ↓ go to alter pattern ↓

NO ↓ go to step 3

The architect has full control over the identification, abstraction, codification, and evaluation of the tool. The tool is in charge only of visualizing the architect's instructions.

Output of the colour study applied to simple facades. At the top are four types of colour relationships between the base, trim, and door colours, abstracted into positions on a colour wheel. Each row of facades holds a different colour constant, allowing the others to change according to the colour relationships.



Sketch of how design effort by Gramazio and Kohler for the Gantenbein Winery facade could be reused by altering parameters fed into their design tool, creating smaller screens or even benches (Gramazio Kohler Architects, 2018).

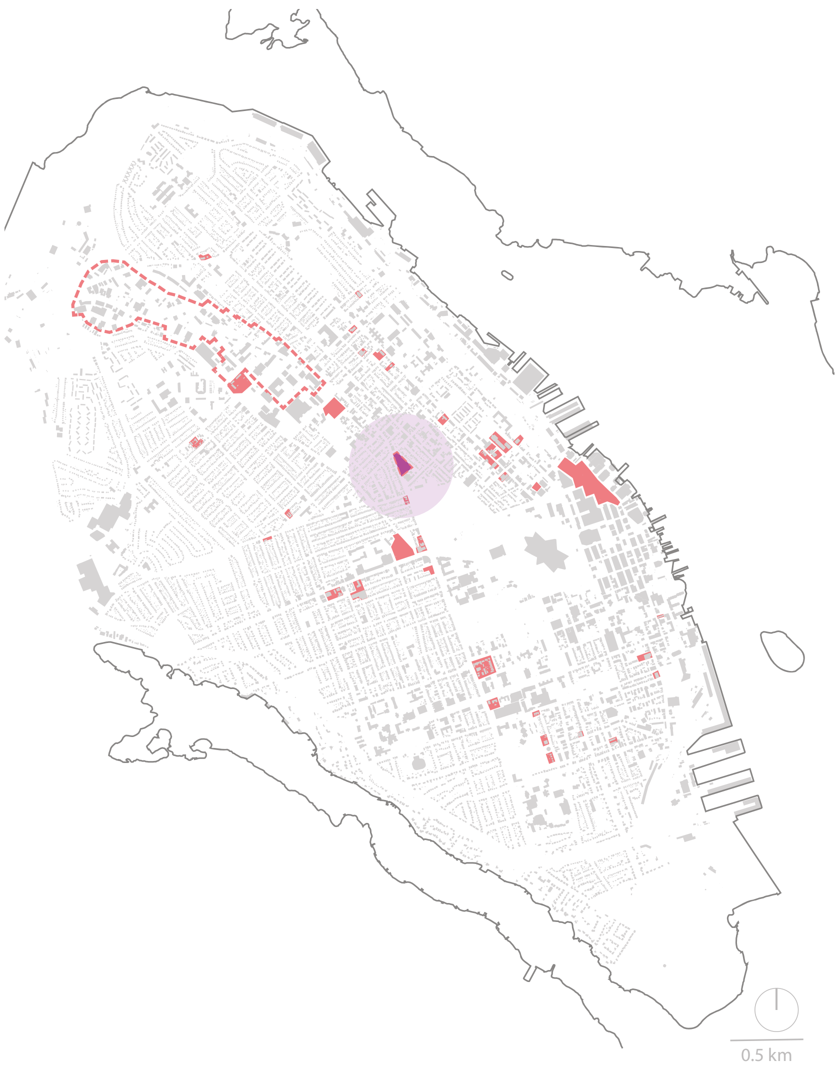
Chapter 4: Design

The previous chapters discussed the tension that the demand for high population density and financial return urban residential developments, and the opportunity of making a custom computational tool to help design a development that addresses these pressures while providing a beneficial living environment. This design chapter lays out a case study to explore the proposed methodology to create a design that satisfies both motivations, describing the use of the tool at the urban, building and inhabitation scales. The final design offers nearly the same population density as the isolating high-rise typologies, while providing the engagement of the surrounding neighbourhood typology and adding community space.

The study area (right) interrupts the beneficial North End neighbourhood.
Will this split be repaired, or made permanent?

Study Area

The Halifax peninsula exemplifies urban population growth pressures discussed in chapter 2. With a population of 300,000, there are 20 major developments under construction and 73 additional developments in various stages of planning (Halifax, 2019). These developments present opportunities to strengthen established neighbourhoods by weaving more density into their urban fabric, but in reality often lead to neighbourhood fragmentation.



The Halifax peninsula. Development proposals submitted to the city or under construction (red fill), underused parking lots (red dashed line), study area (purple).

The proposed site is the O’Reagan’s car lot and Irving gas station, which currently interrupts the engaging, colourful homes that establish the urban fabric of the quickly growing North End neighbourhood.


Sample of the typology in the surrounding established neighbourhood.


The car lot interrupts the experience of the established neighbourhood form.


Providing shelter for cars, not people.

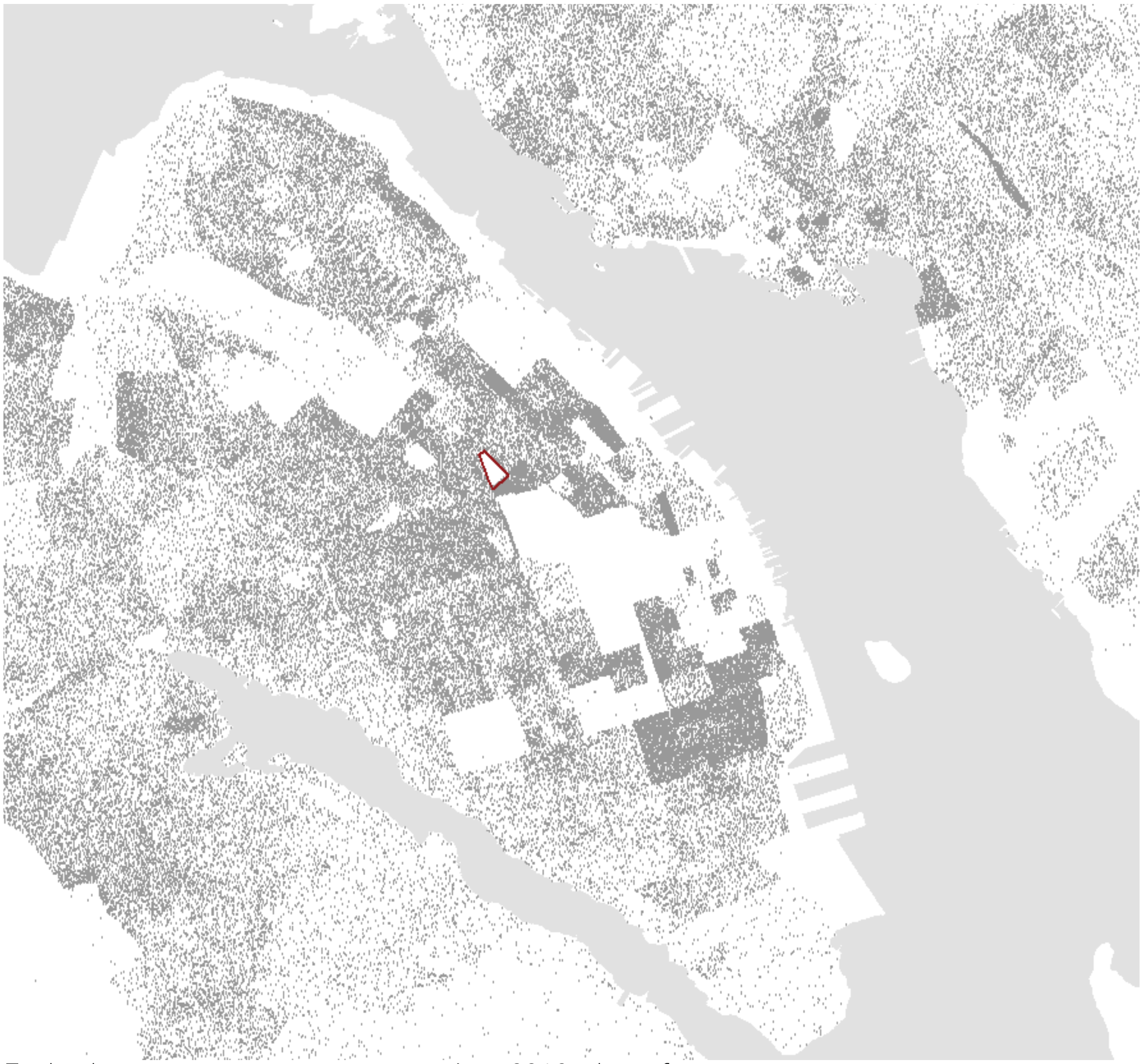
The study area (purple), bounded by homes that create an engaging public realm. Proposed developments or underused land that will be developed (red). The population density (dots) and urban grain of the neighbourhood is currently interrupted by the study area.

The North End neighbourhood is changing fast, and the large amount of developable land shows more changes are coming. The O'Regan's dealership and Irving gas station occupies 3.6 acres (14,500 sqm) of the North End neighbourhood in Halifax, creating a distinct interruption in the otherwise strong urban fabric. Within Halifax, this study area is an excellent location for employing the methodology described in previous chapters, because;

- It is surrounded by an established neighbourhood, providing a strong architectural typology to discover patterns in and respond to.
- It spans multiple city blocks, allowing the design to incorporate elements at the urban scale.

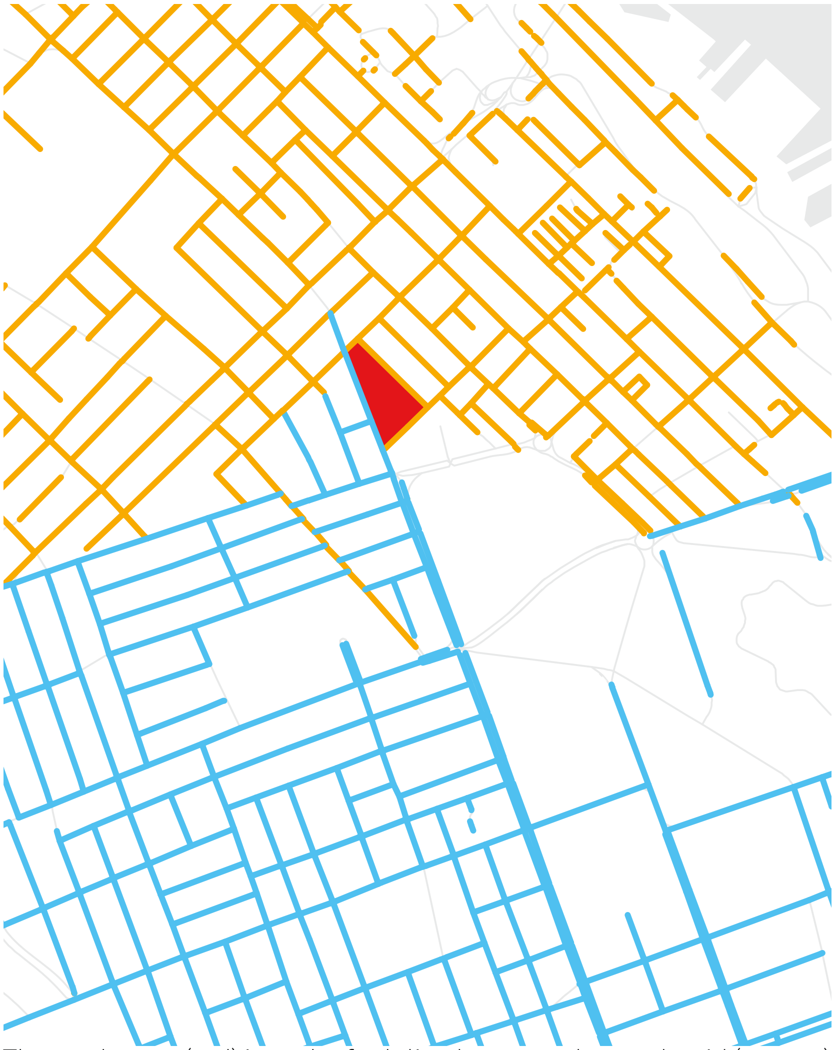
• Its current use lends itself to redevelopment in the coming years, creating an opportunity to enrich the experience of the area.

In essence, this block provides a blank canvas surrounded by a single strong architectural typology to respond to. The site does no have complicating factors such as existing buildings worth keeping (such as the Bloomfield Centre, or on the Cogswell and Gottingen block) or being at the confluence of many neighbourhoods (Cogswell interchange, Young and Robie super block). While the methodology can accommodate these challenges like any other design methodology, it is not necessary to prove the usefulness of patterns in designing meaningful variation.



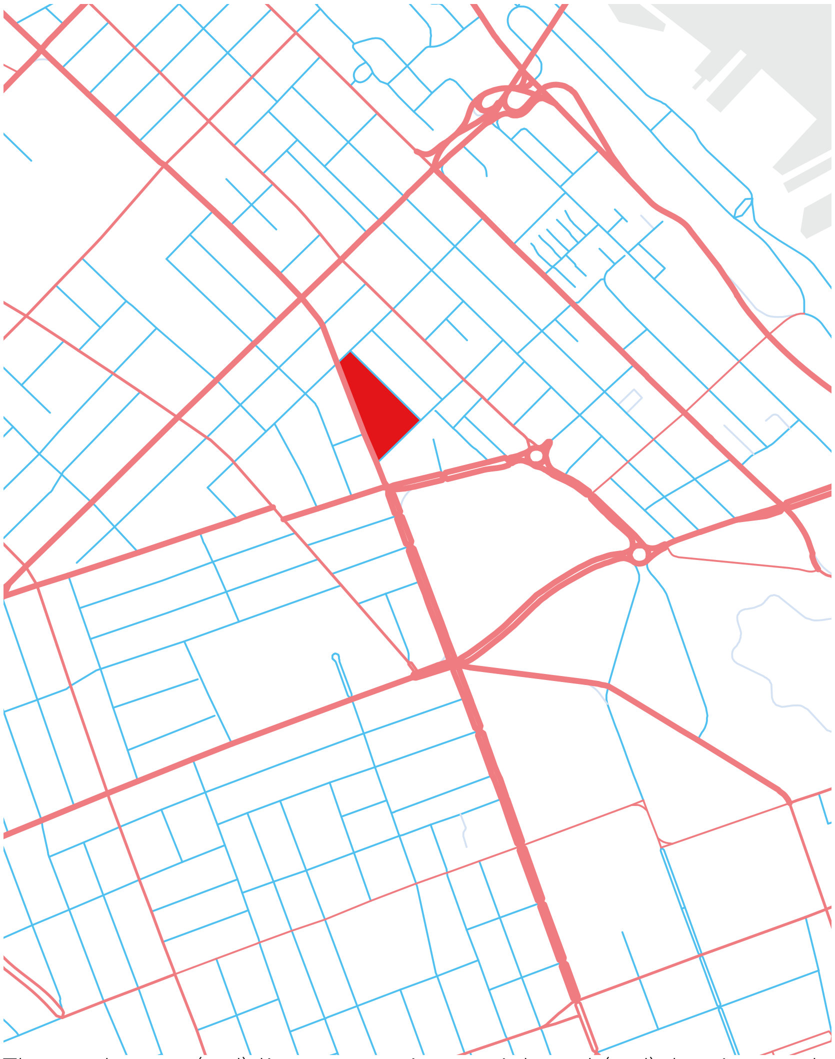
Each dot represents a person, using 2016 data from census dissemination blocks. Study area outlined in red.

This map shows the critical place in population distribution that the study area holds. Other empty areas have uses that are institutional (university campuses, hospitals), commercial (office towers), park land (the Commons, Point Pleasant), military (various bases and docks), or water uses (container and cruise ship ports). As it is possible to move the car lot, and the critical location of the study area to the quickly growing North End, the development of this site will set the tone for many future developments and therefore the neighbourhoods future.



The study area (red) is at the fault line between the north grid (orange) and the south grid (blue), resulting in an irregular block shape.

Another reason to choose this site was its irregular block shape. This would necessitate the inclusion of manual overrides in the tool to accentuate the unique conditions on the site. If the tool can be successful on this site, it can tackle other complex sites.



The study area (red) lies on a main arterial road (red), but is mostly bounded by quiet residential streets (blue).

This map shows the necessity for the development to respond to various conditions in its context. The built form that responds properly to a busy traffic road must protect the rest of the development, while the built form facing the established neighbourhood can open up to it much more.

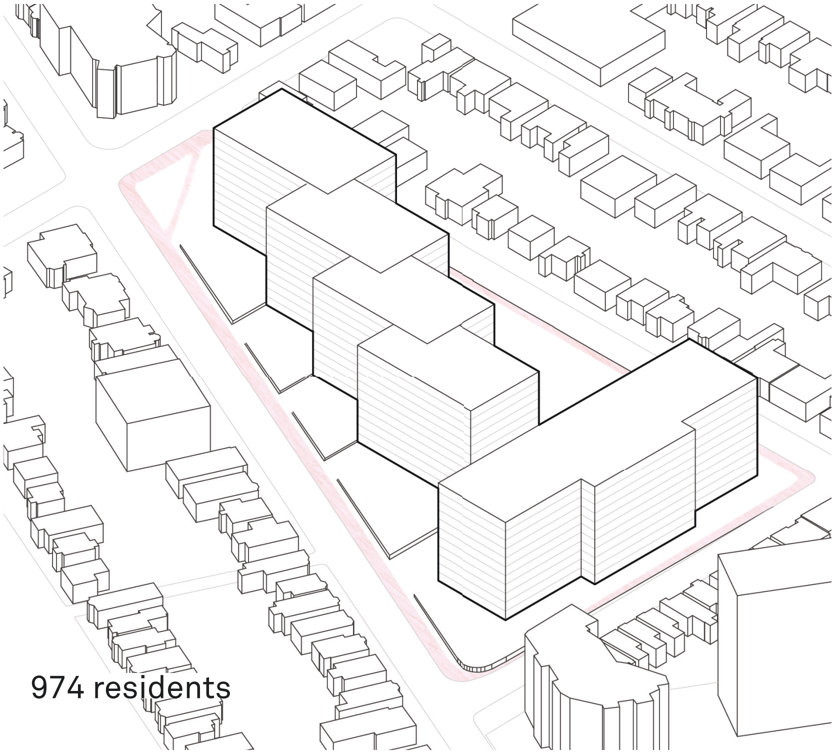
The study area, as it was mapped in 1878 (Nova Scotia Archives, 2018).

This historic map shows that the study area was once three separate blocks, which were merged over time to accommodate industrial uses such as the lumber and shingle depot.

The site is in itself a good location for a residential development, as evidenced by the high population density of surrounding blocks. It is close to lively areas (Agricola St, Gottingen St, Quinpool Rd), open recreation (the commons), grocery store (Quinpool Rd Superstore and Windsor St Sobeys), employment, and education on all levels. To take advantage of the proximity to necessities, the proposed residential development will learn from the benefits and drawbacks of both historic and newer housing typologies.

Observed Patterns

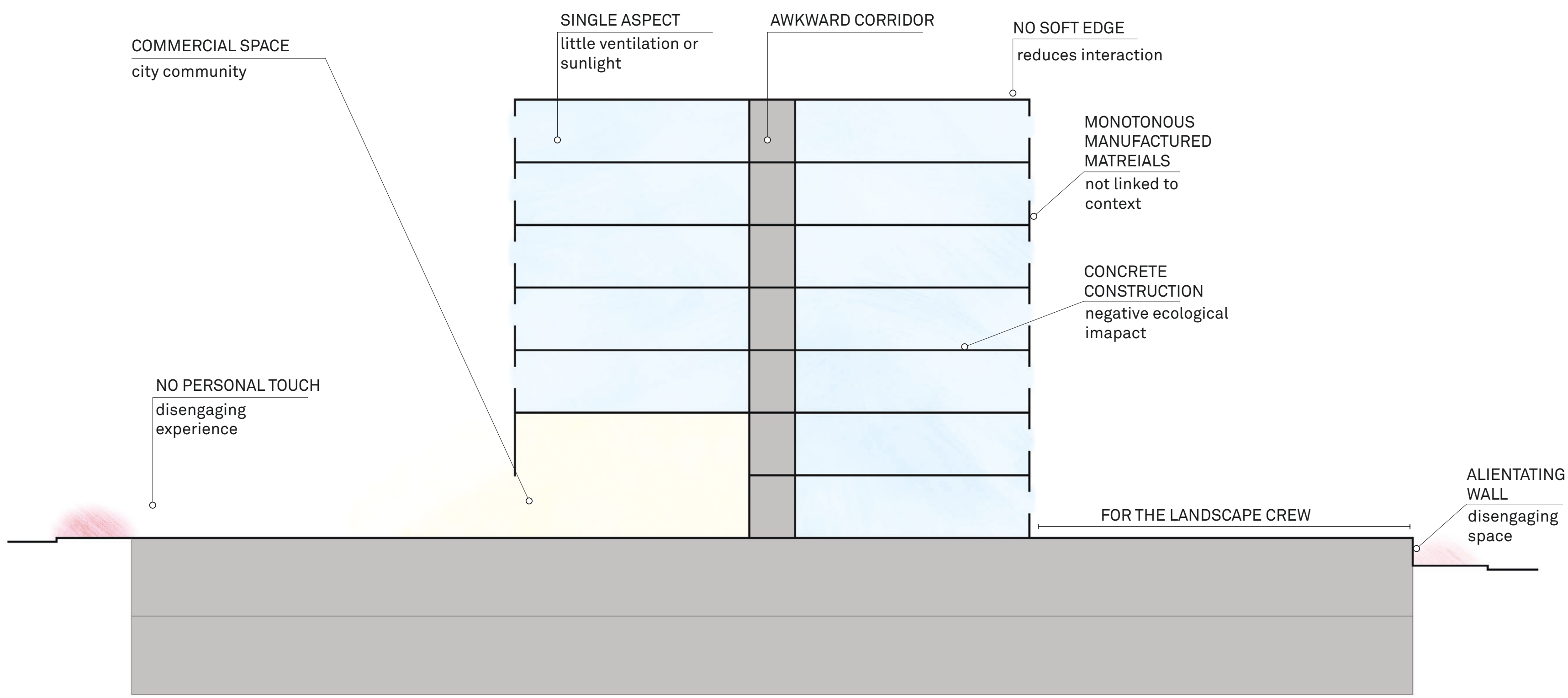
This section will analyze the context of the study area to observe formal patterns that can establish soft edges and encourage interaction (Gehl, 2010). To begin, I analyzed the beneficial blocks surrounding the site, as well as the three most dense blocks in Halifax. Focusing on the potential population, site coverage, height, and massing of the precedents (see Appendix 2 for the data), I drew two possible extremes of what could be built on the site to show what is at stake. Both typologies have strengths and weaknesses, but at the end of the day the site will either be housing that makes the split in the neighbourhood permanent, or housing that weaves itself into the existing urban fabric and encourages more community growth. In the words of Peter Barber, “When we design urban housing we are designing cities. [These projects] are fundamentally a celebration of the life of our city” (Brown et al, 2018, 42).



Two extreme typologies placed on the study area: high-rises, or neighbourhood fabric. Outdoor space on the study area coded to public (red), private (blue), and undefined (white).

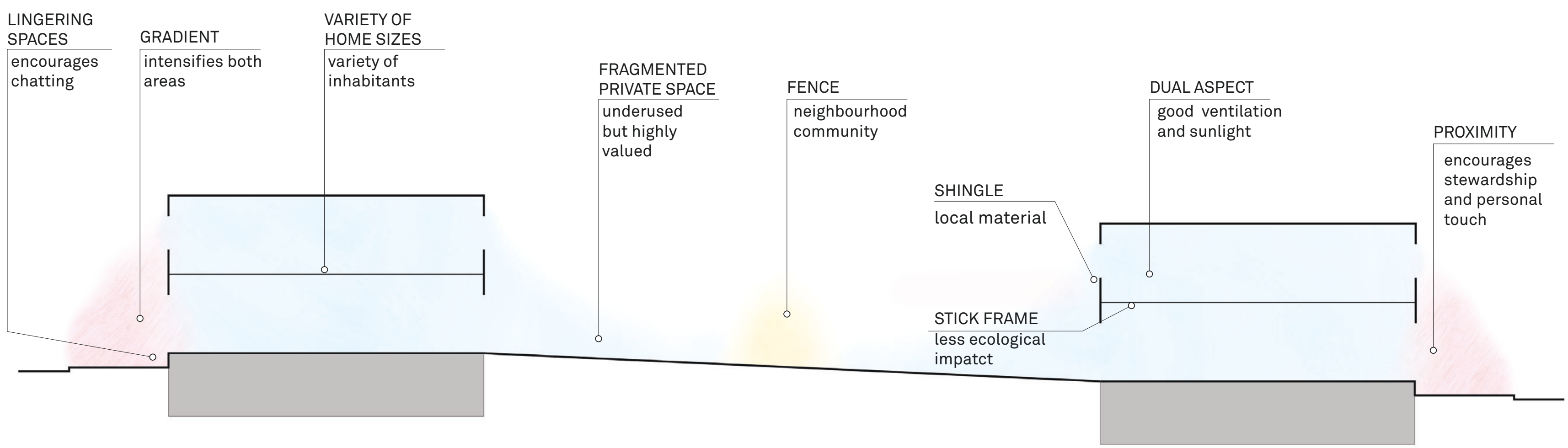
While the high-rise typology offers a higher population density, it makes the break in the neighbourhood fabric permanent. The historic typology creates an engaging fabric, but does not house enough people to sustain the growth of the city, nor be economically enticing enough to be a viable option for future development. Further, the high-rise typology makes the majority of the remaining open space an awkward no-man's land that is uncomfortable to inhabit, whereas the neighbourhood typology uses the open space for engaging public sidewalks and private backyards. Both options have strengths and weaknesses, but how to combine the strengths into a new hybrid typology?

Inspired by Christopher Alexander's *A Pattern Language*, I observed formal patterns in these blocks that make an engaging or isolating public realm. This continues the work done in chapter 2. The tower typology offers high density and commercial space that could encourage community on the city level by becoming a destination. However, there are often blank walls along the sidewalk and the ground area is often ill-defined, preventing soft edges and gradients of inhabitation. The doors open from the unit into an internal corridor, where it is often awkward to run into your neighbours.

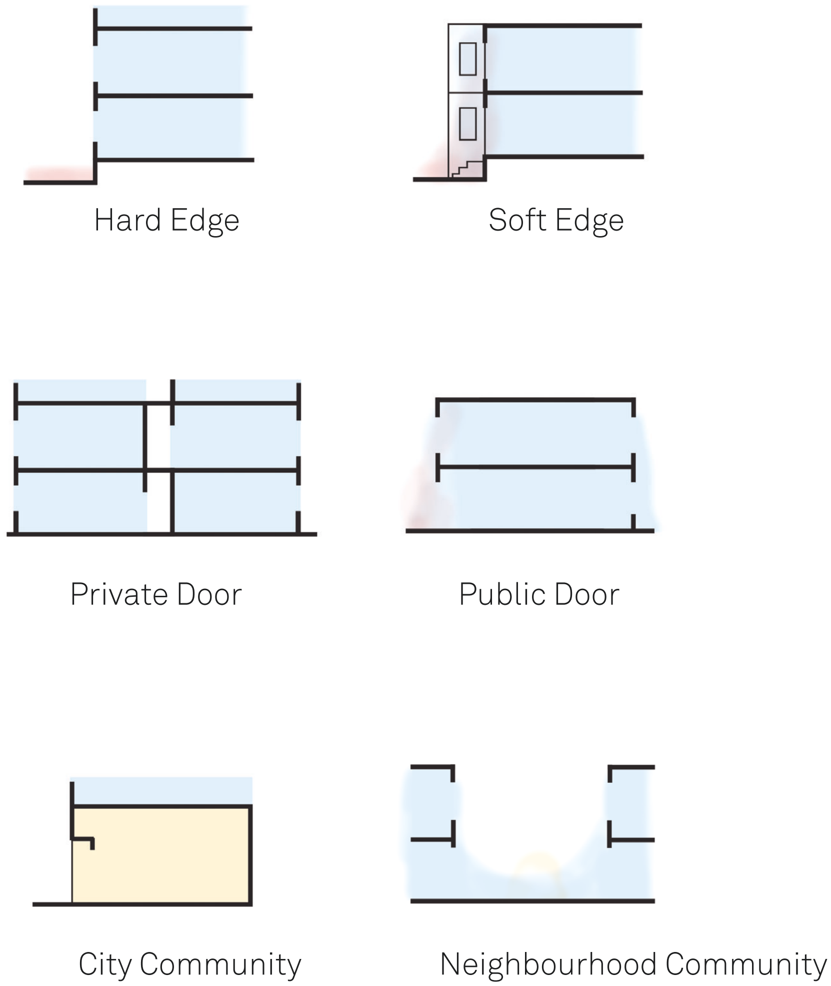


A diagram of patterns in the tower typology. Public (red), private (blue), and city community (yellow).

The neighbourhood typology on the other hand offers entry doors that are linked directly to the street with stairs that provide a space to linger, making running into a neighbour on their porch more comfortable. Combined with the bay window, these elements create the soft edges that offer a gradient of inhabitation to occupy as you wish. This amplifies the experience of both public realm and private domain. Further, the units are typically dual aspect, allowing healthier access to sunlight and natural ventilation. Finally, the back yards often underutilized but do encourage some neighbourhood community around the fence or deck.

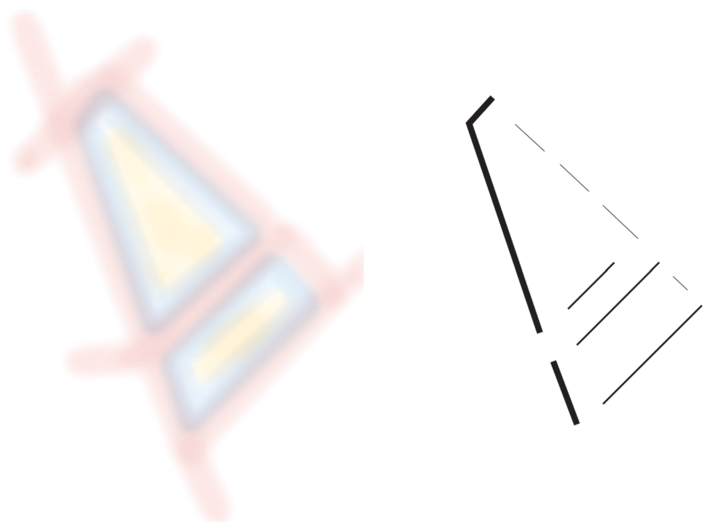


A diagram of patterns in the neighbourhood typology. Public (red), private (blue), and neighbourhood community (yellow).



A comparison of patterns in the tower typology (left) and neighbourhood typology (right).

Patterns in plan were also analyzed. The rhythm of the neighbourhood revolves around facades that face a frontage between 18 and 28 feet. This size was reduced, responding to changes in society that demand smaller, more affordable units. It also became evident that the development had to be buffered from the traffic and noise on Robie street, while opening out into the quiet neighbourhood street to the east.

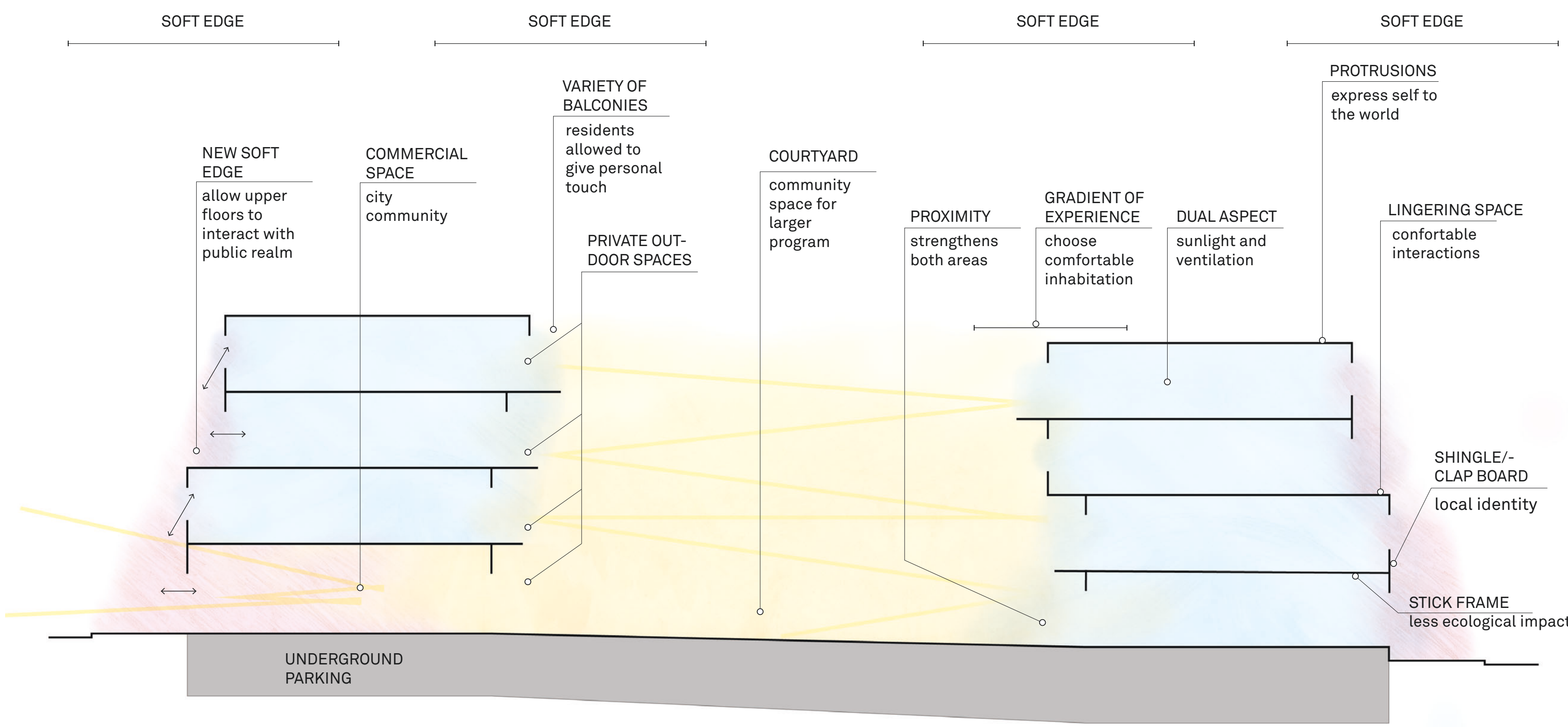


Diagrams of design intentions in plan. Left, create community space in the centre of the block. Right, protect the development from the busy Robie St traffic, while opening up to the established neighbourhood.

These patterns describe the better density Jan Gehl speaks of, but there still must be a high population density to sustain urban growth and for the project to be economically viable. While the tower typology would house almost a thousand people on the study area, the neighbourhood typology would house just 138. How can we maintain the formal patterns that engage people while increasing density?

Hybrid Pattern

This is the hybrid typology I arrived at that combines and amplifies the beneficial patterns of both case studies. It provides 530 bedrooms in 300 units, housing more than two-thirds of what the extreme tower typology would provide, but provides all units with two aspects, private outdoor space, and a soft edge to interact with the world.

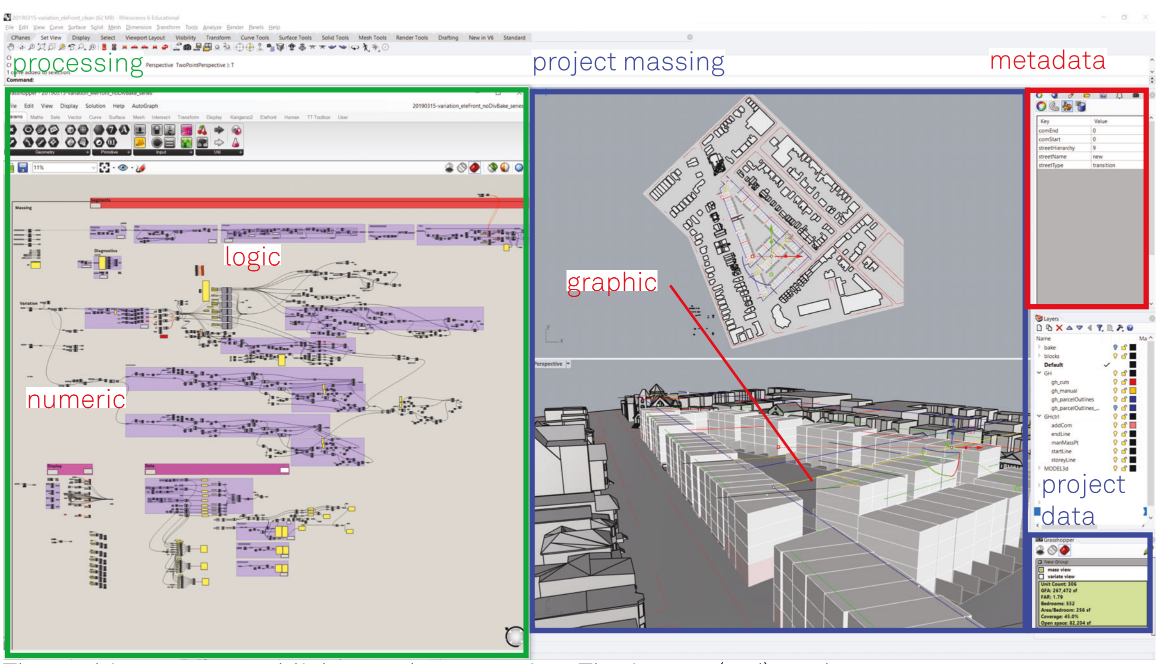


The hybrid pattern that combines beneficial aspects of both case study typologies, while adding an idea of community space from examples in other cities.

The neighbourhood form is stacked on itself, creating a four-storey walk-up with external circulation for the upper floors to form a soft edge with. The backyard depth is reduced, opening space for a common courtyard to house community-oriented program such as an ice hockey rink, giving neighbours a common goal. The parking is placed out of the way underground, and every unit is dual aspect and has private outdoor space. Light wood framing was chosen as the construction method, responding to local conditions and reducing ecological impact.

Tool Use: Urban Massing

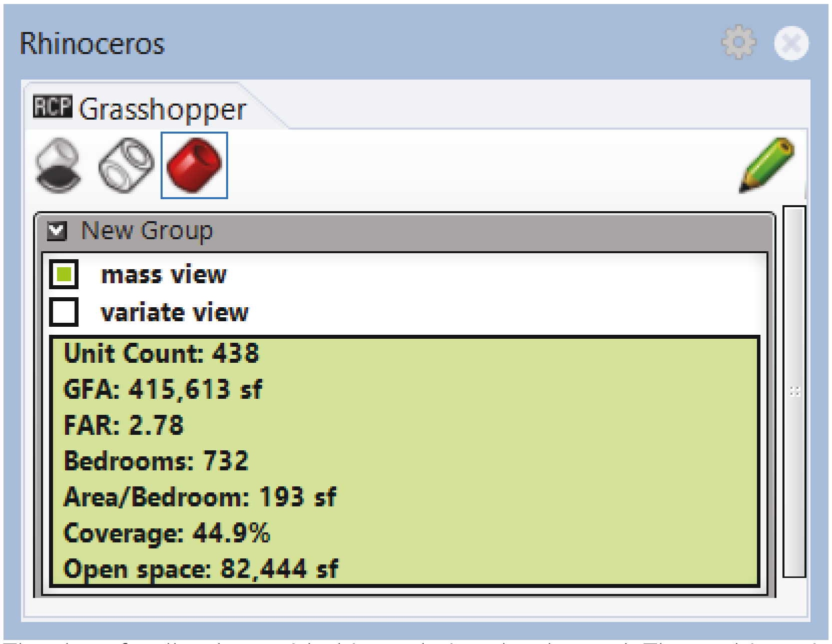
Having established patterns this design responds to, the operation of the custom computational tool will be shown. The tool is broken down into three parts: input, processing, and output.



The tool in use to establish an urban massing. The inputs (red), tool (green), and outputs (blue).

The architect has three methods to input their intentions. First, is the graphic interface, allowing geometric inputs to be drawn and manipulated on the model itself. These include lines such as street wall lines, setback lines, manual building footprints, and height controls. Metadata allows these graphical inputs to have data associated with them, such as the width of a street wall break, the hierarchy of a street, or if a street is allowed to have commercial units. Next, some inputs are put directly into the tools itself. Some numeric data can be inputted directly into the tool itself, for variables such as stair rise and run measurements. The architect inputs all the aggregation logic directly into the tool as well, deciding how elements and patterns interact. Here the algorithms are also encoded.

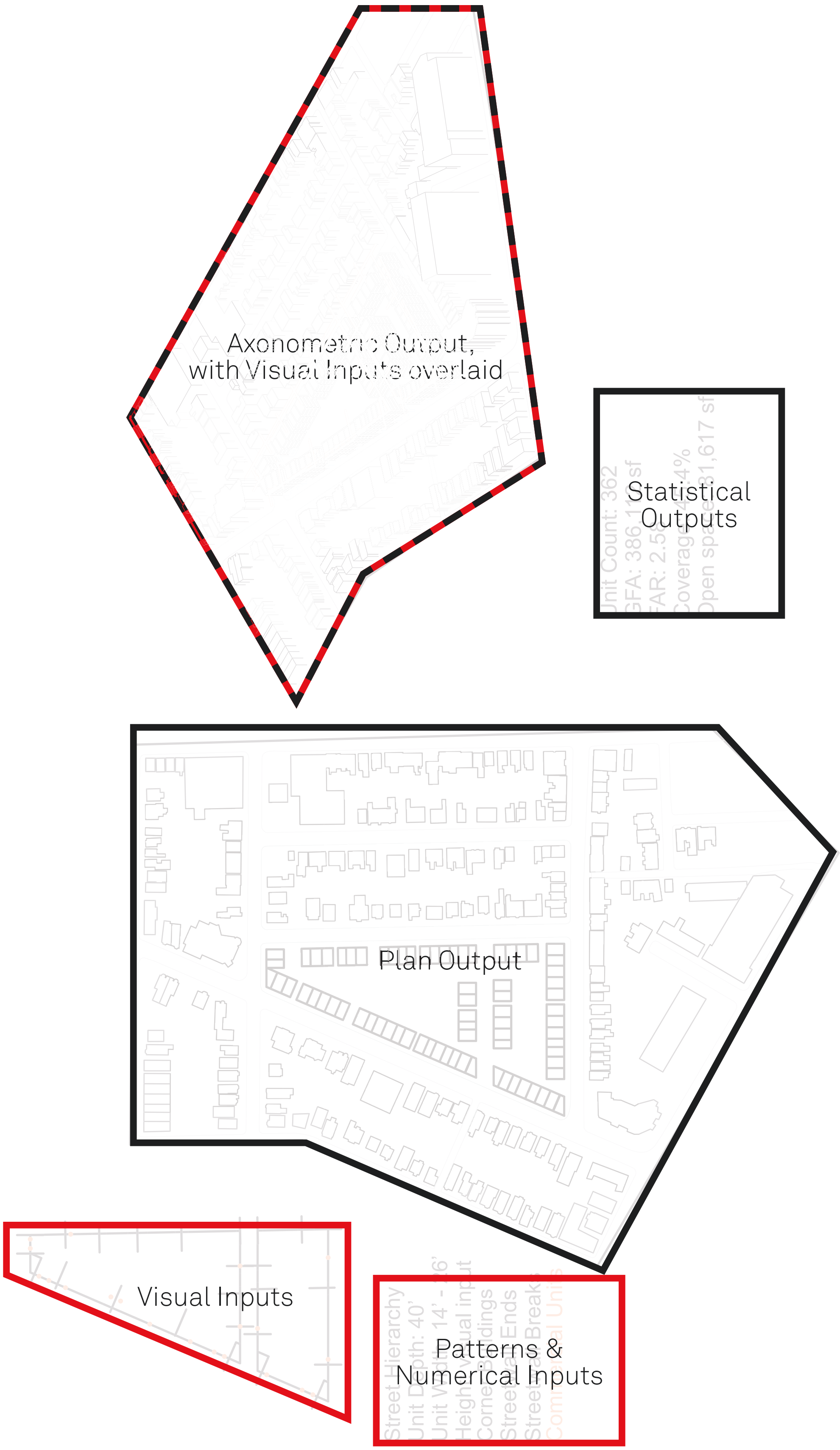
The outputs are both visual and statistical allowing the architect to evaluate both qualitative and quantitative aspects of the design and development goals. By having a massing that updates in real-time, the architect is able to view both birds-eye massing and how the human experience is shaped by design changes. A number of views can be saved to view important stations, such as prominent corners and streetscapes.



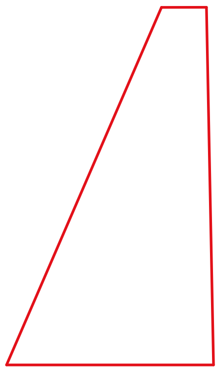
The data feedback provided in real-time by the tool. The architect is able to choose which data to calculate and display, allowing them to prioritize specific targets.

In general, the tool allows the architect to decide how these patterns interact, and then apply this aggregation to the site to establish an urban massing. They are able to evaluate qualitative and quantitative aspects of the design in real time in response to the massing and project statistics tool generates. The tool generates this information based on my manipulation of geometric and numerical formal generators. The tool is flexible enough to allow manual overrides of important areas, such as the acute corners in the study area.

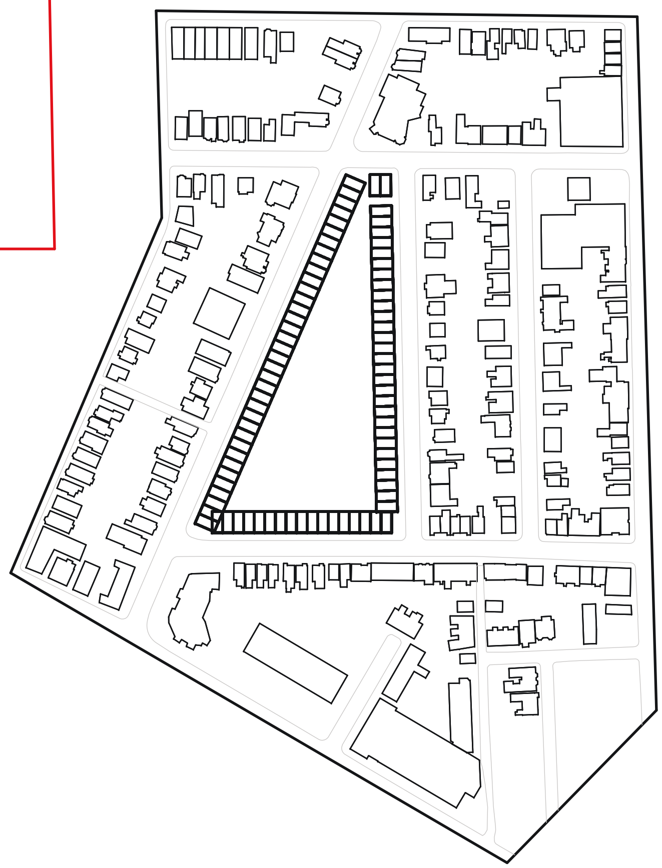
This feedback loop builds on the strengths of computers to quickly and accurately execute a large amount of instructions, and the architect's strength to evaluate information and follow intuition based on human experience. The following pages show the tool in use, aggregating various patterns. Each page shows the input and resulting visual and data output.

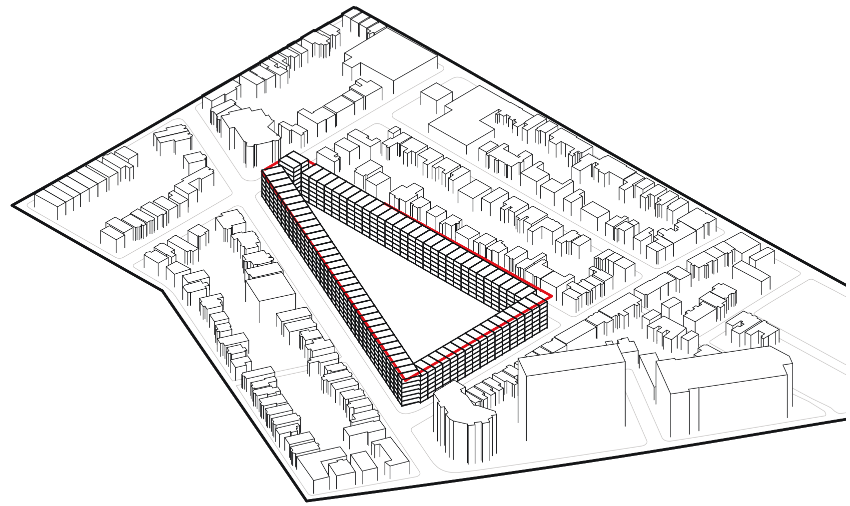


Legend for the following illustrations. Architect’s inputs in red, tool feedback in black.



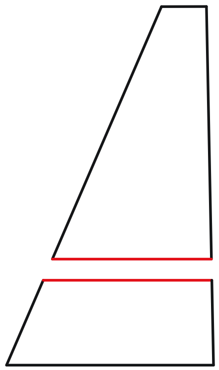
Street Hierarchy
Unit Depth: 40’
Unit Width: 20’
Height: 6 stories



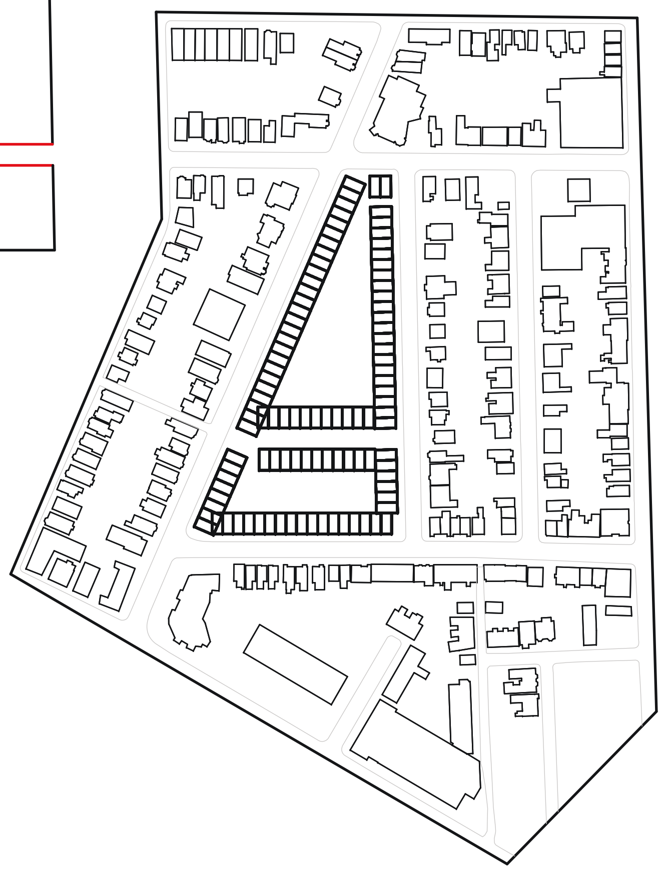


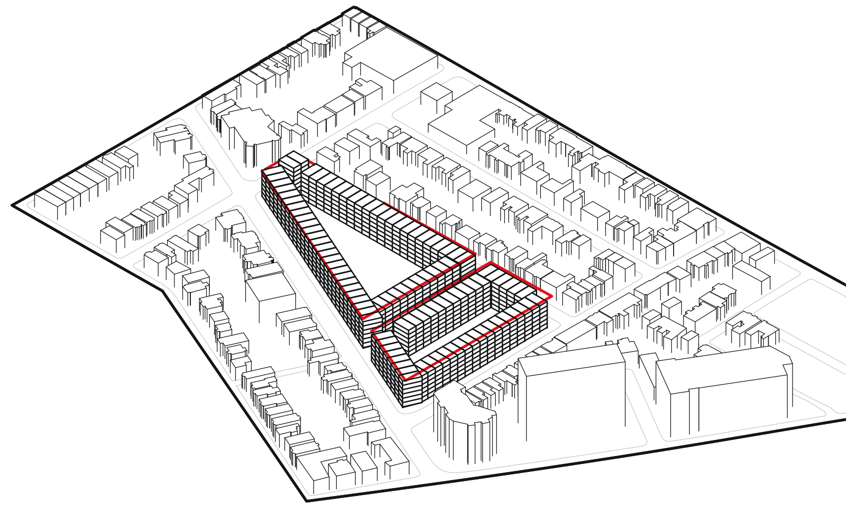
Unit Count: 504
GFA: 403,201 sf
FAR: 2.49
Coverage: 41.5%
Open space: 94,739 sf

The tool begins by ingesting the streets, their hierarchy (at the corner, giving the frontage to the dominant street), a unit depth and width, and base number of storeys.



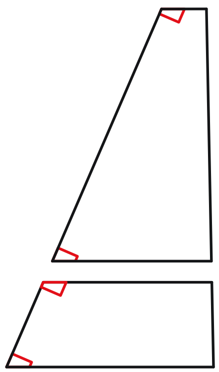
Street Hierarchy
Unit Depth: 40’
Unit Width: 20’
Height: 6 stories



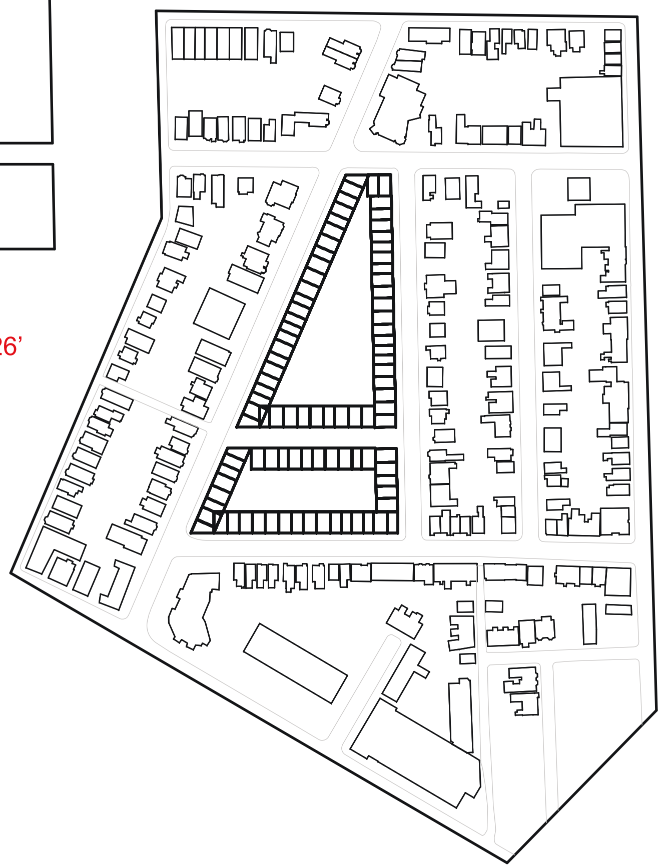


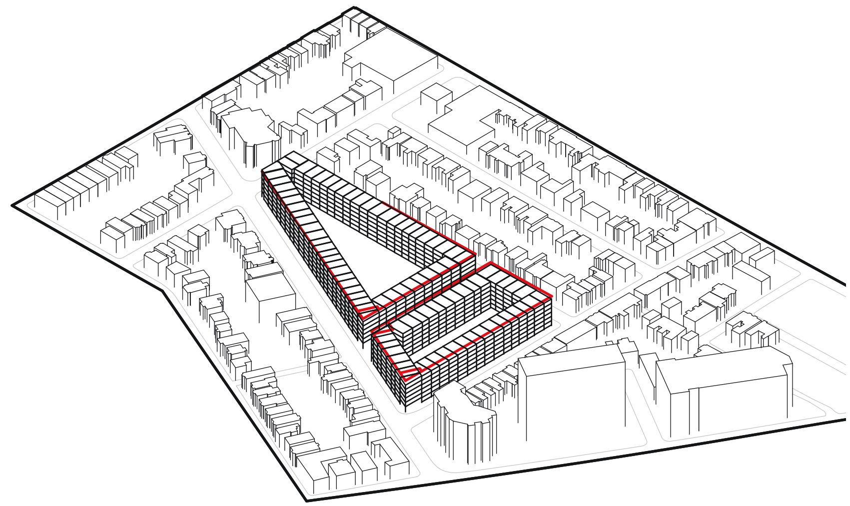
Unit Count: 612
GFA: 489,601 sf
FAR: 3.27
Coverage: 54.6%
Open space: 67,922 sf

The streets were altered to create two distinct blocks.



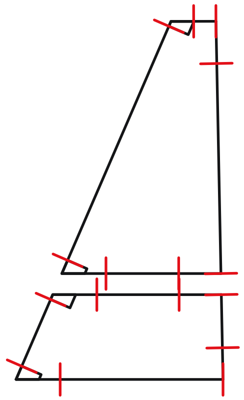
Street Hierarchy
Unit Depth: 40’
Unit Width: 14’ - 26’
Height: 6 stories
Corner Buildings



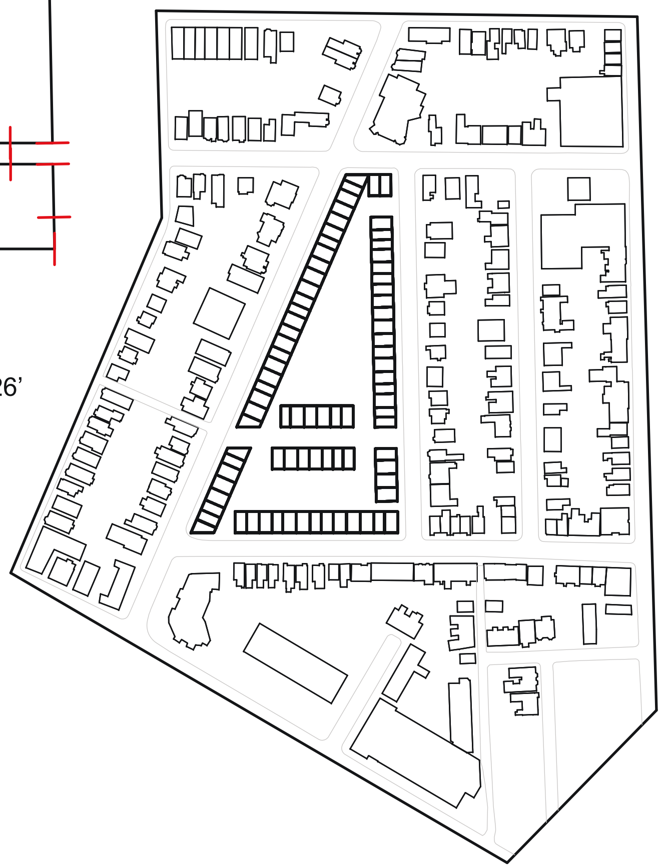


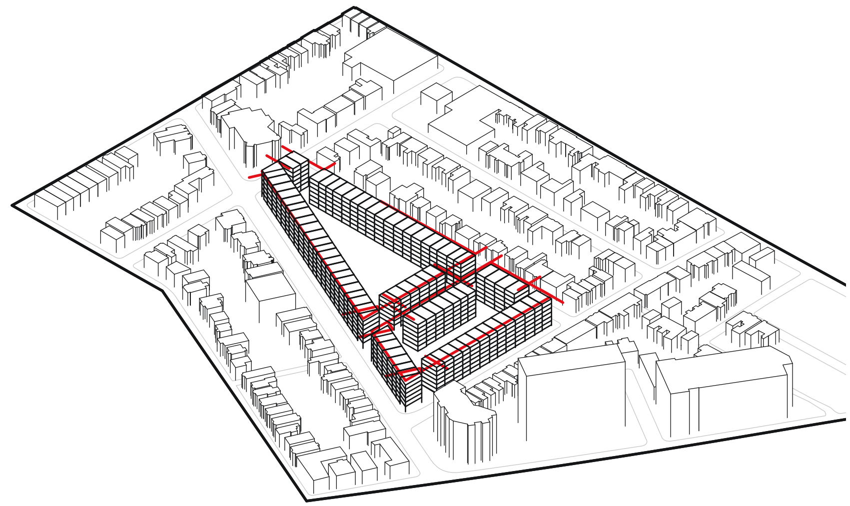
Unit Count: 558
GFA: 557,152 sf
FAR: 3.73
Coverage: 56.1%
Open space: 65,617 sf

Buildings were added on the corners to respond to the unique geometry of the site. Unit width was randomized between a minimum and maximum value, creating different sizes of units.



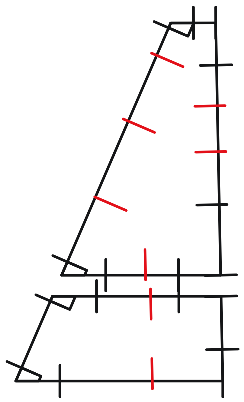
Street Hierarchy
Unit Depth: 40’
Unit Width: 14’ - 26’
Height: 6 stories
Corner Buildings
Streetwall Ends



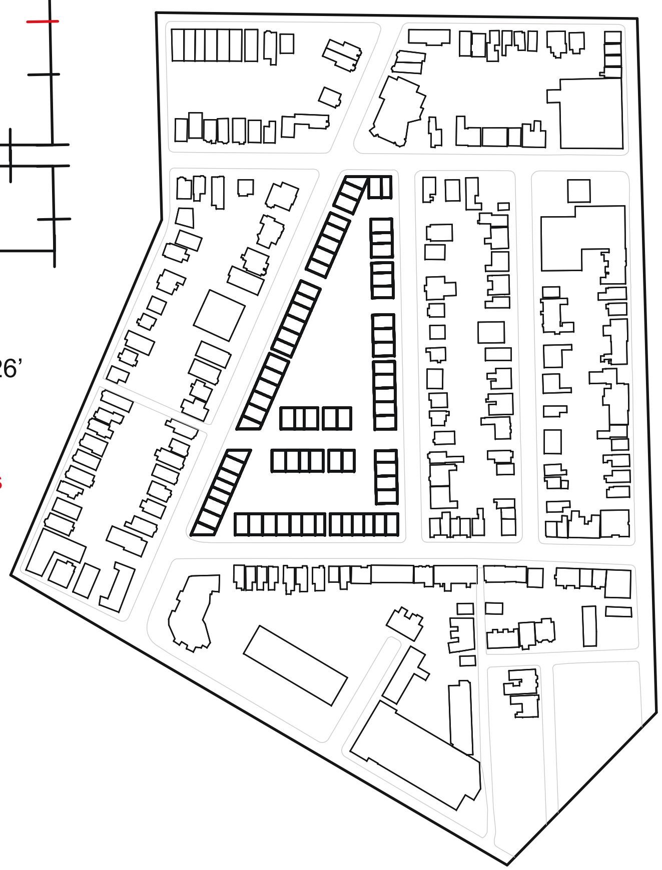


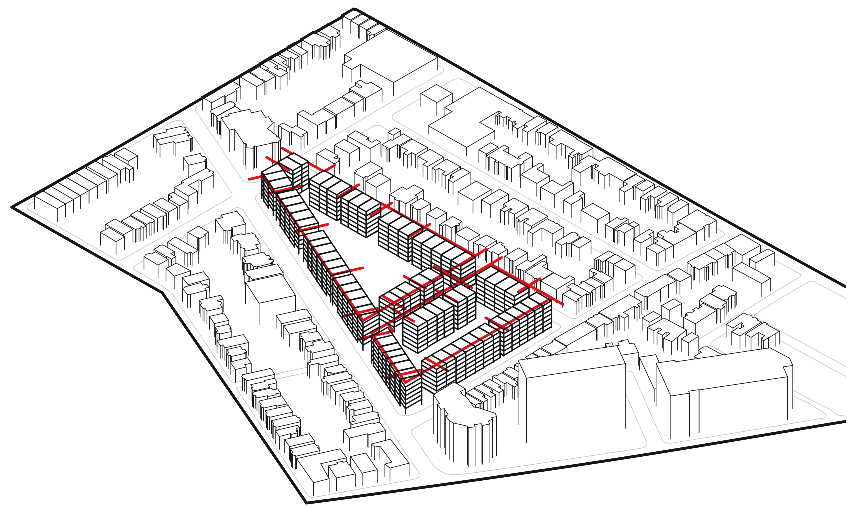
Unit Count: 486
GFA: 494,032 sf
FAR: 3.30
Coverage: 49.1%
Open space: 76,137 sf

Manual control of the end points of the street walls. This allows commercial pockets to emerge in response to the site shape. This control geometry was generated by the massing at the end of evey street wall segment.



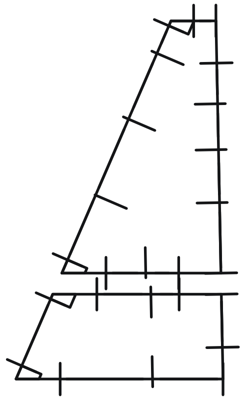
Street Hierarchy
Unit Depth: 40’
Unit Width: 14’ - 26’
Height: 6 stories
Corner Buildings
Streetwall Ends
Streetwall Breaks



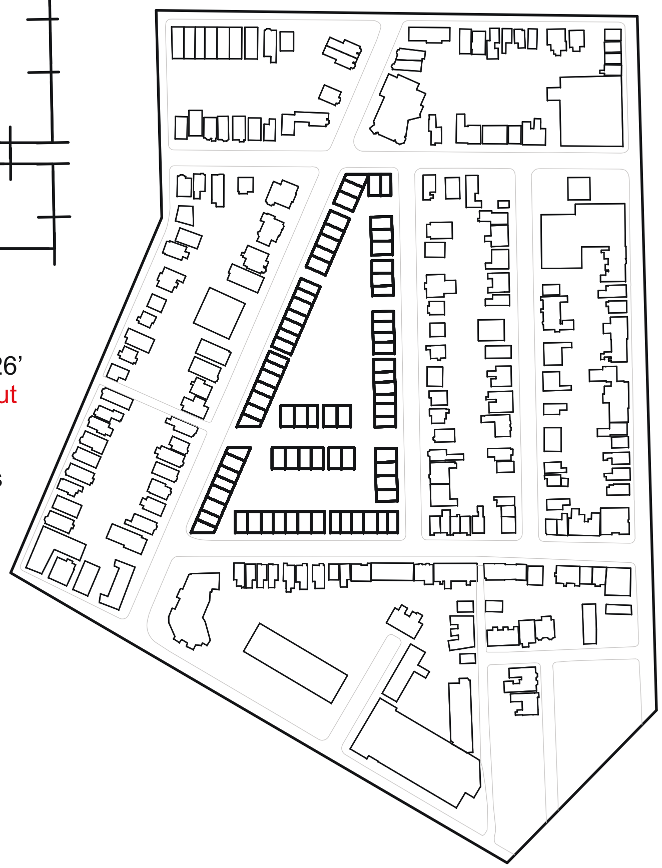


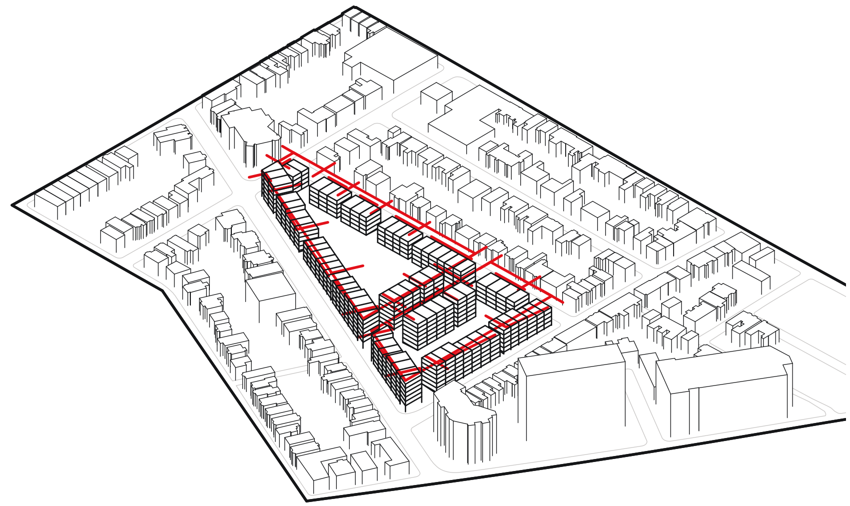
Unit Count: 432
GFA: 460,672 sf
FAR: 3.08
Coverage: 45.4%
Open space: 81,697 sf

Adding breaks into the street wall. Each is given a width, responding to its use from pedestrian passage to underground parking entrance.



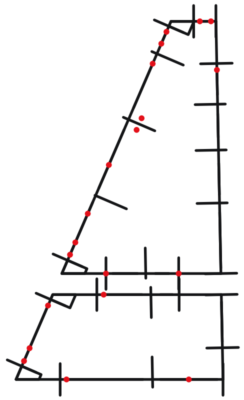
Street Hierarchy
Unit Depth: 40’
Unit Width: 14’ - 26’
Height: visual input
Corner Buildings
Streetwall Ends
Streetwall Breaks



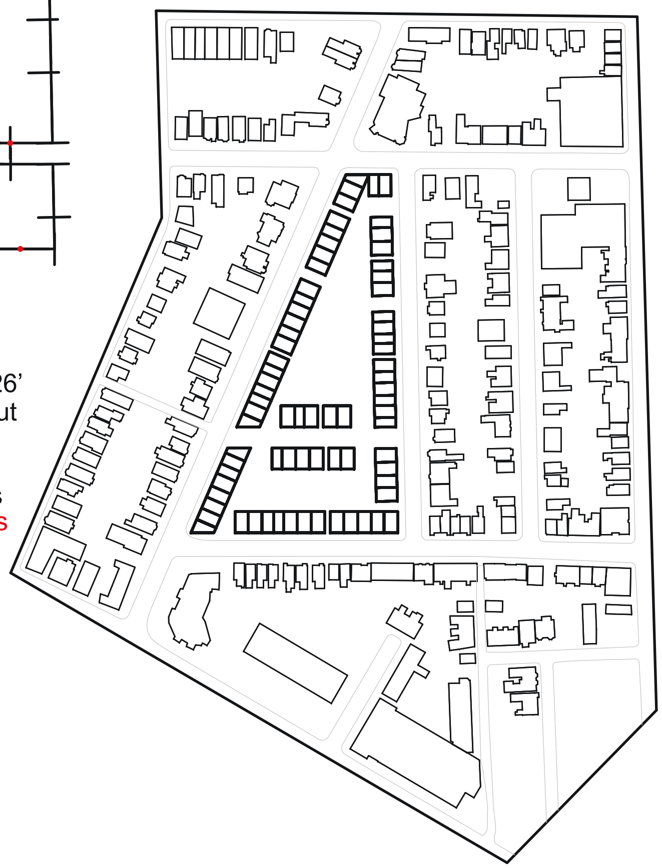


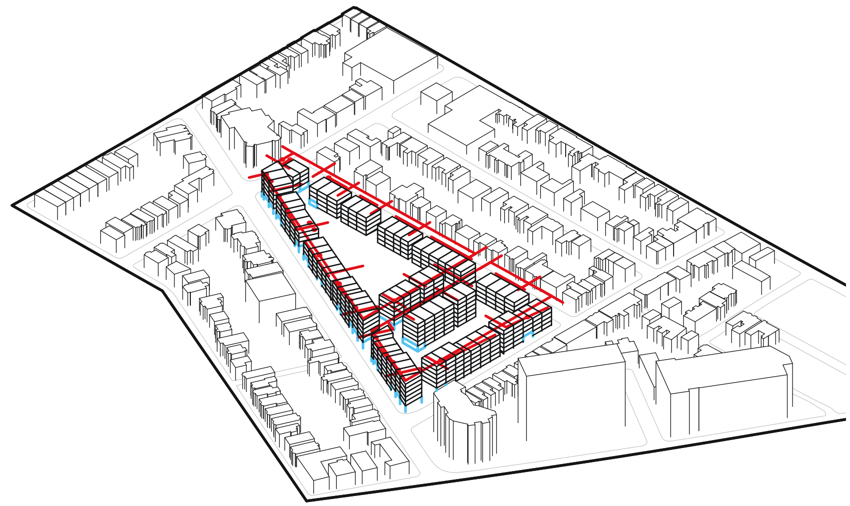
Unit Count: 371
GFA: 386,872 sf
FAR: 2.59
Coverage: 45.4%
Open space: 81,617 sf

Control is given to manage the height of the buildings. This control geometry was created by the tool above each block of units, reducing menial work for the architect and allowing more time to explore height variations.



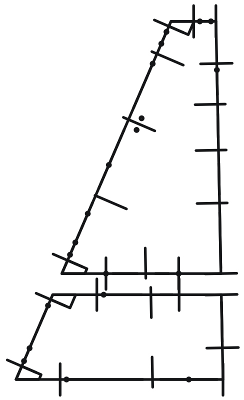
Street Hierarchy
Unit Depth: 40’
Unit Width: 14’ - 26’
Height: visual input
Corner Buildings
Streetwall Ends
Streetwall Breaks
Commercial Units



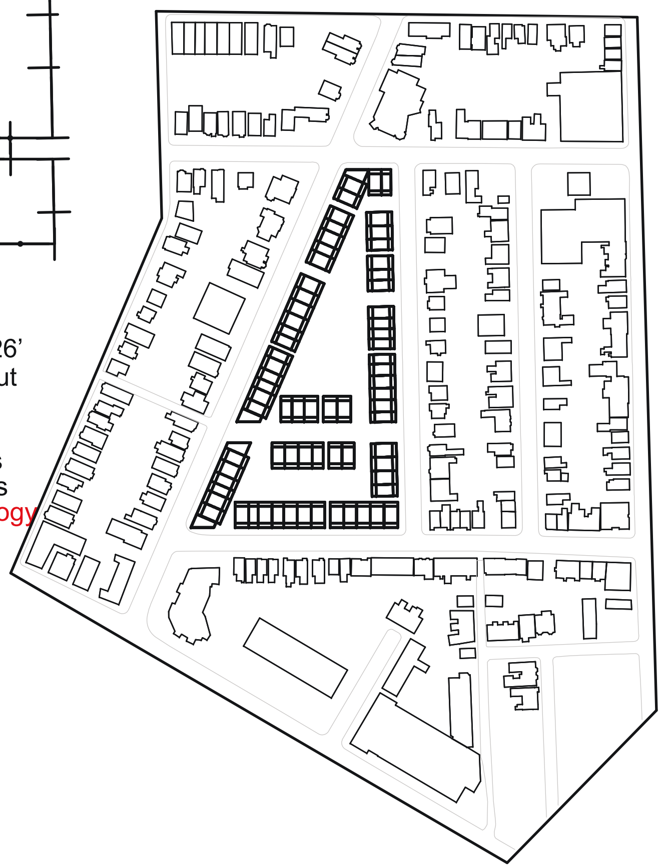


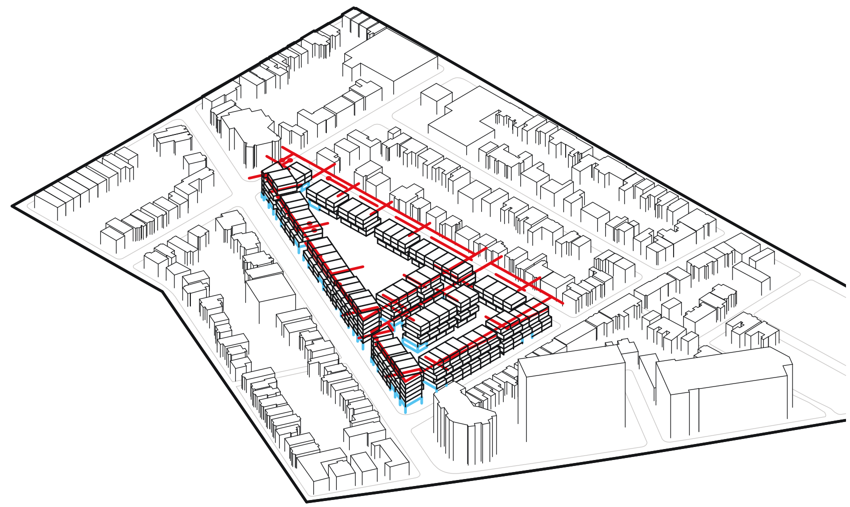
Unit Count: 362
GFA: 386,112 sf
FAR: 2.58
Coverage: 45.4%
Open space: 81,617 sf

Control is given to define where commercial units are placed.



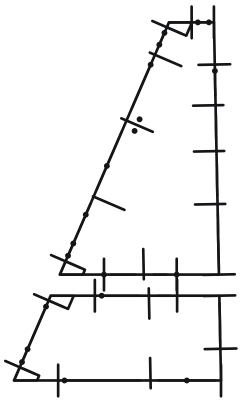
Street Hierarchy
Unit Depth: 40’
Unit Width: 14’ - 26’
Height: visual input
Corner Buildings
Streetwall Ends
Streetwall Breaks
Commercial Units
Massing of Typology

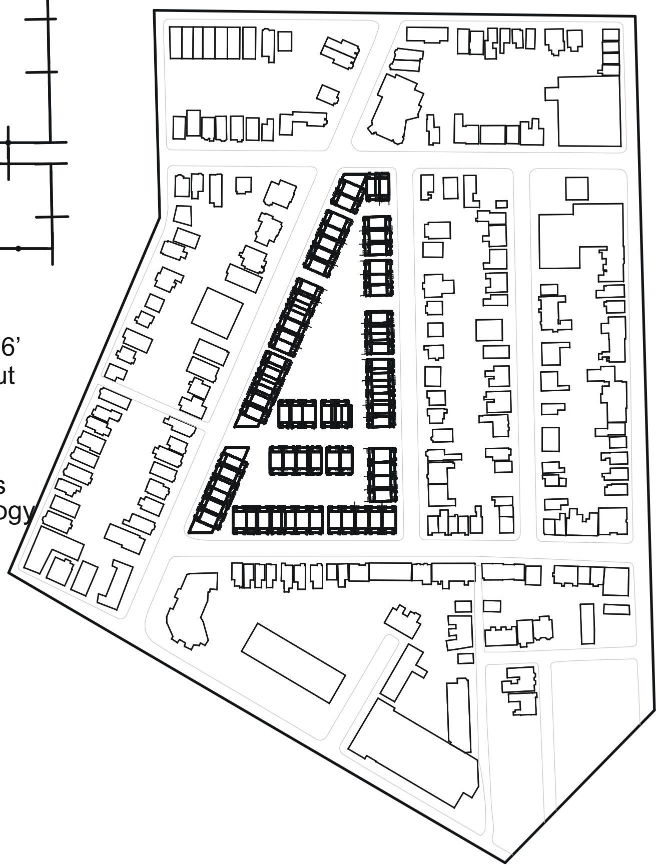




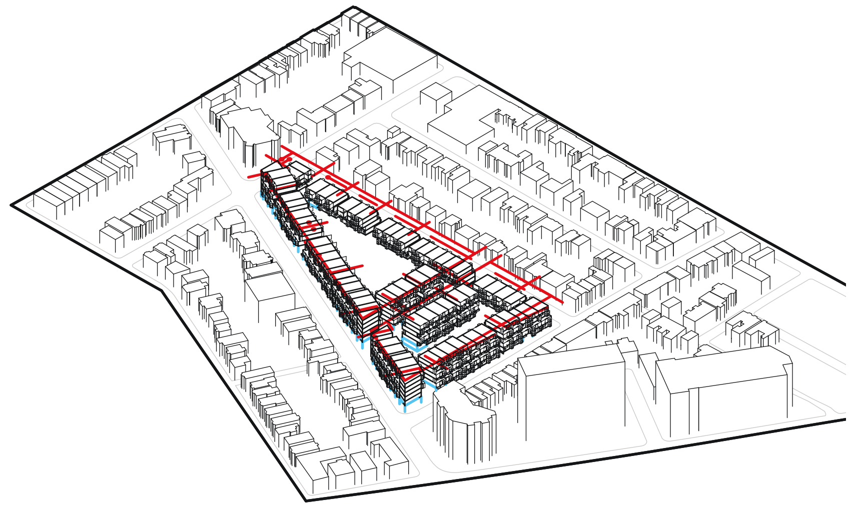
Unit Count: 363
GFA: 386,792 sf
FAR: 2.59
Coverage: 45.4%
Open space: 81,617 sf

The massing of the hybrid pattern is applied.





Street Hierarchy
Unit Depth: 40’
Unit Width: 14’ - 26’
Height: visual input
Corner Buildings
Streetwall Ends
Streetwall Breaks
Commercial Units
Massing of Typology
Adding Blocks

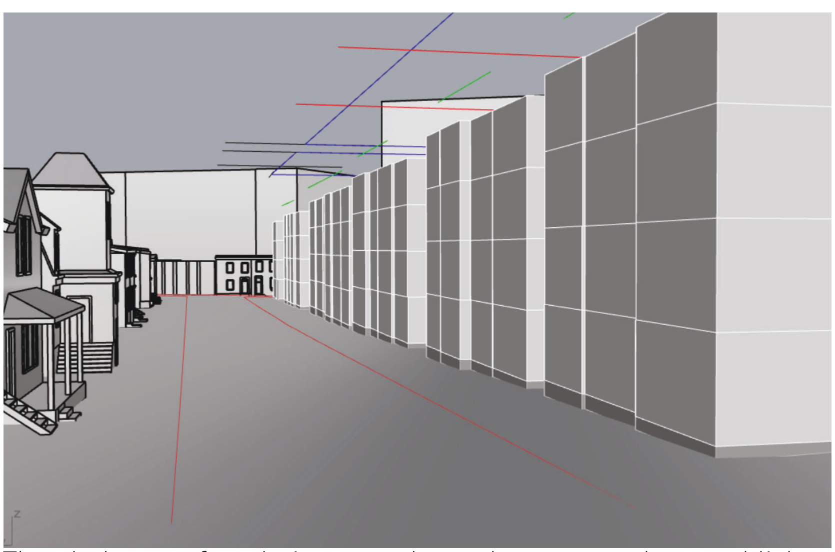


Unit Count: 363
GFA: 386,792 sf
FAR: 2.59
Coverage: 45.4%
Open space: 81,617 sf

Variety is added by placing bays, entry ways, windows and balconies on the facade.

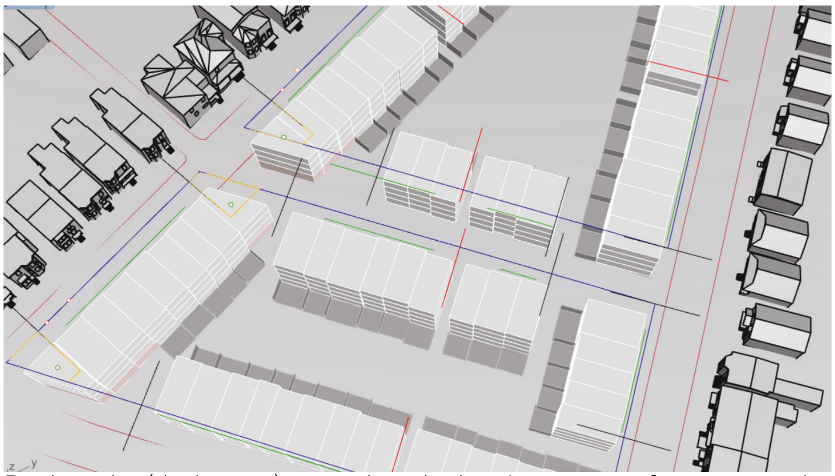
The previous study is not the final proposed design, but shown to illustrate how the tool allows the architect to layer complexity. Any of the inputs may be changed at any time, allowing the design effort expanded to create a massing to be re-applied to a new design idea. For example, the initial streets may be changed at any point, in response to new considerations or ides. This re-use of human design effort is a strength of this tool, allowing more time to be spent investigating and less time on menial visualization tasks. There are a few more fine-grained details to be discussed with this massing tool.

A large detrimental pattern found in high-density typologies is their connection with the ground. Often, grade changes and partially-underground parking garages create a blank concrete wall immediately next to the sidewalk, blocking any possibility of a soft edge. For this reason, the massing tool reacts to the site topography to ensure a reasonable treatment of grade. The tool establishes each segment of units at a common ground floor, creating foundations that reach the topography.

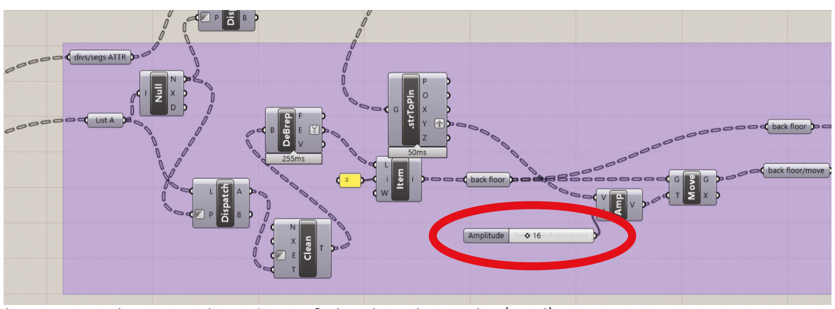


The dark grey foundations reach to the topography, establish a common ground floor. The colourful lines are the graphical inputs.

The massing also includes the private back yards, which are shrunk down to a more usable size that allows private outdoor space while retaining the majority of inner-block space for community activities, such as an ice hockey rink. The tool allows the size of the backyard to be changed, evaluating the resulting space left over for community activities.



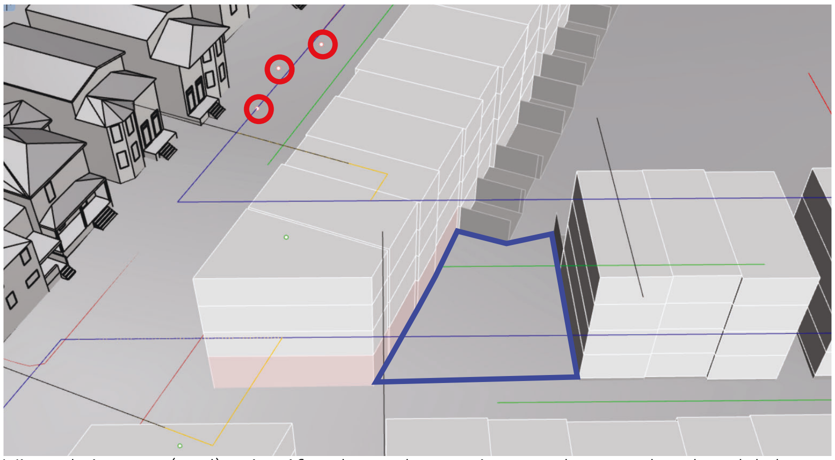
Backyards (dark grey) are shrunk, leaving space for community activities in the centre of the block.



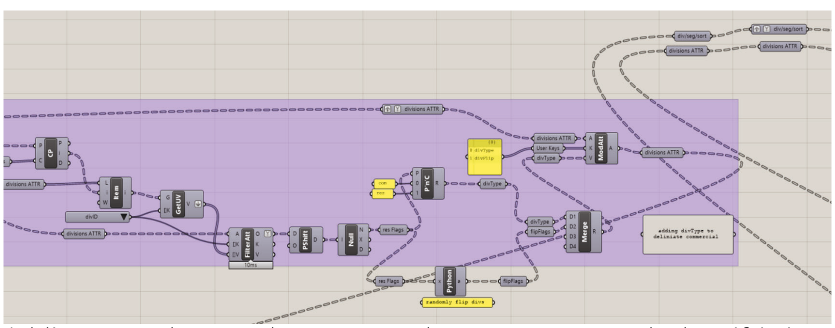
Input to change the size of the backyards (red).

The architect is also able to establish which units are commercial through a graphical interface, placing points above areas indented to be commercial. These units do not have a backyard space, but it is implied that the commercial use will spill out through the back - such as a cafe opening tables during patio season. These units were concentrated into commercial pockets at the corners on

Robie street, emphasizing the unique geometry of the lot with an area of high utilization. Combined with the backyards, this establishes a threshold in the public realm to delineate the community space beyond this pinch point.

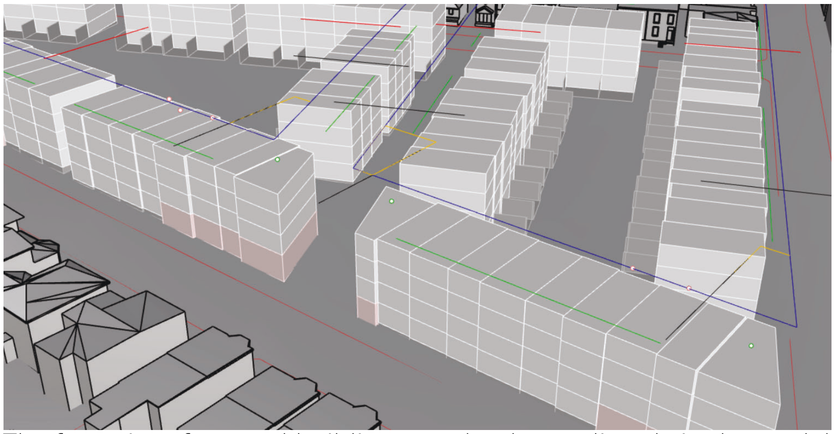


Visual input (red) signify that the units underneath should have commercial at grade (shaded red by tool). This removes the backyard behind these units, establishing a commercial pocket of public space (blue) that also acts as a threshold from the community space beyond. This shows the flexibility of the tool to respond to unique site conditions.

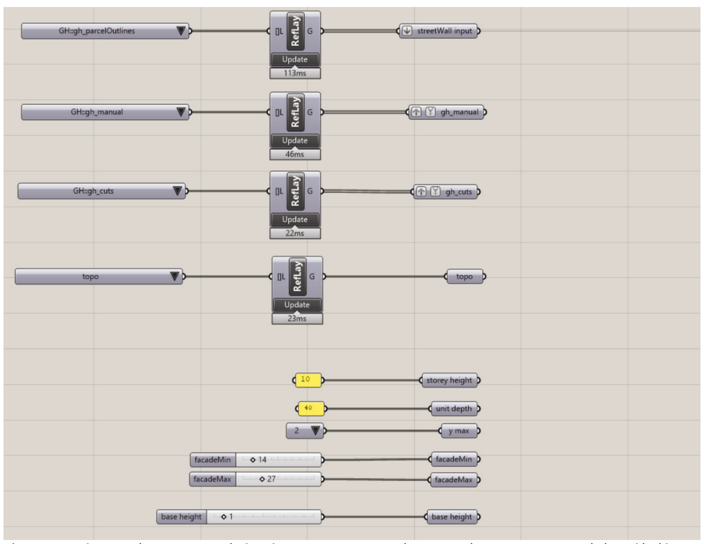


Adding metadata to the generated geometry to mark that if it is a commercial or residential unit. This metadata is used later to display commercial units as distinct from residential units.

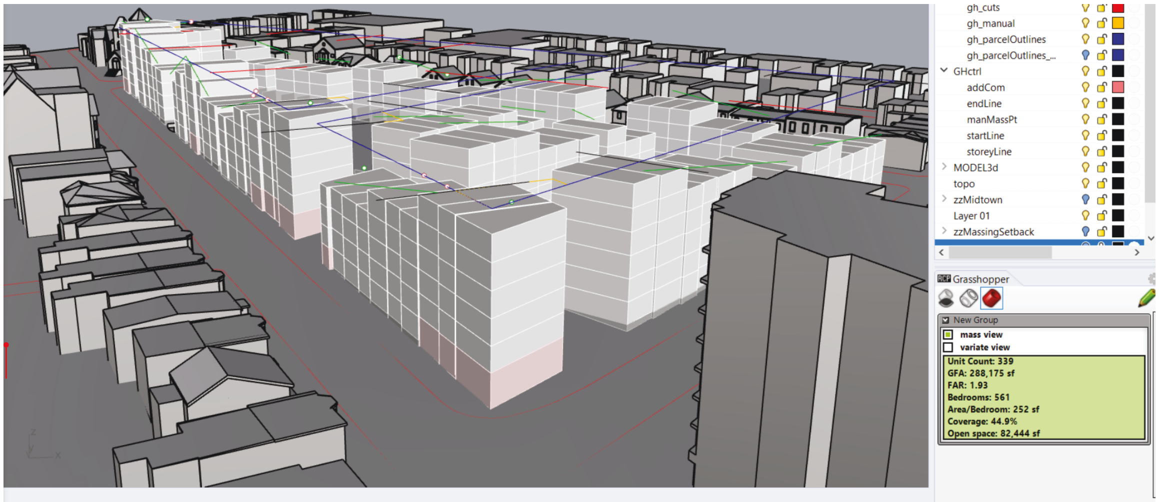
These corners are further accentuated by manually-shaped buildings on the acute corners, creating a well-defined and clear public realm. Without this manual override, these corners would become confused and ill-defined.



The footprint of manual buildings can be drawn directly in the model (orange).

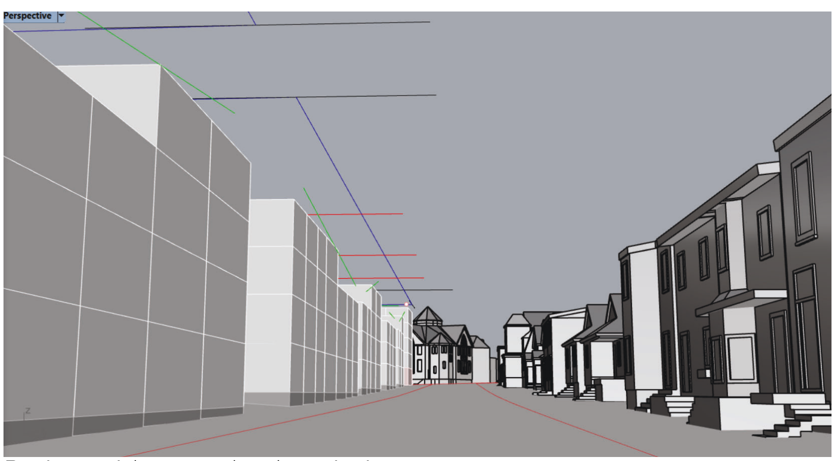


Ingesting the graphic inputs, such as the manual building footprints, as well as various numeric inputs.

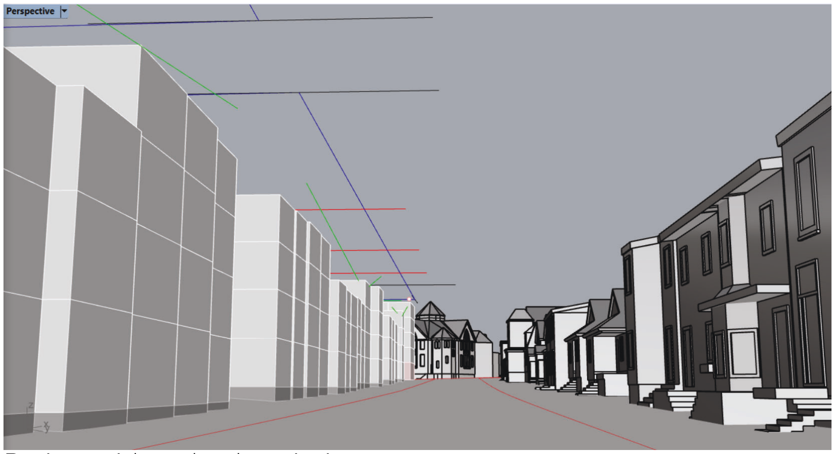


Altering the height controls (green) allows variety in the height of the development, while keeping an eye on the unit count (right). The control geometry was generated by the tool and manipulated by the architect.

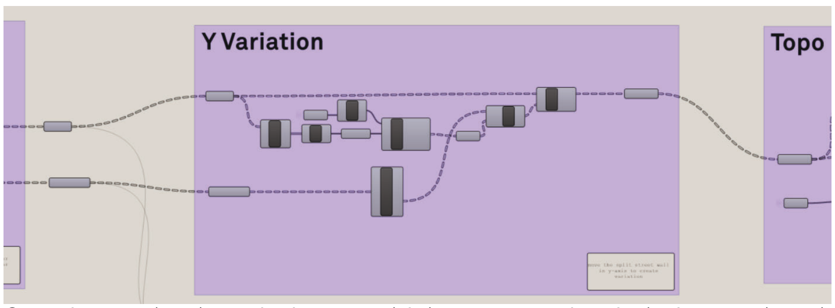
Throughout the development, the tool allows variety in the massing by moving the facade towards or away from the street. This breaks up what would otherwise be a flat facade, creating more interest and a wider range of inhabitable spaces.



Project without setback variation.

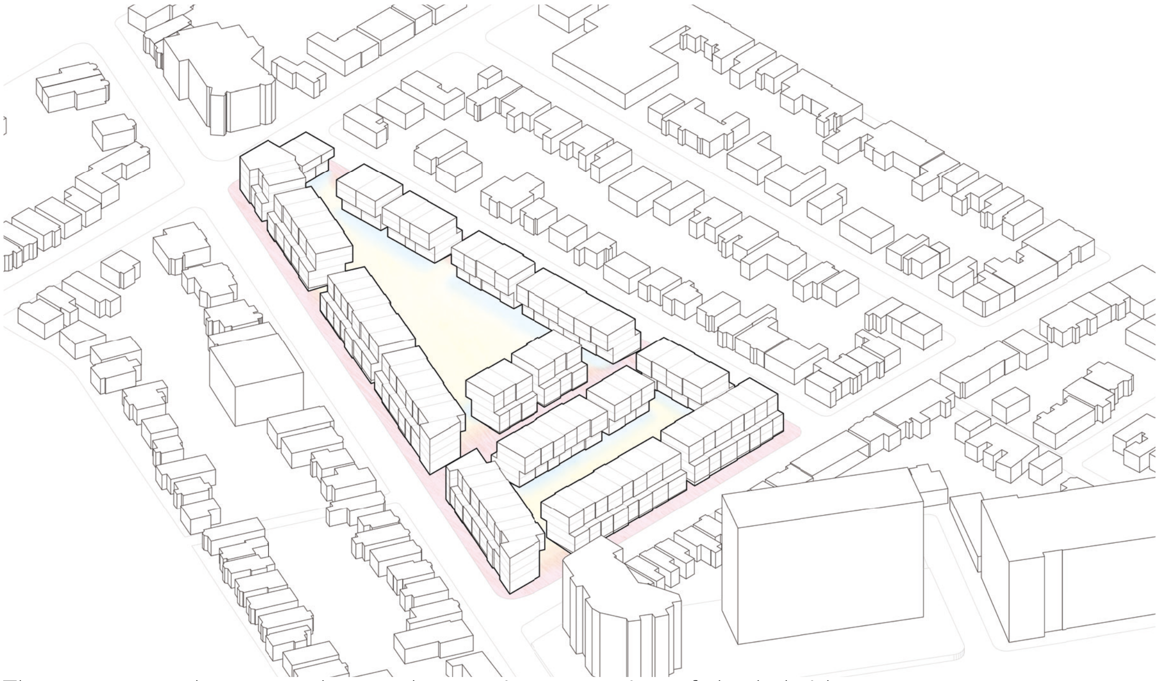


Project with setback variation.



Creating setback variation to whichever massing is being explored. The maximum setback is controlled by the architect.

The final proposal developed with this tool is shown in the next image. The tool allowed many iterations to be explored in the neighbourhood context, and for variety to be established right in the urban massing.

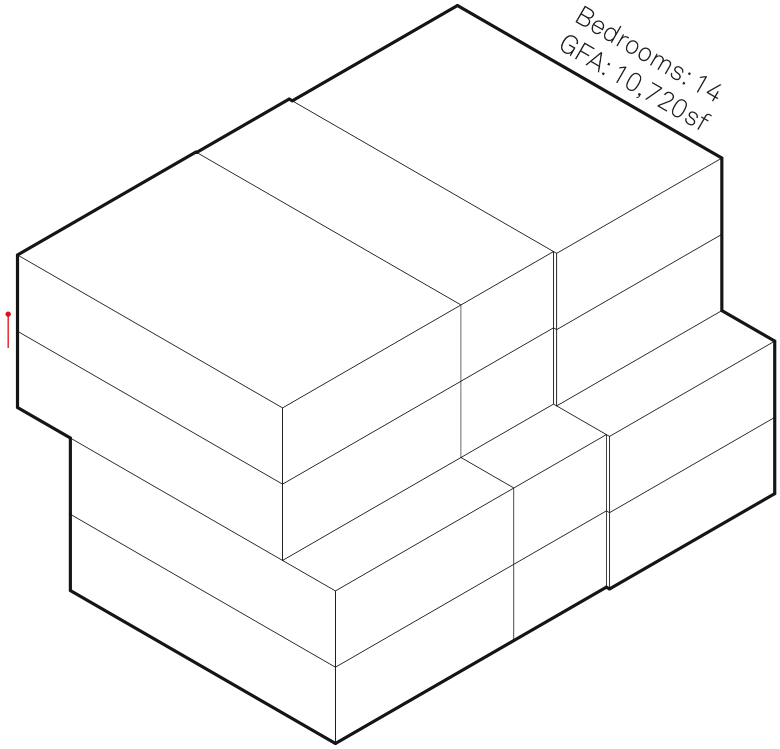


The custom tool was used to explore various massing of the hybrid pattern on the site, ultimately coming to this version. Public sidewalk (red), private backyards (blue), communal space (yellow).

While this methodology is context specific, using patterns observed in the neighbourhood to match those specific urban grain and rhythms, the strength of this tool is that the methodology can be applied to other potential development sites to create a residential design that responds to those local patterns.

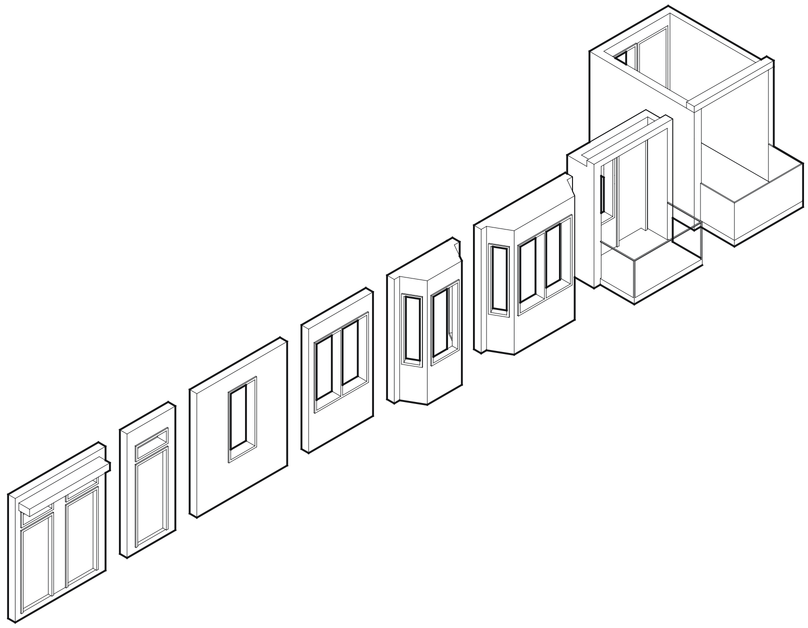
Tool Use: Building and Inhabitation Scales

Having established the urban massing, the building and inhabitation scale must be designed. Specifically, the facade of the development will be developed to provide soft edges, and the unit plans will be developed to offer gradients of inhabitation on the prospect/refuge and inside/outside spectrums. The tool is used here to aggregate these design elements within the established massing.



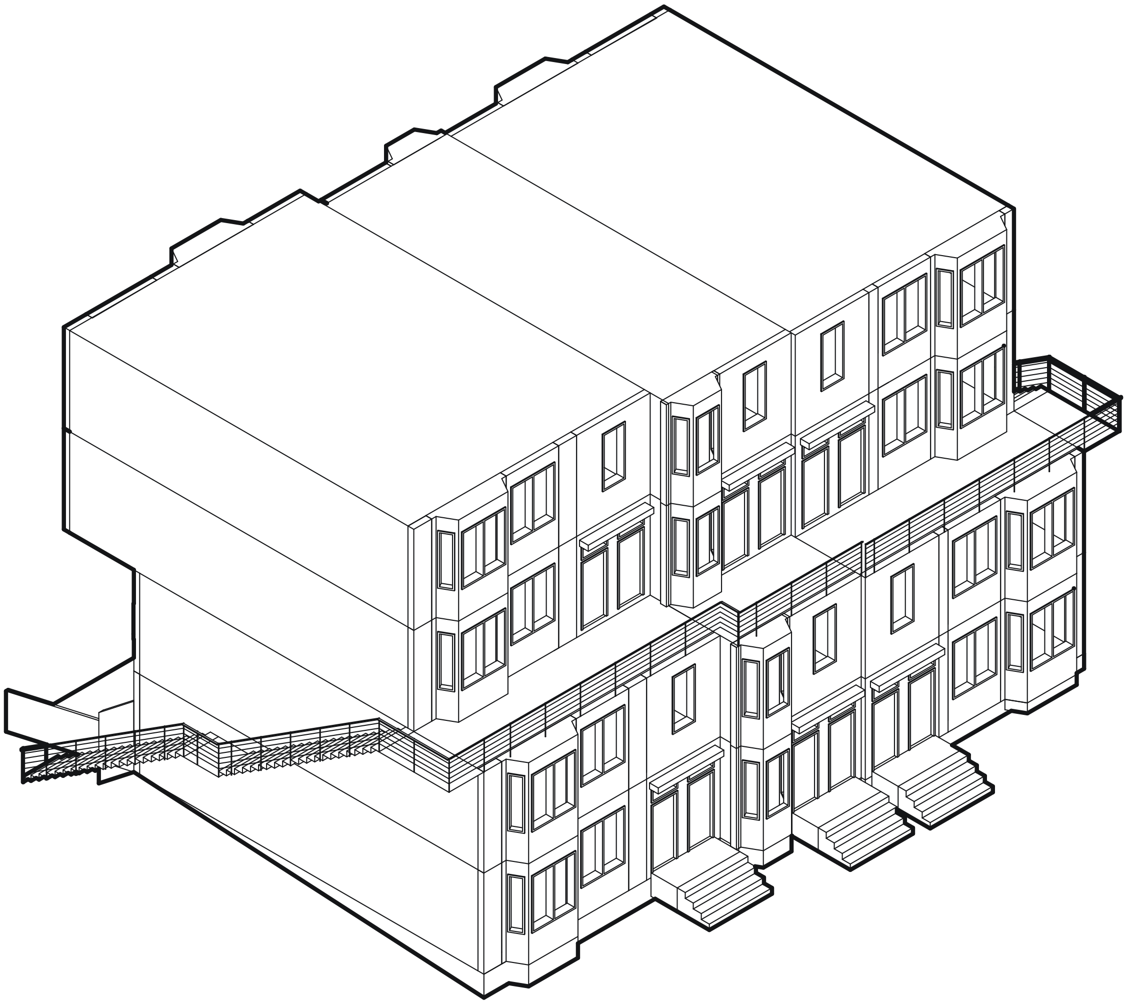
A portion of the established massing used to demonstrate the aggregation aspect of the tool. Continuity of vertical rhythms is maintained, as the unit width does not change vertically - if the ground floor unit is 19' wide, the fourth-floor unit will also be 19' wide.

To maintain neighbourhood identity, the architect uses forms found in the context of the study area. In this neighbourhood, the bay window and entry doors carry the unique identity and are used as building blocks. This aggregation is done using logic codified by the architect, placing facade elements and unit floor plans in response to adjacent units, placement in the massing, site conditions, and inhabitation. This aggregation of soft edges in the facade and related gradients in the unit floor plans results in meaningful variety. By using elements found in the context, the development also holds the neighbourhood identity.



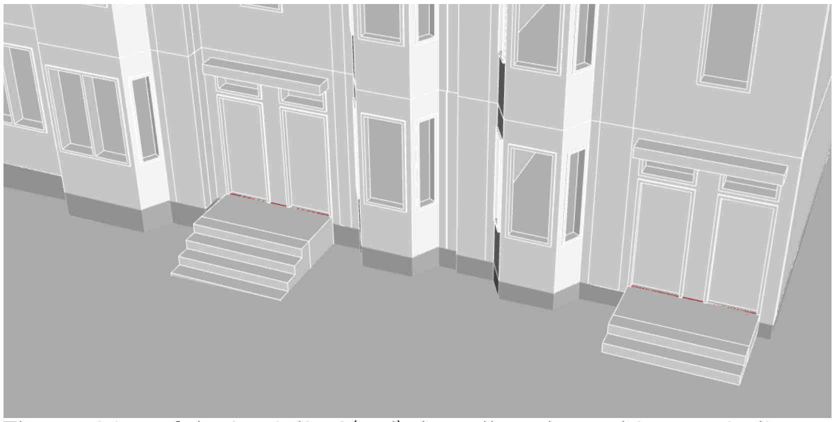
Basic elements from the context, used to carry the local identity. Deep, inset balconies have been added to provide a gradient from inside to outside, and provide each unit with private outdoor space.

Each of these forms have particular rules, created by the architect, dictating where they may be placed. In this massing, the entries may only be placed on the ground and third floors. Windows and balconies may only be placed on the second and fourth floors. Bay windows may be placed on any floor. Which of the elements is placed also depends on the width of the unit. The small bay window is placed only on units between 14’ and 18’ The double window is placed on units between 16’ and 26’. All units over 22’ are placed with both a window and a bay. Similar rules are applied to the balconies and entries. This allows the architect to design using rules, and the tool allows the architect to see the result of their decision propagated through the whole design.

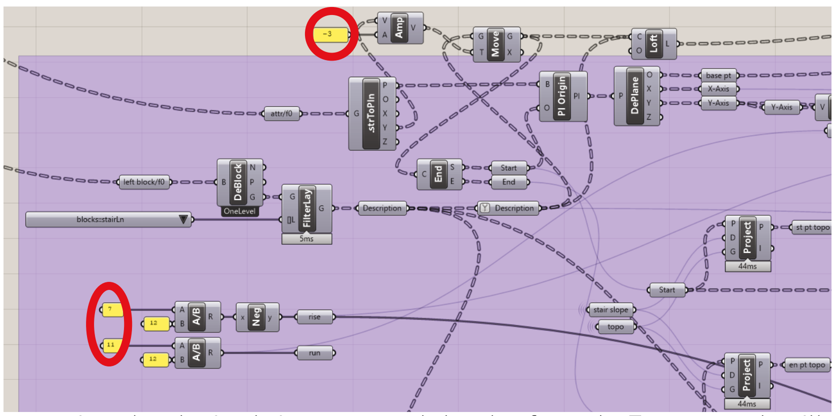


The tool aggregates the forms according to simple rules, responding to the massing to place appropriate elements, neighbours to ensure horizontal and vertical rhythms, and the site to create stairs.

As seen, stairs are also generated by the model to reach the ground. The entry stairs are generated in response to a ‘stair line’ in the entry block that indicates the width of the stairs needed, as well as the depth of a front porch and the desired rise and run. The stairs then automatically descend until they reach the grade.

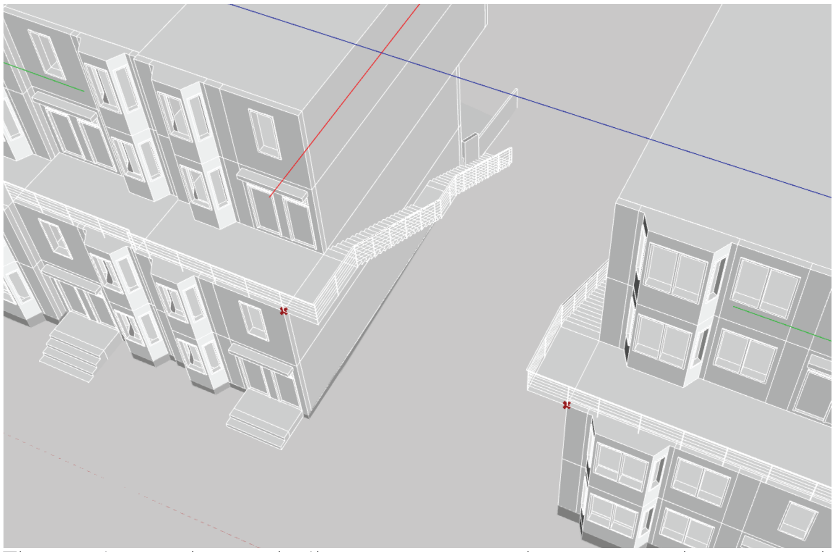


The position of the 'stair line' (red) that allow the architect to indicate where entry stairs are to be placed. The bays also are extended to grade by the tool.

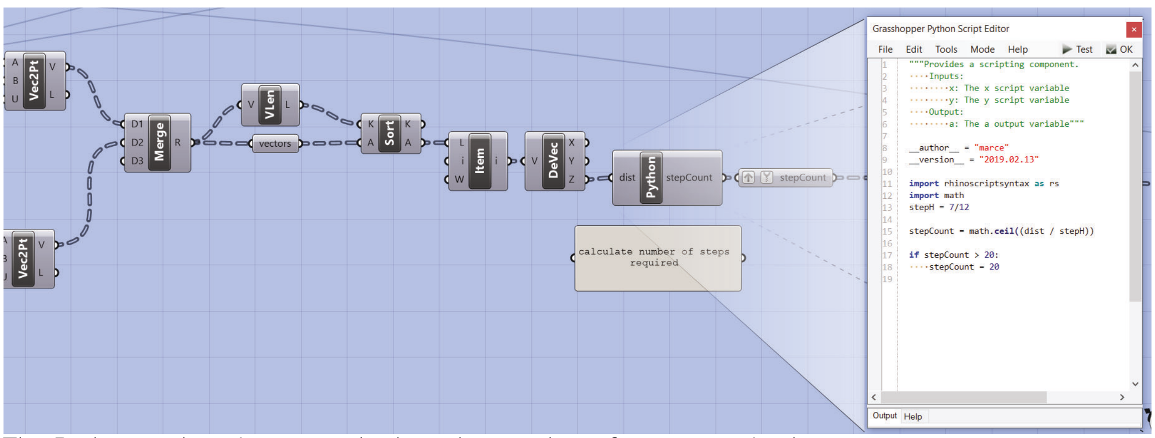


Inputting the desired rise, run, and depth of porch. Future work will add handrails above code-specified heights.

This allows the architect to evaluate the final form of the porch and entry stairs, without having to model them by hand every time. This approach is also taken with the stairs and hand rails of the exterior circulation, allowing the architect to adjust the massing in response to the space taken up by these stairways.

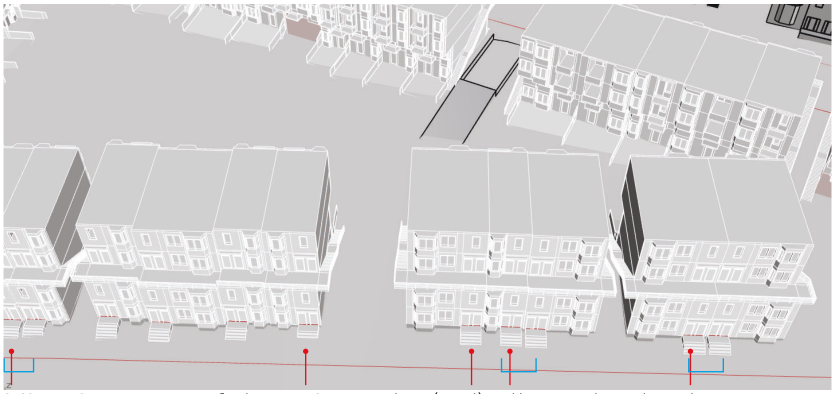


The stairs and guardrails are generated to serve the external circulation. The base point, shown in red, is automatically selected by the tool to be at the end of each block of units, reducing menial work.

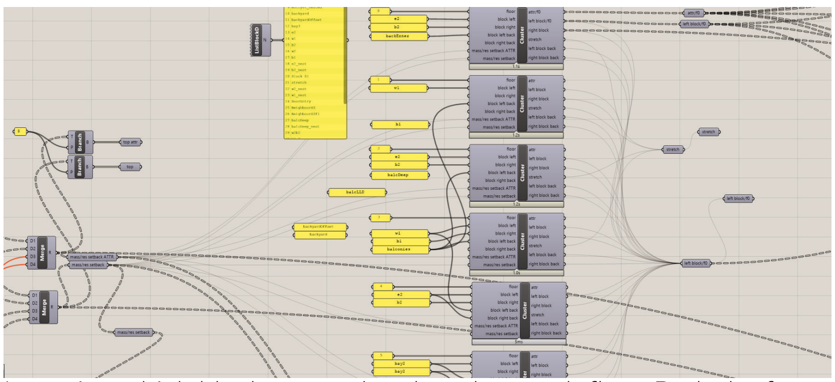


The Python code written to calculate the number of steps required to reach the ground. Also shown is the manual override that creates a landing, ensuring the stairs meet building code standards.

To further add to the structured variety, some of the unit stacks are mirrored, bringing some entries closer to each other. This breaks up the otherwise Soviet-apartment-block-like repetition.

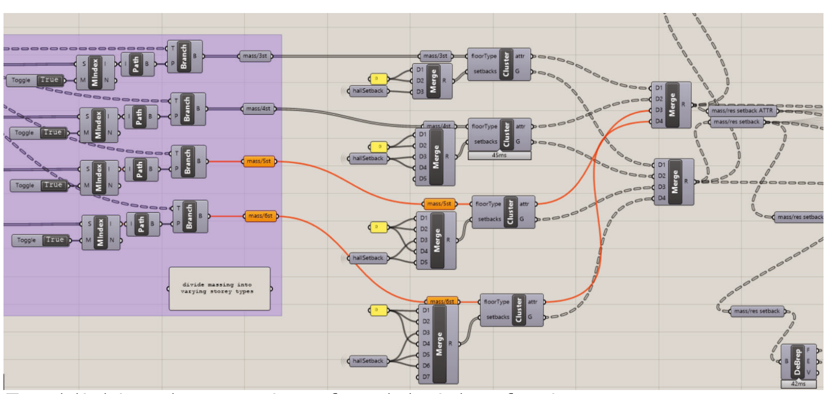


Mirroring some of the unit stacks (red) allows the development to avoid monotonous repetition. The selection is randomized, but it could be weighted to respond to certain conditions. Future work will align neighbouring porches, merging them into one (blue).



Inputting which blocks are to be placed on each floor. Both the front and back elements are defined in this section of the tool.

The tool is able to provide even more variety. It allows the units to be separated by storey count, and for each height to be massed in a unique way.



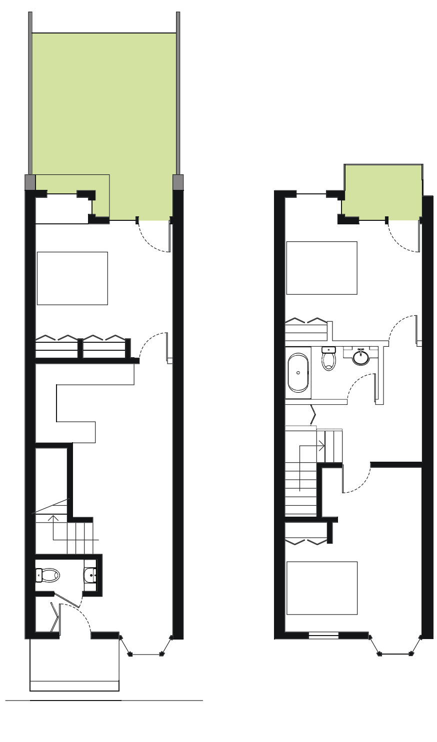
Establishing the massing of each height of unit.

In future work, the floor plans of the units may also be designed to respond directly to the facade elements placed. Currently, they statically incorporate the elements but do not dynamically respond. The largest and smallest units were established to prove the inhabitation of the unit sizes between 14’ and 26’. Every unit is dual aspect, increasing healthy access to natural ventilation and sunlight throughout the day. Each unit also has private outdoor space, with a gradient carefully designed to allow the resident to choose their preferred level of shelter. Finally, each unit has two soft edges. On the front, they interact with the public sidewalk or exterior circulation. On the back, they interact with the communal courtyard. It was important to think about how the development will change over time, so examples of aggregated units were designed, combining units either horizontally or vertically attached.

The largest unit in the design is 1060sqft. The bottom unit (left) provides 2 bedrooms, and the top unit (right) provides three bedrooms.

The smallest unit in the design is 560sqft. Both the bottom unit (left) and the top unit (right) provides one bedroom.

Potential centre-hall units created by merging two horizontal neighbours.



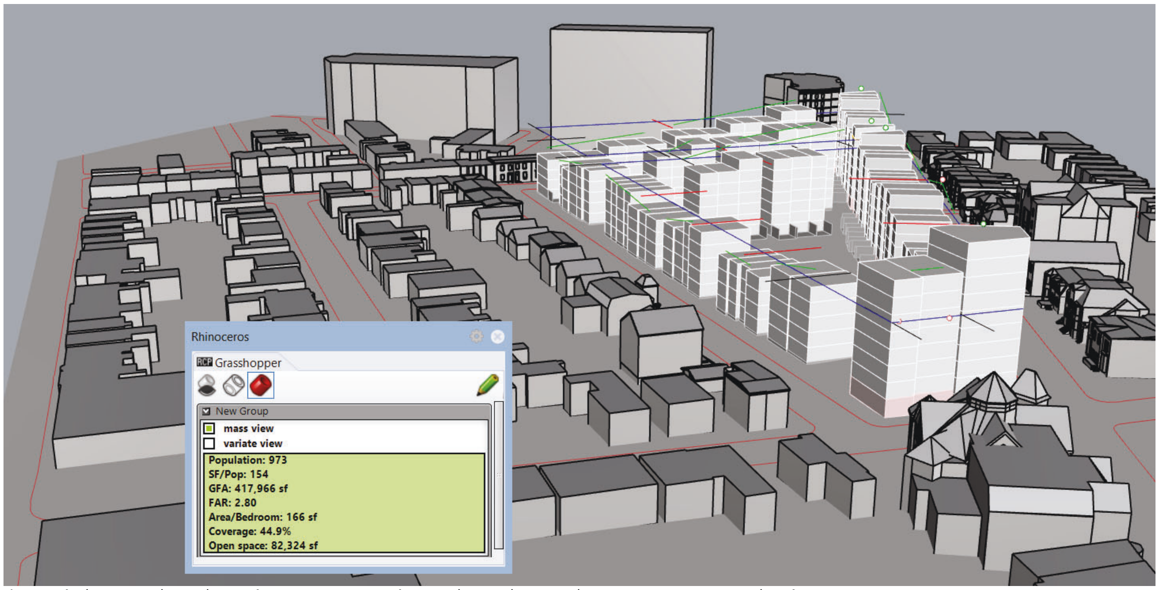
A potential three-bedroom, two storey units created by merging two vertical neighbours.

This proposal stacks the neighbourhood typology, creating external circulation on the third floor to provide a soft edge for those living higher off the ground. This soft edge is created with the custom tool by following a set of instructions in response to the width of massing, its location, and the site. This creates meaningful variety, between banal repetition and unstructured chaos.

In addition to every unit having a soft edge, they are all also dual aspect, allowing natural ventilation and access to sunlight throughout the day. Each unit also has private protected and exposed outdoor space, establishing a gradient for each person to find their comfortable inhabitation.

Final Design

After many iterations, this is the design that achieves a beneficial built form for each unit, as described above. If these conditions were loosened and a variety of settings were offered, the custom computational tool could quickly re-mass the development to increase population density without losing the design effort put into creating soft edges and structured variety. The strength of this tool is that this balance can easily be adjusted, while still providing a much more engaging human experience.

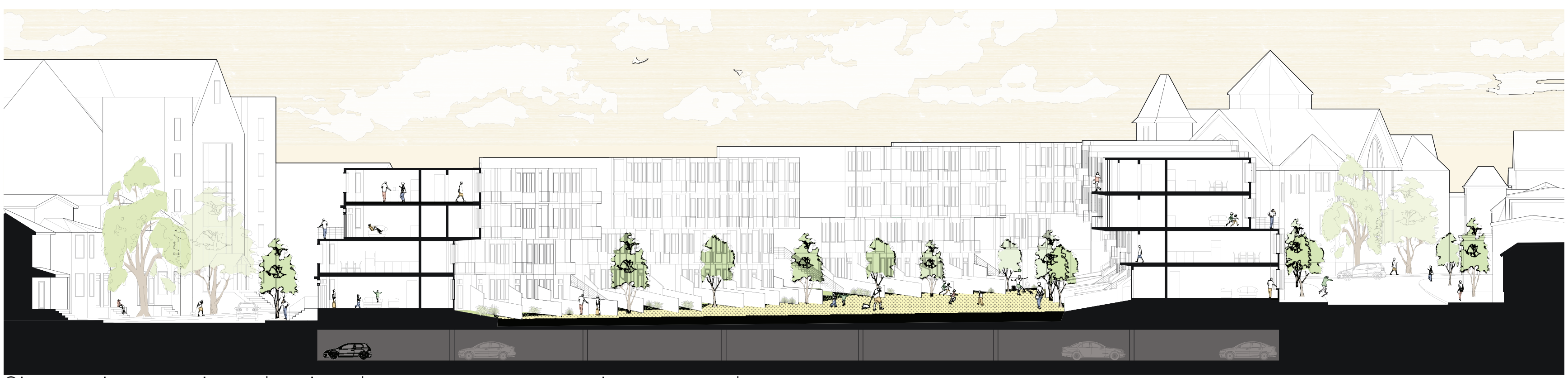


A quick study showing a massing that has the same population density as a high-rise typology.

This final design, where each unit is offered optimal conditions, offers 530 bedrooms in 305 units. Using a modest assumption that one in four units house a couple or use the living room as an additional bedroom, the site can house upward of 606 people. In terms of square feet of ground per person, this makes is four times as dense as its context, and two thirds as dense as the densest blocks in Halifax. The following pages present this final design proposal.

Site plan of the final design, showcasing the flexibility of the tool and the variety it can be used to create.

Site section detail, showing commercial pockets that emerged in response to the site shape.



Site section overview, showing the generous community courtyard and the variety in the facade.

Site section detail, showing soft edge on Robie Street.

Site section detail, showing soft edge to courtyard and backyards.

Site section detail, showing courtyard and facade.

Site section detail, showing soft edge on Davison Street.

Engaging public space that expresses local identity and provides framework for personal touch to be expressed.

Providing space for communal activities in the central courtyard.

External circulation on the third floor provides a soft edge for those living above the second floor.

Chapter 5: Conclusion

The home is the location that has the most impact on a person's life, and many established neighbourhoods nurture their inhabitants by engaging the human mind, encouraging interaction with their cultural, social and physical surroundings. Yet countless people live in residential developments that prioritize financial return and population density over the human experience, resulting in built form that instead fosters isolation and denies the continued emergence of local identity and community. The majority of contemporary developments are of this isolating typology, creating a major issue for the future livability of cities.

Part of the problem is that architects find themselves in a system that has commodified housing, allowing economic greed to be the driving force of many residential developments. The realistic truth is that if an architect wants to design the built form to positively impact people's lives, it must be done in an economically efficient manner: the design must not reduce the unit count of a project. If architects can design beneficial housing that meets this goal, all future housing developments could nurture residents in their private domain, as well as the pedestrians inhabiting the public space defined by the development.

The custom tool developed in this thesis hopes to legitimize the possibility of computation as a way to increase the quality of housing by taking a small step forward. Many architects create tools better incorporate more sophisticated ideas about environmental, sculptural, structural, and/or economic impacts. This tool is developed specifically with the human experience of the built environment as its driving force, in hopes of legitimizing this important goal. This tool establishes three strengths:

- The tool allows architects to aggregate patterns, both observed in the neighbourhood context and introduced with professional judgment, helping to create a design that interacts with its context, instead of imposing on it. This aggregation happens in real time in response to manipulation of graphic, metadata, and numeric inputs by the architect, establishing a feedback loop. The loop provides qualitative and quantitative feedback for the architect to evaluate, shaping the next design move investigated.

- The tool is a work in progress and is designed to be expanded, allowing it to respond to more factors as needed.

- The tool can be used on other sites to respond to those specific contexts. While designing on a site in a new country would likely require all new patterns to be observed and codified, designing within the same neighbourhood could allow many of the patterns to remain, but be aggregated differently in response to the particular site. This efficiency of design could allow architects to prevent the construction of more high-density isolating typologies, by instead designing high-density typologies that emerge from their neighbourhood context and allow local identity and community to continue emerging.

Appendices

Appendix A summarizes the research carried out by exploring the study area's context.

Appendix B summarizes the research carried out by exploring the statistics of the study area's context.

Appendix A: Imagine

This appendix summarizes my thoughts resulting from many walks through the historic neighbourhoods of Halifax, attempting to understand what an architect can learn from these beautiful, engaging streetscapes. This is the quality that the design work strives to achieve in this thesis.

Vignettes. Imagine a street. It's sunny, and as you enjoy your Sunday stroll you notice the light requesting your attention at various points. As the sunlight plays through the leaves onto a facade of painted wood shingles, the shadows tug between two windows. The windows are themselves full of ferns and foliage that delicately screen what lays inside. Did you notice a fireplace inside? There was definitely a copy of Silent Spring displayed in the upstairs window. Elsewhere, a screen breaks up both the direct sunlight and the form of somebody walking through the room inside. As you walk on, you consider how the light inside must be beautifully dappled by such a pretty screen! As you are enjoying this variation, a bright glint of light draws your attention. It's one of a dozen brilliant points of light being refracted from a prism in a yellow bay window. The bay projects within arms reach of your path, letting you appreciate the cross-stitched political slogans displayed in the windows before spotting the creator working at a brightly lit table on her next piece. You think about her point of view, before thinking about your thoughts over the past few minutes.

Dappled light tugging between two windows.

Empathy. Since you left your house, your thoughts have been mostly about the lives of the people who live on the street you are strolling down! This understanding of the inhabitants as distinct people through the vignettes they made is an engaging exercise in empathy.

Thinking about the values other people choose to express.

Mediation. These vignettes serve a purpose related to this self-expression: they are used by the inhabitants to mediate the relationship of their private domain with the common public realm. They create these vignettes by infilling the framework provided by the architecture. In other words, an architectural form like a bay window or entryway is a framework that is inhabited by its resident. This inhabitation allows the resident to express their humanity, while giving form to their desire to engage or disengage with the public realm. They control this by deciding how deeply the public realm is invited to visually penetrate into their private domain.

Thus, a private family moment is shielded while a book signals the values of a bedroom, somebody doing chores is seen vaguely, and an artist proudly displays herself as the source of her artwork. What a wild range of human experience held within a few paces!

Mediating the public realm and private domain; how open is it? What is displayed?

You are jarred from these thoughts when you cross Almon Street.

Where are we?

Anxiety. Gone is the variation of form and human expression, replaced by an ugly and empty forecourt for a new development, whose massing is veiled with an inert facade. Gone is the feeling of enclosure, of belonging in the street. It is replaced by the feeling of anxiety associated with being in the wrong place and hoping a car doesn't hit you. You are no longer in a place made for people, you are in an afterthought, in a space that cannot engage you.

Anxiety, alienation, disengagement, car-focused space.

Inhabitation. You quickly about-face and retreat back into the neighbourhood to continue your walk, your mind racing to figure out why the new development repulsed you. You are slowly soothed by the neighbourhood, and your thoughts start to coalesce. You notice that you are being soothed by observing the inhabitation around you. You hypothesize that a blank facade at eye level and monotonous facade above formed a veil that prevented the expression of people inhabiting the building.

Feeling safe again, at a human scale and complex.

Framework. Looking around the human-scaled neighbourhood, this suspicion is reinforced as you notice copious amounts of inhabitation. It dawns on you that this architecture allows its inhabitants to blur what is visually private and visually public, making this boundary sometimes cleanly defined and sometimes fuzzy. Again, the inhabitation is encouraged by an architecture that acts as a framework that allows residents to control their interaction with the public realm, instead of a finished box that offers no agency for self expression.

The bay window becomes the Haligonian analog to Elemental's half house. While the framework you observe here is not nearly as structured as Elemental's, nor does it need as much intervention by the resident, you are encouraged by this idea of providing an 'incomplete' design for the resident to finish to their desires. Per

Lawrence Halprin, imperfect design accepts change and is enhanced by it. You think that this variation provides a range of possible privacy levels, allowing residents to inhabit at their preferred level.

Providing a framework to be inhabited. Half House by Elemental.

Variation. However, you like the variation for another reason. It seems like it makes a more pleasing public realm, and gives you more things to notice. According to research popularized by Jan Gehl, the human brain needs 1000 stimulations an hour to keep it happy. This variation in the street wall alone would give more than that number of stimuli, not to mention the people going about their day, the gardens in bloom, the dogs barking in the backyard. You notice some designer's have tried to incorporate this variation, but the result seems more like parody than precedent.

Meaningful variety.

Parody. You notice some designers have tried to incorporate this variation, but the result seems more like parody than precedent. Maybe their design tools did not allow meaningful variation to be designed?

Replication, dressed with variety in colour.

Patterns. But, you notice that there are discernible patterns within the neighbourhood that describe the potential massings, interactions with the street, colour, entry ways, and so on that are combined to create a plethora of architecture. You realize these patterns were not designed, but emerged over the course of building and renovating the neighbourhood. You are convinced that within these patterns lie relationships that allow the streetscape to be beautiful and engaging. These patterns are human-scaled and of the city, because they were developed in a time before globalization created a style of towers on podiums that can now be found in any city around the world.

Patterns in the built form.

Urbanity. However, a simple copying of the patterns will not suffice. After all, these neighbourhoods were Halifax's original suburbs, and are not close to the density required for urban growth. These patterns must be altered to suit modern, urban needs. You start daydreaming about new design tools that wouldn't hamstring variety, but engage with these patterns to apply these local and human-centric elements to a typology dense enough to sustain urban growth.

Imagine that, a new development that stems from the elements that define engaging streets in its city and provides enough density to be a viable method for urban growth. Imagine...

Imagining human in habitation through a collage of engaging working-class homes in the UK.

Appendix B: Quantitative Data

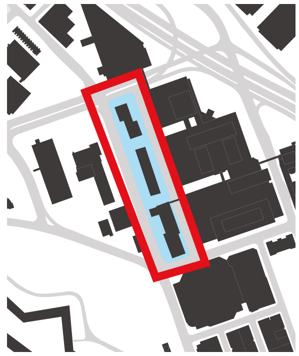
This appendix summarizes the qualitative data gathered about the context of the study area, as well as other typologies found within Halifax. Four typologies were studied; the high-rise tower, the sprawling modern suburb, the dense historical suburb, and the immediate context of the study area.

The first set of data focuses on the population density of these typologies, addressing the pressures of urban population growth and financialization of residential architecture - less units on a lot results in less profits. To prove the efficacity of the design proposal, it must come close to providing the same number of units. This is measured square feet of lot per person. The population of the study area, if the typology was applied, is calculated here, providing real world benchmarks for density.

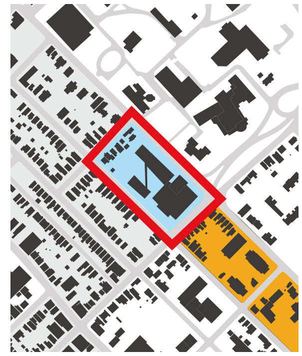
The second set of data ties in qualitative ideas about allowing residents to apply their personal touch. If a person has a private door, they are more likely to feel stewardship over the public realm and inhabit it. Where high-rise towers force 300 people through the front doors, the neighbourhood typology has less than 3 people per door. Another important measure is the distance between doors. The neighbourhood typology is close to the preferred 20’ rhythm for lively streets proposed by Gehl, while high-rises miss the mark at an average of 760 feet between entryways.

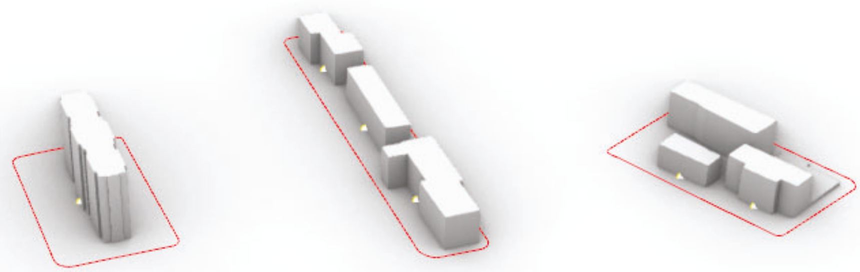
South Park

Cogswell



North





	South Park	Cogswell	North	*Average*	Study Area
sqft area	76,500	108,408	128,845		149,500
population	608	756	676		**972**
sqft ground per person	126	144	190	*153*	153
footprint coverage	30%	44%	47%	*40%*	
FAR	6	4.4	3.5	*4.5*	4.4
GFA per person	690	640	570	*633*	633
people per door	608	252	225	*362*	
door:building	1	1	1	*1*	
feet between doors	1169	662	456	*762*	

DENSEST BLOCKS/HIGH-RISE: under 200sqft ground per person

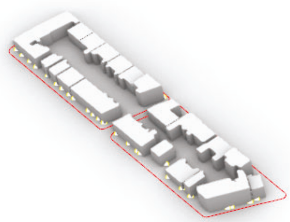
Stratford Central Acadia

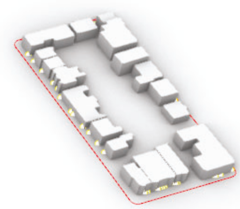
	Stratford	Central	Acadia	*Average*	Study Area
sqft area	197,400	187,100	713,700		149,500
population	130	60	204		**55**
sqft ground per person	1,518	3,118	3,499	*2,712*	2,712
footprint coverage	24%	19%	19%	*21%*	
FAR	0.7	0.4	0.6	*0.55*	0.53
GFA per person	1,090	1,210	1,980	*1,426*	1,426
people per door	3.1	2.1	3.3	*2.8*	
door:building	1.68	1.16	1	*1.28*	
feet between doors	47	73	100	*73*	

SUBURBS: over 2,000sqft ground per person

Bauer W & E

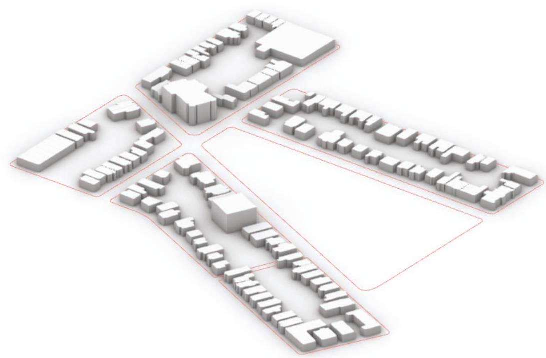
Queen





	Bauer W	Bauer E	Queen	*Average*	Study
sqft area	39,900	36,600	89,900		149,500
population	79	99	124		**280**
sqft ground per person	505	370	725	*533*	533
footprint coverage	56%	53%	44%	*51%*	
FAR	1.7	1.7	1.3	*1.56*	1.5
GFA per person	860	620	960	*813*	813
people per door	2.5	4	2.9	*3.1*	
door:building	2.8	2.5	2.4	*2.6*	
feet between doors	29	35	30	*31*	

DENSEST HISTORIC SUBURBS: about 500sqft ground per person



	Robie S	Robie	Robie N	Charles	Davison	*Average*	Study
sqft area	76,582	94,33	72,944	99,381	110,376		149,500
population	65	107	61	70	117		**138**
sqft ground per person	1,178	882	1,195	1,419	943	*1,080*	1,080

STUDY AREA CONTEXT: about 1,000sqft ground per person

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