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Thickening of the city : a city is a living organism with a complex tissue of events

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THICKENING OF THE CITY: A CITY IS A LIVING ORGANISM WITH A COMPLEX TISSUE OF EVENTS

by

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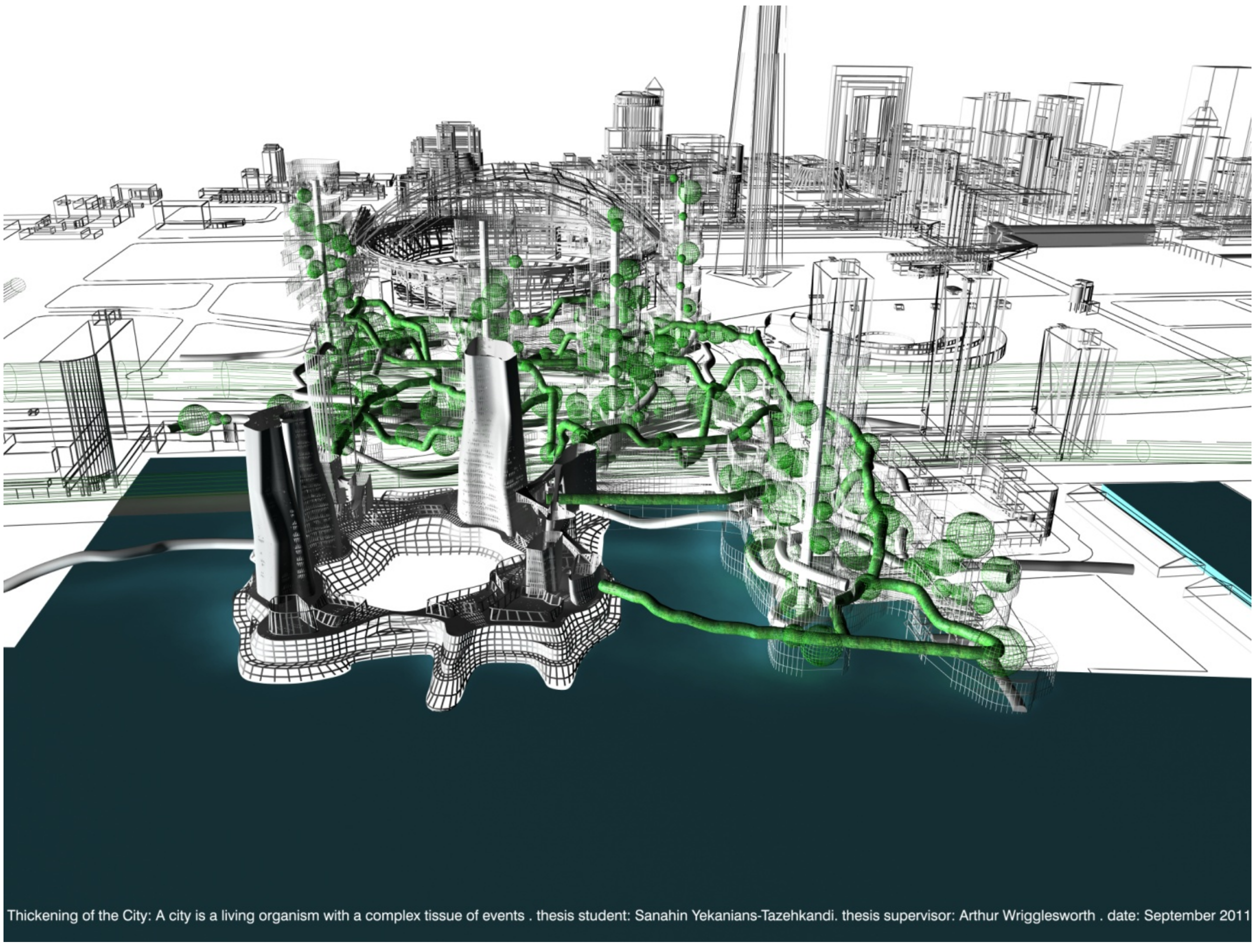

Thickening of the City: A city is a living organism with a complex tissue of events . thesis student: Sanahin Yekanians-Tazehkandi. thesis supervisor: Arthur Wrigglesworth . date: September 2011

"May God us keep
from single vision and Newton's sleep."
William Blake

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Sanahin Yekanians-Tazehkandi

Abstract

Thickening of the city: A city is a living organism with a complex tissue of events

M.Arch. 2011 I Sanahin Yekanians-Tazehkandi I Master of Architecture I Ryerson University

The industrial revolution and *Modernism* brought dramatic changes to our cities and had a negative effect on people's social lives. This thesis considers cities as living organisms and develops systems thinking in city design with the aim of providing a vision that includes a healthier social life. The purpose of this thesis is to investigate how an architecture that views cities as social and natural systems can mitigate the negative effects of the industrialized era on our cities and bring social life into our neighbourhoods.

Since the primary emphasis of this thesis is on the design process and the logic behind the application of some new scientific fields, an abstract architectural formal language is employed to illustrate the design development. The result is an iterative design process that has been repeated in a variety of mediums. The process uses *Five Topics* from different disciplines. At each stage of the research, some of the data collected supports a distinct approach to design intervention. However, in order for the *Five Topics* to work at the same time, the design intervention proposes a three dimensional solution for the city instead of a two dimensional traditional plan. Consequently, the thesis design provides an abstract model for the thickening of the city. This model applies some well-studied social principles to the existing pattern of the city.

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Executive Summary

"May God us keep

From single vision and Newton's sleep"

(William Blake, as cited in Capra, 1997, p.21)

The character of a neighbourhood and its residents' social life have gained attention in architectural discourse after *Modernism* transformed architecture. The *Modernist* revolution in architecture produced designs that had many negative effects on people's social lives in their cities, communities, and neighbourhoods and resulted in many thinkers and writers proposing principles in urban design to mitigate those negative effects. Although society has made efforts to apply those principles in neighbourhood design, none of those principles seem to be strong enough to change the direction in which our cities are currently evolving (Arida, 2002).

This thesis identifies scientific discoveries and the industrial revolution as the main cause of the *Modernist* approach to city design with its consequent negative social effects. Accordingly, it contrasts the *Modernist* approach with a holistic one and suggests that systems thinking is the best way to engage with urban design. This new approach considers three parts of a system (elements, interconnections and purpose) and applies it in the design process. The design process is privileged instead of the final image of design in this approach. All parts of the city are interconnected based on some regulatory process that manifests itself physically or non-physically in the final design. As a system can have more than one function, this thesis introduces healthy neighbourhood social life as another function to the existing system of the city and seeks design innovation to mitigate the negative consequences of *Modernism* in architecture.

To reach this goal, this thesis looks at city design from different view-points, just as one would in nature. Nature and life have been viewed from different view-points and different sciences throughout history. Each field has its own perception of life and defines it in a specific language. The point is not about one science being right or wrong, it is about different perceptions of oneness, a universal system that is called life (Capra, 1997).

Thus, this thesis has selected five ways of analysing the city. The *Five Topics*, selected arbitrarily based on personal interest, are mathematics, sociology, history, biomimicry and computation. The city must respond to all fields simultaneously and in all scales.

Although there have been some suggestions for tomorrow's city patterns previously, studying physical natural laws reveals that applying those suggested principles will conflict with the opportunity to imagine the city (socially and physically) as a natural organism.

In other words, a non-resistive pattern suggested by constructal theory in physical laws of nature provides an easier flow to different parts of the system, increasing the speed of the particles that move in the system (Bejan, 2007). This fast flow system (for the vital purpose of the city) conflicts with the resistive pattern of the city (that is also a desired characteristic of the city to increase the social vibrancy of a neighbourhood).

To enable both functions to work as parts of a coherent city system, these two functions must get nested and operate at all scales of the design project. Therefore, the design intervention superimposed a resistive pattern over the fast flow system of the city as these two characteristics could not exist at one surface simultaneously. This results in a *Thickening* of the city.

The fractal concept was considered the backbone of the design process to ensure the creation of a living organism in which all characteristics co-exist in different scales of the design project. Fractals are observed everywhere in nature and benefit this design project in two distinct ways. First, since the fractal concept increases interactions and promotes the maximum surface within a limited volume, applying the concept in the design project increases people's social interaction with the built environment by reducing the urban scale to match the needs of the human scale. Secondly, a fractal system is self-similar: i.e., a desired characteristic that exists in the whole system also exists on a smaller scale in other subsystems of the design. Therefore, the *Five Characteristics* that exist in the large scale must also manifest in every neighbourhood of the city.

The design project started from a conceptual design for the entire site, then it looked more closely at one portion of that site and eventually picked just one corner of that particular site to develop further. The main consideration in the design project was the application of research principles to an iterative process that was applied repeatedly in a variety of mediums. For this purpose, an abstract architectural formal language was used to advance the development of the thesis.

The results and experiences gained through this thesis show that considering the city as a living organism requires systems thinking in developing principles for tomorrow's cities. Nature is a process rather than accumulation of elements. A design project can therefore benefit more by learning lessons from nature from a dynamic developmental point of view than by applying a formal and one-to-one application of a static image from nature.

Chapter 1 - Introduction

1.1. Introduction

Among the many forces that have influenced and reshaped the built world over centuries, architecture has continuously evolved alongside scientific and technological advances. The profession has presented new theories in response to changing views within the broader society. One of the most significant examples of this interaction is the effect of Newtonian physics and its perspective on the world as a machine that helped frame the cultural and economic transformation, which marked the industrial revolution (Arida, 2002).

Florida (2010) declares that during the latter half of the 18th century, key industries including railroads and steel were consolidated. New systems, industries, and technological advances took shape, paving the way for a period of significant industrial growth. According to Fontenot (2006), the very end of the 19th century came to represent progress and the development of the city with high rise buildings and massive urban territories that had been reconfigured by modern planning.

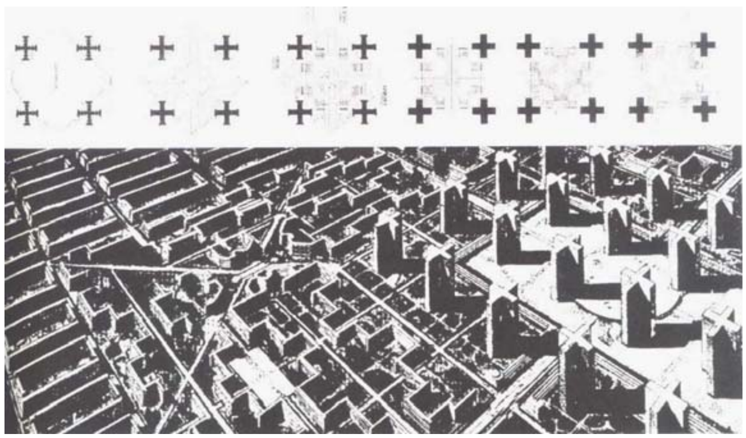
The city form continued to change significantly over the course of the 20th century. One of the most influential planners of the time, and leader in the “Modern Movement” (Johnson & Hitchcock, 1932), was a Swiss architect named Le Corbusier.

In the 1920’s, Le Corbusier developed a theoretical urban design proposal that he named the Radiant City. It consisted of skyscrapers situated within a park, and it had an incredible population density of 1,200 inhabitants per acre. The skyscrapers occupied 5 per cent of the ground, low-rise, luxury housing around courts took another 10 per cent of the acre, leaving 85 per cent of the ground for the parks. Theaters and restaurants were dispersed over different parts of the city (Jacobs, 1969).

This city was created to deal with the population growth of the cities, provide housing units for a large number of people, and raise their quality of life. The previous urban form was not able to meet these needs of residents after the population started to grow rapidly.

The idea of the *Modernist* city was appealing to planners, designers, developers, lenders, and mayors. It prompted progressive municipal authorities to write laws encouraging builders to make Le Corbusier's vision a reality. As a result, cities became segregated. Vague open spaces and unfriendly, rigid, overly rational housing projects that were intended to bring order to the lives of the masses generally failed to touch their spirits. The change dramatically affected people's social lives (Jacobs, 1969; Arida, 2002).

The effects of the *Modern Movement* in architecture gave way to a crisis that provoked thinkers, writers and architects - like Jane Jacobs, Charles Jencks and Christopher Alexander - to respond to the hazardous social influence of modern, soulless cities.



(Source: Arida, 2002, p.89)

Figure 1.00 Le Corbusier's 1925 Vision Plan for Paris

In her writing, Jacobs (1969) described the living city and put forward valuable principles in city design. According to her, Le Corbusier's intention was to keep pedestrians off the streets and in the parks. He reduced the number of streets because "cross roads are an enemy to traffic" (Jacobs, p. 23). Instead, Le Corbusier proposed large roads for express one-way traffic. He also included underground streets for deliveries and heavy vehicles. Jacobs believes his conceptualization of the city had impressive clarity, simplicity, and harmony. The design seemed like an advertisement and it was very easy to understand. Nevertheless, Jacobs believed that the Radiant City had a vulgar and clumsy design, with dreary and useless open spaces and a dull close-up view. Charles Jencks (1995) provides the following explanation:

> Le Corbusier demanded that buildings should look as "neat, clean, and healthy" as ships; they should work like airplanes and resemble cars. "A house is a machine for living in" he prophesied, and soon mass-housing looked like factories. (p. 13)

Christopher Alexander (1966) also criticized *Modernist* city structures and proposed new ideas to increase social interaction in urban areas. There have been many such critiques over the years but none of them seemed to be able to change the clear direction in which the city was evolving.

However, the criticisms did seem to have an effect upon the 21st century, which saw the demolition of many monuments of *Modernism*. According to Fontenot (2006), one of the examples of the fall of *Modernism* and public housing was the 1972 demolition of the Pruitt-Igoe development. He believed that urban restructuring in the 21st century offered new opportunities to redefine the inner city. However, it also presents problems for low-income families that have lived in public housing for generations. Dilemmas caused by the demolition of "urban mistakes" (Fontenot, p. 58) pose new challenges with urban reformation in America, France, Germany, Netherlands, and the United Kingdom.

(Source: Newman, 1972, p. 12)
Figure 1.01 Pruitt Igoe in the process of being torn down

This thesis identifies scientific revelation as the main cause of the *Modern Movement* and its consequent negative social effects. Then it studies the most recent scientific concepts to mitigate the negative effects of *Modernism*. The idea is that a science that defines life must have the ability to create life if used in design process. To reach this goal, this thesis looks at city design from different points of view, just as one would in nature. Nature and life have been viewed from different points of view and different scientific fields throughout history. For instance, chemistry, physics and biology (to name a few) have always advanced competing views that define life and the system of the world, from the view-point of their discipline. The point is that each field has its own perception of life and defines it in a specific language. In each historical era, one science has dominated the others by having new discoveries in the field. The point is not about one science being right or wrong, it is about different perceptions of oneness, a universal system that is called life (Capra, 1997).

Accordingly, this thesis has selected five ways of analysing the city. The *Five Topics*, selected arbitrarily based on personal interest, are mathematics, sociology, history, biomimicry and computation. These *Five Topics* are explained in Chapter 2. The important point is that the city must respond to all fields simultaneously and in all scales. For instance, a desired characteristic of a city from one *Topic* must not conflict with a desired characteristic from another *Topic*.

This contrasts with the Newtonian linear mechanical view that resulted in motorized and rigid urban non-places. Essentially, the goal of this thesis is to develop methodologies that can be used to create built forms in the urban context that will improve the social vibrancy of neighbourhoods. This change will enhance the relationship people have with their environment, and it will provide a design solution that is society-oriented.

To increase social interaction, this thesis makes use of the holism principle of modern physics that views everything from a variety of perspectives. Thus, if a city is seen from different view-points, the design outcome will be able to consider a variety of aspects that a healthy city needs. One of these aspects that seems to be neglected by *Modernist* design is the social life of residents. However, adopting a holistic approach ensures that increasing the quality of people's social life will not conflict with other aspects of the cities' function. Each *Topic* suggests a unique resolution that represents a linear approach to a problem. However, it is the union of these ideas that shapes the main argument of this thesis.

1.2. Problem Statement

Following industrialization, shifts in city design presented challenges for modern society. Problems such as limited social interaction within the site, exposure to crime and drug use particularly within public housing, lack of ownership and care of green spaces are among the major issues affecting *Modernized* cities (Newman, 1972).

Because of the theories presented by Le Corbusier and the *Modern Movement*, cities have become segregated. City plans show restricted use within each part of the city, zoning is clearly separated, and there is little to no overlap among different activities. As a result of Modernist planning, vague open spaces as well as unfriendly, rigid and overly rational housing projects intended to bring order to the lives of the masses do not account for the interpersonal nature of social exchanges. This approach demonstrates a failure to address people's social lives within modern cities (Alexander, 1966; Arida, 2002).

Jacobs (1969) exposes the negative effects of this type of planning on people's social activities. She criticizes *Modern*, orthodox cities and describes a living city. She provides suggestions and principles in urban planning such as small blocks, neighbourhood parks, and mixed-use developments that contribute to the social vibrancy of a neighbourhood.

1.3. Research Question

If scientific revelation was the main cause of the *Modern Movement* in architecture and its consequent negative social effects, what are the most recent scientific concepts to mitigate the negative effects of *Modernism*?

1.4. Research Methodology

The first chapter of this thesis identifies the city as a natural organism. Then it shows that a natural organism is a system. Identifying some of the characteristics of a system, it introduces systems thinking that is one of the recent theories in scientific fields. In systems thinking, everything is viewed in relation with other things. A system is viewed as more than the sum of its parts. Accordingly, the research methodology follows the principles of a system. In other words, the design outcome is more than the sum of the data that are collected in the research process.

To mitigate the negative effects of Modernism in architecture on neighbourhood character, the city is studied and analysed from different fields of reference (in this thesis, *Five Topics* have been chosen (see Section 2.2)) and points of view. These areas include mathematics (graph theories), sociology (attractions in urban public spaces), history (Iranian Bazaar as linear social space), biomimicry (physical laws of nature/ constructal theory of social dynamics) and computation (producing algorithms for tomorrow's cities). These *Five Topics* are selected arbitrarily and are, to an extent, based on personal interest. The idea is to show how linear thinking principles for cities do not work when applied to design. Applying these *Five Topics* to design illustrates the practicality of looking at the city as a system. If, for instance, 50 areas were chosen instead of five, another design would result which is definitely more mature than the one based on only five fields because more principles will be applied to the design and they have to work simultaneously. The higher the number of these principles, the more challenging it will be to realize a design

In addition, some observations from nature are analysed in the biomimicry section (e.g., analysing the movements of social wasps inside their nests) as are fractal systems in natural patterns. These areas bring interesting views in relation to human settlement patterns and their social lives.

At each stage of the research, some collection of data suggests a linear approach to design intervention. However, in order for all these principles to work at the same time, the design intervention proposes a three-dimensional solution for the city (based on data analysis) instead of a two-dimensional traditional plan. As a final point, if these five aspects are extended to five billion an ideal model for tomorrow's cities could be produced.

1.5. Literature Review

Many writers and thinkers have criticized *Modernism* in architecture and its negative effects on people's social lives. This literature review will examine those criticisms using work from Arida (2002), Fontenot (2006), Jacobs (1969) and Berman (1983). The review will then describe the effects of new scientific fields on architecture by studying work from Jencks (1995), Salingaros (2007) and Kohr (2007).

Considering the fact that the mechanical approach to design of *Modernism* resulted in negative effects on people's social lives, this thesis looks at the recent scientific fields that define nature and life and seeks ways to apply their methodologies into design. The question is which laws define nature and life and can overcome the limitations of the *Modernist* approach. To answer this question the review examines work from Wheatley (2006), Mittelstaedt (2005), Capra (1997) and Meadows (2009). Ultimately, this thesis makes use of the holism principle of modern physics that views everything from a variety of perspectives.

This thesis looks at the cities as systems. It selects *Five Topics* to analyse cities and proposes creative design solutions that would enable cities to maintain vital and social aspects of people's lives. The balance of this literature review examines the writings that support the approach taken in this thesis. These writings include work from Gleick (1987), Alexander (1966), Hillier and Hanson (1988), Bejan (2007), Whyte (2001) and Von Werz (2007). Subsequent chapters will assess whether all of these views can work simultaneously on a city or not.

Arida (2002) discusses the effects of *Modern Movement* on city planning. According to him, as a result of *Modernist* planning, vague open spaces as well as unfriendly, rigid and overly rational housing projects intended to bring order to the lives of the masses do not account for the interpersonal nature of social exchanges. This approach demonstrates a failure to address people's social lives within modern cities

The negative consequences of *Modernist* city planning are also mentioned by Fontenot (2006). Buildings and spaces that were regarded as exemplifying progress and development in the 19th century became viewed as errors in the 21st century. However, when these "urban mistakes" (Fontenot, p.58) were demolished, new challenges were created for cities in America, France, Germany, Netherlands, and the United Kingdom.

Another critic of *Modern* cities and their social influences is Jacobs (1969). She analyses cities based on social activities that bring vibrancy to neighbourhoods and she strongly criticizes *Modern* cities in this respect. She attacks the goals and principles that form *Modern*, orthodox city planning and re-establishment then goes on to write about how cities function in real life and what principles and practices stand in the way. Jacobs pays a lot of attention to the pedestrian street sidewalks in her critiques of *Modernism*. She believes that city sidewalks bring people together. The existence of stores and industries along pedestrian pathways also plays a major role in making the area socially vibrant.

Berman (1983) illustrates the *Modernist* image of ruin and demolition by describing the construction of the cross-Bronx expressway through the neighbourhood in which he grew up. He explains how a neighbourhood that was alive and thriving rapidly turned into a place to leave since the construction of the expressway started.

Jencks (1995) examines ecological stress, urban alienation and spiritual confusion. One of his major themes is the new post-Christian science of complexity, compared to the old "Christian" science of simplicity. This theme concerns the first post-Christian creation of a new revelation. This new revelation is illuminated by the new sciences of complexity, which include complexity theory, chaos theory, self-organizing systems, and nonlinear dynamics. The reason behind dependence on these concepts is their progress "towards a more creative world view" (Jencks, p. 9), when compared to *Modernism*.

Salingaros (2007) believes that there is a distinct difference between the process and the final appearance in an architectural design. Although complex forms arise from fractal growth, as well as emergence and adaptation in nature, application of these images onto the final image of a design is frivolous and unjustifiable in his opinion. For instance, he criticizes Jencks' claim for being founded on elementary misunderstandings. According to Salingaros, "There is a new paradigm in architecture and it is indeed based on the New Sciences, but it does not include deconstructivist buildings" (p. 129). As an example of a "mere visual and a functional appreciation of fractals" (Salingaros, p. 131) he points to the Guggenheim Museum at Bilbao, saying it is "disjoint[ed] and metallic and as far removed from any flower that he can imagine" (Salingaros,p. 131).

One of the architects who was inspired by nature and cell growth was Leopold Kohr (2007). He promoted local communities by observing the way a cell divides into two parts after reaching a certain point. One of the benefits of creating local communities is the promotion of regional self-sufficiency and *polycentral regeneration*. He applies this phrase instead of decentralization. In other words, Kohr believes that instead of dispersing the central offices of a city over its diverse areas, we can turn the regions into self-sufficient communities, where every citizen finds all their daily needs in places that are central, but small and nearby.

Wheatley (2006) focuses on living systems and new theories emerging from biology and chemistry. She identifies information as the main resource for generating forms in our self-organized universe. In her view, to create new forms of life there must be new interpretations. Wheatley contrasts Newtonianism with holism and systems thinking.

Mittelstaedt and Weingartner (2005) answer the question of whether the laws of quantum logic are laws of nature. They believe that the laws of quantum logic are not genuine laws of nature. The complexity and uncertainty that exists in quantum logic is partly why this thesis looks at cities as systems and applies systems thinking to research and design development.

Capra (1997) believes that we cannot define the world as an object filled with other objects, which is how classical physics was trying to define the world. Instead we are part of an interconnected and self organized pattern that he calls the web of life. In this view, the universe is looked at as a system.

Meadows (2009) views cities, individuals, companies and economies as systems. She defines a system as "A set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviours, often classified as its function or purpose" (p. 11). According to this definition, a system consists of elements, interconnections and function or purpose. Meadows gives an example of a football team as a system. The elements of that system are players, coach, field and ball. The rules of the game and players' communication are interconnections. Having exercise or winning the game can be the purpose of that team.

Gleick (1987) illustrates natural geometric concepts such as fractals and self-similarity. He suggests that the human mind cannot fully envision the never-ending, self-embedding complexity of nature. But the study of structures on smaller and smaller scales can make a significant difference to someone thinking from a geometric perspective. According to Gleick, Benoit Mandelbrot explored fractal shapes and their possibilities, uncovering deviations that were previously unrealized. As a result, fractional dimensions have been a significant point of reference for architects since Mandelbrot's time.

Alexander (1966) claims that cities designed by the human mind cannot provide for overlapping activities in urban spaces and will have the effect of reducing social interaction. Alexander claims that growth over time causes different city activities to develop within a certain area and overlap, which increases the vibrancy of the social life in that area. He contrasts natural cities with artificial ones. Alexander defines cities that are designed by humans as "artificial cities" (p.2). He believes that these cities are all organized in a tree shaped graph with no overlapping urban activities, a feature typical, he believes, of cities that are designed by human minds. These artificial cities are seen by Alexander as lacking a vibrant social life.

The idea of criticizing modern cities based on analysing the interrelation of components has also inspired architects like Hillier and Hanson (1988). They analyse the social consequences of city design using graphs and diagrams. They establish a descriptive theory of how spatial patterns can carry social information and content. Although they analyse the cities based on graphs, their approach is entirely different from Alexander's. They introduce the concept of distributed systems by analyzing city patterns like French hamlets, contrasting these systems with non-distributed ones, and conclude that Modern cities fit in the latter category. Whereas the former pattern possesses characteristics that provide a vibrant social life for people, the latter lacks those properties.

Bejan (2007) summarized a theory that studies flow systems in nature. Social dynamics refer to veins, lungs, trees, river basins, cities and billions of similar examples in nature. This theory explains that design in nature – including shape, structure, configuration, pattern, rhythm and similarity - follows a physical principle that unites all flow systems. This phenomenon is summarized in the Constructal law of the generation of organization, which states "For a finite size flow system to persist in time (to survive) its configuration must evolve in such a way that it provides easier and easier access to the currents that flow through it" (p.2).

This thesis uses constructal theory to maintain the fast flow system of the cities despite all the critics against Modernism in architecture that encourage a resistive pattern for the city to improve social interactions.

Whyte (2001) discusses the social life in small urban places. He explains his observation and research of the social life in urban public places and mentions that people are attracted to each other in urban places. For instance, people prefer to sit in urban public areas and they enjoy being among other citizens.

Von Werz's (2007) description of Zaha Hadid's computational model was reviewed. The project helped this thesis to identify a design that does not follow the constructal law in nature. Linear thinking in areas of computation cannot provide an ideal model for tomorrow's cities.

Chapter 2 – Research

Overview

This chapter begins by introducing the effects of science on architecture. It then identifies the Newtonian view as the main reason behind *Modernism* in architecture and its subsequent negative social effects. It identifies cities as natural organisms and systems. Then it introduces holism as the recent philosophy in defining life and makes use of that concept to examine cities. Finally, the chapter selects *Five Topics* (see Section 2.2, Table 2.00) to examine the city and lays the ground work for the argument put forward in the next chapter.

2.1. Effects of Science on Design

What is the reason behind a decreasing social life of neighbourhoods as city design evolves? What influences the direction in which design evolves?

Among many forces that have influenced and reshaped the built world over centuries, architecture has continuously evolved alongside scientific and technological advances. The profession has presented new theories in response to changing views within society. One of the most significant examples of this relationship is the effect of 17th century Newtonian physics and its perspective on 'the world as a machine' that helped frame the cultural and economic transformation, which marked the industrial revolution. This scientific theory paved the way for the *Modern Movement* in architecture and Le Corbusier's "building as a machine" (Arida, p.89) vision, which resulted in the creation of vague and open urban spaces that failed to meet social needs or to touch the soul (see Section 2.3.2). Family-oriented communities were replaced by individual-centered non-places. Skyscrapers were built in cities designed for speed, leading to reduced opportunities for social interactions. The crime and violence in soulless neighbourhoods increased (Berman, 1983; Arida, 2002).

Looking more closely at the *Modern Movement* in architecture, as well as social and political movements of the past century and their effect upon our current cities, it becomes evident that a primary reason behind these trends is the scientific progress that occurred in the 18th and 19th centuries. Given that architecture is closely tied to the sciences, the effect of developments in science on architectural thought during the 19th and 20th centuries is not surprising. Nevertheless, if scientific revolutions have such a powerful influence on the city structure, how can recent advances in physics, chemistry and biology affect city design? Furthermore, which one can mitigate the negative effects of *Modernized* cities on society?

2.1.1. Looking for the Proper Science to Shape the City Design

If Newtonian theory and industrialization – beside social and cultural factors – account for the social problems of the city, is there any evolution in science that contrasts with that mechanical view and can potentially mitigate the negative effects of *Modernism* in architecture? Computational techniques, fractal theory, complexity theory, chaos theory, self-organizing systems and nonlinear dynamics are all scientific concepts that have inspired new architectural approaches. The persistent challenge is in determining appropriate sciences to apply in the design process.

Over time, Newtonian theory has been transformed by new fields in science - such as complexity, fractal systems and chaos theory - that aim to explain natural systems in the world. These scientific investigations have introduced new concepts to architects. Accordingly, architects have changed their approaches to the design of built forms. The incorporation of computational techniques to manifest natural complex shapes and patterns in architectural world has resulted in numerous building designs that could not exist without these applications (Salingaros, 2005).

Jencks (1995) examines ecological stress, urban alienation and spiritual confusion. One of his major themes concerns the first post-Christian creation of a new revelation. He suggests that the new revelation is uniting scientists, theologians, architects, artists, and to a large extent the general public.

This new worldview is illuminated by the new sciences of complexity, which include complexity theory, chaos theory, self-organizing systems, and nonlinear dynamics. The reason behind dependence on the new sciences is their progress towards an improved worldview, when compared to Modernism. Additionally the new sciences are grounded in facts and evidence (Jencks, 1995). He identifies 1995 as the highest point of the biomorphic tradition in the 20th century:

> Biology, nature, the organic tradition have always been inspirations for architecture, but they are particularly relevant today because we have a different view of nature and our place in it (Jencks, 1995, p. 10).

Arida (2002), author of *Quantum city*, believes the paradigm presented in *Architecture of the Jumping Universe* (Jencks, 1995) could not but affect our philosophies and attitudes. He believes the book is a powerful explanation of how architecture resonates with scientific thought. But he also believes the book to be slightly exaggerated in its formal interpretations and implications, citing the example of its interpretation of wave aspect through a literal formal motif of "wavy lines". He goes on to compare his book to that of Jencks and suggests that "Jencks' interests are more formal and aesthetic," while his own are "spatial and inter-relational"(p. 69).

According to Salingaros (2007), "There is a new paradigm in architecture and it is indeed based on the New Sciences, but it does not include deconstructivist buildings"(p.129). As an example of a "mere visual and a functional appreciation of fractals" he points to the Guggenheim Museum in Bilbao, Spain saying it is "disjoint[ed]and metallic and as far removed from any flower that he can imagine" (p.131). He also argues that:

> It turns out that there is a basic confusion in contemporary architectural discourse between processes, and final appearances. Scientists study how complex forms arise from processes that are guided by fractal growth, emergence, adaptation, and self-organization. All of these act for a reason. Jencks and deconstructivist architects, on the other hand, see only the end result of such processes and impose those images onto buildings. But this is frivolous and without reason. They could equally well take images from another discipline, for this superficial application has nothing to do with science (Salingaros, 2007, p.130).

The above quote suggests the need for in-depth research into the rules and logics behind the generation of any algorithm in architectural projects. It proposes that the application of concepts from fields such as fractal growth, emergence, and adaptation - when chosen arbitrarily - will not provide a solution for design. As Salingaros (2007) suggests, there must be a reason behind the application of any image from a discipline in design processes. In other words, if only the end result is seen in such processes and the imposed images could be replaced with others from different disciplines, the resulting shallow application will have nothing to do with science.

Digitalizing information from nature has changed architects' views towards nature. New fields are introducing models that resemble nature, however the question lies in the role of those concepts in nature. If fractal growth, emergence, adaptation, and self-organization define natural systems, then what is the role of these concepts in natural organisms? One would hardly argue that these concepts are frivolous in nature. Hence, further analysis of natural systems is required before applying these concepts into the design. Nevertheless, can biology define life in natural organisms?

On the other hand, Leopold Kohr (2007) applies natural rules by understanding the biological systems. The fact that cells divide once they reach a certain size instead of combining together inspired Kohr to argue that our cities, like the cells, must divide. His solution to city expansion and population growth was decentralization. In his opinion, once the city population reaches between twelve to fifteen million, problems amplify at a much more rapid rate than they can be solved. Kohr declared that dinosaurs could not survive because of their huge size.

2.1.2. From Biology to Life

Seeing nature as a source of inspiration, architects have found ways to incorporate nature into their profession. For instance, a study was conducted on the relationship between green roofs and the thermal environment in Taipei City, Taiwan (Sun, 2010). Research results showed that in addition to benefitting housing by providing interior thermal environment, green roofs also helped to improve the city environment. Another example is the glasshouse exposition building by Bruno Taut, a German architect who was inspired by Victoria regia, a giant South American water lily (Nielsen, 2010).

Numerous articles reveal the importance of nature in design as well as the role of related new sciences in simulating life and introducing possibilities for growth. In *Leadership and the New Science*, Margaret J. Wheatley (2006) focuses on living systems and new theories emerging from biology and chemistry. She identifies information as the main resource for generating forms in our self-organized universe. In her view, to create new forms of life there must be new interpretations. This concept will be discussed shortly, in this section.

This leads to the discussion about the definition of life and whether biologists can define life. A clear and convincing theory about the molecular structure of genes was composed in 1944 by Erwin Schrödinger in his book *What is Life*?. By introducing molecular biology, this book opened a new world to scientists working during succeeding decades. However, the unravelling of the genetic code did not help biologists to answer what life was (as cited in Capra, 1997).

Brian Keeley (1997) states that biologists study life as-we-know-it, an Earth based, carbon-chain phenomenon. On the other hand, artificial life science explores life as-it-could-be. Artificial life manifests itself in the digital world by mimicking information from real life. Therefore, to create artificial life, one must pay close attention to life as-we-know-it. The more similar artificial organisms are to natural life and biological systems, the more successful they will be.

However, this methodology in the architectural field brings some controversy (see section 2.1.1, Salingaros's quote).

In*The Web of Life*, Fritjof Capra (1997) declares that systems theory is a new language in scientific fields that defines complex and highly integrative systems of life. He explains that fractals, chaotic attractors, self-organisation and dissipative structures are some of the key concepts of this new language. This thesis promotes systems thinking for structuring the design invention.

2.1.3. A City is a System and must be looked at from Different Points of View

Jane Jacobs (1969) defined the city as a living organism and proposed principles that should underlie the design of tomorrow's cities. But were those principles in accordance to definition of a natural living organism? If a design is inspired by nature, is it privileged over other designs? If nature is ultimate perfection, then why do modern cities not shift back to their previous "natural" state and have the cosy streets with less automobile traffic that were proposed by Jacobs? What is the stronger force that resists Jacob's vision?

The fact is that a city is a system and must be looked at from different points of view. There are other forces that are viewed in different fields of science that could be called upon to affect the design of city infrastructure. Hence, the city must be considered as a whole system. In *Leadership and the New Science*, Margaret Wheatley (2006) discusses the replacement of Newtonian sciences by others that are focused on holism:

> One of the first differences between new science and Newtonianism is a focus on holism rather than parts. Systems are understood as whole systems, and attention is given to relationships within those networks. Donella Meadows, an ecologist and author, quotes an ancient Sufi teaching that captures this shift in focus: "You think because you understand one you must understand two, because one and one makes two. But you must also understand and" (1982, 23). When we view systems from this perspective, we enter an entirely new landscape of connections, of phenomena that cannot be reduced to simple cause and effect, or explained by studying the parts as isolated contributors. We move into a land where it becomes critical to sense the constant workings of dynamic processes, and then to notice how these processes materialize as visible behaviors and forms (p.10).

She also observes that in biology:

> Non-mechanistic models are only beginning to be replaced by more holistic, dynamic ones. Traditional mechanistic thinking still prevails in the field of molecular biology and most work in genetics. But many scientists now seek to understand life as life, moving away from machine imagery. For example, in The Web of Life (1997), Fritjof Capra presents a new synthesis of the

> science of living systems, drawing together scientific discoveries and theories from many branches of science. Capra's synthesis reveals processes that are startlingly different from the mechanistic ones that had been used to explain life (Wheatley, 2006, p.11).

Cities, individuals, companies, and economies have been considered as systems by Meadows (2009). As mentioned earlier, Jacobs (1969) also suggests that cities are living organisms. Such understanding of cities as living organisms requires a design that is intended for a system. A system can be approached from different perspectives. Capra (1997) shows how different sciences such as biology, chemistry and physics study a particular aspect of life and nature. These sciences articulate a particular aspect of oneness: i.e., a universal system that is called life. Accordingly, this thesis applies *Five Topics* to the research and design process. Interestingly, it reveals that the reason behind the failure of previous theories for city design was the linear application of a single methodology in their process. For instance, Alexander (1966) and Jacobs (1969) support a high resistive pattern (that limits fast movement by short and narrow passages) for the city, but Adrian Bejan (2007) justifies the current low-resistive pattern (that provides fast movement by long and wide passages) of the city. These theories articulate a particular aspect of the city. Thus it is further evidence that cities are natural systems.

To provide a better social life for residents, Alexander (1966) proposes a semi-lattice, Hillier and Hanson (1988) propose distributed systems, and Jacobs (1969) proposes small blocks and mixed-use neighbourhoods. According to Bejan (2007), for a natural organism to survive, the relevant law in nature proposes a fast flowing system that is not resistive. In contrast, parametric urban projects, such as Open Source Fabric which has curved roads on the ground surface, force people to travel along a series of curves from one point to another (see Section 2.3.3).

If the city is viewed as a system, it must address many factors in unison. Since the isolated application of one principle contradicts other principles, this design project aims to provide an appropriate model that will solve the problem. This thesis asserts that these contradictions are the result of looking at the city from one point of view. Understanding the city as a whole system and studying the relationships within those networks forms the basis of this thesis. *Five Topics* are selected to analyse the city. This thesis forms an iterative process that is investigated over and over and in a variety of mediums. Accordingly, the design intervention proposes thickening the city to satisfy all these principles in a three-dimensional world.

2.2. Five Topics

This thesis makes use of *Five Topics* that could contribute to city design within the system of a city (see Table 2.00). The design project develops a model based on application of these views as a system that can provide grounds for the generation of algorithms for tomorrow's cities.

This section pushes the discussion forward by choosing *Five Topics* to leverage in creating a vision for tomorrow's cities. The *Five Topics* are mathematics, sociology, history, biomimicry and computation. Over the next chapters, the application of these associated principles within context of the city as a system is analysed. Then the combination of these theories is analysed and the agreements and contradictions within the resulting system shapes the argument and design intervention of this thesis. This way, the city is viewed as a system comprised of numerous dimensions that collectively have the potential to provide a model from which to generate an algorithm for the design of future city structures.

Five Topics	Key Concept Selected from the field to be used in this thesis
Mathematics	Graphs
Sociology	Public spaces
History	Bazaars
Biomimicry	Constructal theory & fractals & wasps' movement
Computation	Algorithms for generation of tomorrow's cities

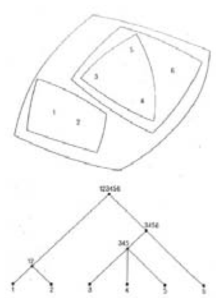
Table 2.00 Five Topics that could contribute to city design within the system of a city

2.2.1. Cities and Mathematics

By way of the graph, mathematics has provided architects and planners with an essential analytical tool. Graphs are simple structures consisting of nodes and lines. Lines illustrate relationships between nodes. If there is no line connecting two points to one another, there is no relationship between those two elements. Graphs have been used by some architects and planners to analyze the structure of cities. In one approach, graphs are used to analyse the hierarchical order of city structures. Alternatively, they are used to define the spatial relationships between different parts of the city structure. For instance, one of the influential criticisms of the *Modernist* city is made by Christopher Alexander in his 1966 essay *A City is not a Tree*. Possessing a Masters degree in Mathematics from Trinity College, Cambridge and a doctorate in architecture from Harvard, Alexander introduces a new system for evaluating city structures. His essay uses graphs to illustrate segregated activity patterns within cities. On the other hand, Hillier and Hanson look at the spatial relationship of adjacent spaces in city circulation systems and use graphs to demonstrate those patterns (Alexander, 1966; Hillier & Hanson, 1988).

Whether the city is analysed based on its segregated activities or its circulation patterns, something seems to be missing within the city structure if it can be distilled in a "tree" graph. Authors reveal that a tree-shape graph illustrates a lack of social interaction within that area (Alexander, 1966; Hillier & Hanson, 1988).

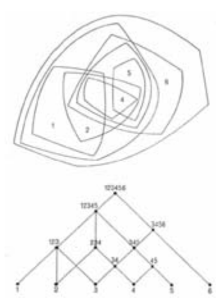
In graph theory, each node on graph demonstrates a separate activity. In cases where the activities overlap, the resulting graph would be a semi-lattice, not a tree. Of course there are cases that show elements of both structures, but only the extremes are discussed here to illustrate the idea more clearly.



(Source: Alexander, 1966, p .5)
Figure 2.00 A tree-shaped graph

The tree axiom states: A collection of sets forms a tree if, and only if, for any two sets that belong to the collection, either one is wholly contained in the other, or else they are wholly disjoint (Alexander, 1966, p. 5).

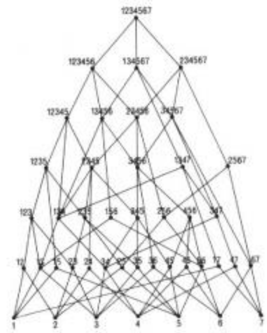
A tree shaped graph shows minimal interaction of activities. The other type of graph that is claimed by Alexander (1966) to show more vibrant cities is referred to as a "semi-lattice".



(Source: Alexander, 1966, p. 5)
Figure 2.01 A semi-lattice

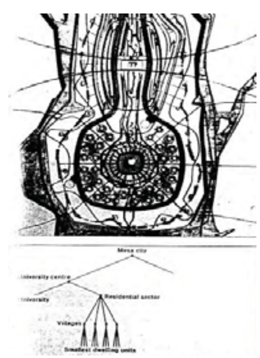
The semi-lattice axiom goes like this: A collection of sets forms a semi-lattice if and only if, when two overlapping sets belong to the collection, then the set of elements common to both also belongs to the collection (Alexander, 1966, p. 4).

Tree-shape graphs are more simple than semi-lattice graphs. For instance, a tree based on 20 elements can contain a maximum of 19 subsets of the 20, while a semi-lattice based on the same 20 elements can contain more than one million different subsets (Alexander, 1966).



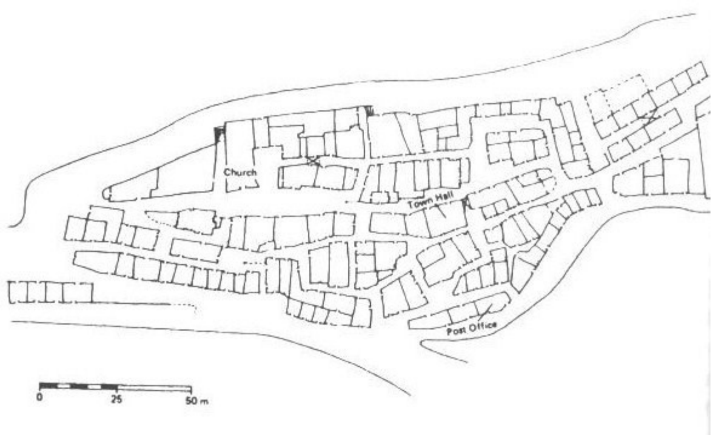
(Source: Alexander, 1966, p. 16)
Figure 2.02 A semi-lattice that shows overlapping of activities

A typical example of hierarchical divisions of city components is an isolated university campus within a city. For instance, Paolo Soleri's Mesa City (Figure 2.02) separating the university from the rest of the city can be outlined in a tree shaped graph, demonstrating that there is no overlap among components. On the other hand, Cambridge University is a good example of a campus that can be described by a semi-lattice graph. At certain points, city streets become almost indistinguishable from those of the adjacent college. The undergraduate buildings contain coffee shops, banks and stores on ground level and are part of the lives of the citizens. In some cases, the fabric of the city buildings melts within the fabric of the college buildings so that altering one of these buildings becomes almost impossible without altering others (Alexander, 1966).



(Source: Alexander, 1966, p. 7)
Figure 2.03 Mesa City —tree shape structure

The next example differs from the one above in terms of analytical approach. Although both examples use graphs, this one focuses on circulation systems whereas the former examines the overlapping activities. According to Hillier and Hanson (1998) the urban hamlets of Vaucluse region of France are a good example of a city structure that is analyzed by graphs to illustrate the spatial relationship of the city parts. Represented by a semi-lattice, the structure of the urban hamlet provides a high degree of permeability and reciprocated accessibility between dwellings. In other words, there are at least two ways to move from building to building. Hence, the probability of seeing a random stranger increases dramatically and this results in the social vibrancy of the neighbourhood.



(Source: Hillier & Hanson, 1988, p. 90)

Figure 2.04 The small town of G in Var region of France

Whether the city is analyzed mathematically - based on the hierarchical order of city structures or on spatial relationships among different parts of it - a living city with vibrant social life can be characterized by a semi-lattice graph. The point is to make the city activities permeable by applying design interventions that enable social vibrancy within the urban context.

2.2.2. Cities and Sociology

Modern cities have been criticized by many architects and urban planners. Jacobs (1969) focuses on the diminishing urban social activities caused by the realization of the *Modernist* agenda and proposes principles for the design of a living city. The use of sidewalks, city neighbourhoods, parks, and the need for mixed uses, small blocks, aged buildings, and the concentration of activities that are analyzed in this book all tie into social activities in cities. For instance, the need for mixed uses is significant to the extent that it is believed that it would be a disaster for residents if the mixed uses did not exist.

Another *Topic* involves the social attraction of people in urban areas. It is believed that people are mostly attracted by other people. But today's urban spaces are designed as though the opposite were true. The reason behind this seems to be misunderstandings that stem from everyday conversations and popular responses to questionnaires that show people associate positively with words such as 'escape,' 'oasis,' and 'retreat' and negatively with the idea of sitting in the middle of a crowd. However studies show that, in reality, people demonstrate different preferences (Whyte, 2001).

(Source: Whyte, 2001, p. 19)

Figure 2.05 Men show a tendency to take the front-row seats

Thus, attracting people to urban areas that are not necessarily considered to be social spaces becomes as important as creating social spaces within neighbourhoods.

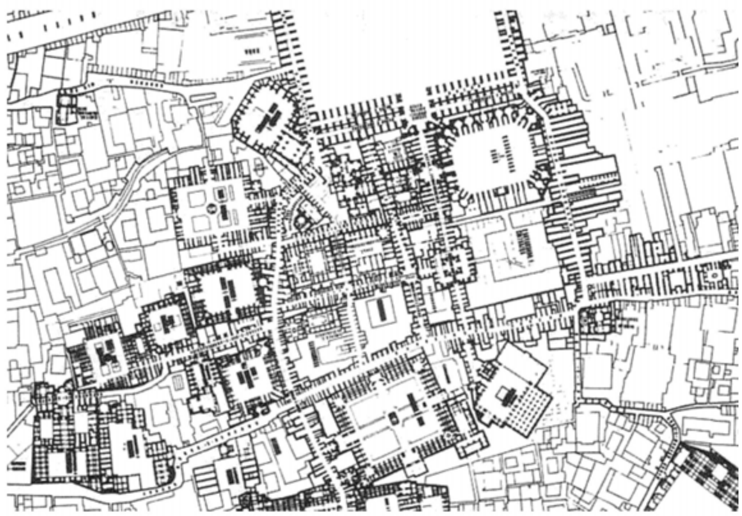
(Source: Whyte, 2001, p. 20)

Figure 2.06 What attracts people most, it would appear, is other people -- street conversations

2.2.3. Cities and History

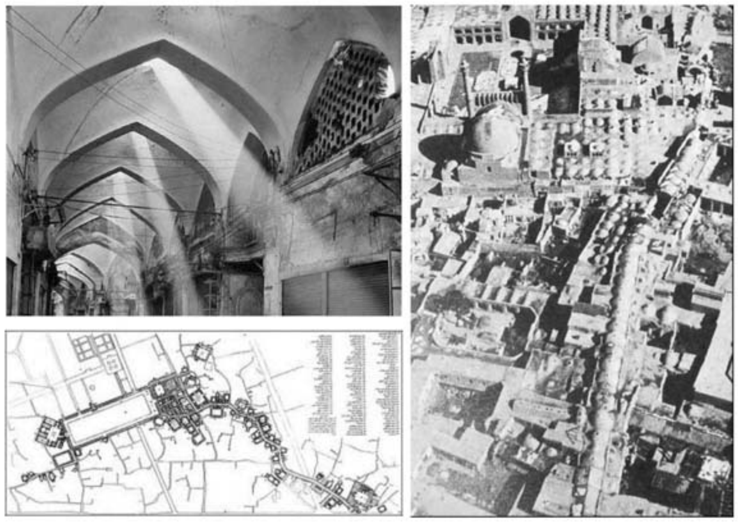
There are several complex and interrelated features at work in historic architecture and urban form. A thorough study of these influential features is required for an understanding of the physical structures and formal values of the towns and architecture of the past. One of the most important features in the social infrastructure of Persian cities, as well as other Islamic countries, is the enclosed marketplace called the bazaar. Despite the phenomenal commercial success of spaces like the bazaars, their character has yet to be understood well enough to be applied elsewhere (Tavassoli 2002; Salingaros, , 2005).

Figure 2.07 shows the physical infrastructure of Bazaar in Isfahan, Iran. This linear infrastructure is an integral part of the city that plays a major role in social vibrancy of that city.



(Source: http://www.iranchamber.com/architecture/articles/bazaar_of_isfahan4.php)
Figure 2.07 The structure of Bazaar in Isfahan-Iran in Safavid period

The bazaar is a linear marketplace with shops along the sides that connects important social nodes of the city to one another. The economic core of the city, the main bazaar within the context of the city serves as both a marketplace and an exhibition area. People spend spare time either shopping or browsing in the bazaar. In addition to its social and economic functions, bazaars have a significant political value. From the social history of Iran, particularly the socio-political events within the city, one can discern the role of bazaars and their link to Friday mosques (Tavassoli, 2002).



(Source: http://www.iranchamber.com/architecture/articles/bazaar_of_isfahan2.php)
Figure 2.08 The structure of Bazaar in Isfahan-Iran

Since pedestrian circulation within the context of the city and the social life of citizens is an important focus of this thesis, the example of bazaars as linear social spaces for pedestrians within the large scale of the city is an historic factor that figures prominently in the design explorations of this thesis.

2.2.4. Cities and Biomimicry

The imitation of nature as an approach to design, or biomimicry, could prove to be revolutionary. Contrasting with the *Modernist* design approach, the biomimicry asks, what we can learn from nature, not, what we can extract from it. This is referred to as the “conscious emulation of life’s genius” (Benyus, 1997, p.2).

Studies have been done on structural morphology by looking at structures inspired by nature such as the buckyball carbon 40 model, seashell computer model, and dragonfly wing computer model. These structures introduce new systems for constructing our environments (Stach, 2010).

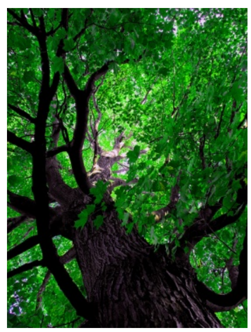
However, these examples show a one-to-one extraction from nature rather than learning from nature. Emulating the forms of nature in a superficial way is not of interest in this thesis; living systems as studied in allied fields do however have great potential to contribute to this investigation.

2.2.4.1. Constructal Theory in Nature

This thesis studies flow systems in the natural world. Cities are thought of as natural organisms and there have been studies on the relationship between human circulation systems, specifically city transportation patterns, and people's social lives (Jacobs, 1969; Hillier & Hanson1988).

According to Adrian Bejan (2007), if a flow system, such as a river basin or blood vessel, can change its configuration with ample freedom, the system will reveal configurations that offer improved access paths for flowing currents. This is based on consistent universal observations that suggest a time arrow is linked with the progression of flow configurations that amount to existence of the system. Existing patterns are replaced by easier flowing patterns. This principle was formulated in 1996 as the constructal law of the generation of flow configuration:

> For a finite size flow system to persist in time (to survive) its configuration must evolve in such a way that it provides an easier and easier access to the currents that flow through it (Bejan, 2007, p.2).



(Source: http://flickr.com/photos/vst/2905067523/sizes/m/in/photostream)
Figure 2.09 Tree branches

This law is the foundation for the constructal theory of organizations in nature. Interestingly, cities were among the universal flow systems, along with river basins and blood vessels, observed in order to generate this law. In 1997, this law was summarized for the first time in a book by Adrian Bejan. Today this theory embodies an extension of physics in thermodynamics of flow systems (Bejan, 2007).

(Source: Peitgen & Jurgens& Saupe,1992, p. 176)
Figure 2.10 Cast of a child's kidney, Venous & arterial system

Human society, with all its layers and characteristics, can be modelled as a flow system. In fact, it is the most complex and baffling living system that we know. It is, in many respects, very similar to the structure and development of other complex flow systems like blood vascularisation, river basins and deltas, and animal movements (Bejan, 2007).

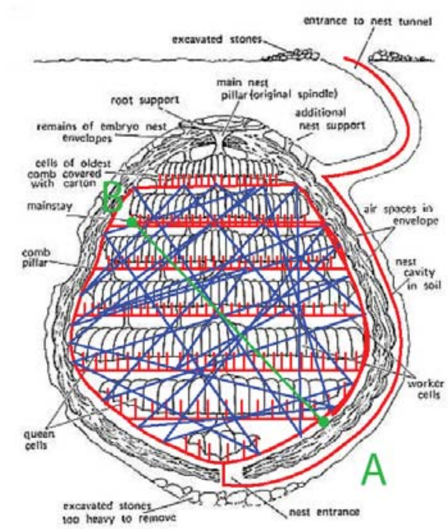
(Source: Bejan, 2007, p. 81)

Figure 2.11 Downtown Lisbon, Low resistivity pattern (at the left) was developed after an earthquake

In conclusion, according to the constructal theory, a fast flowing configuration is required for a system to survive over time. For instance, to distribute food – a primary need for survival - to all parts of the city, a fast flowing transportation system is needed. This system would ensure that nutrition can be provided to all parts of the city with high efficiency, much like a tree. Similarly, a fast flowing transportation system is necessary in emergency situations when a citizen needs to get to the hospital. Thus, a less resistive flow system is essential for the city to persist through time.

2.2.4.2. Social Wasps' Movement Pattern

To further illustrate movement patterns within society, the thesis focused on social wasps and the transportation system within their built habitat. A sectional analysis of wasp nests shows that they are very organized in their configuration and are not dissimilar to our Modern city blocks. If this sectional analysis used graphs, the graphs would be tree shaped. Although wasps move fast from one point to another there would be limited social interactions. However, the habitat of social wasps is in fact a three-dimensional structure with a hollow shell that surrounds the built structure. This allows wasps to fly around freely. There are countless ways of moving within the three-dimensional structure, which provides a semi-lattice and increases randomness and social interactions. Additionally, the wasps can move quickly and easily access different nodes of their habitat. This analysis demonstrates the existence of both systems (high random interactions and fast movement) within natural social colonies.



(Source: Wasps' movement analysed May 2010 by S. Yekanians)
Figure 2.12 Social wasps' circulation analysis

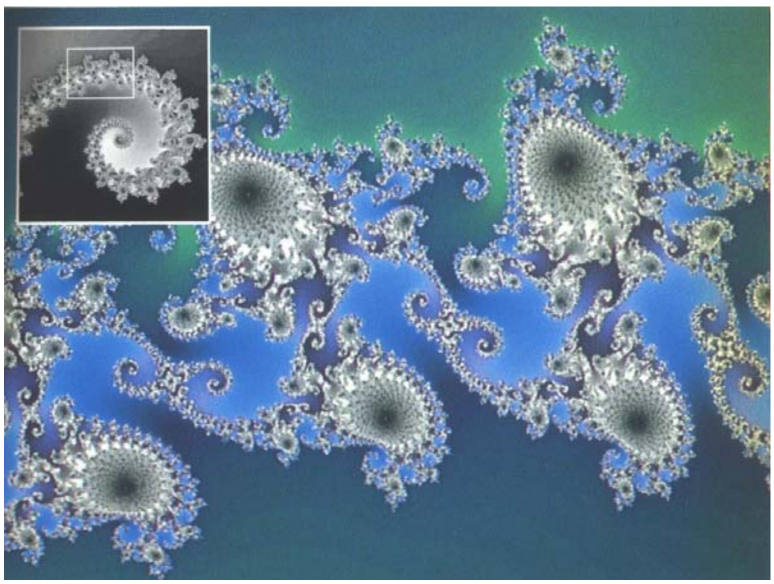
2.2.4.3. Fractals in Nature

The claim that nature is fractal represents a major breakthrough in the modeling and production of natural patterns and structures (De Castro & Von Zuben, 2005). James Gleick (1987) suggests that the human mind cannot fully envision the never-ending, self-embedding complexity of nature. But the study of structures on smaller and smaller scales can make a significant difference to someone thinking from a geometric perspective.

Benoit Mandelbrot explored these shapes and their possibilities, uncovering deviations that were previously unrealized. One of the advantages he had over his mathematical predecessors was access to computation. He could draw shapes on the computer and run programs repeatedly. As a result, fractal dimensions have been a significant point of reference for architects since Mandelbrot's time (Gleick, 1987).

According to Van Bilsen (2005), having structure on all levels of scale and self similarity are fractal properties:

> The first property of a fractal is occurrence of structure on all scales. This property can also be identified in cities, which also have structure on all scales. Self similarity means that parts of a fractal are similar to other parts of a fractal. In particular, we find the parts (structure)repeated on different scales. Especially property 1 gives confidence that one can use elements of the fractal concept to increase the understanding of cities. (p. 140)



(Source: Gleick, 1988, p. 114)

Figure 2.13 Mandelbrot fractals

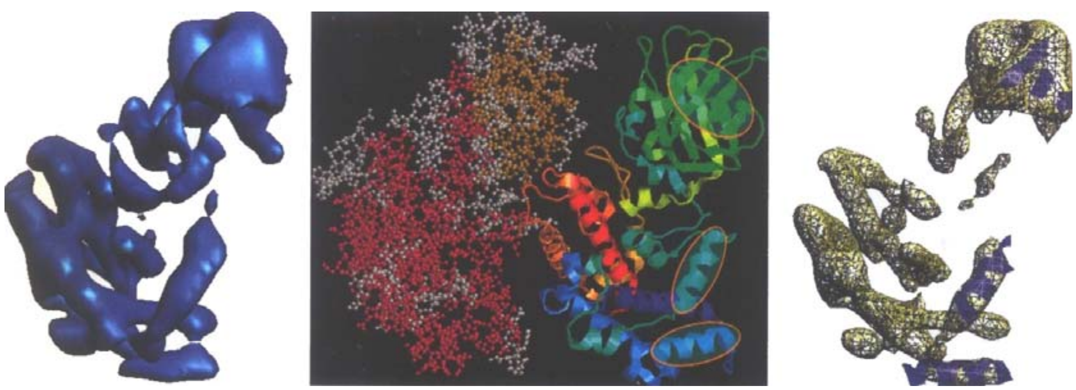
Fractals increase interactions in a limited surface in nature. For instance, the circulatory system of veins in the body has to pack a vast surface area into a small volume. The vessels branch continuously until they become small enough to force the blood cells to slide through in one single file. This fractal nature in the body demonstrates incredible efficiency because, while a blood vessel is never more than three or four cells away from each cell, the blood vessels take up no more than five percent of the body's volume. Another example of fractals in nature is the lungs that need to squeeze a large surface into a small space. The surface area of an animal's lungs indicates their ability to absorb oxygen. Human's lungs can squeeze in a surface area that is larger than a tennis court. Trees also branch continuously to a point where there is a single leaf on each branch, which enhances the green surface of the tree and increases its interaction with sunlight (Gleick, 1987).

The same philosophy applies to pedestrian scale and the environment that continues to get close to the human scale at the pathways. Instead of living the design at a tower and a park scale, this thesis project continues the principles of the system into smaller and smaller streets and buildings to increase interaction of humans with the built form.

2.2.5. Cities and Computation

The modeling process is described in three parts: First, to choose the model: (To describe a given aspect of reality). Secondly, to construct an algorithm: (To create a set of rules that illustrate how a model functions). Here, if these rules are applied systematically, they can offer a solution to a problem. Finally, to draw conclusions that includes checking acquired results against the primary hypothesis (Bialynicki-Birula, & Bialynicka-Birula, 2004)

With regard to selecting the dataset, Birula (2004) suggests using the elements of reality that have the most important effect over the phenomenon being described. For instance, when observing the motion of an apple falling from a tree, the necessary elements would be the apple's weight, height from the ground, and perhaps air resistance. Properties such as taste, color, and the planet configurations - elements that have very little impact on the motion - would be omitted.



(Source: Eulenstein, 2006,p. 20-4)

Figure 2.14 Computational biology- digital model of a protein

Accordingly, setting rules for generating algorithms for cities requires a model from which to derive the dataset. This thesis provides a model that can be used for computational generation of future city forms. More importantly, the dataset selected to make the model is the result of the analysis of *Five Topics* in relation to the social lives of humans. Since the primary goal of this thesis is the design process, actual mathematical algorithms were not used in this thesis; but instead conceptual algorithms were applied to define constraints and opportunities that guide this intuitive design process. The form generating of tomorrow's cities will be a back and forth process of programming by a programmer and an architect's supervision on the outcome at each level. This concept will be elaborated throughout this thesis and in Section 5.3.

In bioinformatics, biological systems are composed of a great number of elements that have many interactions. Models of biological systems account for not only the molecular level, but also the cellular and organism level. In his book, *Cities and Complexity*, Michael Batty (2005) refers to cells as the "basic building blocks of life" (p.67). This may be the reason mathematics endeavours to simplify biology by creating models that resemble building blocks. The cellular growth process was discussed for the first time by D'Arcy Thompson in *On Growth and Form* (as cited by Batty, 2005). At the time, he was limited by early mathematical formalism. According to Zvelebil & Baum (2008), it was not until the introduction of digital computation that scientists began to see that organic development could be understood through computation and that the process of communicating information could play a major role in cell development.

Tierney (2007) proposed that "process rather than substance was the fundamental constituent of the world and that nature consisted of patterns of activity"(p. 78) In this regard, algorithms are seen as the key elements in the design process. Computational models can generate and examine designs, and develop forms and structures, to ultimately allow design to be viewed in new ways

The role of algorithms becomes more accessible with Larry Liebovitch's description (1998) of how the human genome with a mere 100,000 genes contains all the information needed to create a heart with 1,000,000 capillaries, or a brain with 100,000,000,000 nerve cells. It is not the genes that build these structures - it is the rules that the genes generate. Recurring application of these rules may result in the creation of similar structures with many pieces at different situations.

Cellular automata, L-systems, iterated function systems, and particle systems are examples of techniques used to model the natural patterns and structures studied by De Castro and Von Zuben (2005). Accordingly a technique would be applied to algorithmically develop this thesis model in future.

The following chapters will analyze how uniting these sciences can build the foundation for a design intervention. These areas of research will support and, in some cases, contradict each other. The intersection of the resulting statements forms the main argument for this thesis. If the city is viewed as a system, the only way to analyze it is to consider various fields of relevant sciences that provide input data for an ideal model.

2.3. Case studies

This section presents five case studies that were crucial in forming the argument of this thesis: i.e., Mountain Dwellings, Ordos, The Grand Egyptian Museum, Pruitt Igoe and Open Source Fabric. Each case study aids in understanding some significant aspect of this thesis project.

2.3.1. Mountain Dwellings

"Mountain Dwellings" is a residential complex that consists of a multi-story parking structure with residential apartments on top that is designed by Danish Architects Bjarke Ingels Grop (BIG). According to Faris (2008), the project hides parking areas under a layer of residential units in a way to provide the maximum sunlight for the apartments. This building, completed in 2008, is located in Copenhagen, Denmark. The design intervention considers the parking area as the base upon which terraced housing is placed. It looks like a concrete hillside covered by a thin layer of apartments flowing from the 11th floor to the street edge. By placing the apartment units on top of the hillside parking, there is a suburban neighbourhood of garden homes cascading over a 10-story building. Consequently, all units get proper sunlight, fresh air and views and they have access to parking at each level of the building. The residents of the apartments are the first in the area to have the opportunity of parking directly outside their homes and to benefit from the roof gardens and amazing views at the same time.

The design stage of this thesis looks into hiding parking areas, movie theatres big box stores, utilities and other service uses under a mass of public-oriented uses, including residential units.

(Source: http://www.archdaily.com/15022/mountain-dwellings-big/)

Figure 2.15 Mountain dwellings

2.3.2. Pruitt Igoe

Pruitt-Igoe is an example of the failure of the “Tower and Park” concept in the twentieth century and could be said to mark the end of *Modernity*. This housing project was built in St. Louis, United States, and was designed by George Hellmuth and Minoru Yamasaki. Construction on Pruitt-Igoe started in 1954 and was completed in 1956. Located just north of downtown St. Luis, the project included thirty-three, eleven-story buildings on a 35 acre site. The design of this project expressed beliefs of the *Modern Movement* in architecture precisely - with dramatic formal success and equally dramatic social failure. Due to a variety of social problems that the project caused in the neighbourhood, the first building was demolished on 1972 Four years later, the whole complex was knocked down. Keel (2011) argues that the demolition demonstrated the failure of *Modernist* thinking and rational planning.

(Source: Newman, 1972, p. 12)

Figure 2.16 Pruitt Igoe in the process of being torn down

This case study elaborates the effects of *Modernist* architectural design and urban planning on neighbourhood character. Because the main reason behind this demolition was the social problems, it was selected to support the negative consequences of *Modernism* on people’s social lives. Newman (1972) argues that the areas proved unsafe and the vast open space, lobbies, elevators and stairs became a sewer of garbage and human waste.

2.3.3. Open Source Fabric

This project is a masterplan to promote new industries for Zorrozaurre, Bilbao, Spain. This project challenges the integration of both city centres and their suburbs onto the peninsula. One of the primary goals of this design is to revitalize the post-industrial waterfront by introducing new industries to the site. This project contains multiple dense centers in the city centre. Each center creates a different industry and disperses outwards towards loose edges (Van Werz, 2007).

(Source: Van Werz, 2007, p.89)

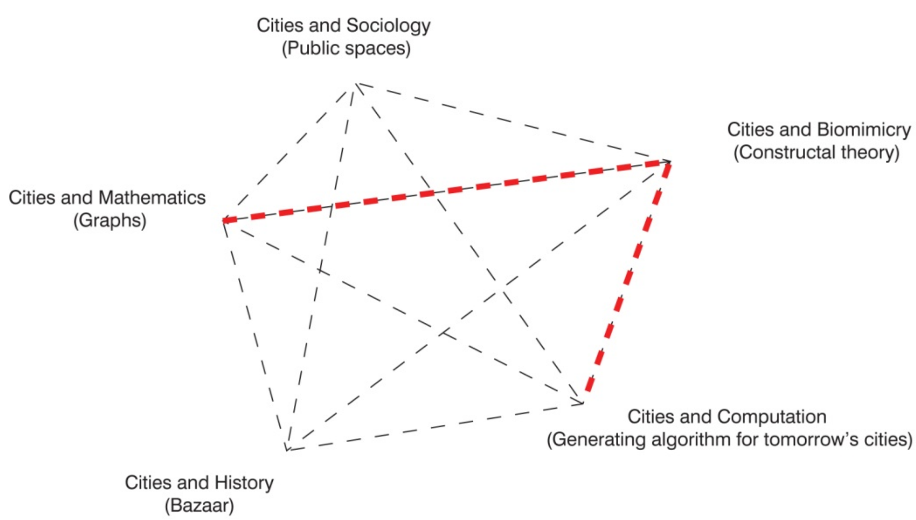
Figure 2.17 Open Source fabric

This project shows a parametric urban design strategy that does not reflect the constructal law in nature. This thesis argues that such a linear approach to design (in this case study computation) is the reason behind the failure of many proposed urban designs. For instance, the pattern created in the Open Source Fabric conflicts with the constructal law of social dynamics in nature (see Section 2.2.4.1). By restricting the fast flow movement, this pattern impedes transportation efficiency. This pattern causes delays in the rapid delivery of food, emergency trips to hospital and many other cases that relate to the vital needs of humans. Therefore, it is always crucial to consider the city as a system and ensure that the design responds to several viewpoints simultaneously.

Chapter 3 – Research Analysis

Overview

This chapter analyses how unifying the *Five Topics* described in chapter 2 (see Table 2.00) can be used to build the foundation of a strategy for developing a design model for cities. These *Five Topics* will support and, in some cases, contradict each other. The intersection of the resulting statements forms the main argument for the thesis project. If the city is viewed as a system, the only way to analyze it is to consider various fields of relevant disciplines (in this thesis, *Five Topics*) that can provide input data for an ideal model.



(Source: Diagram developed June 23, 2010, by S. Yekanians)

Figure 3.00 Unifying Five Topics and identifying Topics that contradict each other

Figure 3.00 shows how the *Five Topics* of research are unified to work simultaneously. The black lines link *Topics* where there is no conceptual conflict, allowing these *Topics* to work simultaneously. The red lines indicate a significant conceptual contradiction that would impact their simultaneous operation.

The conflict that exists between computation and constructal theory is discussed in Section 2.3.3. The computational pattern for development of tomorrow's city must not conflict with the other four disciplines that were discussed earlier.

Although authors such as Alexander (1966), Jacobs (1969) and Hillier and Hanson (1988) have previously proposed models for urban design, an analysis of physical laws of nature would argue that application of those suggested principles will in fact conflict with the analogy of cities as natural organisms. For instance, small blocks, overlapping of city activities and the distributed streets system all refer to a city pattern that is resistive; in other words, reducing the speed of moving vehicles within an urban area leads to an increase in cities' social vibrancy (Alexander, 1966; Jacobs, 1969; Hillier & Hanson, 1988; Bejan, 2007).

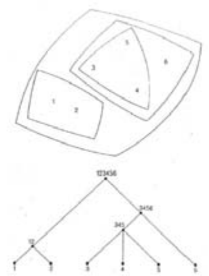
On the other hand, constructal theory justifies the *Modernist* city pattern transformation as a natural flow system. This theory mentions the importance of a non-resistive pattern for natural organisms to persist in time (survive). In other words, a non-resistive pattern provides a significantly easier flow to different parts of the system than does a resistive pattern. Therefore, it increases the speed of the particles that flow in the system. Such a fast flow system as explained earlier reduces social vibrancy of urban areas (Alexander, 1966; Bejan, 2007).

The above principles can fit into two distinct categories. The first category prioritises the social life of the residents and idealizes neighbourhood character. This pattern is resistive and resistive patterns are not designed to facilitate rapid travel for people. The second one prioritizes the vital aspects of the neighbourhood (such as food delivery, easy access to hospitals, etc.) and intends to provide speed for the passengers. The fact is that humans live socially and need both aspects for living. To determine whether these patterns can co-exist at the same time in a city, we must analyse their characteristics.

3.1. A Pattern for the City

The graphs Alexander (1966) proposes show whether or not different activities in the city overlap. Each node on a graph represents a separate activity. Where the activities overlap, the resulting graph would be a semi-lattice; otherwise it will be a tree. There are cases that show elements of both structures, but only the extremes are analyzed here to illustrate the idea more clearly. An example of overlapping activities is a university campus, such as Cambridge University, which evolved naturally within the context of the city. City streets with coffee shops and stores meld with the university campus; streets that serve the city cannot be distinguished from streets that serve the university. The graph that represents such a situation is a semi-lattice.

On the other hand, there is something missing in our *Modern* and artificial cities that cannot evolve on its own. These kinds of cities tend to fit a tree shape graph. These artificial cities are seen as lacking a vibrant social life. On the other hand, the “patina of life” (Alexander, 1966, p.2) exists in most ancient cities. Our cities - just like the ancient ones that have acquired the patina of life - must take the shape of a semi-lattice. All artificial cities form tree shaped graphs.

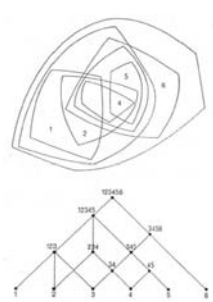


The tree axiom states: A collection of sets forms a tree if, and only if, for any two sets that belong to the collection, either one is wholly contained in the other, or else they are wholly disjoint (Alexander, 1966, p.5).

(Source: Alexander, 1966, p.5)
Figure 3.01 A tree shaped graph

If there is a connection between two components, it has to be through the medium of those units as a whole. Taking the plans of *Modernized* cities as an example, there is a clear distinction between different urban activities. Alexander (1966) argues that Greenbelt, United States, Tokyo, Japan and Mesa City, Arizona are among the cities that demonstrate a tree structure. He insists that well-functioning cities are not and cannot be tree structures and points to those structures as the reason for social deadness within the cities.

Tree structures contrast with semi-lattices. The semi-lattice is the structure of a complex fabric and the structure of living things.



The semi-lattice axiom goes like this: A collection of sets forms a semi-lattice if and only if, when two overlapping sets belong to the collection, then the set of elements common to both also belongs to the collection (Alexander, 1966, p.4).

(Source: Alexander, 1966, p.5)
Figure 3.02 A semi-lattice

Cities that develop naturally fit within this category and provide a better social life for humans (Alexander, 1966).

Furthermore, if a city can be laid out in a tree shape diagram it does not provide social vibrancy for residents. A tree shape diagram here refers to the linear spatial relationship of different parts of the city. If there is just one way to travel from one point to another, then the resulting graph will be a tree. Tree shape graphs are also called non-distributed systems in pattern analysis. In contrast, if there is more than one way - almost equal in length - to travel from one point to another, the resulting graph will represent a distributed system. In other words, when analyzing patterns there is always a loop in the system. Hillier and Hanson (1988) illustrate how the patterns of medieval cities represent distributed systems, which they claim as the reason the city was socially vibrant. In any distributed system there is always a choice of paths when going from place to place. Therefore, the probability of seeing a random stranger increases dramatically in this system and results in the social vibrancy of the city. On the other hand, the probability of seeing a random stranger in areas such as the suburbs is almost zero, because people who travel in a certain area are usually the same individuals. This is the main reason for the low quality of social life in suburban neighbourhoods.

Although there are other factors in determining the quality of social lives in an urban area - such as the ones proposed by Jacobs (1969) - this section analyses the role of city "pattern" in social vibrancy of the urban areas. Other factors proposed by Jacobs are discussed later in this chapter.

(Source: Hillier & Hanson, 1988, p.59)

Figure 3.03 Four hamlets from the Vaucluse region demonstrating distributed patterns

Although all these arguments suggest a shift to a city pattern that provides high resistivity, applying a recent discovery in physics and natural sciences leads to a very different conclusion. The constructal law of social dynamics describes configuration patterns in nature and constitutes a law for the physical sciences (Bejan, 2007). Constructal theory comprises a major part of the biomimicry section of the thesis due to its relevance in the analysis of circulation systems.

> For a finite size flow system to persist in time (to survive) its configuration must evolve in such a way that it provides an easier and easier access to the currents that flow through it (Bejan, 2007, p.2)

This law states that for any flow system to survive over time there must be a configuration that provides an easy flowing pattern for its particles. For instance, human lungs and trees are organized in a specific pattern called fractals, which provide a flow system that ensures the easiest and fastest movement for its particles. If a tree were configured any differently, it would not have an efficient system to transfer nutrition from the root to each leaf. This law justifies the shift in our urban patterns from highly resistive medieval city patterns to a less resistive Modern city patterns (Gleick, 1987; Bejan, 2007).

To survive over time we need to have a fast flow system that nourishes every part of the city balanced with easy access that enables a person to get to the hospital quickly. This law shows the vital aspect of the citizens. This is heading towards a focus of commuting efficiency which undermines the earlier focus of this thesis on social determinants of a neighbourhood.

(Source: Bejan, 2007, p.81)
Figure 3.04 Downtown of Lisbon, Low resistivity area (left) vs. high resistivity area (right)

The fact is that our cities as natural organisms need both patterns at the same time. They need a fast flow and non-resistive system in order to provide food and nutrition throughout the urban areas.

This fast flow system also helps, for example, fire and rescue services to get to an accident promptly. These factors refer to the needs of humans to survive. On the other hand, the cities need a resistive system to offer a vibrant social life and the sense of living in a community. The problem is that both these systems cannot exist on a “two-dimensional surface” at the same time. The simultaneous existence of these systems on a “surface level” will reduce the quality of them both.

The contradiction between constructal theory and the results derived within the mathematics section lead the main argument of this thesis; in order to address social issues in the city and also survive as natural organisms we need both systems within our city’s transportation systems. This argument forms the basis of the design intervention described herein.

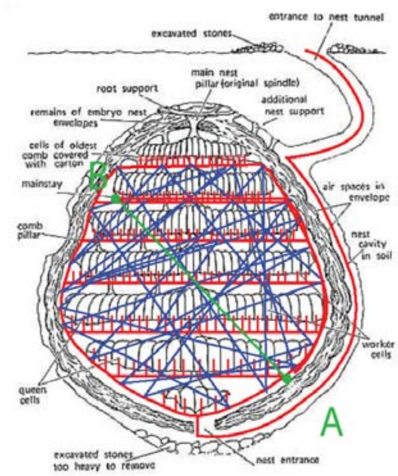
This thesis project proposes a resistive system over the existing non-resistive system of our modern cities. The resistive system grows three-dimensionally and manifests the social principles that were described in the previous chapter. This methodology keeps the fast flow system untouched while superimposing social layers on it. This results in a thickening of the city with complex layers of events.

(Source: Bejan, 2007, p.81, analysed July 14, 2010 by S. Yekanians)

Figure 3.05 Design invention superimposes the resistive pattern over the existing fast flow pattern

The co-existence of these two circulation systems is visible in wasps’ nests. Figure 3.06 shows a clear organizational division of the nest. Section of the nest can be described as having a tree structure.

Wasps need to fly freely and fast in these organized spaces. On the other hand, they need to interact with each other at the same time. The hollow sphere around the structure provides endless ways to travel and increases the probability of their random interactions. This architecture of the nest complements the wasps' abilities to fly and meets their social needs.

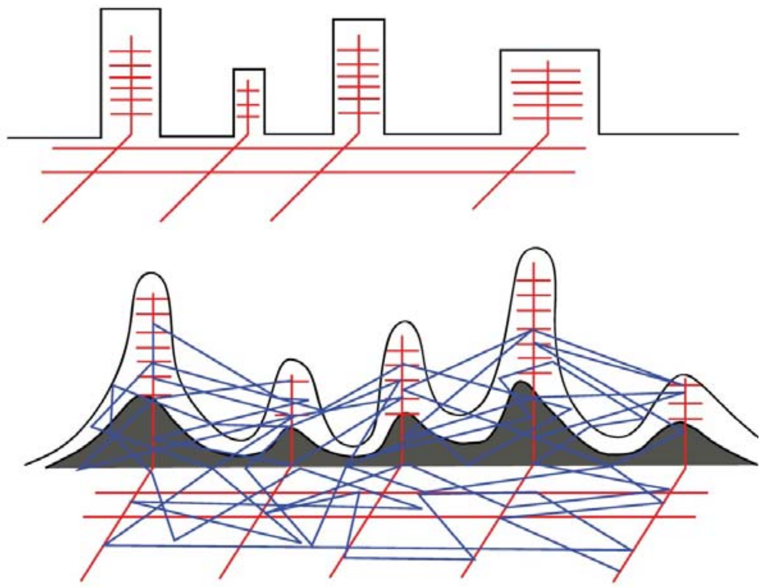


(Source: Wasps' movement analysed May 23, 2010, by S. Yekanians)
Figure 3.06 Social wasps' circulation analysis

3.2. A city is a Three-Dimensional Organism and cannot be a Two-Dimensional Map

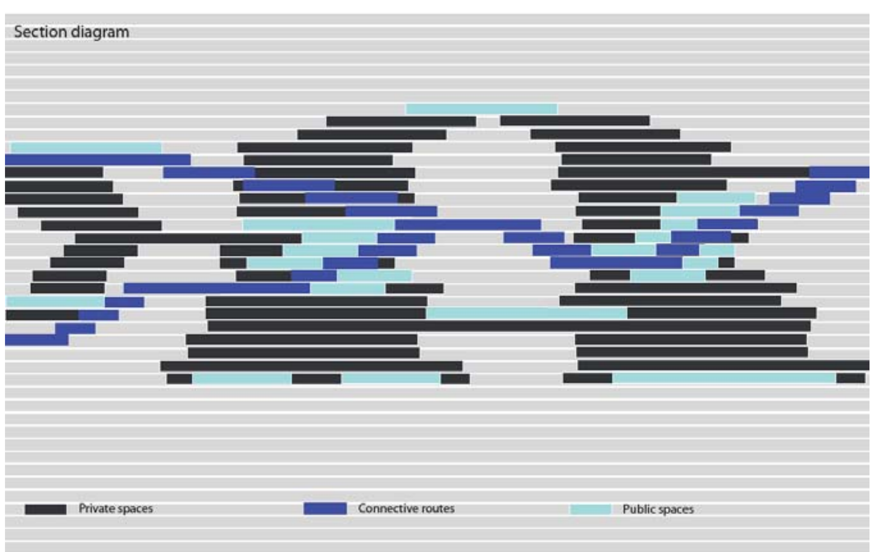
As stated in previous sections, for an ideal city that provides socially vibrant neighbourhoods as well as an easy flow system to survive over time, both systems are needed. The existence of one of these patterns on a "two-dimensional surface" would mean denying existence of the other. This thesis suggests superimposing one system upon the other, hence thickening of the city.

This thesis provides an abstract model for thickening of the city. This model proposes the studied social principles over the existing city pattern. In this approach, a series of pedestrian resistive patterns along with housing development and mixed use living areas are superimposed on the existing non-resistive street pattern of the city. The idea of looking at the city as a three-dimensional object instead of two-dimensional surface is to provide both systems of resistive and non-resistive patterns for citizens. It also gives the opportunity to hide service areas and other places that do not need sunlight or a visible connection to the exterior, within the building mass of the "thickened" neighbourhood.



(Source: Diagram developed August 21, 2010, by S. Yekanians)
Figure 3.07 Sectional diagram showing existing tree shape circulation vs. Thickened city's proposed tree shape and distributed system

Figure 3.07 describes how this design concept is not simply a hyper version of the insular towers that Jacobs (1969) describes as the bane of *Modernity*.



(Source: Diagram developed August 30, 2010, by S. Yekanians)
Figure 3.08 Public and private spaces in section

In order to draw pedestrians upward, there must be social magnets or public places to motivate them to pass through the mass. Otherwise, if public places remain on the street level, no one will use the distributed pedestrian passageways. Thus, the design looks into combining these public and private places together in a three-dimensional world and connecting the public places to each other by a connective route displayed in the image above (Figure 3.08). Aside from connecting these points, this public passageway provides shops and restaurants along the path and plays a similar role as the Bazaar does in the Middle East or the PATH system in Toronto. The Bazaar and the underground pathway both provide a shelter from adverse weather conditions and contribute to the city's economy at the same time. This connective route is a distributed circulation system. In other words, there are always two similar ways to travel from one point to another. This increases the probability of seeing a random stranger and also gives pedestrians freedom of choice for their trip. This objective of decreasing pedestrian boredom was addressed by Jacobs (1969) who proposed small blocks. This thesis looks at those similar objectives and provides an alternative solution in a three-dimensional world on the superimposed layers. The next section explains how the critiques against *Modernism* in architecture contribute to applying social factors on superimposed layers of the thickened city.

3.3. Applying Social Factors on Superimposed Layers

The previous section illustrated the need for superimposing a resistive pattern over the existing fast flow city to provide social vibrancy for the neighbourhoods. This section shows how the critiques against *Modernism* and related principles can shape the superimposed layers of the city.

3.3.1. A need to Mitigate Segregated Urban Activities

Our current city activities are segregated. Streets and highways are one sort of activity that cuts through other activities and isolates people. This approach in *Modern* planning reduces the social vibrancy of urban areas. The streets and highways play the role of a razor blade cutting communities into pieces (Alexander, 1966).

(Source: GIS software, 2007, analysed October 28, 2010, by S. Yekanians)
Figure 3.09 Toronto satellite map, Highways and railroads cut into urban activities and cause segregation

> For the human mind, the tree is the easiest vehicle for complex thoughts. But the city is not, cannot and must not be a tree. The city is a receptacle for life. If the receptacle severs the overlap of the strands of life within it, because it is a tree, it will be like a bowl full of razor blades on edge, ready to cut up whatever is entrusted to it. In such a receptacle life will be cut to pieces. If we make cities which are trees, they will cut our life within to pieces (Alexander, 1966, p.55).

The satellite image above (Figure 3.09) shows the section of Toronto around the CN Tower and the Rogers Centre. The railroad at the North and the Gardiner Expressway at the South clearly segregate this area of the city into three distinct parts. This segregation negatively affects people’s transportation routes and the local activities and the neighbourhood character.

(Source: Picture taken January 17, 2011, analysed February 12, 2011, by S. Yekanians)
Figure 3.10 South of the Rogers Centre, looking to the south-east.

This photograph (Figure 3.10) is taken from south of the Rogers Centre, looking to the south-east. It shows how urban activities are segregated by the roads and highways. In such areas, cars are given a higher priority over pedestrians. If a pedestrian wants to move to the adjacent parking lot, they need to walk along the road, cross the street and again walk along the highway. This illustrates how roads and highways block pedestrian flow and cause frustration for them. An area that has the potential to experience a vibrant neighbourhood has turned into a lifeless urban non-place that is full of roads, parking lots, and highways that block pedestrian flow and act as a razor blade dissecting urban activities.

Comparing this situation with the social wasps' nest, if humans were able to fly, the problem of segregation could have been mitigated some extent. But the act of flying would not maximise interactions, since the space above the ground is boundless. The main purpose of superimposing the layers in Figure 3.11 is to maximise interactions and increase vibrancy of the neighbourhood. Pedestrians need enough freedom to pass over the highways and railways without jeopardising their lives. They also need enough entertainment along the way and a non-deterministic network of circulation to travel around. Thus, the first step of imagining secondary layers is to consider a distributed infrastructure of local pedestrian routes that float over the existing city structure.

(Source: Picture taken January 17, 2011, analysed February 12, 2011, by S. Yekanians)

Figure 3.11 Connective Pedestrian Routes for segregated areas in neighbourhoods

Figure 3.11 proposes potential local routes for pedestrians within a developed community that operate independently from the vehicular system. These *Pedestrian Roads* prevent expressways and other vehicle-dominated roads from segregating urban activities. These are abstract formal illustrations of a response to a design that prioritizes cars over people. In this case pedestrians get as much attention as cars in the design process. In order to travel to the other side of the highway, they do not need to walk to the intersection, wait for the pedestrian traffic light, cross the street and travel all that way back on the other side.

The flexibility of the *Pedestrian Routes* in Figure 3.11 also allows for different slopes at different areas and could facilitate bike routes at some points, providing for a potential hybrid condition. This stage of the design just adds another layer to the complex tissue of the city.

The design intervention superimposes layers of urban activities over the existing rigid infrastructure and looks at pedestrian movement in a three-dimensional world where they can easily pass over the existing streets that currently separates urban activities. Looking at the circulation infrastructure of the city in a three-dimensional way results in the physical thickening of the city.

3.3.2. A need for Social Nodes along the Pathways

The previous sections clarified the need to provide alternative *Pedestrian Routes* to mitigate the effect of activity segregated by highways and fast flow streets. But are these secondary *Pedestrian Routes* enough to provide vibrancy for a neighbourhood? What are the other critiques on *Modernised* cities aside from isolation?

(Source: Picture taken January 17, 2011, analysed February 12, 2011, by S. Yekanians)
Figure 3.12 South of the Rogers Centre looking to the north-east Toronto.

Figure 3.12 illustrates Jacobs' (1969) critique of the role of sidewalks and mixed use areas on the social vibrancy of neighbourhoods. Apparently, the only view and experience that this particular sidewalk provides for pedestrians is the dull view of the large parking lot. This results in an unpleasant experience for pedestrians when they walk along the street. In addition, the area is not safe for children to play.

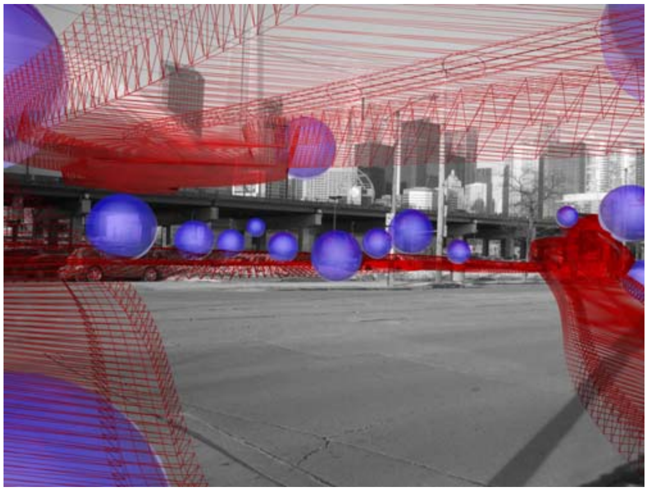
The same characteristic could potentially apply to the secondary pedestrian routes that float over the highways and streets. If there is merely a distributed circulation system for pedestrians without any shops or public squares or leisure areas, the roads will not provide social vibrancy for the neighbourhood. Such a system will generate the deadness described by Jacobs (1969). Neighbourhood streets must provide mixed use areas to make the streets pleasant enough to attract pedestrians, and streets safe enough for children to play.

(Source: Picture taken January 17, 2011, analysed February 12, 2011, by S. Yekanians)
Figure 3.13 Addition of secondary Pedestrian Routed is not enough to provide social vibrancy

Figure 3.13 shows that merely connecting different parts of the neighbourhood is not sufficient to provide a vibrant social life. There must be some social nodes introduced to the system in order to bring life to the area.

The design intervention looks at passageways as linear social places that connect the social nodes together. These linear passageways are inspired from historic Bazaars that were enclosed marketplaces within urban areas. Bazaars connected different social nodes of the city to each other.

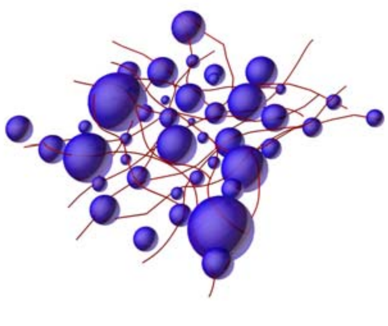
Thus, once a pedestrian is inside the social network of this project, they will not experience rigid walkways that serve merely as a means of access.



(Source: Picture taken January 17, 2011, analysed February 12, 2011, by S. Yekanians)
Figure 3.14 The spheres demonstrate social activities along the Pedestrian Routes

3.3.3. A need for a Resistive Pattern

The next step is to analyse the three-dimensional pattern in which these roads and social nodes will be laid out. If there is just one way to travel from one point to another, it does not, according to Hillier and Hanson (1988), provide social vibrancy for residents. In contrast, if there is more than one way - almost equal in length - to travel from one point to another, the resulting graph will demonstrate a distributed system. In other words, when analyzing patterns there is always a loop in the system. In any distributed system there is always a choice of paths when going from place to place. Therefore, the probability of seeing a random stranger increases dramatically in this system and results in the social vibrancy of the city.



(Source: 3D diagram, developed March 10, 2011, by S. Yekanians)
Figure 3.15 Distributed Pedestrian Circulation system

This diagram shows the relationship between the social nodes and connective routes in proposed urban areas. There is at least two ways to go from place to place that contributes significantly to making these areas become socially vibrant. This resistive pattern will be superimposed over the existing fast flow pattern of the city.

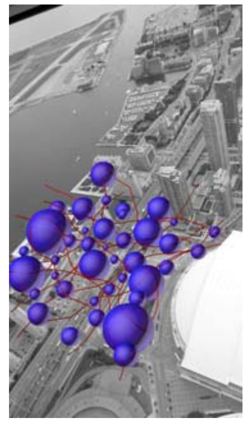
3.3.4. A need for both systems (resistive and fast flow) to work simultaneously

The three-dimensional distributed system of roads and social nodes is intended to raise social vibrancy in neighbourhoods that are affected by highways and streets that cut through the neighbourhoods. But this system needs to work with the city's fast flow system simultaneously.

(Source: http://www.flickr.com/photos/drewdoo/2804644822/
http://www.flickr.com/photos/sfazli/820988737/
analysed September 17, 2010, by S. Yekanians)
Figure 3.16 Comparing the Cross-Bronx Expressway with the Gardiner Eexpressway in Toronto

Figure 3.15 compares the Cross-BronxExpressway in New York City with the Gardiner Expressway in Toronto. Although the Gardiner Expressway is not as devastating to the city as the Cross-Bronx Expressway is, there are some similarities between the two. Both expressways seem to cause social divergence as they cut through urban neighbourhoods.

In order to mitigate this negative effect on neighbourhoods, complex and distributed layers of pedestrian activities should be superimposed upon the existing fast flow pattern of the city. In this case, pedestrians can walk over the Lakeshore Boulevard and Gardiner Expressway easily. Aside from that, the mixed use character of the proposed neighbourhood makes the area socially vibrant. This design also makes the area permeable to strangers and increases the safety of the neighbourhood (Jacobs, 1969; Hillier & Hanson, 1988).



(Source: http://www.flickr.com, analysed September 17, 2010, by S. Yekanians)
Figure 3.17 Proposed secondary distributed Pedestrian Circulation system at the South of Rogers Centre

3.3.5. A need to control the growth and expansion

The previous sections showed that when the resistive and distributed pattern are superimposed upon the existing non-resistive and fast flow pattern of the city, it addresses both aspects of social and vital needs of residents simultaneously. This section explains how this approach can also protect the city against expansion.

(Source: GIS software, 2007, analysed November 11, 2010, by S. Yekanians)
Figure 3.18 Satellite image South of Toronto- Planners constantly adding new roads and widening the old ones

According to Leopold Kohr (2007), lack of self-sufficient communities and higher speed of transportation in our current cities results in population growth and expansion into new territory. Kohr's theory of *Velocity Population* explains the relation between population growth, widening of the roads and cities' expansion:

> The further an integrated population spreads, the greater is the distance it must cover to attend its daily chores. And the greater the distance, the faster it must move. And the faster it moves, the larger becomes effective (or velocity) size (Kohr, 2007, p.204).

This is what is happening to our current cities. Planners constantly add new roads and widen the old ones in response to existing, and in anticipation of, ever growing demand for capacity. The fast flow system in fact encourages dispersal. This approach questions the superimposed outcome of the city that was discussed in previous sections. If we keep the fast flow system as the base layer, will not that still encourage dispersal? The fact is that thickening of the city will introduce mixed use and self-sufficient neighbourhoods over the fast flow system and encourage residents to use local roads to meet their daily needs. This will take an enormous load off the high speed routes to curtail their rate of expansion.

Kohr (2007) believes that instead of dispersing the central offices of a city over its diverse areas, we can turn the regions into self-sufficient communities, where every citizen finds all their daily needs in places that are central, but small and nearby. Therefore, he thinks that the answer is not in decentralization but polycentral regeneration which means centralization on a small scale.

(Source: GIS software, 2007, analysed November 11, 2010, by S. Yekanians)
Figure 3.19 Polycentral regeneration

Figures 3.18 and 3.19 show the application of Kohr's (2007) theory at the south portion of downtown Toronto. The green areas show polycentral regeneration ideas. The region that is at the south of Rogers Centre is the area that the earlier critiques examined. The red circulation pattern along with blue social nodes within the region illustrates some of the critiques and principles that were discussed earlier in this chapter.

(Source: GIS software, 2007, analysed November 11, 2010, by S. Yekanians)
Figure 3.20 Polycentral regeneration and regional self-sufficiency

The design intervention looks at *Pedestrian Passageways* as linear social places that connect social nodes together. These linear *Pedestrian Passageways* are inspired from historic Bazaars that were enclosed marketplaces within urban areas. Thus, once a pedestrian is inside the social network of this project, they will not experience rigid walkways that serve merely as a means of access. If there are multiple regions in the city like this example that are designed as self-sufficient nodes where citizens can meet all their needs, then people will experience a healthier social life within their communities (Kohr, 2007).

The photographs in this chapter that illustrate some of the critiques in Chapter 2 were taken from a site that eventually shaped the context of this project. Since the focus of this thesis was to formulate some methodologies that could be used in the generation of tomorrow's city forms, the site that was chosen for this project supports the examination of those ideas and theories within a limited physical environment that is already involved in the city's social life. In other words, the thesis does not provide an entire city design from scratch but creates a three-dimensional neighbourhood in the heart of Toronto.

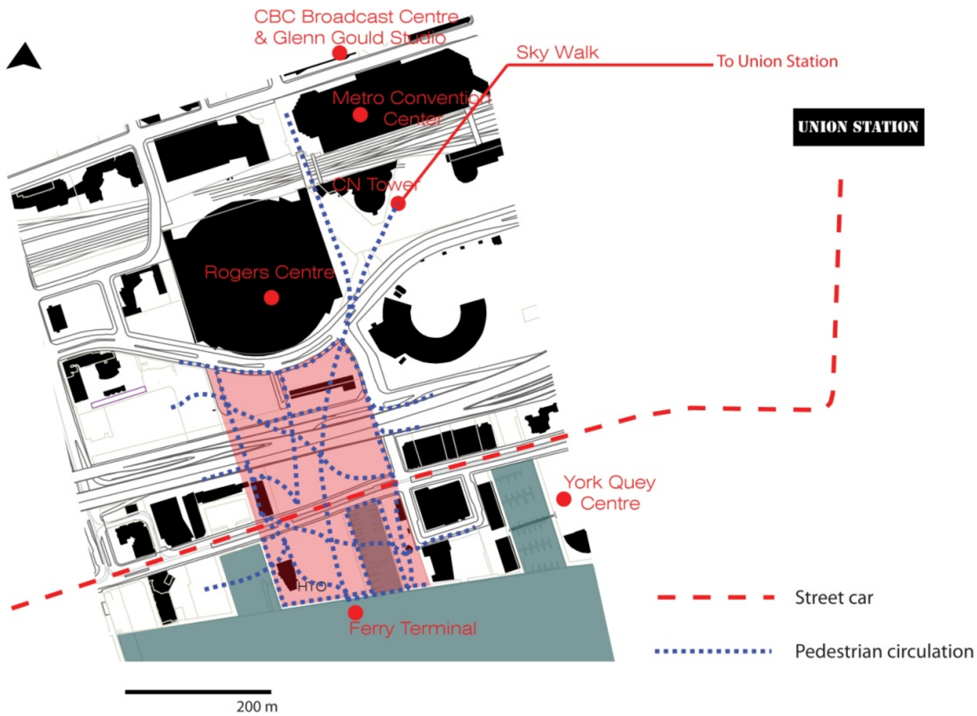
Chapter 4. Design

Overview

The photographs in Chapter 3 that show some of the critiques against *Modernism* in architecture are taken from the site in downtown Toronto that the design project of this thesis uses to test some of its ideas. This chapter begins by introducing that site and then explains the design methodology of the thesis. The design project starts with a conceptual design for the entire site, then it looks more closely at one portion of that site, and concludes by selecting one corner of that particular site to develop further. A diagram in Section 4.2 (Figure 4.05) shows the progression of these levels of design clearly. Section 4.3 of this chapter presents some of the preliminary models that were made as the first experiments of the design process. The design experiments with models occurred simultaneously with the research phase of the thesis work. Therefore, each design experiment with physical models manifests one aspect of the entire project and the design outcome develops step by step as the research provides further input during the process. The last section of this chapter describes the design process starting from the entire site and developing one part of the site as the design develops further. This method continues until the design develops in more detail at one portion of the site.

4.1. Project Context

The project site chosen for the exploration of the ideas of this thesis is south of the Rogers Centre in downtown Toronto. It extends from Bremner Boulevard on the north to Lake Ontario on the south. The Gardiner Expressway and Lakeshore Boulevard cross the site and almost completely block pedestrian flow, except for uninviting crossings at vehicle-dominated intersections. Although the site is extremely close to the Rogers Centre and the CN Tower, the site exemplifies some of the deadness that critics find in *Modernism* (see Sections 3.3.1 and 3.3.2). There are no shops or buildings along the sidewalks. There are two large parking lots within the site that not only do not provide any urban amenities or activities, they also block access to activities in adjacent neighbourhoods. These characteristics make the site an ideal focus for the thesis design project. The goal of this thesis is not to provide a definitive or complete solution to any particular problem of the site, but rather to study strategies for developing and enhancing the social vibrancy of urban areas.



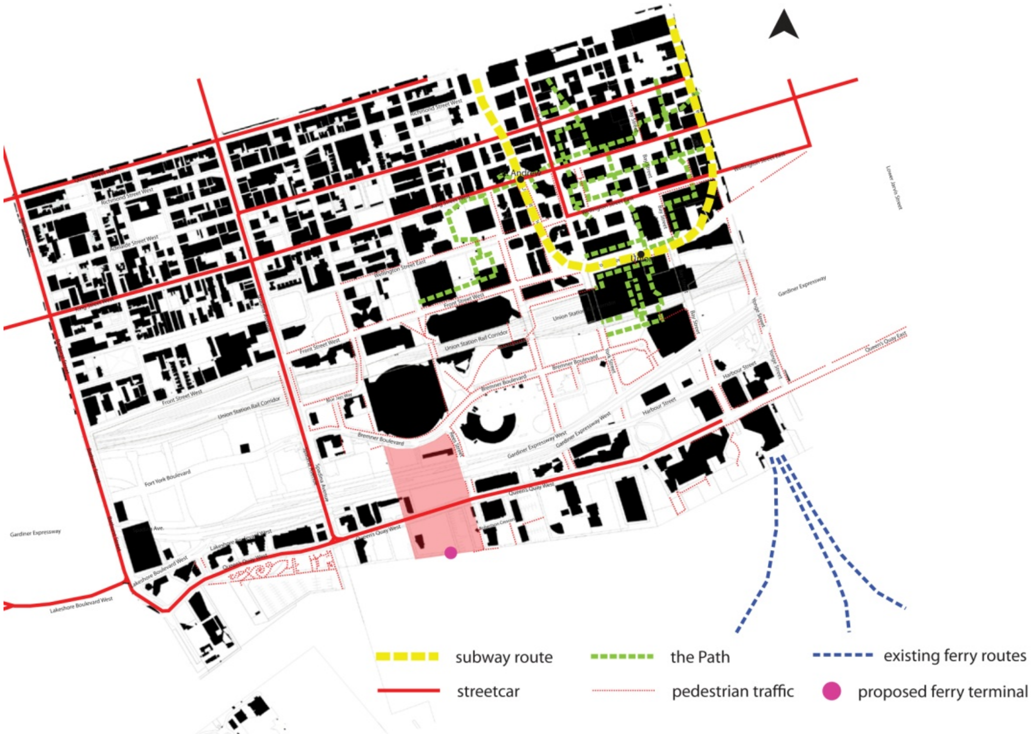
(Source: GIS software, 2007, analysed November 27, 2010, by S. Yekanians)
Figure 4.00 Site analysis- proposed Pedestrian Circulation Routes

The site is located at the south end of Toronto's entertainment district. There is a new neighbourhood development project west of the Rogers Centre. In addition, an existing pedestrian skywalk connects the Rogers Centre to Union Station. Along the water's edge to the east is a popular cultural area anchored by the York Quay Centre and extending westward through the site in a diffuse manner. Perhaps because of its proximity to the entertainment district, the north portion of the Rogers Centre experiences a vibrant social life. But the site for this project – despite some seasonal harbour related activities - lacks pedestrian interaction and social vibrancy.

As a result, there was an opportunity to introduce a new ferry route from this site to the Toronto Islands. The introduction of a new terminal south of the site will draw pedestrians from the Skywalk and CN Tower to the Toronto Islands, will make the area permeable to passengers and thus make it part of the vibrant social network of the city. The skywalk-ferry terminal contour will shape an important aspect of populating the neighbourhood. Furthermore, it will provide a 'loop' with the other existing terminal and will make the area socially intelligible.

(Source: GIS software, 2007, analysed November 27, 2010, by S. Yekanians)
Figure 4.01 Existing ferry routes

(Source: GIS software, 2007, analysed November 27, 2010, by S. Yekanians)
Figure 4.02 Proposed ferry terminal



(Source: GIS software, 2007, analysed November 27, 2010, by S. Yekanians)
Figure 4.03 Public transportation systems

(Source: GIS software, 2007, analysed November 27, 2010, by S. Yekanians)
Figure 4.04 Major streets and highways

4.2. Design Methodology

The design methodology of this thesis follows the logic of fractals in order to maintain the hypothesis at each scale of design. This means that some important aspect of a design rule (quite abstractly applied in some cases) that governs the design at the larger scale will also do so in smaller scales. This approach helps to define the materiality of the city as an analog to a living organism.

First, in a larger scale, it looks at the entire area south of the Rogers Centre (Figure 4.05, Phase 1). At this scale, a new ferry terminal is introduced at the south end of the site. The goal is to introduce a social 'magnet' to draw people from the North (downtown, entertainment district), through the neighbourhood and towards Harbour Front and the ferry terminal, thereby facilitating the social vibrancy of the whole area. Aside from the ferry terminal, other social magnets also are introduced in the site that that are connected to each other within a distributed *Pedestrian Roads*. The weight of these social magnets is measured by the importance and the size of these node within the scale of study. This process starts with utilizing some abstract architectural language to formalize the research ideas into the design project.

Secondly, it focuses on the south-west block of the site and develops that further (Figure 4.05, Phase 2). Lastly, the design project looks more closely at the north-east corner of the selected block (Figure 4.05, Phase 3) with attention to spatial programming, accessibility and three-dimensional zoning. The abstract architectural formal language disappears gradually until a conceptual three-dimensional zoning of that area is complete. The design process is a fusion of iterative processes between spatial programming and form making of the thickened city.

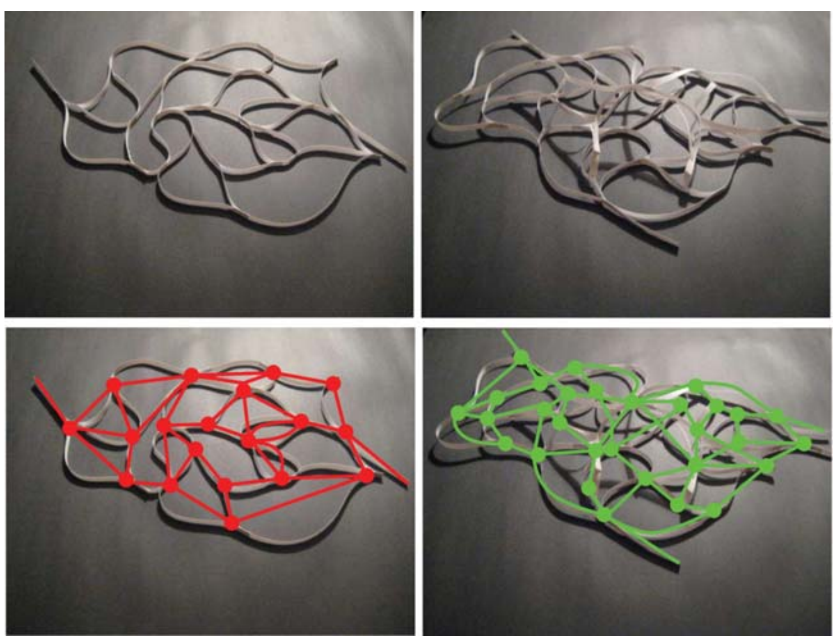
The design project aims to propose a model that will provide some principles for programmers to generate algorithms for the design of our future cities. This is the first step of modeling process (see Section 2.2.5).The main intention of the design project is to propose a sample application of the principles identified in the previous chapters to an urban context.

(Source: GIS software, 2007, analysed December 15, 2010, by S. Yekanians)
Figure 4.05 Design areas

4.3. Design Exercises

The initial stage of the design investigation introduced an abstract formal language through some precedents in order to analyse and inform the research methodology and conceptual development. The model below, left (Fig. 4.06) shows connections in a distributed/semi-lattice mesh. In this mesh, there are at least two ways to go from one point to another. Therefore, the probability of seeing a random stranger increases. The model below, right (Fig. 4.06) shows that these routes have grown three-dimensionally. By introducing new routes, there is more complexity to the mesh and there are more options for pedestrians to take as they walk through the mesh. Therefore, the probability of seeing a random stranger increases dramatically when other nodes and lines are defined outside the surface area. This experiment –although very abstract- was evidence that thickening of the city was definitely worth investigating in more depth.

There is slight connection between this exercise and the social wasps' movement observation (see Section 2.2.4.2). The hollow sphere around the blocks of the nest provides a space that gives endless travel options to the wasps. The fact that wasps can move three-dimensionally in space is the reason that they have more options to take as they travel. This exercise shows that moving three-dimensionally in space can increase a quality that is appreciated for pedestrians' social interactions on a two-dimensional surface.

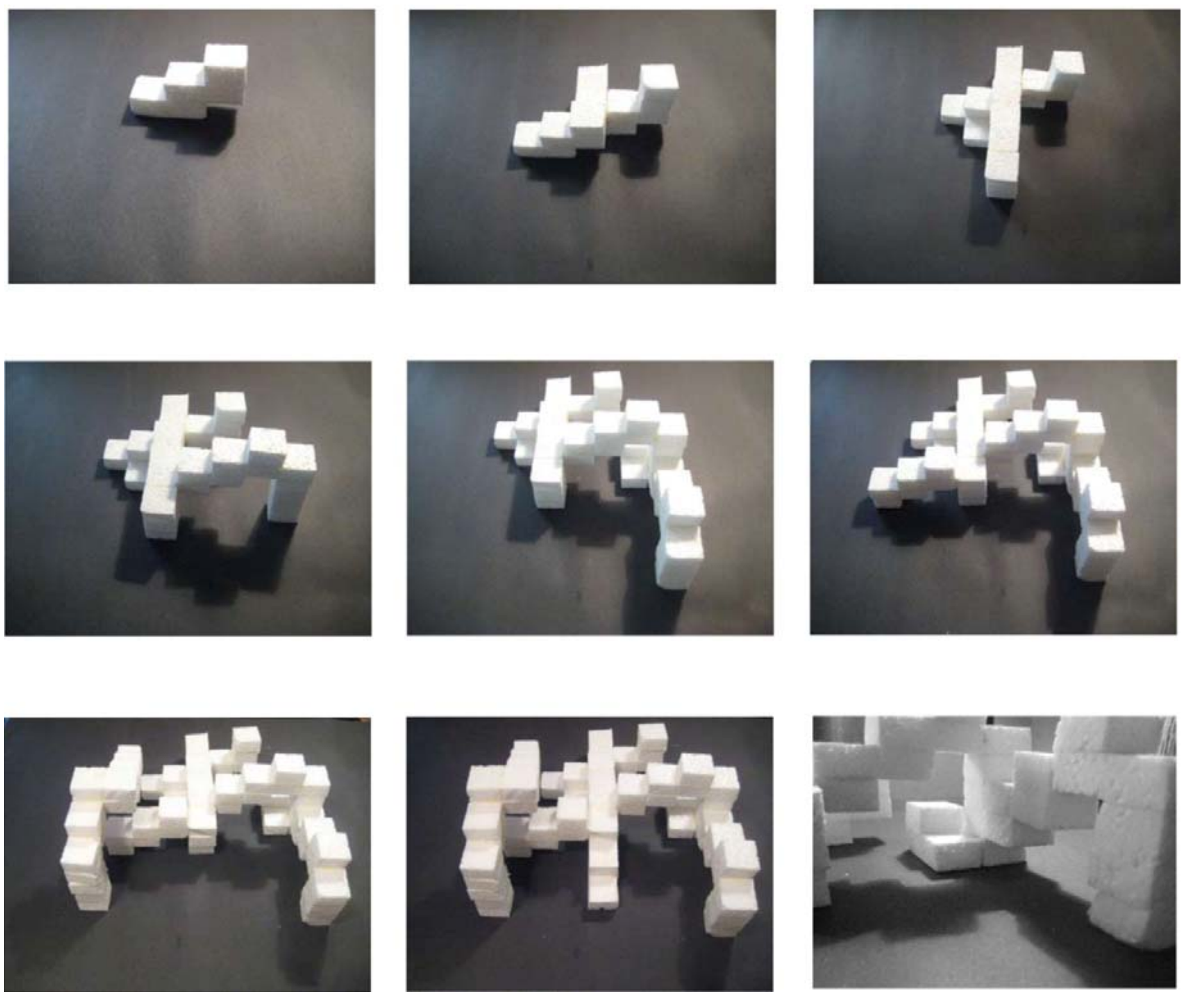


(Source: Physical model, developed August 12, 2010, by S. Yekanians)

Figure 4.06 Distributed circulation systems in two-dimensional and three-dimensional worlds

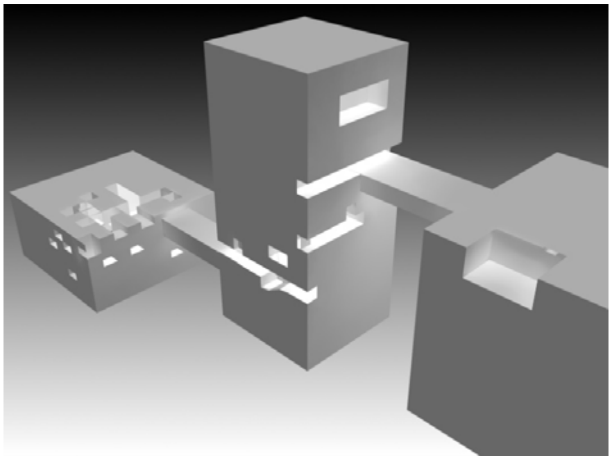
The next idea was to look at buildings as a means to draw pedestrians upward and have them move in a three-dimensional way. The purpose was to think about buildings and roads as one entity. At this stage a pixelated mass (see Section 2.2.5, cellular growth) was developed to examine this preliminary scheme. The model below (Fig. 4.07) shows the possibility of using building masses as a means of *Pedestrian Circulation*.

However, this model did not totally fulfill the goal of having buildings and roads as one entity, since the leftover areas on ground level were not explicitly designed. This experiment illustrated the potential benefits of pixelated massing as an abstract architectural formal language to develop the design project.



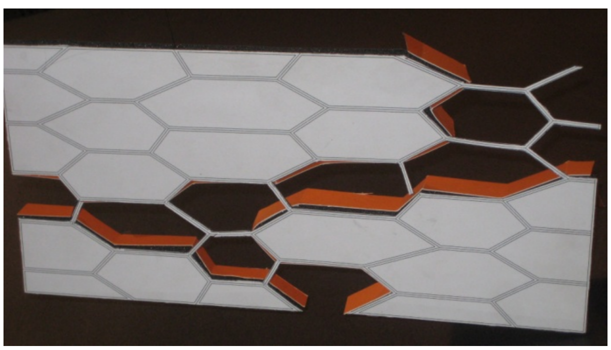
(Source: Physical model, developed September 20, 2010, by S. Yekanians)

Figure 4.07 Early investigations in looking at buildings and roads as one entity



The model in Figure 4.08 represents a study of the potential for developing the previous concept into an occupiable proposal. The idea is to use the built form and introduce three-dimensional *Pedestrian Circulation* systems. In this case, pedestrians can walk over the streets, like the way social wasps travel over the nests' blocks. The voids in built forms represent public places with visual connection to other parts of the city.

(Source: Digital model, developed September 14, 2010, by S. Yekanians)
Figure 4.08 Integration of public and private places



The idea of drawing pedestrians upward into the built form created the next design exercise. The pixelated facade in the model shown in Figure 4.09 model allows pedestrians to walk upward into the built form, providing them with a potential shortcut to their destination. .

(Source: Physical model, developed October 18, 2010, by S. Yekanians)
Figure 4.09 Pixelated facade physical model

This model is the digital representation of the pixelated facade. The disadvantage of this system is that the facade surface is considered separately from the rest of the building. Although hexagons provide a flexible pattern to move on, they are also effective on the outside surface of the built form.

(Source: Digital model, developed August 14, 2010, by S. Yekanians)
Figure 4.Figure 4.10 Pixelated facade digital model

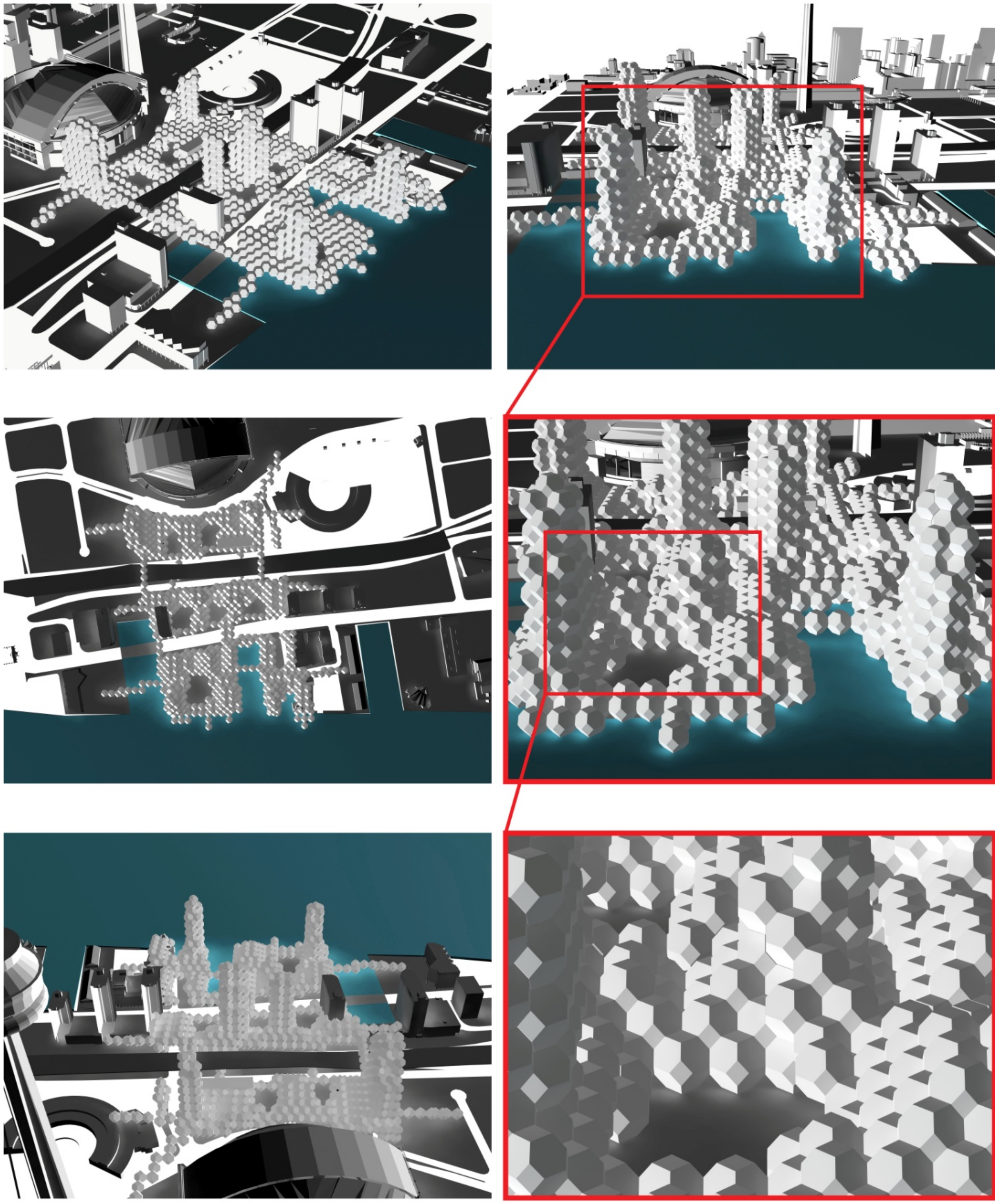
Research was conducted in 'packing geometry' as a design strategy for replacing pixels with other modules that would give more flexibility to the entire mass growth. The pixel units that were selected for this stage were polyhedrons. Unlike the cubic pixels that would grow in just three dimensions (x,y,z), the introduction of polyhedrons gave the mass more flexibility to grow in more than three directions. In packing geometry, there is no void created between the modules and they literally pack the entire mass. This realisation paved the way to look at the buildings and the circulation system within the mass as one entity. Thus, some pixels would be selected from the mass simply to serve as circulation paths within the entire built form.

(Source: Digital model, developed November 14, 2010, by S. Yekanians)
Figure 4.11 Packing geometry—polyhedrons

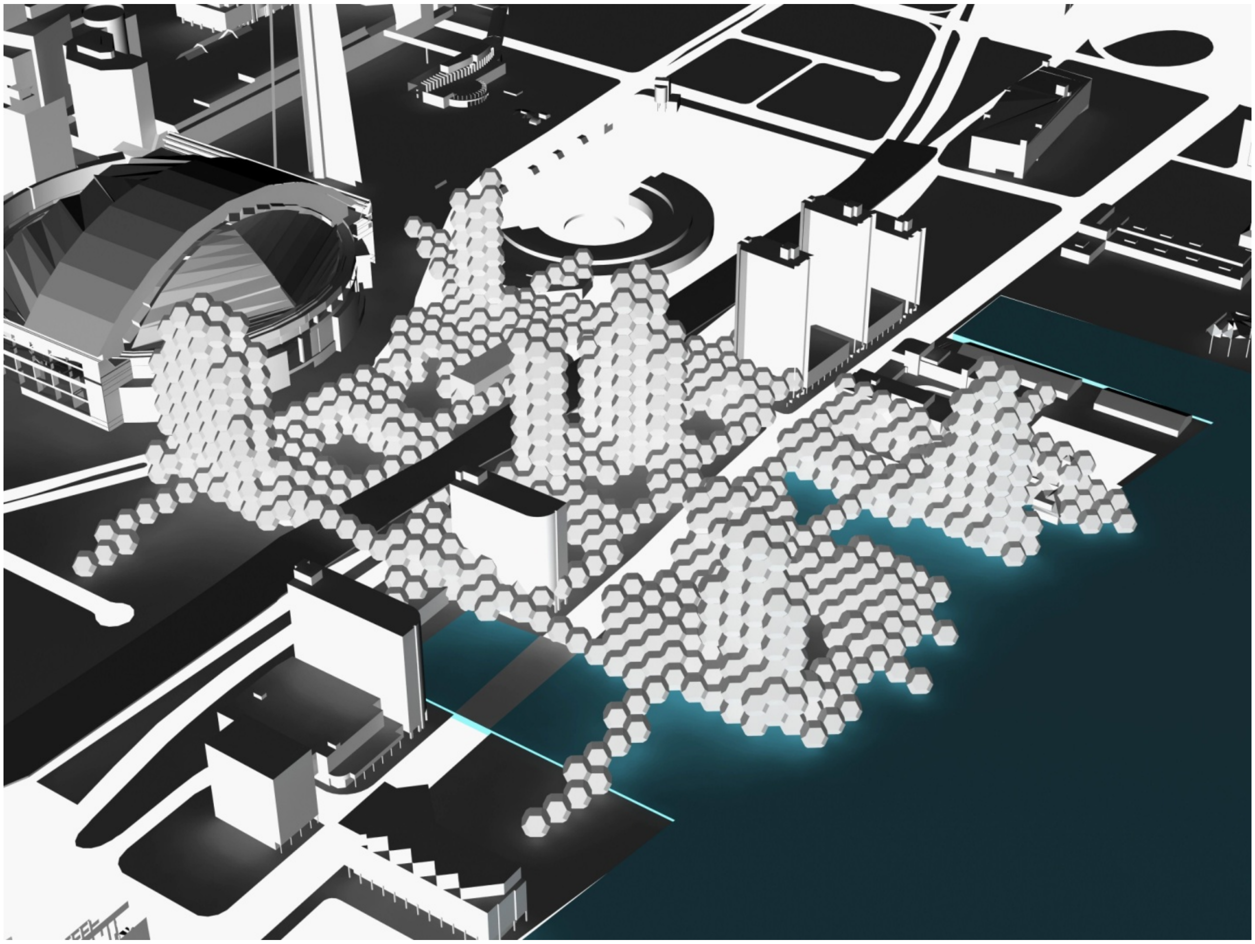
4.4. Design Process

A mixed-use neighbourhood development is one of the programmatic goals of the design project. Therefore, equal attention was paid to residential, educational, and commercial uses as well as the circulation patterns (Alexander, 1966; Tavassoli, 2002). This section will explain the step-by-step approach that was followed in the design process. An abstract architectural formal language was used to advance the development of the thesis using an iterative process that had been designed in a variety of mediums.

This section explains step-by-step completion of the design project. First it looks at the entire site and develops the conceptual ideas. Then it looks more closely to the south-west block. Lastly, it designs the north-east corner of this selected block. The design process and the proper application of research analysis outcomes in the design has more significance than the final image of design in this thesis.



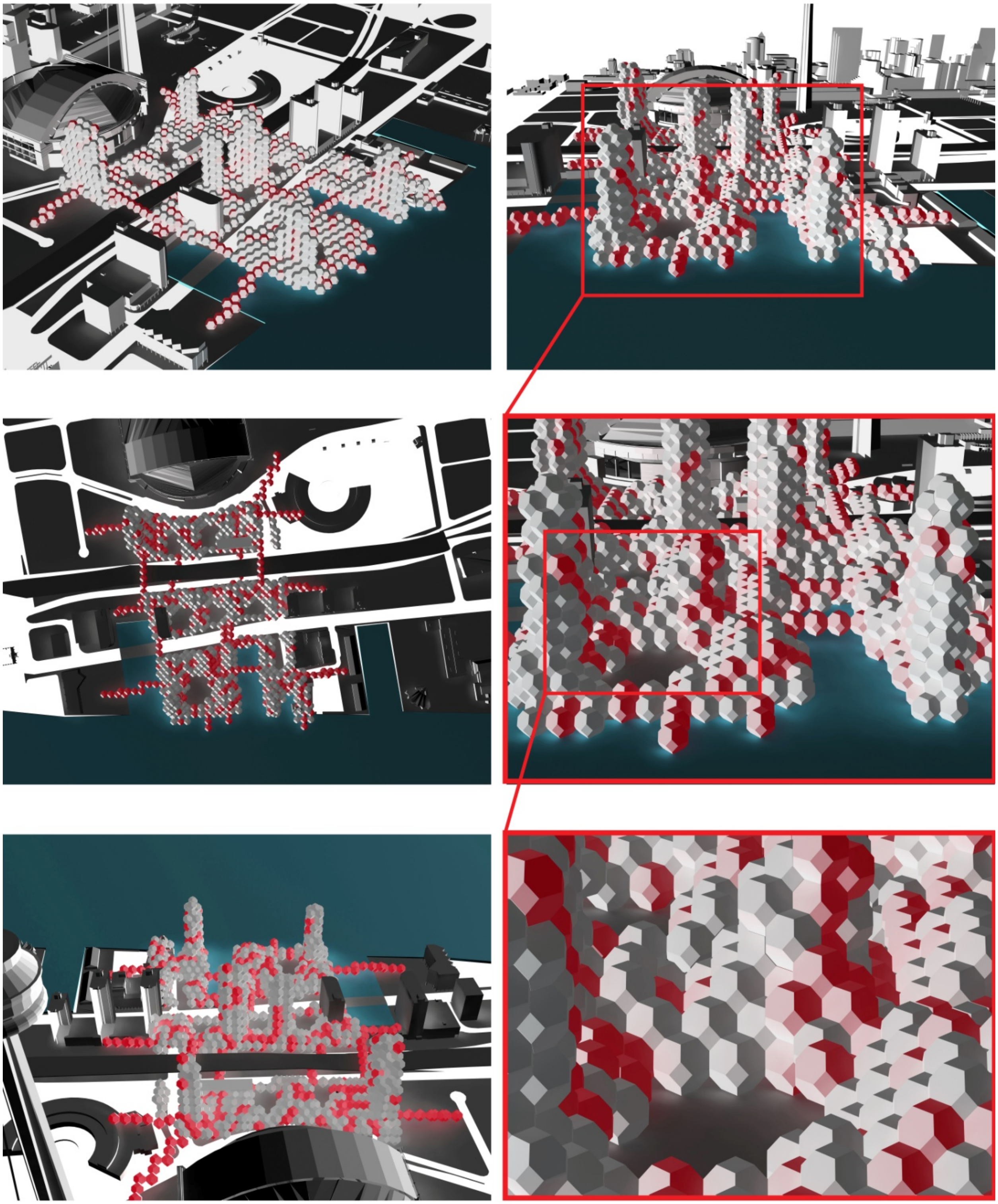
(Source: Digital model, developed November 30, 2010, by S. Yekanians)
Figure 4.12 Filling the site with polyhedrons



(Source: Digital model, developed November 30, 2010, by S. Yekanians)

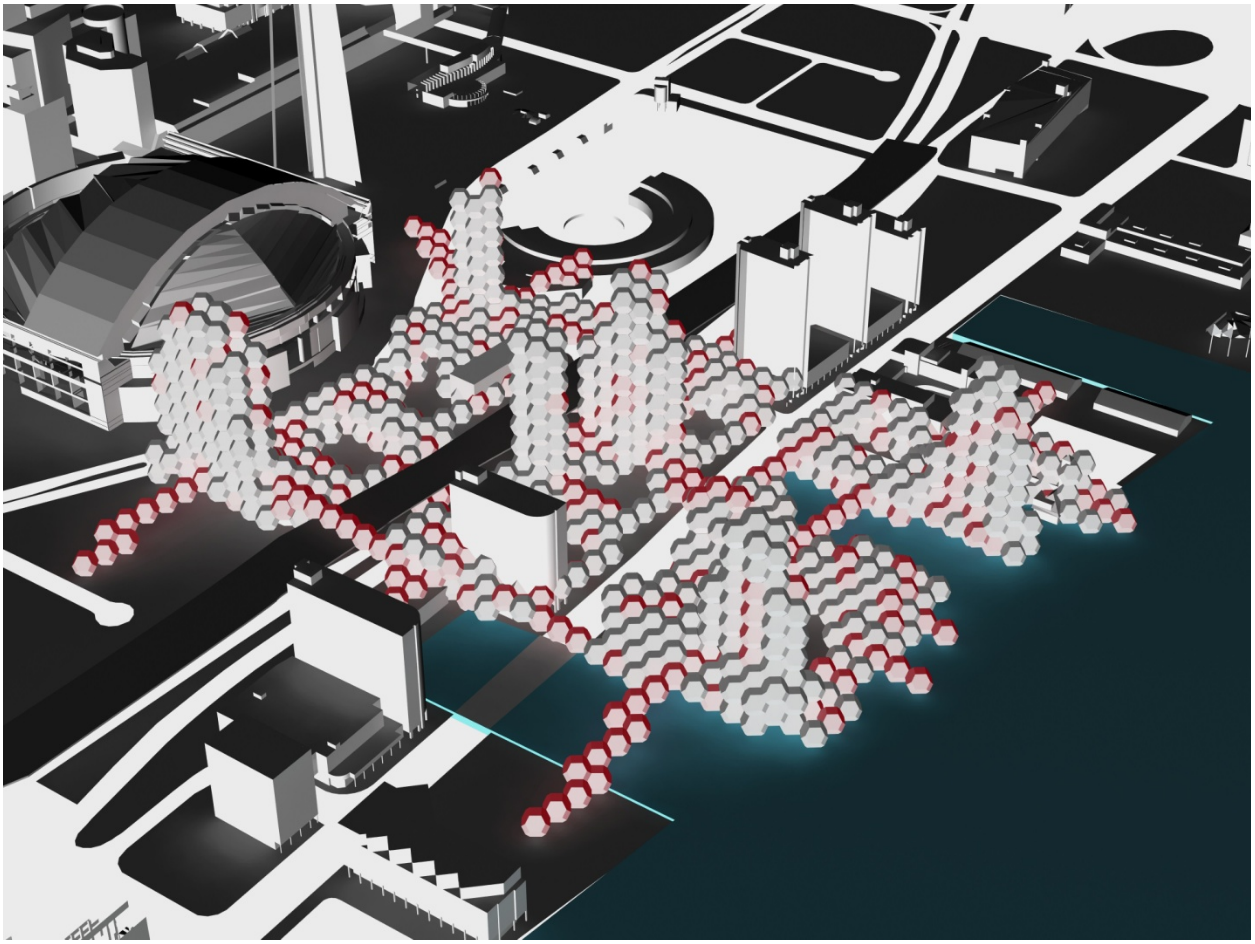
Figure 4.13 Filling the site with polyhedrons

To experiment with the design process of the site, the polyhedron modules initially filled the entire site with specific attention given to the general massing, shadow analysis, exposure to sunlight and providing relief spaces within the mass as shown in Figures 4.12 and 4.13. Although at this stage there was no significant attention given to the circulation pattern, there were some extensions that would grow over and under Gardiner Expressway or overhang the massing and connecting to the existing infrastructure of the city. The purpose of filling the whole site with the same modules was that later on some of these modules would be selected as circulation paths and public places. The advantage of this method was that the circulation pattern and the solid volumes could be designed at the same time, as one entity. This method prevented the solid elements from being islands and the left over parts, by default, becoming the circulation paths. The scale of these cells was chosen to be close to an average residential apartment, which made the sunlight and shadow analysis more clear. This design stage gave a resolution of the general massing of the proposed city.



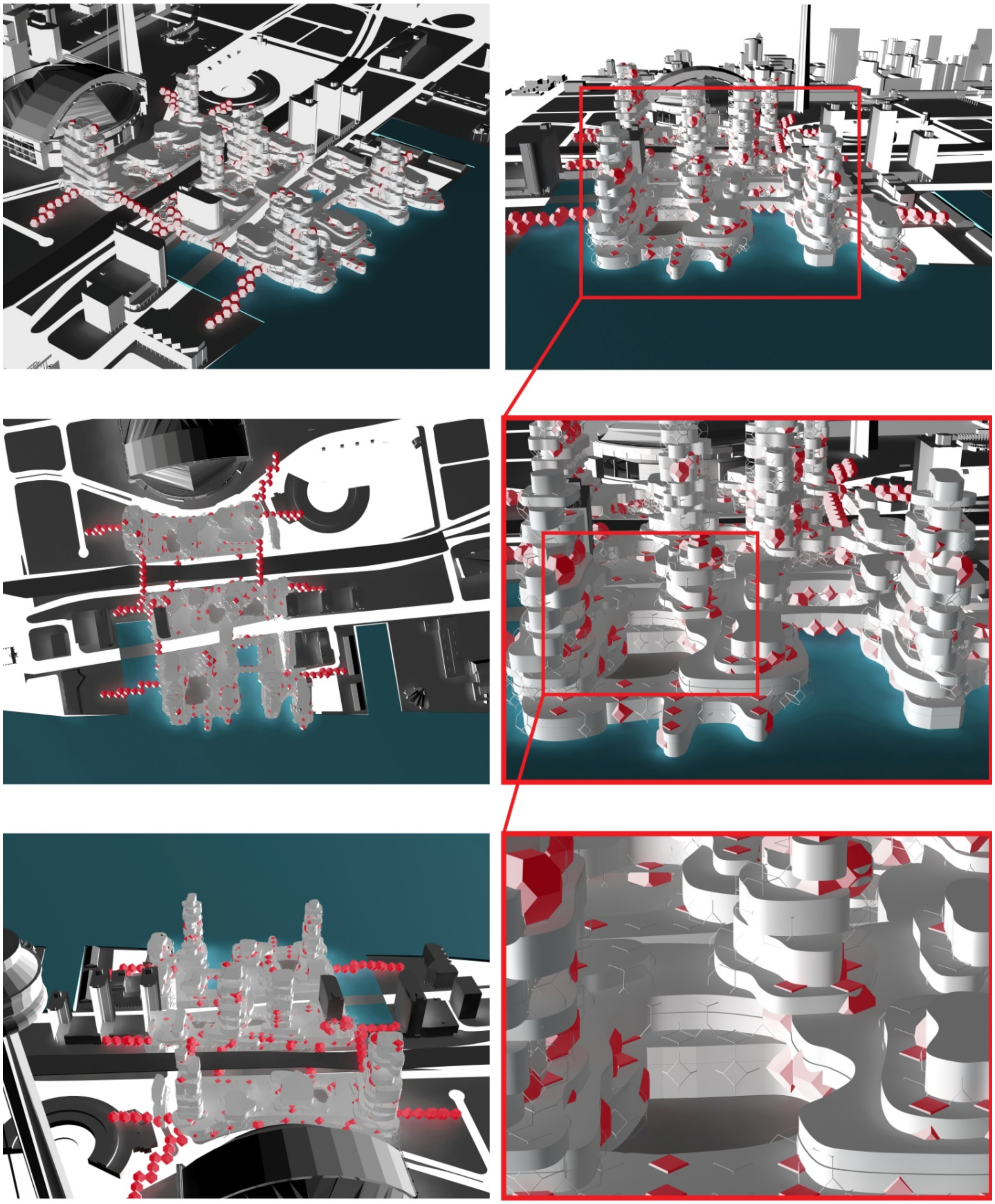
(Source: Digital model, developed December 07, 2010, by S. Yekanians)

Figure 4.14 Identifying a social infrastructure within the mass

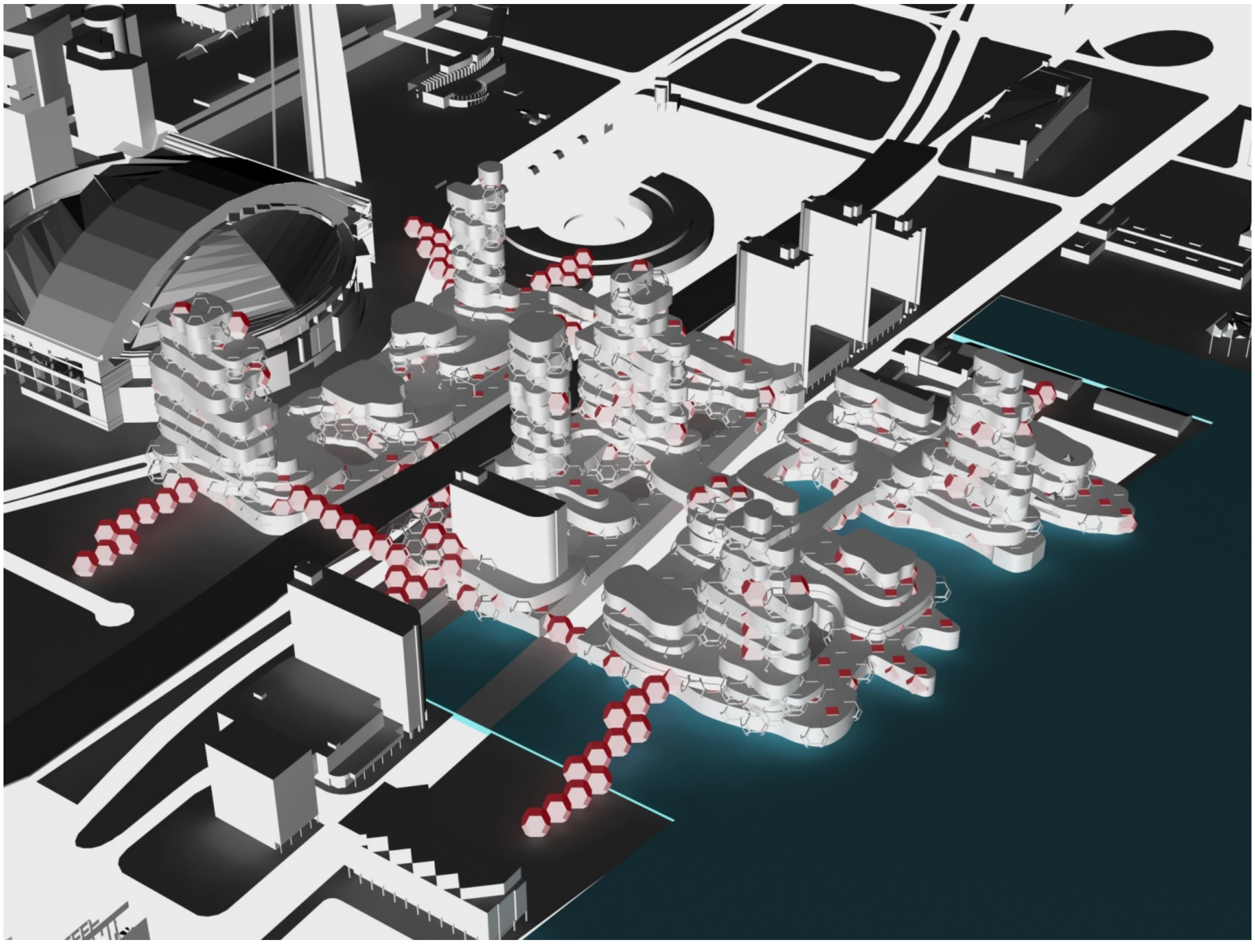


(Source: Digital model, developed December 07, 2010, by S. Yekanians)
Figure 4.15 Identifying a social infrastructure within the mass

The next step was to identify circulation routes as well as social areas within this mass as shown in Figures 4.14 and 4.15. Therefore, some of the modules were identified with red color. In this approach, the circulation area was not the leftover pieces on the ground level after designing the built masses. It was an inevitable part of the general mass that would penetrate all over the area and create a three-dimensional distributed system of circulation pattern for pedestrians (see Figure 4.06). All the red modules were connected to each other. There were areas with higher concentrations of red modules that represented the social nodes or stations. There were also some linear social areas that had the potential to re-invent the functionality of Bazaars in urban communities. The linear social places connected social nodes together and formed a three-dimensional distributed mesh representing the entire city's social network. Hence, in order to go from one point to another, there were at least two similar ways and this increased the probability of seeing a random stranger in the neighbourhood.



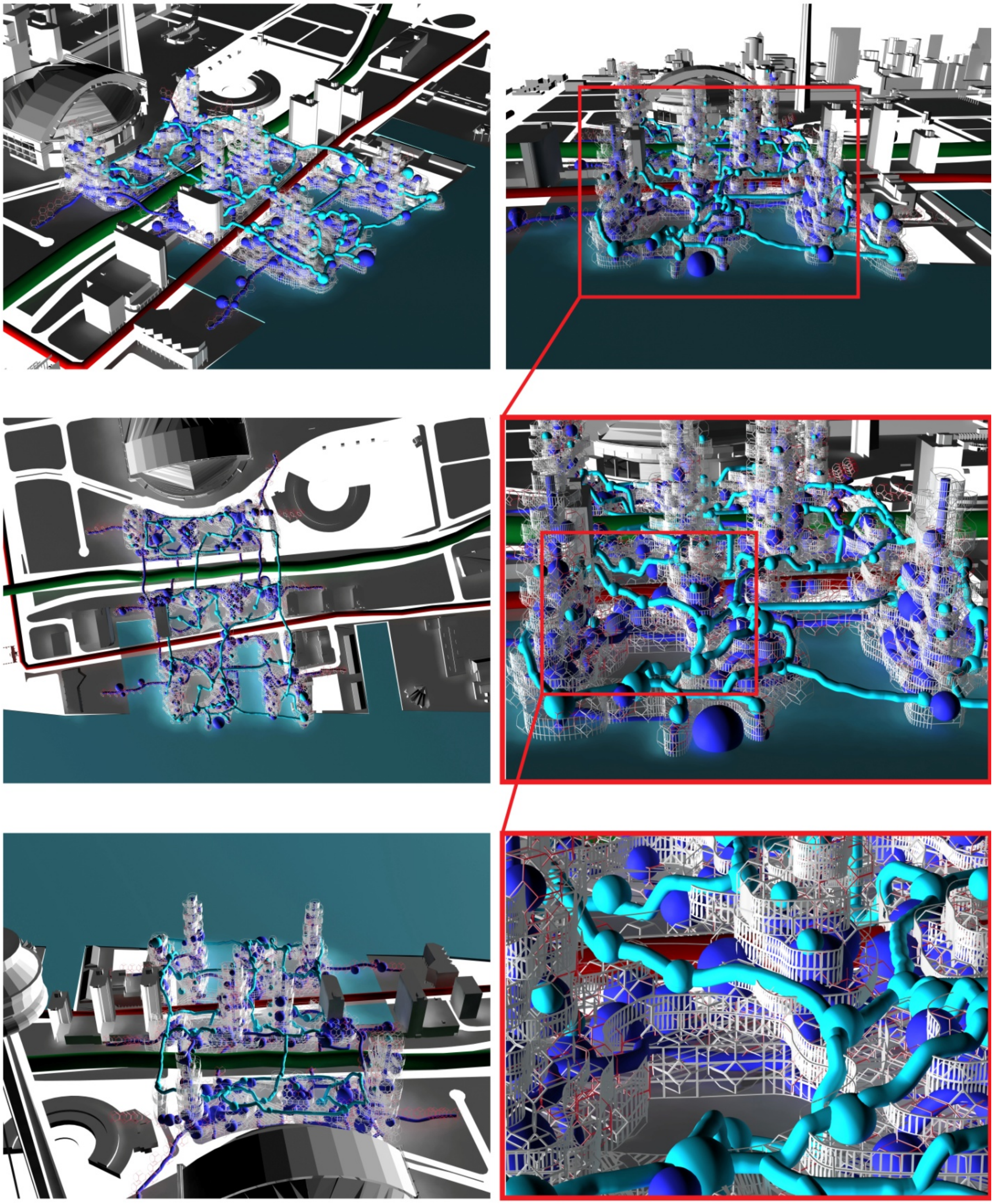
(Source: Digital model, developed December 16, 2010, by S. Yekanians)
Figure 4.16 Stacking layers



(Source: Digital model, developed December 16, 2010, by S. Yekanians)
Figure 4.17 Stacking layers

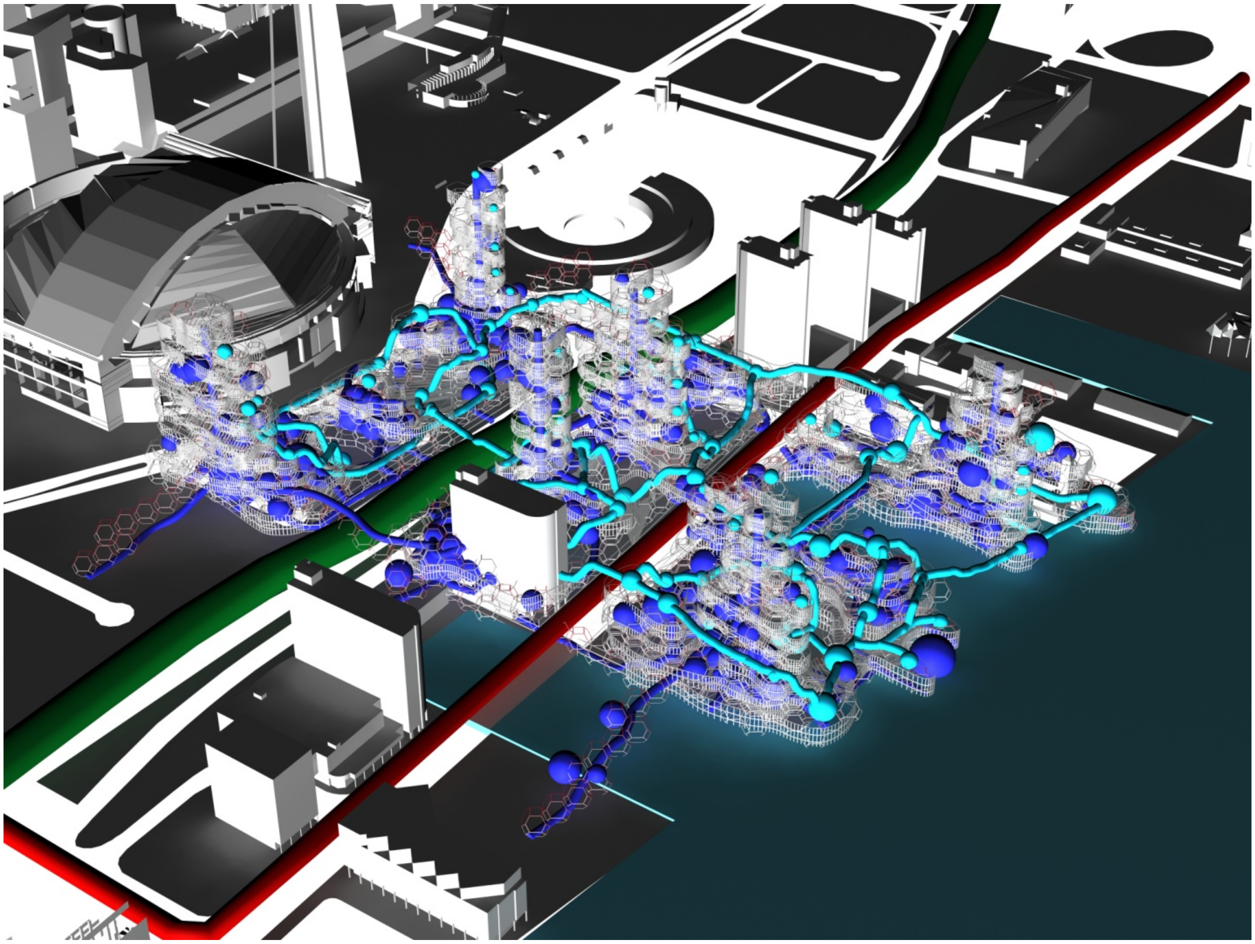
The next stage looked at the general massing again. At this stage several layers were stacked over each other to give a conceptual overview of the general massing (see Figures 4.16 and 4.17). The purpose was to get a clear reading of the heights at different parts of the neighbourhood as well as the depth of relief spaces. Each layer represented one story of a built form. Vertically, for every two polyhedrons, there were five layers covering the mass.

This phase clearly showed that the final moulding of the neighbourhood mass needed to be designed in sections. Although this stage of the design was done to evaluate the heights of different parts of the design, it also revealed that the stepped outlook of the mass appeared as a barrier for pedestrians, impeding their ability to move smoothly over and through the mass. Since pedestrians would move upward into the mass, there must be a proper gradient to provide a comfortable passage for them.



(Source: Digital model, developed December 27, 2010, by S. Yekanians)

Figure 4.18 Introduction of tubes and spheres to represent urban social areas



(Source: Digital model, developed December 27, 2010, by S. Yekanians)
Figure 4.19 Introduction of tubes and spheres to represent urban social areas

Then, a series of tubes and spheres were introduced to present a more tangible resolution of the social areas (see Figures 4.18 and 4.19). The tubes presented an abstract manifestation of pedestrian flow within the site and the spheres represent social nodes or stations. The red modules were replaced by a new 'tubes and spheres' system. The rules that govern this distribution depend on the location of each activity, the proximity to other activities and the existence of a particular activity within a certain distance of each node in the neighbourhood. As this was a back and forth process within programming and form making, the distribution of spheres and tubes was expected to change at each level of the design.

Following the introduction of a three-dimensional circulation system within enclosed areas of the mass (in dark blue) there was another circulation network with distributed properties introduced on the surface level of the general massing (in light blue). These two meshes combined with each other in some areas. The introduction of a new mesh on surface areas gave the opportunity to have an entirely exposed social circulation system that was still a distributed pattern and could function independently when needed.

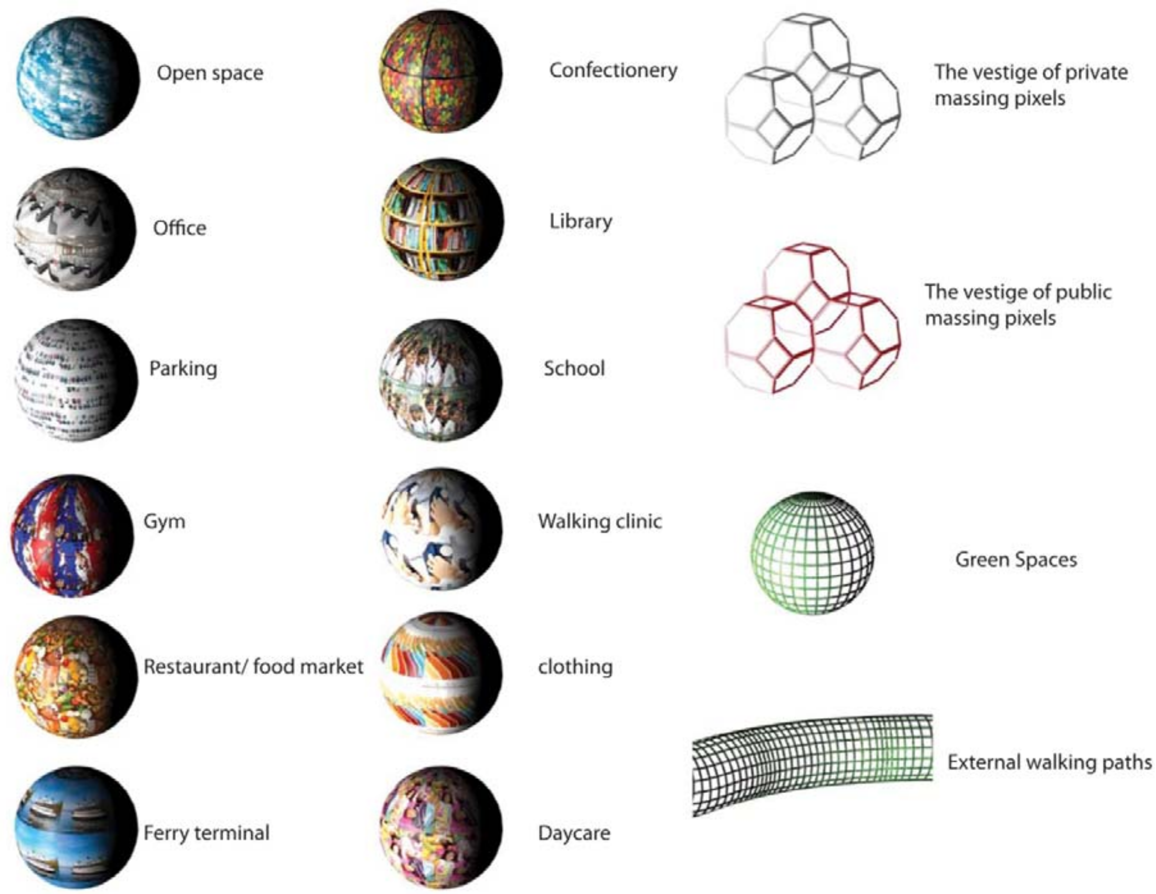
The next step was to give characteristic properties to the social nodes (spheres). Thus, they were graphically labelled with social programs (Figure 4.20) such as elementary schools, libraries, stores, gyms, parking areas, etc.

This experiment illustrated the shift away from the traditional two-dimensional city zoning planning. Here, the city activities were conceived of as operating in a three-dimensional world and were represented by spheres. These activities were organized as a semi-lattice system, represented by other spherical zones or linear social places. On the other hand, our current city zoning is primarily focused on a plan and interaction between activities is only through the ground plane and largely depends upon their own initiative.

In some cases, the scales of these spheres represent the importance of the social activities; in others they represent an approximate physical scale of that activity. For example, the ferry terminal is represented in a larger scale than the rest of the social nodes. This scale indicated the importance of the terminal in the neighbourhood. Given the fact that this is the first stage of the conceptual three-dimensional 'zoning' design it is not required to provide a concrete resolution of the final image of the designed artefact. The fluidity of scales and the form of these spheres at this stage of design proved to be very powerful, with the implicit understanding that they would change during the next design phases.

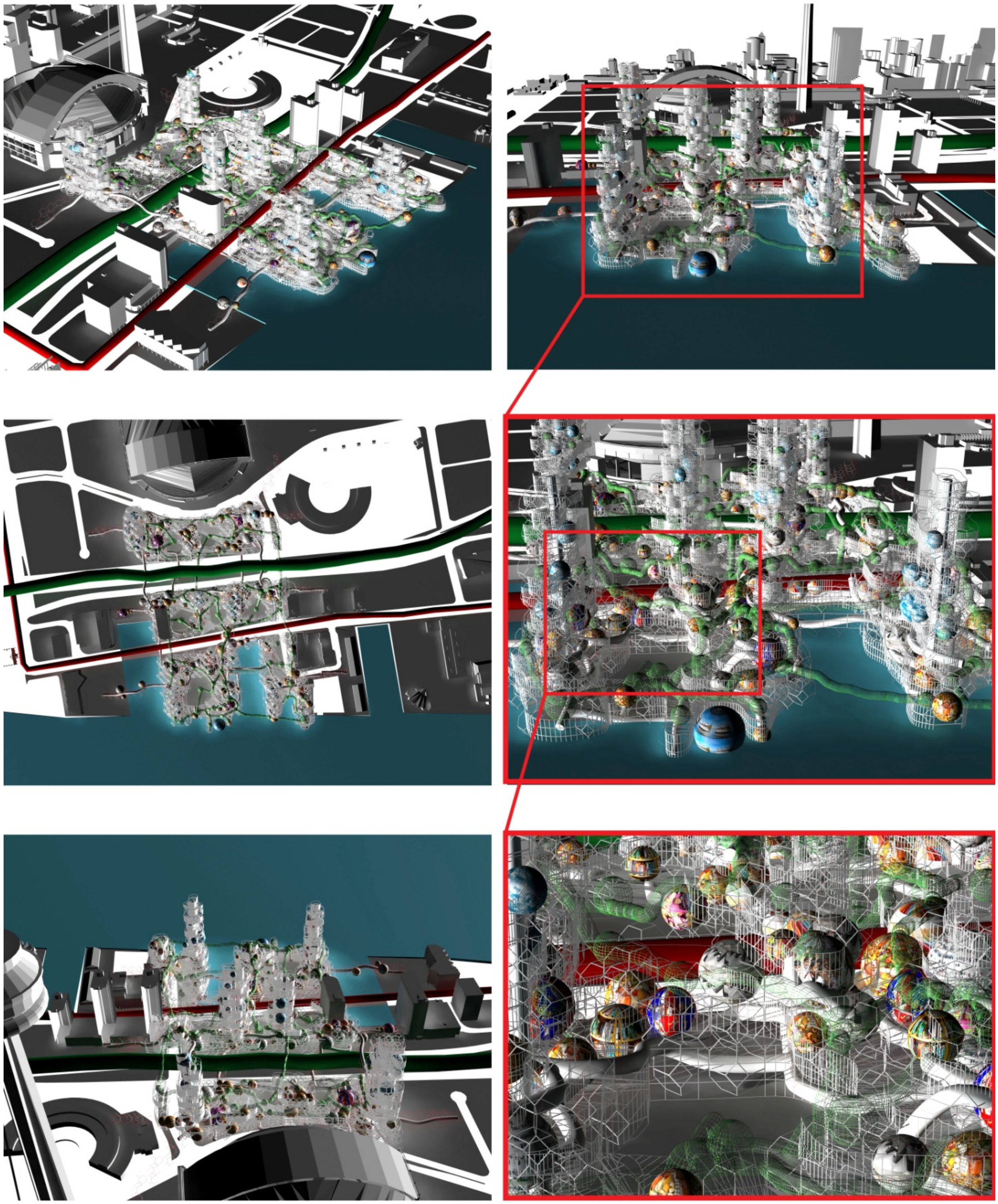
The majority of activities that are hidden inside the thick mass of the city are the ones that do not need sunlight. Parking spaces, movie theatres, utilities, and big box stores are among those activities. In regards to the latter activity, there are two ways to arrange the stores inside the mass. First, the large size of that store can be maintained and it can operate as a big box store (but with a very constrained presence on the surface). This will still encourage the big businesses to participate in the city's economy. The second option is to divide these stores into several local shops that operate independently inside and outside of the mass. This will encourage local businesses to develop within neighbourhoods and will make the areas socially vibrant.

The social nodes that are on the surface of the city are the ones that need sunlight for their activities. These include elementary schools, offices, some local restaurants, coffee shops, local libraries and so on. These places add to the social vibrancy of the neighbourhood in the surface areas by creating visual connections to different activities of the neighbourhood.

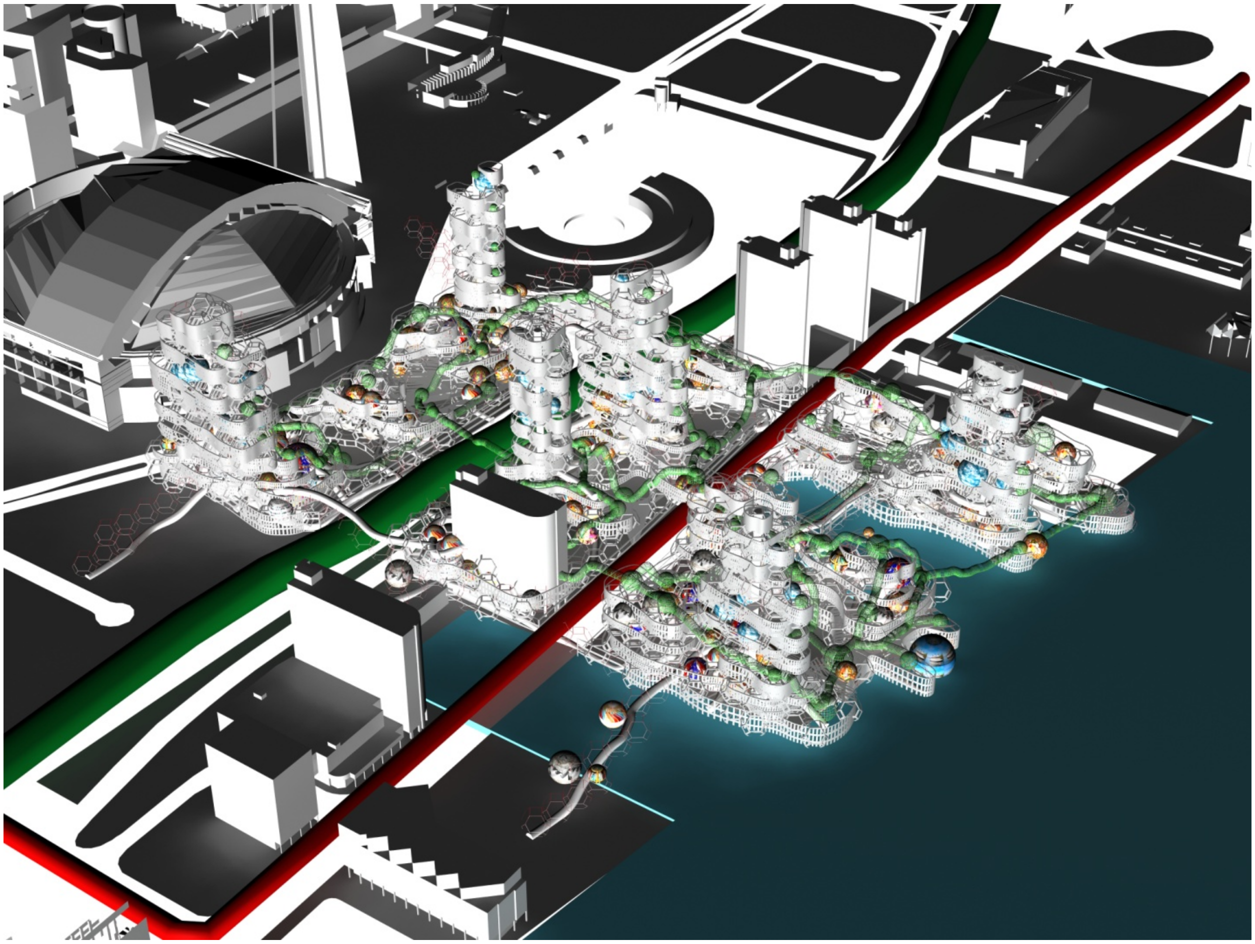


(Source: Legend, developed January 07, 2011, by S. Yekanians)
Figure 4.20 Identifying an abstract architectural formal language to illustrate three-dimensional zonings

Figure 4.20 shows the abstract architectural formal language that is used to illustrate some of the thesis ideas. At the top right, the polyhedrons represent the vestige of private and public places from the previous stages of design. At the lower right, the external *Pedestrian Circulation Paths* and the open public spaces are shown in green wireframe spheres and tubes. Open public spaces include the neighbourhood parks, neighbourhood squares, and other public areas. At the left side, the social nodes or stations are shown with distorted images of an activity on them. The sphere at the top left with an image of the sky represents semi-private open spaces between apartment units.



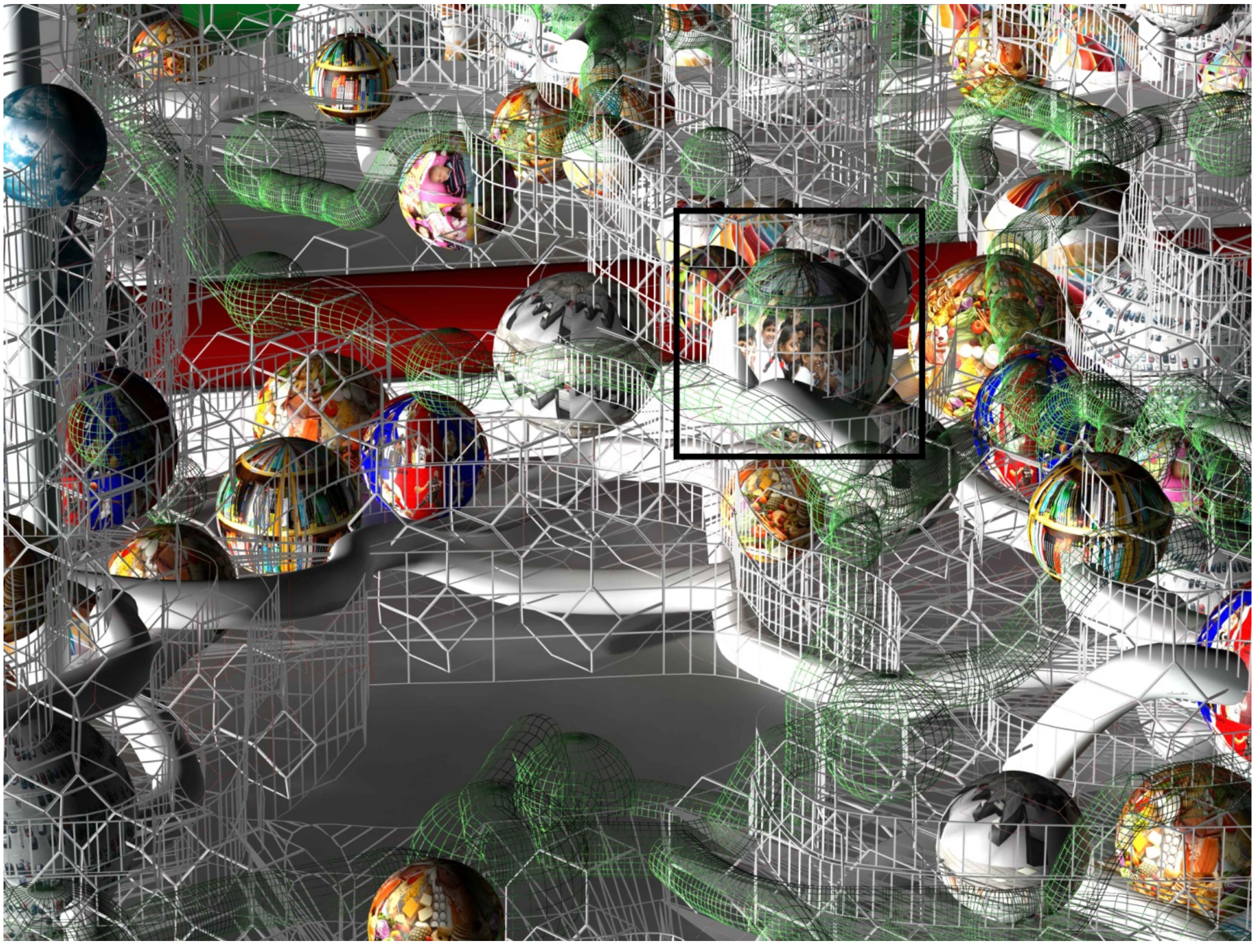
(Source: Digital model, developed January 17, 2011, by S. Yekanians)
Figure 4.21 Assigning programmatic functions to social nodes



(Source: Digital model, developed January 17, 2011, by S. Yekanians)
Figure 4.22 Assigning programmatic functions to social nodes

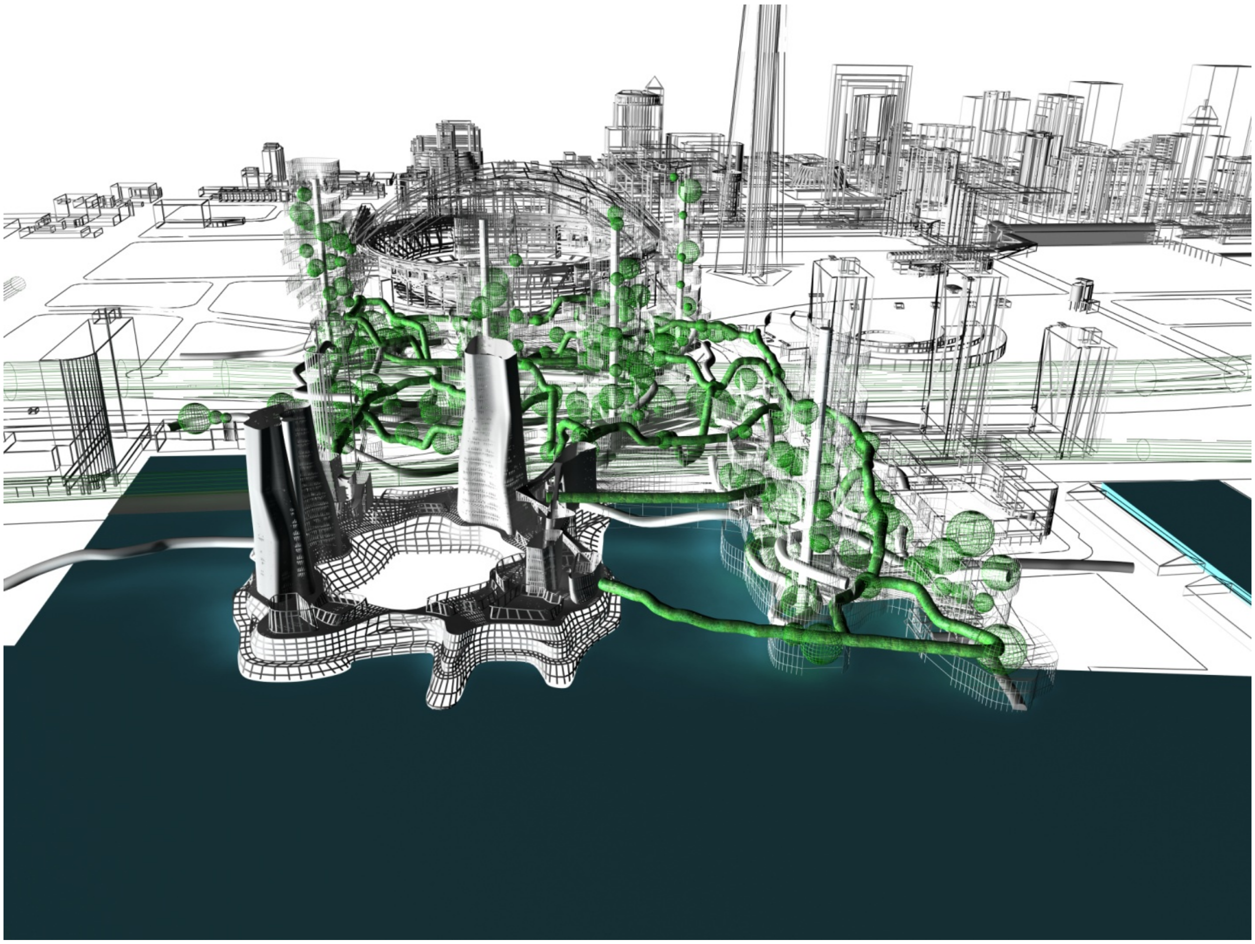
In Figures 4.21 and 4.22, the green tubes represent distributed *Pedestrian Circulation* systems that crawl over the entire mass. This system is exposed entirely over the mass. The grey tubes represent a distributed three-dimensional system that is hidden under the mass. These two systems are attached together at several points in the neighbourhood. The main *Pedestrian Route* that connects the ferry terminal to the north part of the site is also shown in green color. The overall fusion of the city activities is clearly shown in this image. There is no area that is isolated from access to other activities within the neighbourhood or without connection to the broader community. This demonstrates the mixed use character of the neighbourhood and supports the proposition of social health at the heart of the thesis.

The general programming and circulation systems (both resistive and fast flow) also follow the logic of fractals. The main fast flow vehicular streets branch continuously into smaller ones. The three-dimensional distributed paths also branch into finer local routes. The characteristics that are shown in this picture occur again in finer details when one part of the site develops further (Figures 4.25, & 4.26).



(Source: Digital model, developed January 17, 2011, by S. Yekanians)
Figure 4.23 Conceptual three-dimensional zoning

Figure 4.23 shows the new system of the city's conceptual three-dimensional zoning. This view provides a close look at one portion of the south-west section of the site. The new way of labelling the social nodes with distorted pictures of spheres provides maximum comprehensibility as one navigates through the entire system. The tubes represent the accessibility of one activity to another. For instance, the sphere in the middle of this picture (towards upper right corner) with a picture of children with school uniforms represents a school in the neighbourhood. Towards the left part of it, there is a gym that is completely hidden under the mass. The gym is represented by a picture of athletes playing basketball. In the next sections, these two activities will start to deform and connect to each other. The underground gym becomes part of the school building. Nevertheless, the process of programming and form-making continues to be a back and forth process in this project.



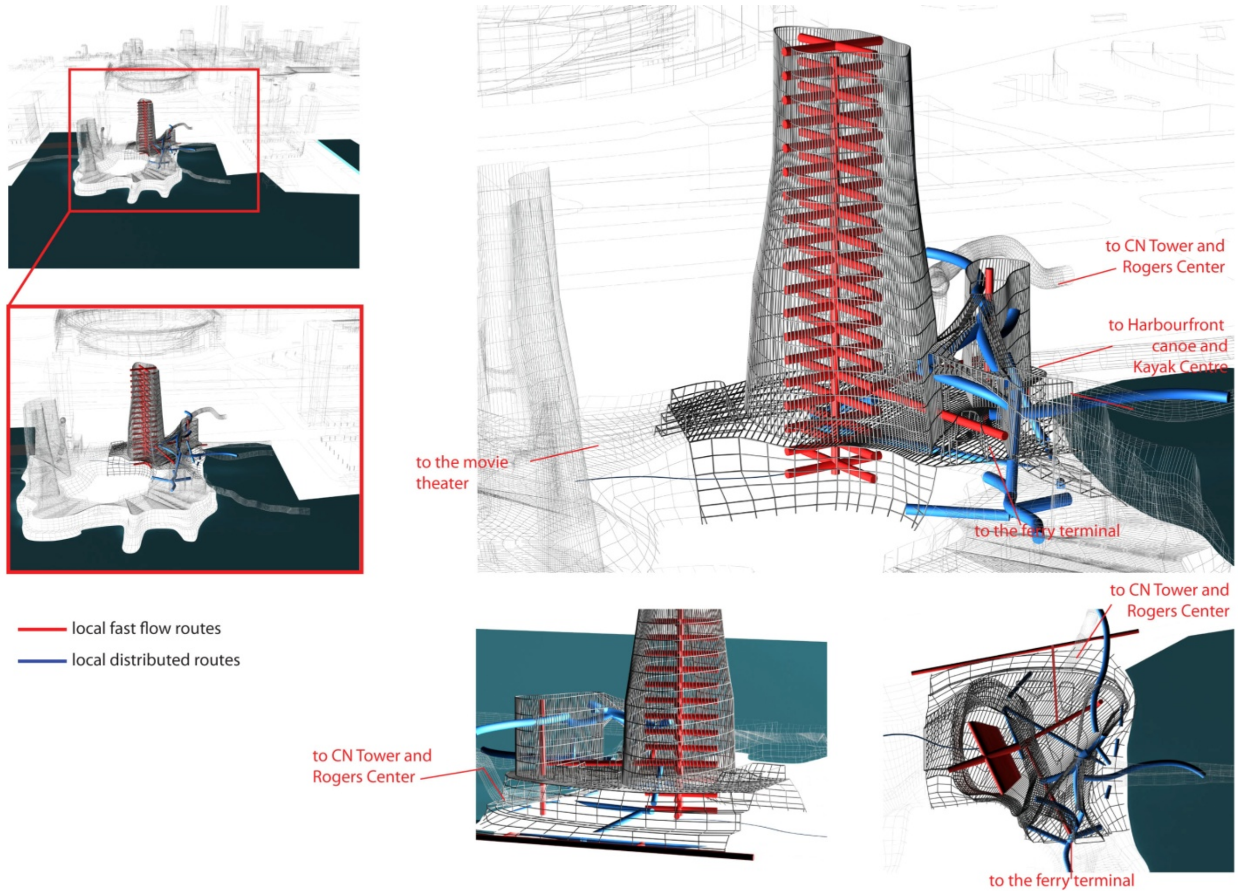
(Source: Digital model, developed January 24, 2011, by S. Yekanians)
Figure 4.24 Form making- south-west corner

Form making:

In order to develop the scheme further, the next stage of the design investigation focussed on the south-west block of the general massing. At this stage the goal was to make the conceptual ideas more realistic and to carve the general form of that portion of the site.

For example, a continuous path started to shape around the edge of the block slightly higher than the street level in order to provide a walking path for pedestrians along the lake. This path was part of the general distributed network of the whole block and connects to other pathways.

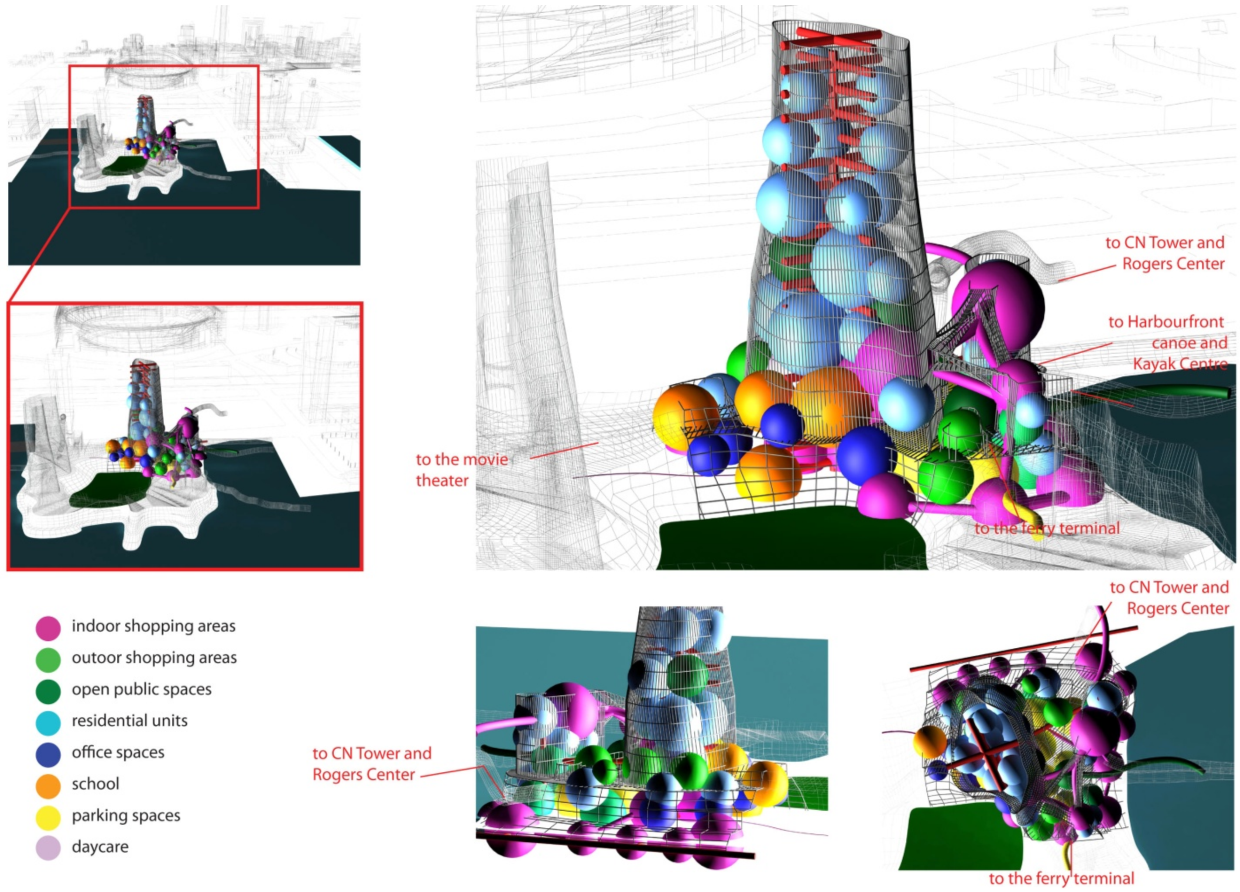
Another example is the sloping contour of the block towards the interior neighbourhood park. This made the neighbourhood park accessible from a variety of directions and provided a relief space for the general mass. The form of the residential towers is shaped to provide adequate sunlight for all units.



(Source: Digital model, developed February 10, 2011, by S. Yekanians)

Figure 4.25 Local distributed and fast flow routes

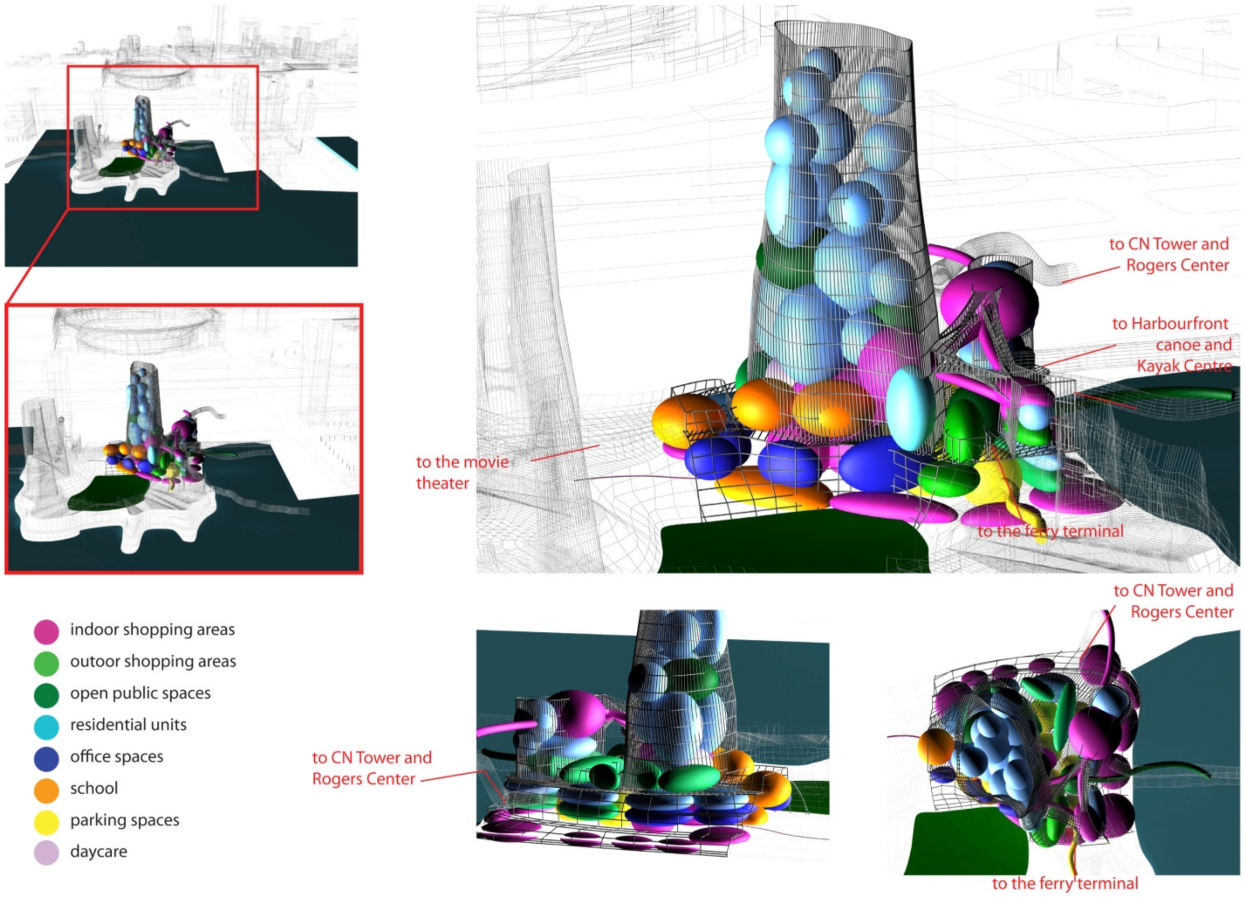
The last stage of the design process looked more closely at the north-west corner of the south-west block (Figure 4.05). First, a distributed local transportation system started to branch from the main road that connected the north side of the site to the ferry terminal (dark blue routes in Figure 4.25). These routes are parts of the neighbourhood with a vibrant social life. By branching into finer routes with the same regulation they ensure that this quality manifests in smaller scales as well. At the same time, the fast flow system of the city, along with the vertical routes to the buildings, branched into a tree shape diagram to provide fast access and emergency routes to different parts of the neighbourhood (red routes in Figure 4.25). This process was an indication that the design followed the fractal concept in order to maintain desired characteristics at different scales of the design project.



(Source: Digital model, developed March 12, 2011, by S. Yekanians)
Figure 4.26 Local conceptual three-dimensional zoning

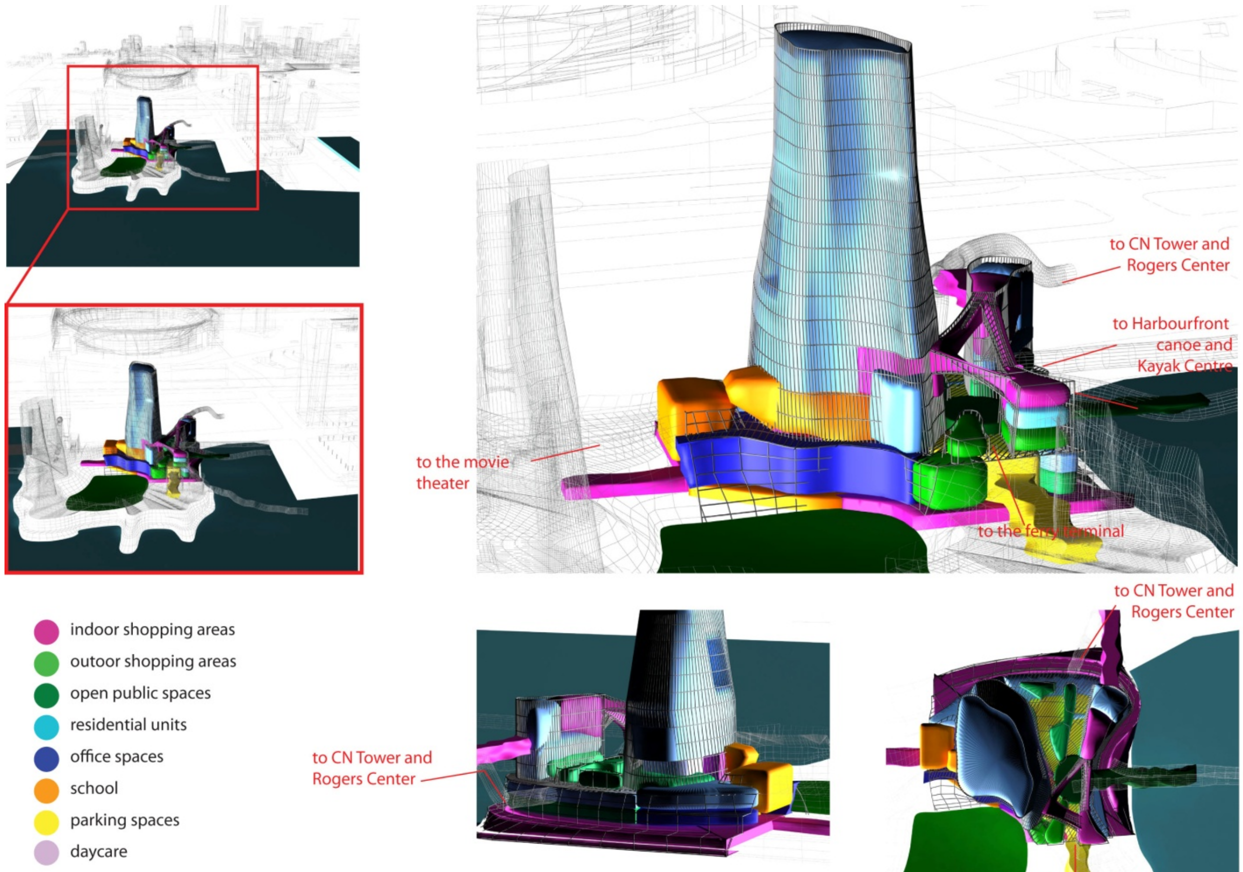
Then a series of social activities were introduced to the system. This introduction was basically a modification of the social activities that were created in the previous stages of the design. Once more, following the fractal concept, each sphere became divided into smaller spheres (with the same activity for the majority of the divided parts). For instance, the sphere that was representing the school was divided into six spheres. Four of these spheres represented the school and two small spheres represented a small office and a small food court that worked with the school program.

At this stage the labelling of spheres was replaced with colors (see Figure 4.26). This made the design more comprehensible at this scale. The tubes also changed color, since they became part of a specific activity in the neighbourhood.



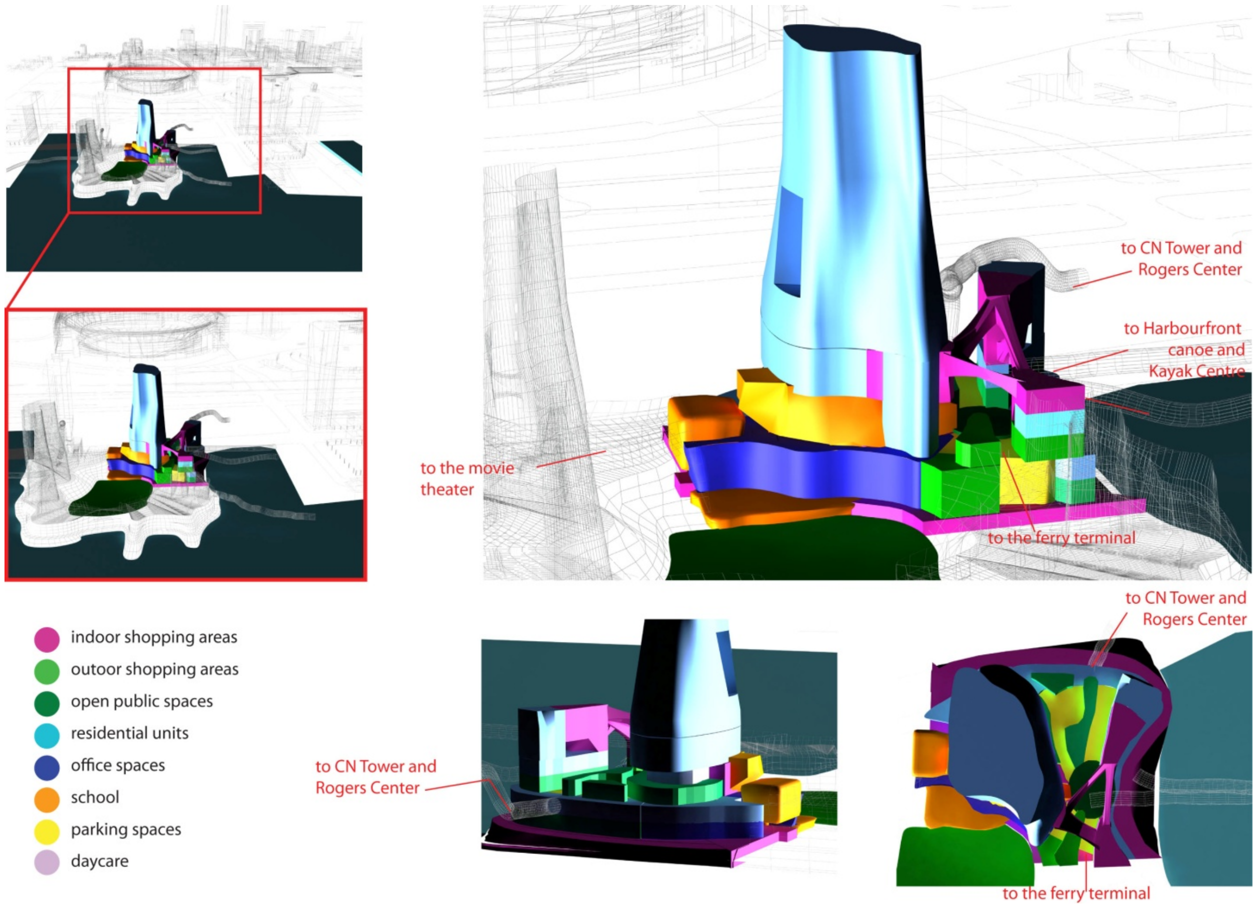
(Source: Digital model, developed March 12, 2011, by S. Yekanians)
Figure 4.27 Deforming spheres

Then the spheres started to deform and juxtapose in order to get a proper location based on their need to get sunlight or be involved with the external neighbourhood activities. For example, the orange spheres that represent the school started to stretch along the edges of the general mass to get the maximum sunlight for the classrooms. On the other hand, parking areas that are represented in yellow started to stretch vertically inside the mass in order to take the dark nodes of the mass and make more room for the rest of the spheres at the sides. Then again, the routes and the spheres that represented open public spaces (in dark green) started to shrink and provide actual open spaces for the neighbourhood. Indoor shopping areas began to stretch along the connective routes to resemble the character of the bazaar in ancient cities (see Section 2.2.3). The light green areas that represent outdoor shops stretched along the outdoor distributed *Pedestrian Routes*.



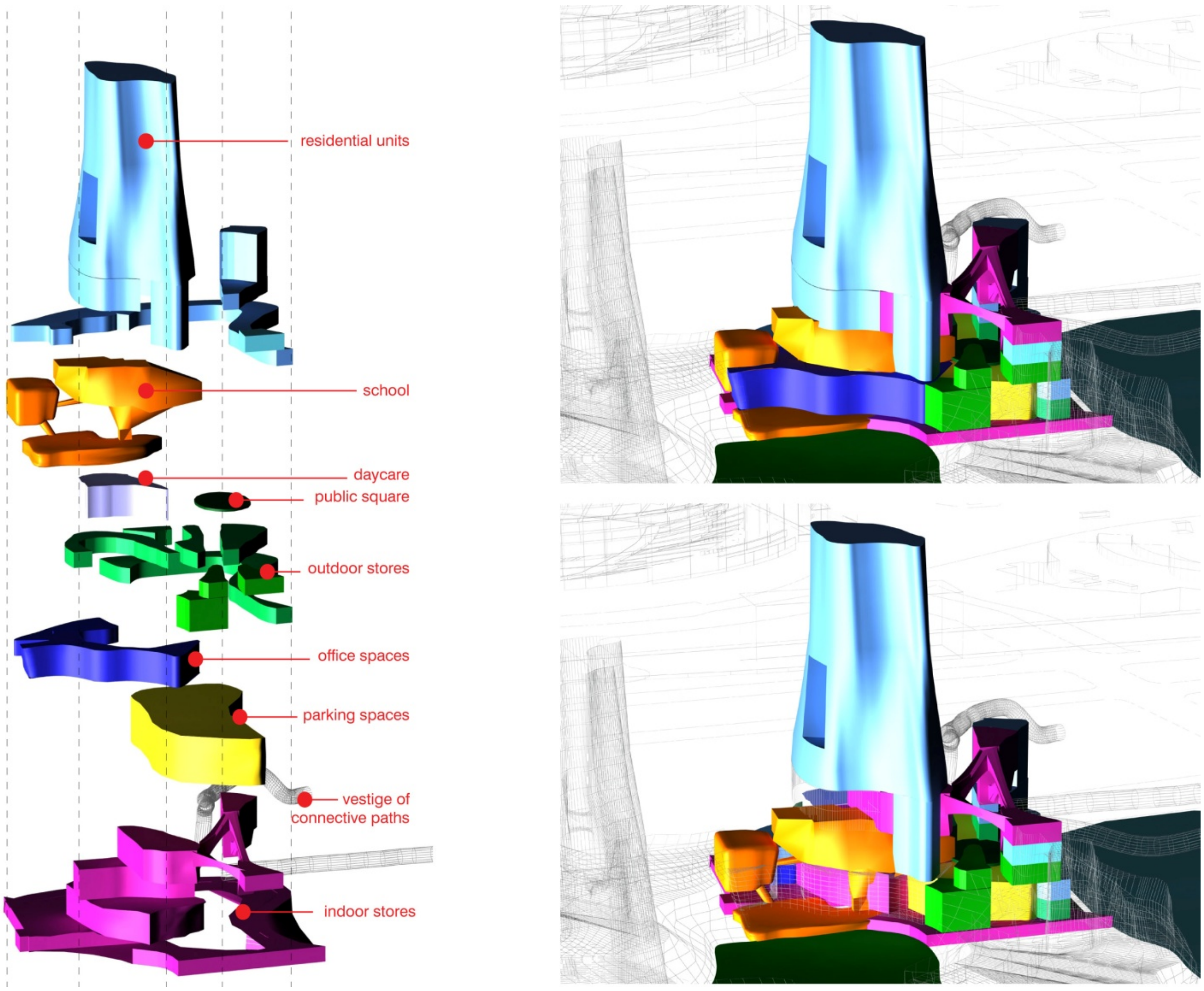
(Source: Digital model, developed March 12, 2011, by S. Yekanians)
Figure 4.28 Juxtaposition and combination of spheres

The shrinking of the tubes and open public spheres demonstrate that the open spaces were designed in the same way and at the same time as the rest of the neighbourhood programs. In Figure 4.28, the area under the triangular bridge is the neighbourhood's public square and was formerly represented by a sphere. This area was opened up after the shrinkage of the sphere. The void in the residential tower is a semi-private open space that also provides natural light to the interior of the building. This was formerly represented by a sphere, too. The school that protrudes from the mass to provide connection to the children's outdoor playground also respects the *Pedestrian Passageway* underneath that area that was formerly represented by a tube. This *Pedestrian Route* is also exposed to the shopping areas along the way. There are also several small residential units that are scattered within different activities of the neighbourhood.



(Source: Digital model, developed March 12, 2011, by S. Yekanians)
Figure 4.29 Site analysis

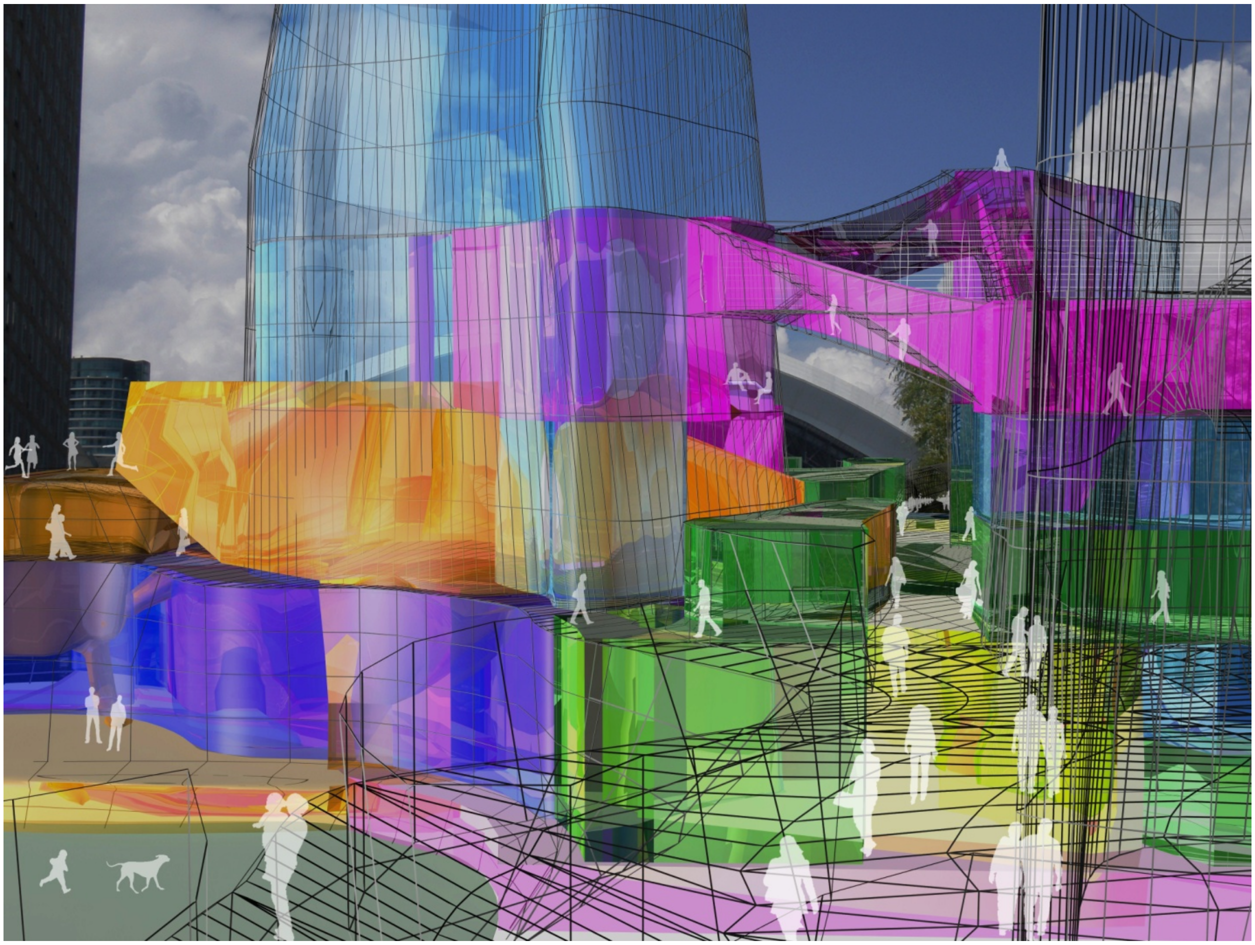
Figure 4.29 shows the final conceptual three-dimensional zoning of the neighbourhood. The triangular bridge is part of the indoor shopping space that provides the main entry to the residential tower. This encourages the apartment residents to use the shopping areas on a daily basis. The school building extends to the public square and provides the main entry to the school. This makes the public square socially vibrant at certain times of the day. The school's library has maximum access to sunlight as well as a peaceful view of the neighbourhood park. It also serves as the balcony for the offices at the top of the school. The gym gets light through clerestory windows where it extrudes over the thick mass of the adjacent office spaces. The roof above the gym provides an outdoor open space for children to play. The indoor shopping areas connect to the existing surface streets at the ground level perimeter of the neighbourhood in order to make the adjacent sidewalks a socially vibrant element of the whole. This space is permeable to pedestrians at certain points on the ground level. Once a pedestrian enters this network they can navigate through all over the public areas of the neighbourhood.



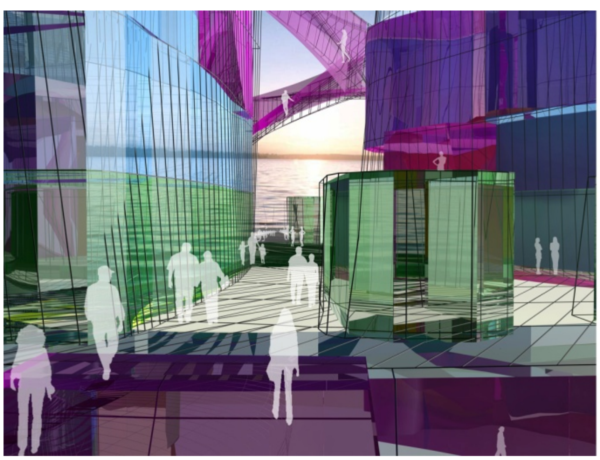
(Source: Digital model, developed April 03, 2011, by S. Yekanians)
Figure 4.30 Spatial interrelations of the city components

The public square is on the axis of the main *Pedestrian Road* that connects the north part of the main site to the ferry terminal. Thus, there are always pedestrians passing through this area. The green shopping areas that are exposed to the surface routes also make the area socially vibrant. The apartment building provides diverse views from the thickened city, neighbourhood parks and Lake Ontario.

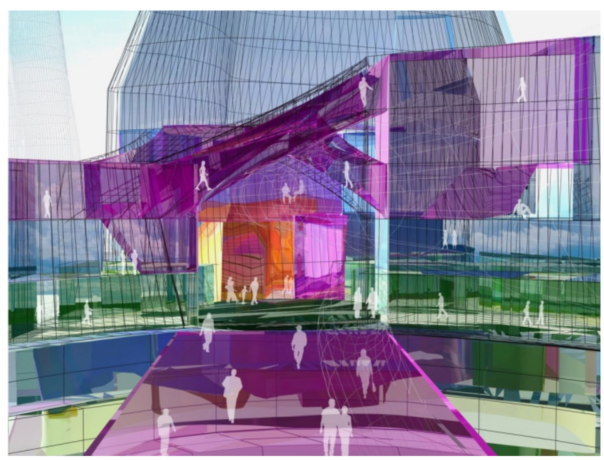
This image (Figure 4.30) shows the spatial interrelations of the thickened city's components. The spheres that once represented elements of the system and the tubes that represented the interrelations within the elements now have melted to mold the thickened city. Although the tubes are not visually apparent, the interrelation of the new forms confirm their consequence to maintain the system's function.



(Source: Digital model, developed April 28, 2011, by S. Yekanians)
Figure 4.31 North view



(Source: Digital model, developed May 14, 2011, by S. Yekanians)
Figure 4.32 South view



(Source: Digital model, developed May 23, 2011, by S. Yekanians)
Figure 4.33 East view

Figures 4.31, 4.32 and 4.33 show some renderings of the north-east corner of the site (see Figure 4.05, phase 3). As the design shows a conceptual resolution of the neighbourhood, the mass was rendered with the same color codes of the three-dimensional zoning to maintain the clarity of the design project. The reflection and the opacity of the volumes allow the viewer to engage with the spatial relationship of the design's components.

The main *Pedestrian Road* of the neighbourhood that brings people from the North to the Ferry terminal is pictured in the north and the south views. The small outdoor shops in light green color are exposed to this street. Although this is the most socially vibrant street of the neighbourhood, pedestrians have a range of choices and can take an alternate route to get to a destination.

The neighbourhood square is full of life for two reasons. First, it is on main *Pedestrian Road* of the neighbourhood; secondly, the entrance to the school and the shopping areas are indirectly related to this square.

Children playing at the school playground are exposed to the neighbourhood. They engage with the social life of the neighbourhood while the privacy of the playground is preserved by its elevation above the adjacent walkway. The area under the playground is the school gym that gets natural light through the windows underneath the playground.

The relationship of the components in these renderings illustrates the continuation of the research measures in the design project. The next chapter analyses this design project and proposes future areas of investigation for the thickened city.

Chapter 5. Design Analysis

Overview

This chapter analyses the design of the thickened city. It explains how the final design outcome is based on systems thinking. It illustrates how the five points of views that were discussed in previous chapters contribute to the design outcome. In other words, it examines acquired results against the primary hypothesis. Lastly, it explains some areas that have the potential to be investigated in future.

5.1. A Design based on Systems Thinking

The previous chapters showed that architecture has continuously evolved alongside scientific and technological advances. Scientific advances were identified as a main cause of the *Modern Movement* and consequent negative social effects. Although new ideas were proposed to increase social interaction in urban areas and mitigate these negative social effects, none of them could completely alter the direction in which our cities are changing. This thesis identified the linear approach of thinkers and urban designers as the main reason for the failure of their approach. By looking at the scientific concept of systems thinking, this thesis initiated a new approach towards city design.

The thesis design project manifests three parts of a system: (1) the polyhedrons and spheres that were used in the design process are the 'elements', (2) the tubes that connected certain points to each other are the 'interconnections' and (3) the social and vital aspects of the neighbourhood are the function or purpose of the system (see Section 1.5, Meadows (2009)). The point is that a system can have more than one function and that these functions are nested. Thus, to fulfill each function, the thesis looked at the city from a particular point of view. For example, to provide a better social life, a distributed circulation system was proposed for pedestrians. For vital needs, the existing fast flow circulation system was maintained unchanged. The process of modeling the design also used the computational process in generating tomorrow's city forms. The research analysed *Five Topics* in regards to city design and proposed a design outcome that fulfills those aspects accordingly. The next sections will give details about these *Five Topics* and their role in the design outcome.

5.1.1. Mathematics and the Design Outcome

The field that was selected from mathematics in this thesis was graph theory. The tubes in the design project connect the social nodes to each other and form a distributed network of circulation for pedestrians. This network is characterized by semi-lattices in graph theories. The characteristic of this type of network and its potential in increasing social interactions were analysed in the earlier chapters. Although these tubes disappear as the design project evolves, they transform into actual physical circulation routes. This is the interconnection that exists in the city system. The design structure promotes a high degree of permeability and reciprocated accessibility between dwellings. In other words, there are at least two ways to move from building to building.

5.1.2 Sociology and the Design Outcome

The area of study that was extracted from sociology was public spaces in urban areas. The spheres in the design process display the social nodes. These social nodes are points of social attraction for people in urban areas. Small blocks of activity, primary mixed use and high density, were among other social factors that were considered in the design project.

5.1.3. History and the Design Outcome

The concept that was selected from history was the role of Bazaars in contributing to the social vibrancy of ancient Middle Eastern cities. The tubes that were used in the design to promote social life in neighbourhoods are thought to function like the Bazaars in the old cities of Iran. The Bazaar is a linear marketplace with shops along the sides that connect important social nodes of the city to one another. The *Pedestrian Routes* of the thesis design project are lined with a wide range of activities and services, including retail, to increase pedestrian interest and activity, and contribute to the city's economy.

5.1.4. Biomimicry and the Design Outcome

This thesis analysed physical laws of nature, wasps' movement and fractal patterns. The area of study that was extracted from physical laws of nature was constructal theory. The research chapter also illustrated a need to maintain a city's fast flow system. Thus, by superimposing layers on the existing city, the functionality of the city as a flow system remained unchanged. The superimposed layer had a distributed circulation system that increased random interaction. This circulation system was discussed in Section 2.2.4.2 in the analysis of how the structure of wasps' nests reflects and facilitates their movement. Both patterns are considered fractal to maintain the desired characteristic at each scale of design.

5.1.5. Computation and the Design Outcome

The field of study that was extracted from bioinformatics was computation. Just as biology provides the model for digital computation, this thesis provides a model that has the potential to be programmed for tomorrow's cities. The rules of general massing, circulation systems and social programming can be done by generating algorithms in some cases. The details of this process are discussed in Section 5.3 *Future areas of investigation*.

5.2. Some of the Benefits of the Design Intervention

This section explains that thickening of the city not only increases the sense of neighbourhood in urban areas but also preserves natural resources by hiding them under the thick mass of the city. Although this was not discussed in the research chapter, it is a possibility that can be considered in the development of tomorrow's cities. This section also explains the role of fractals in increasing interactions in nature and illustrates the practical use of this concept in design to increase human social interaction. In addition, it shows how differently neighbourhood parks are viewed in this design approach. As for the circulation system, both the distributed network and the fast flow network are integrated with each other at all levels of the thickened city.

5.2.1. Preserving Natural Resources

The sustainable approach of preserving natural resources has gained in importance with cities' population growth and expansion. The suburbs cover vast areas with low densities. In urban areas, parking lots take urban lands and are exposed to sunlight. Nevertheless, one of the advantages of thickening the city is that it preserves natural resources such as sunlight and land by hiding spaces under the mass of the thickened context. These areas include parking lots, service areas, movie theaters, etc.

that do not need sunlight. The fast flow system of the city penetrates into these spaces and provides emergency fast flow routes. Aside from sunlight, a great amount of land also gets preserved by hiding service areas under the mass.

Neighbourhood parks provide relief spaces for the general population. Making parks work for other reasons than merely being a park is another way to preserve land. The nature of these relief spaces is fractal and will be explained in the next section.

5.2.2. A Fractal Outcome and Vibrant Neighbourhood

Fractals maximise interactions in a limited space in nature. The pattern continues to branch to the smallest scale that interaction happens. Thickening of the city keeps the fractal character by descending to the smallest size of the buildings and shops when it comes to the pedestrian passageways. This is where the interaction between people and built forms happens. Jane Jacobs (1969) explains this from a different point of view. She critiques the concept of "Tower in a Park" and explains that it does not provide life for the city. The fact is that the concept of the "Tower in a Park" does not contribute to the fractal nature of the city. The vast space of the park around the building decreases interaction of humans with their environment.

Another characteristic of fractals is self-similarity. This means that different scales of design have the same geometrical characteristics. This principle was used in maintaining the fast flow and distributed systems in all scales of design. For instance the highway and streets provided a fast flow system and the main connective *Pedestrian Route* that extended from north to south along with adjacent similar routes provided a distributed circulation system. The former served vital needs and the latter met pedestrians' social needs. On a smaller scale, when we look at the third phase of design, these two branching systems continue with their same geometrical characteristics to maintain the vital and social purpose of the city in smaller scales as well. For example, streets branch to fast flow fire routes, elevators and hallways, while major *Pedestrian Routes* branch into local pedestrian routes that still have the distributed characteristic of a mesh and provide reciprocated circulation for pedestrians in neighbourhoods.

The way that the fractal concept is used in form making of this project is different from applying an image of a fractal concept to the city. The role of fractals in nature has been studied first and then the same concept has been applied appropriately to benefit the design.

5.2.3. Increased Safety of Neighbourhoods' Parks

By enclosing parks within the thickened mass of the city, not only do they provide relief spaces for the mass, but they increase safety by being surrounded with a live neighbourhood. In contrast to the *Modernized* cities where parks are remote and individuals do not feel safe to take a route from the park to go home (Jacobs, 1969) The parks in this project are an inevitable constituent of a neighbourhood that facilitates the system's proper functioning They are safe because they are surrounded by residential buildings and shops because they contain several pathways that get to other public spaces of the city.

5.2.4. Accessibility to both Transportation Systems

The thickened city provides integrated transportation systems for vital and social needs of the residents. As for the vital needs, a fast flow system operates as 'emergency routes' and provides food deliveries and access to hospitals, fire escape routes, garbage routes, etc. at different parts of the city. On the other hand, the superimposed distributed system provides multiplicity of choice for pedestrians and decreases boredom in neighbourhoods.

5.2.5. Elimination of Big Box Stores

Big box stores are among the places that this project looks to hide under the thickened mass of the city. Though it might not need direct sunlight, indirect sunlight can get through the space easily. By hiding these places under the mass, we not only preserve natural resources such as sunlight and land, but we increase the sense of neighbourhood by squeezing and stretching these forms and making a linear marketplace. This is where the historic concept of the Bazaar contributes to the formation of the hidden pedestrian circulation system. Ideally, people who work close to their living spaces would take these paths to shop for their daily needs and contribute to the city's economy. *Pedestrian Roads* provide shopping areas along with accessibility to different points of the city. Another advantage of these hidden linear marketplaces is (like the underground 'PATH system in Toronto) is that they provide a secondary option for pedestrians during adverse weather conditions.

5.2.6. Not to Build from Scratch

Thickening of the city looks at superimposing new layers of design over the existing surface of the city. This intervention not only keeps the fast flow system of the city, but also preserves other important factors that have contributed to the city's formation over the years. One of these factors is economic. A city that is designed from scratch is unlikely to attract new residents because it has no economy. Ordos, which is a ghost city in China, illustrates this point (Aqeel, 2010). The city has constructed a new addition thirty kilometres away from its old part. Despite all housing units being sold, the owners do not want to live there because there are no businesses in the new section. People invest their money in real estate and buy the residential units. The only residents of the city are the construction workers and their families. Thus, by superimposing new layers of design in this thesis project, all tangible and non-tangible factors that are necessary for existence of a city become preserved.

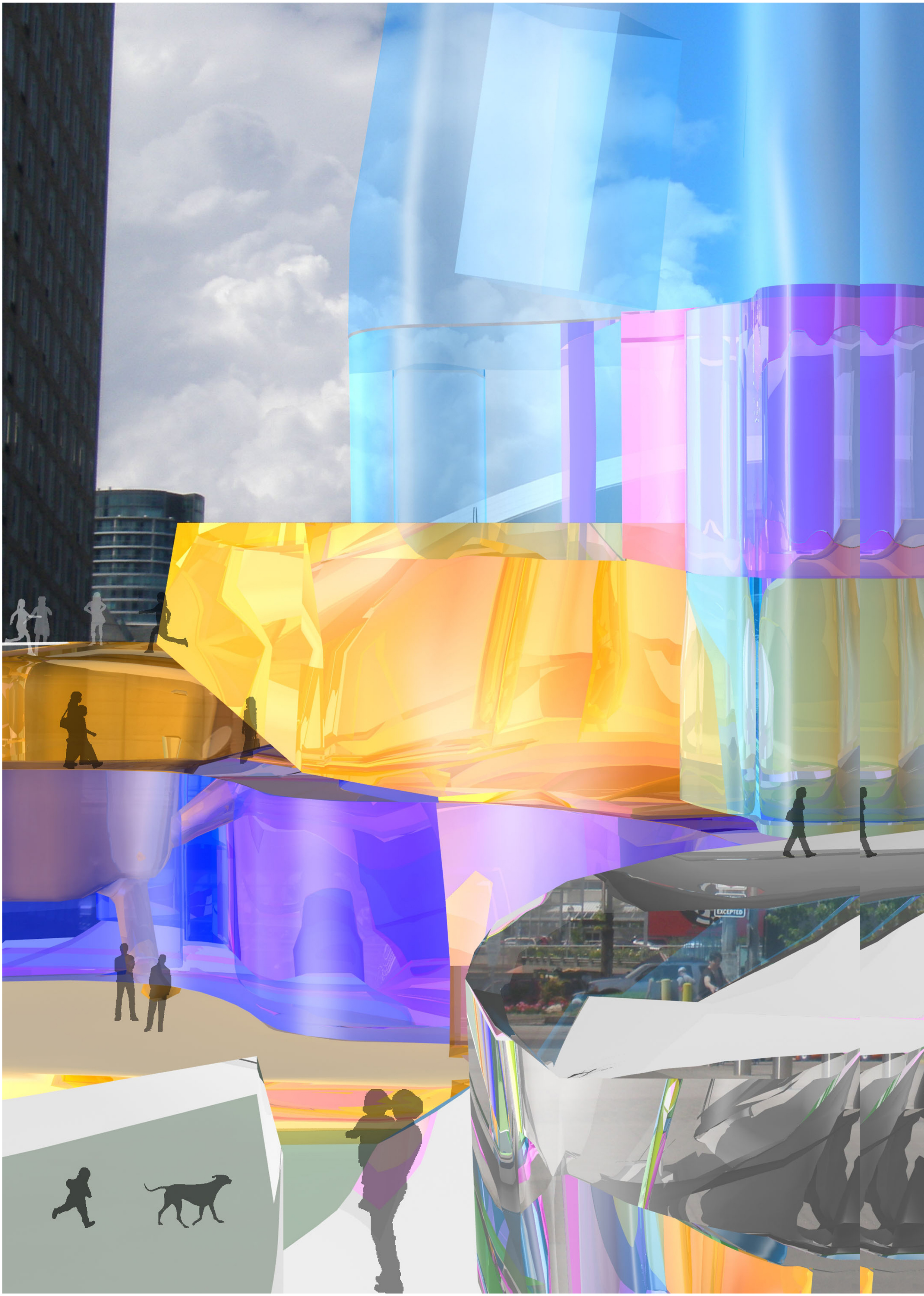
5.3. Future Areas of Investigation

This thesis considers the possibility of generating algorithms to form a city based on the model provided in the previous chapter. The form generating of tomorrow's cities will be a back and forth process of programming by programmers and an architect's supervision on the outcome at each level. The stages of programming in this particular case will be the same stages of design process. For instance, the first stage will be general massing by polyhedrons It will be necessary to define the maximum number and height of the polyhedrons (which will become the highest point of the city), the maximum and minimum distance between any two polyhedrons (which describes the size of relief spaces), the rules of stacking polyhedrons and other relevant measurements. Another example of defining parameters can be defining the branching rules of the tubes depending on the characteristic of that particular circulation system by generating a tree shape network or a distributed network among the spheres that were previously defined within the mass. An architect can alter the generated form based on their understanding of the city life after each level of generating tomorrow's city form.

This thesis also suggests the potential of adding other layers to the complex tissue of the city to address some other issues in our existing cities or in the model provided by this thesis for further development. It also suggests looking at nature as an inspiration not just in form making but also in spatial programming of architectural projects in future.

If engineers use sciences when they look at the building structurally, then why do architects not use sciences when they look at the building programmatically? Architects are artists and engineers. They are engineers, not in the sense of working with building statics, but in applying natural theories to the design. The goal is not to apply those images as a one- to- one imitation from nature, but to provide a practical concept in fulfilling the purpose and functionality of the design outcome.

The results and experiences gained through this thesis show that a design project can benefit more by learning lessons from nature from a dynamic developmental point of view than by applying a formal and one-to-one application of a static image from nature.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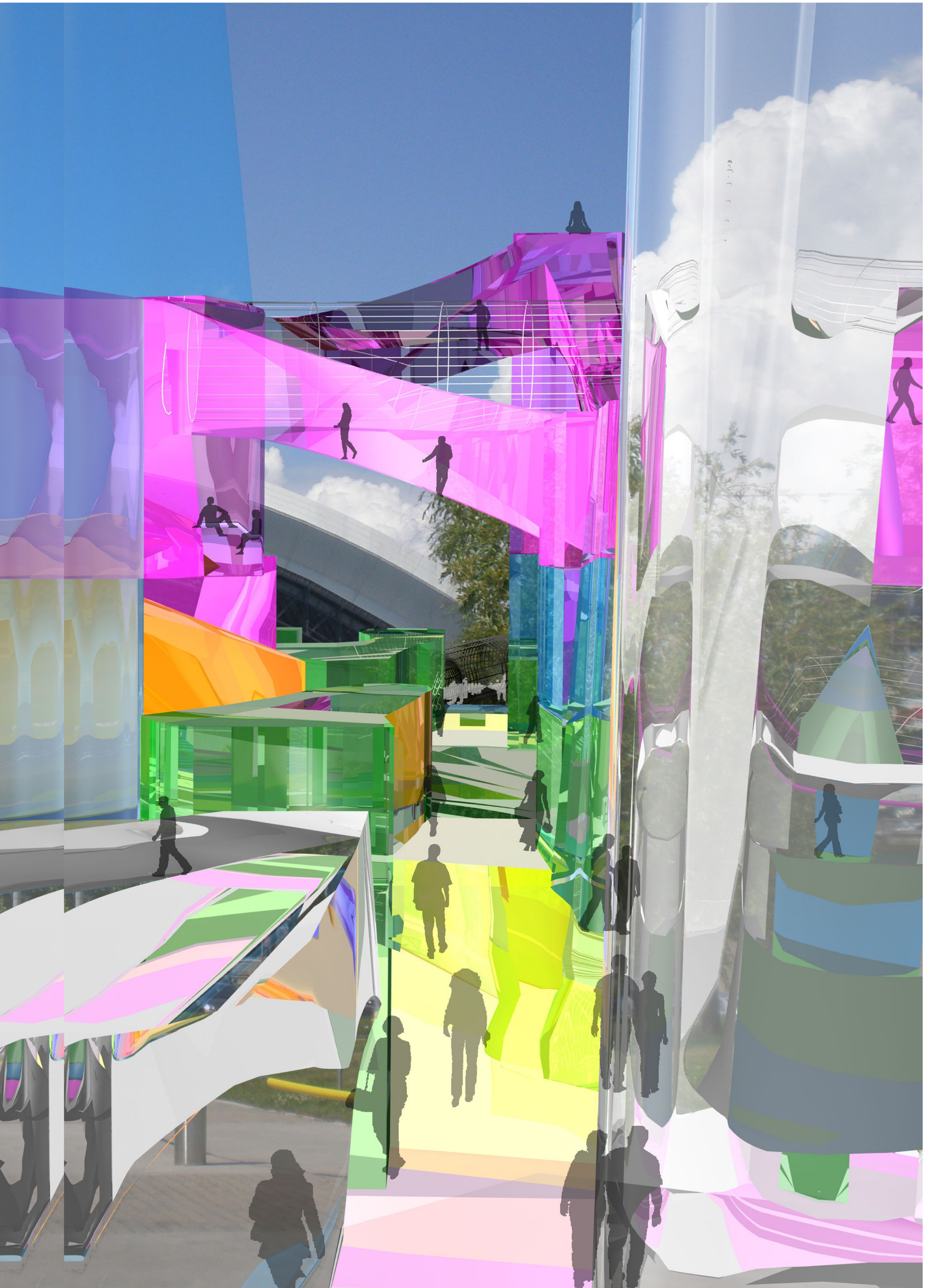
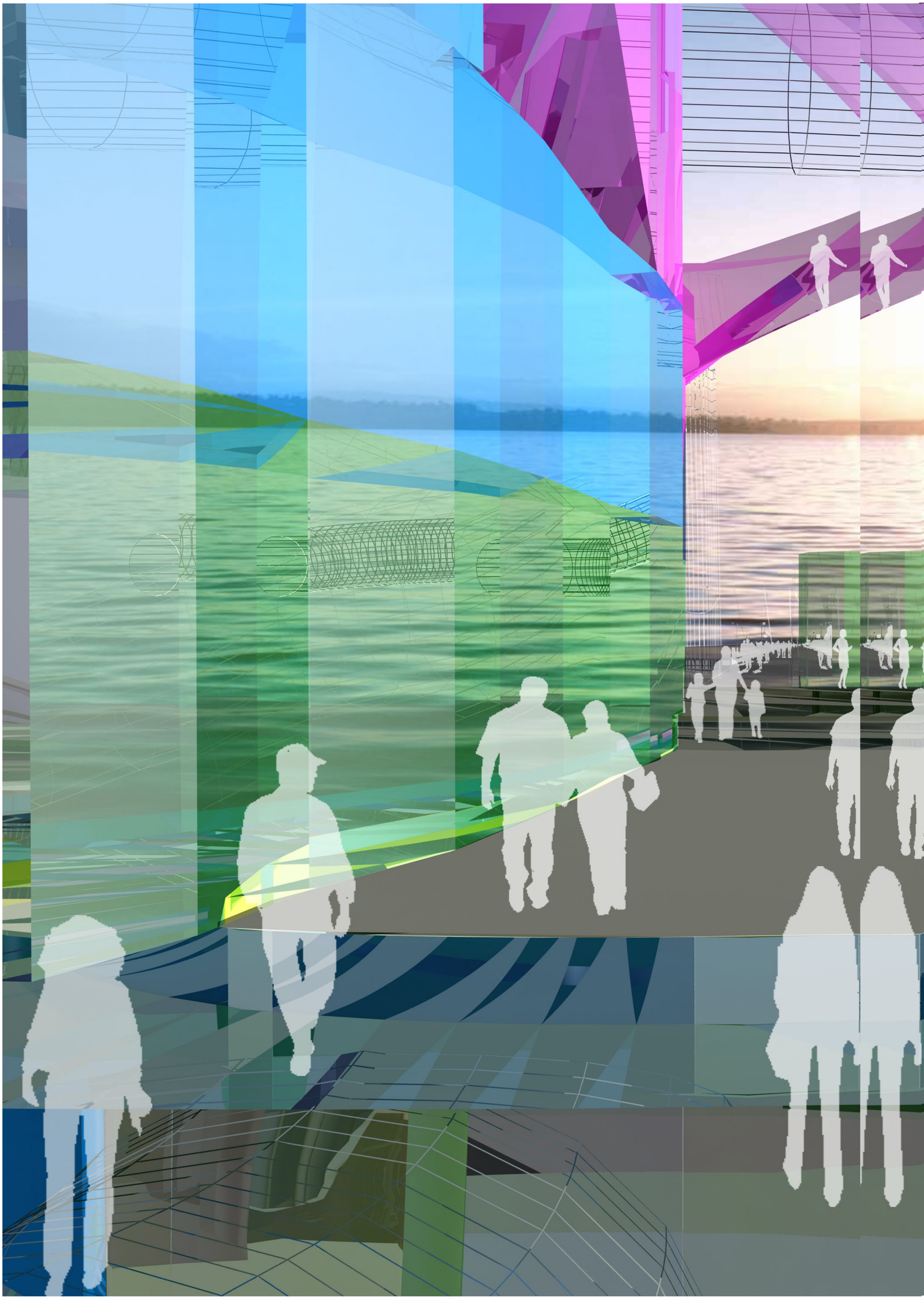


Figure 5.00: North view



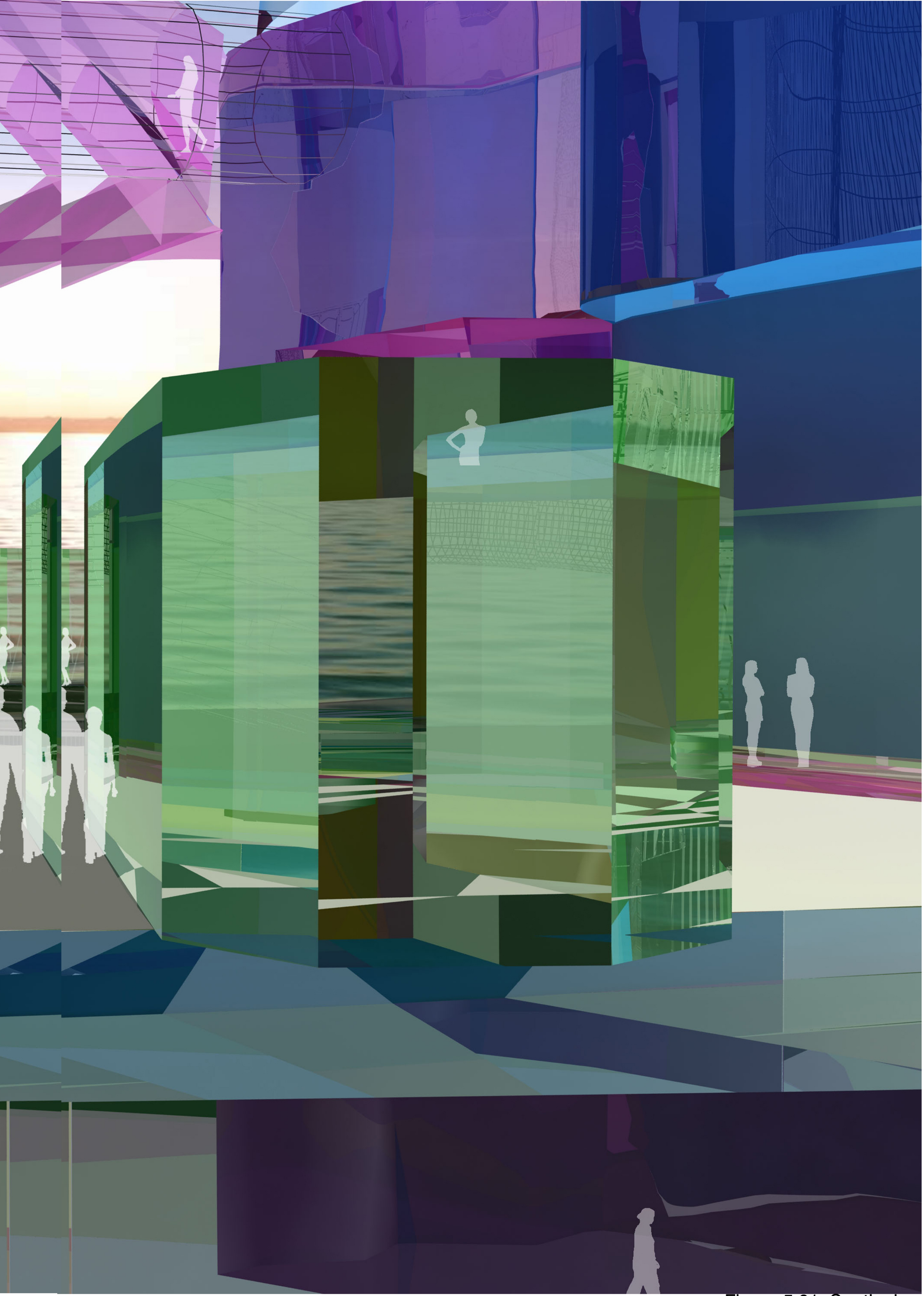
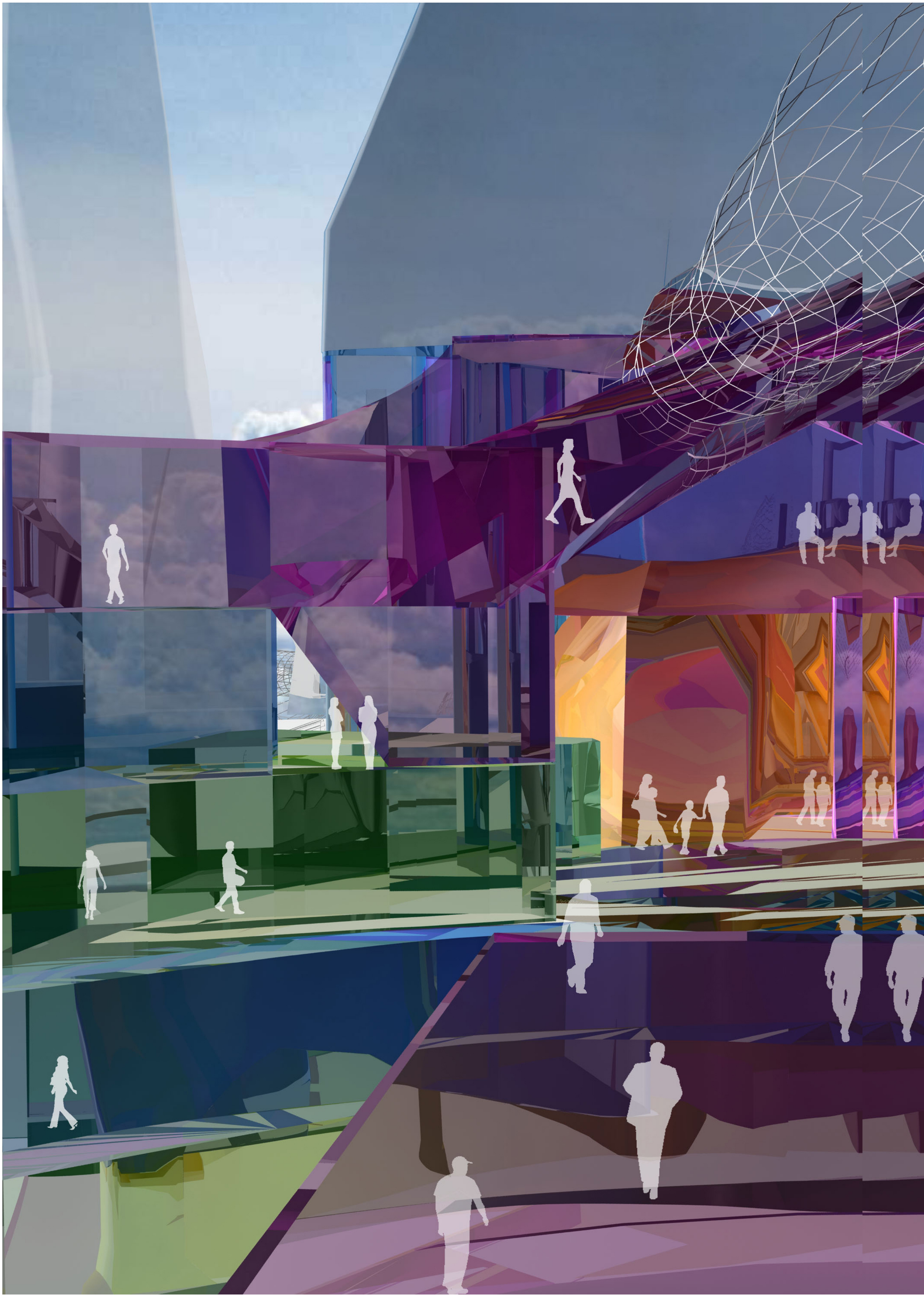


Figure 5.01: South view



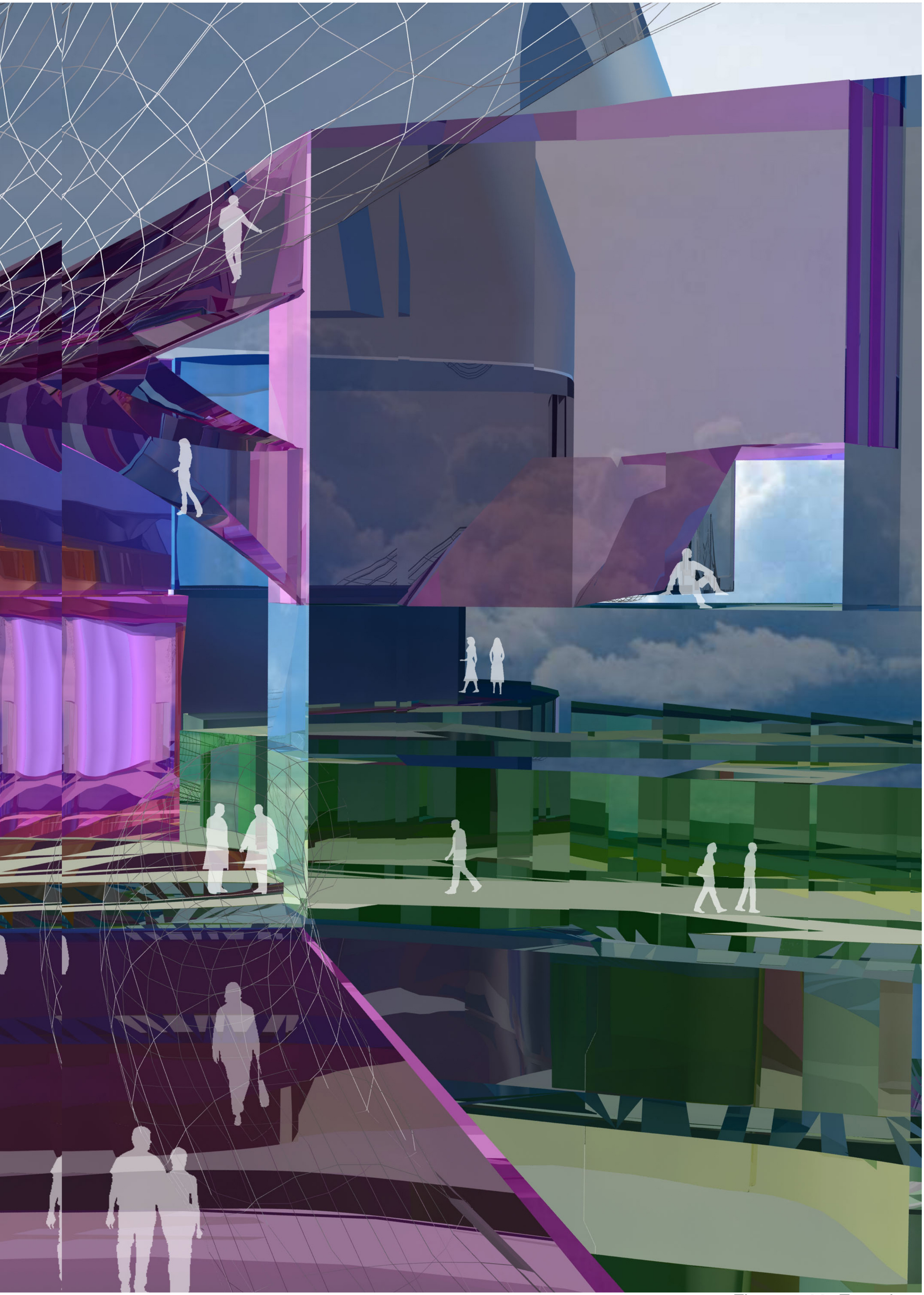


Figure 5.02: East view

Appendix A

Annotated Bibliography – Key References:

Alexander, C. (1966,). *A city is not a tree*. Design, 206. London: Council of Industrial Design. Retrieved June 12, 2010, from http://www.chrisgagern.de/Media/ A_City_is_not_a_Tree.pdf. 17 pages.

Alexander (1996) claims that cities designed by the human mind cannot provide for overlapping activities in urban spaces and will have the effect of reducing social interaction. Alexander claims that growth over time causes different city activities to develop within a certain area and overlap, which increases the vibrancy of the social life in that area. He contrasts natural cities with artificial ones: i.e., cities that are designed by humans are called “artificial cities”. He believes that these cities are all organized in a tree shape graph and urban activities do not overlap in cities that are designed by human minds. These artificial cities are seen as lacking a vibrant social life. Alexander contrasts these cities with ancient ones, stating that the patina of life exists in ancient cities.

He uses graphs to analyse city patterns and concludes that all artificial cities form tree shaped graphs. The tree axiom states “A collection of sets forms a tree if, and only if, for any two sets that belong to the collection, either one is wholly contained in the other, or else they are wholly disjoint” (Alexander, 1966, p. 5). If there is a connection between two components it has to be through the medium of those units as a whole. Taking the plans of modernized cities as an example, there is a clear distinction between different urban activities. Columbia, Greenbelt, Greater London, Tokyo and Mesa City are among the cities found by Alexander to demonstrate a tree structure. He insists that well-functioning cities are not and cannot be tree structures and points to those structures as the reason for social deadness within the cities. Alexander goes on to contrast tree structures with semi-lattices, describing the semi-lattice as the structure of a complex fabric and the structure of living things: “The semi-lattice axiom goes like this: A collection of sets forms a semi-lattice if and only if, when two overlapping sets belong to the collection, then the set of elements common to both also belongs to the collection” (p. 4). Therefore, social vibrancy decreases in urban areas that are not grown naturally.

Alexander believes that cities that are grown naturally fit within this category and provide a better social life for humans.

Arida, A. (2002). *Quantum city.* Oxford: Architectural Press

Arida (2002) discusses the effects of the Modern movement on city planning. According to Arida, as a result of modern planning, vague open spaces as well as unfriendly, rigid and overly rational housing projects intended to bring order to the lives of the masses do not account for the interpersonal nature of social exchanges. This approach demonstrates a failure to address people's social lives within modern cities.

He continues his discussion by describing some of the effects of recent scientific developments upon design. He believes that the paradigm presented by Jencks (1995) is a powerful explanation of how architecture resonates with scientific thought. But he also believes the book to be slightly exaggerated in its formal explanation and implications, citing the example of its interpretation of wave aspect through a literal formal motif of "wavy lines". He goes on to compare his book to that of Jencks and suggests that Jencks' interests are more "formal and aesthetic", while his own are "spatial and inter-relational" (Arida, 2002, p. 69).

Bejan, A. (2007). The Constructal law in nature and society. In A. Bejan & G.W. Merkx (Eds.), *Constructal theory of social dynamics* (pp. 1-33). New York: Springer.

Bejan (2007) summarized the theory of social dynamics that studies flow systems in nature such as veins, lungs, trees, river basins, cities and billions of similar examples. This theory explains that design in nature – including shape, structure, configuration, pattern, rhythm and similarity - follow a physical principle that unites all flow systems. This phenomenon is summarized in the constructal law of the generation of organization, which states "For a finite size flow system to persist in time (to survive) its configuration must evolve in such a way that it provides easier and easier access to the currents that flow through it" (Bejan, p. 2). It explains that there is a tendency for systems to change form from a resistive pattern to a fast flow system in order to survive over time. The theory has added a new extension to physics: the thermodynamics of flow systems with configuration.

This thesis adapts and applies this theory to maintain the fast flow system of the cities despite all the critics against *Modernism* in architecture that encourage a resistive pattern for the city to improve social interactions.

Berman, M. (1983). Robert Moses: The expressway world. In *All that is solid melts into air: The experience of modernit*y (pp. 290-312). London: Verso.

Marshall Berman (1983) illustrates the modern image of ruin and demolition by narrating the construction of the cross-Bronx Expressway through the neighbourhood that he grew up in. He explains how a neighbourhood that was alive and thriving, rapidly turned to a place to get out of since the construction of the expressway started. The terrible effects of this were probably not understood by hundreds of thousands of motorists that pass the expressway every day, but experienced by the residents. Apartment houses that had been part of the neighbourhood for twenty years emptied out and many commercial blocks got destroyed.

Robert Moses was the man who was responsible for this project. He was the vehicle of the moving spirit of modernity. He managed the construction of the expressway through the heart of Bronx for ten years, through the late 1950s and early 1960s. During these years he changed or transformed the center of the Bronx from an ordinary neighbourhood to spectacular ruins. At that time, the image of immense steam shovels, steel and timber beams, and bulldozers influenced residents' perception of modern cities. Soon after the construction, the road became jammed with heavy traffic. Nevertheless, it was always deadly fast and full of trucks and cars that seemed to rush out of the Bronx as fast as they could. In Berman's (1982) opinion, this transformation, along with urban nightmares such as drugs, gangs, and murders contributed to the modern culture in the Bronx.

Capra, F. (1997). *The web of life: A new scientific understanding of living systems*. New York: Anchor Books.

Capra (1997) explains that we cannot define the world as an object filled with other objects. This is how classical physics tried to define the world. Instead we are part of an interconnected and self organized pattern that he calls the web of life. In this view, the universe is viewed as a system.

Fontenot, A. (2005). Planned destruction: Modern planning, war, and public housing. In P. Oswalt (Ed.), *Shrinking cities* (pp. 52-61). Ostfildern, Germany: Hatje Cantz Verlag.

The negative consequences of modern city planning are also mentioned by Fontenot (2005). Although the 19th century came to represent progress and development of the city with high rise buildings (at the end of the century) and massive urban territories that had been reconfigured by modern planning, the 21st century became an icon of destruction. Dilemmas caused by the demolition of 'urban errors', pose new challenges with urban reformation in America, France, Germany, Netherlands, and the United Kingdom.

Gleick, J. (1987). A geometry of nature. In *Chaos: Making a new science* (pp. 81-118). New York: Penguin.

Gleick (1987) analyses natural geometric concepts such as fractals and self-similarity. He suggests that the human mind cannot fully envision the never-ending, self-embedding complexity of nature. But the study of structures on smaller and smaller scales can make a significant difference to someone thinking from a geometric perspective. According to Gleick, Benoit Mandelbrot explored fractal shapes and their possibilities, uncovering deviations that were previously unrealized. One of the advantages he had over his mathematical predecessors was access to computation. He could draw shapes on the computer and run programs repeatedly. As a result, fractional dimensions have been a significant point of reference for architects since Mandelbrot's time.

Hillier, B., & Hanson, J. (1988). *The social logic of space*. New York: Cambridge University Press.

The idea of criticizing modern cities based on analysing the interrelation of components has also inspired architects like Hillier and Hanson (1988). They further analyse the social consequences of the city design based on graphs and diagrams. They establish a descriptive theory of how spatial patterns can carry social information and content. Although they analyse the cities based on graphs their approach is entirely different from Christopher Alexander's.

Hillier and Hanson (1988) also use graphs to analyse spatial relationships. They introduce distributed systems by analyzing city patterns like French hamlets, contrasting these systems with non-distributed ones, and concluding that modern cities fit in the latter category. Whereas the former pattern possesses characteristics that provide a vibrant social life for people, the latter lacks those properties. In patterns, such as the French hamlets, there are two or more ways to travel from one house to the other. The paths are similar in length and, importantly, loops like these increase the probability of seeing a random stranger and thereby increase social interaction. This contrasts with suburban areas where the probability of seeing a random stranger is zero. Thus, suburbs lack the vibrant social life of cities.

Hillier and Hanson (1988) focus on the properties of circulation patterns in naturally grown cities and suggest that they provide safer, more social environments for citizens. According to Hillier and Hanson, these cities are permeable by strangers. The strangers police the area and the inhabitants police the strangers, thereby increasing the safety of the area. Additionally, the probability of seeing a random stranger increases in these patterns and the area becomes socially vibrant. They contrast this with isolated suburban areas where the probability of seeing a random stranger is almost zero. People who pass the streets in such areas are usually the same people every day. The circulation pattern of these areas also demonstrates a non-distributed pattern that indicates the area is not socially vibrant.

Jacobs, J. (1969). *The death and life of great American cities*. New York: Modern Library.

Another critic of modern cities and their social influences is Jacobs (1969). She analyses cities based on social activities that bring vibrancy to neighbourhoods and she strongly criticizes modern cities to this end. She attacks the goals and principles that form modern, orthodox city planning and re-establishment then goes on to write about how cities function in real life and what principles and practices stand in the way. She writes about the safety of city streets, sidewalks, and social characteristics of neighbourhood parks and she idealizes neighbourhoods with small blocks, primary mixed uses, and high densities. According to her, Le Corbusier's intention was to keep pedestrians off the streets and in the parks. He reduced the number of streets because "cross roads are an enemy to traffic" (p. 23). Instead, Le Corbusier proposed large roads for express one-way traffic. He also included underground streets for deliveries and heavy vehicles. Jacobs believes his conceptualization of the city had impressive clarity, simplicity, and harmony. The design seemed like an advertisement and it was very easy to understand. Nevertheless, Jacobs believes the Radiant City had a vulgar and clumsy design, with dreary and useless open spaces and a dull close-up view.

Jacobs (1969) pays a lot of attention to the pedestrian sidewalks in her critiques of modernism. She believes that city sidewalks bring people together. The existence of stores and industries along pedestrian pathways also plays a major role in making the area socially vibrant. She thinks that it would be disastrous if there were no shops and industries in a neighbourhood. She also discusses the role of sidewalks in neighbourhoods on serving children. Children need to play and learn. Living city sidewalks can serve magnificently for this purpose.

Jencks, C. (1995). The simplicity and complexity. In *The architecture of the jumping universe: A polemic : How complexity science is changing architecture and culture* (pp. 6-41). London: Academy Eds.

Jencks (1995) examines ecological stress, urban alienation and spiritual confusion. One of his major themes concerns the first post-Christian creation of a new revelation. This new revelation is illuminated by the new sciences of complexity, which include complexity theory, chaos theory, self-organizing systems, and nonlinear dynamics. The reason behind dependence on these concepts is their progress towards an improved worldview, when compared to *Modernism.*

Kohr, L. (2007). Velocity population. In W. W. Braham & J.A. Hale (Eds.), *Rethinking technology: A reader in architectural theory* (pp. 203-206). New York: Routledge.

One of the benefits of creating local communities is illustrated in Leopold Kohr's (2007) essay, *Velocity population.* In this essay Kohr shows that lack of self sufficient communities and higher speed of transportation in our current cities, results in population growth. He gives examples of increasing the mass of atomic particles as a result of a higher speed and also increase in "quantity" of money in a fast circulation system.

> The further an integrated population spreads, the greater is the distance it must cover to attend its daily chores. And the greater the distance, the faster it must move. And the faster it moves, the larger becomes effective (or velocity) size (Kohr, 2007, p.204).

Furthermore, Kohr (2007) promotes regional self-sufficiency and encourages *polycentral regeneration*. He applies this phrase instead of decentralization. In other words, Kohr believes that instead of dispersing the central offices of a city over its diverse areas, we can turn the regions into self-sufficient communities, where every citizen finds all their daily needs in places that are central, but small and nearby. Therefore, he thinks that the answer is not in decentralization but polycentral regeneration which means centralization on a small scale. Urbanizing the suburbs instead of suburbanizing the slums is one of the examples that Kohr gives to illustrate his idea. He believes that this method will turn the unmanageable velocity overpopulation of our cities into manageable statistical dimensions.

Meadows, D. H. (2009). System structures and behaviour. In D. Wright (Ed.), *Thinking in systems: A primer* (pp. 11-34, 188). London: Earthscan.

Meadows (2009) views cities, individuals, companies, and economies as systems. He defines a system as "A set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviours, often classified as its function or purpose" (p 188). According to this definition, a system consists of elements, interconnections and function or purpose. Meadows gives an example of a football team as a system. The elements of that system are players, coach, field and ball. The rules of the game and players communication are interconnections. Having exercise or winning the game can be the purpose of that team.

Meadows (2009) explains that interconnections in systems can be physical (students progressing through a University) or they can be a flow of information which are signals that go to decision points and are usually harder to see. The rules of the game for the football team can be an example for the non-physical interconnection in a system. He also discusses how systems can be nested within systems and explains that in such cases there can be purposes within purposes.

This thesis looks at the cities as systems and proposes creative design solutions that will enable cities to maintain vital and social aspects of the people's lives.

Mittelstaedt, P., & Weingartner, P.A. (2005). Why are laws of nature valid? In *Laws of nature* (pp. 309-346). Germany: Springer.

Peter Mittelstaedt and Weingartner (2005) answer the question of whether the laws of quantum logic are laws of nature. They state that:

> ... the apriority of quantum logic is somewhat invalidated by the fact that the pragmatic preconditions (value definiteness, repeatability, restricted availability etc.) and the underlying ontology depend – as in case of classical logic – on experience. ... For that reason the laws of quantum logic are a priori valid and thus not genuine laws of nature but with a small empirical impurity, which makes them – in a weak sense – being laws of nature. (p.346)

This opinion that quantum physics is not a genuine law of nature and that the theory is full of complexity and uncertainty shifted this thesis approach. Instead of examining cities based on the quantum theory, the thesis focused on looking at cities as systems and applied systems thinking to the research and design development.

Salingaros, N. A. (2007). New paradigm architecture. In N. Sala (Ed.), *Chaos and complexity in the arts and architecture* (pp. 129-133). New York: Nova Science Publishers.

Salingaros (2007) believes that there is a distinct difference between the process and the final appearance in an architectural design. Although complex forms arise from fractal growth, emergence, and adaptation in nature, application of these images to the final image of a design is frivolous and without reason. For instance, he criticizes Jencks' (1995) claim for being founded on elementary misunderstandings. According to Salingaros, "There is a new paradigm in architecture and it is indeed based on the New Sciences, but it does not include deconstructivist buildings" (p.129). As an example of a "mere visual and a functional appreciation of fractals" he points to the Guggenheim Museum, saying it is "disjoint[ed]and metallic and as far removed from any flower that he can imagine" (p.131).

Von Werz, M. (2007). Open source fabric. In C. C. M. Lee & S. Jacoby (Eds.), *Typological formations: Renewable building types and the city* (pp. 82-92). London: Architectural Association.

This book provides a collection of projects in digital design and computational design tools. The projects in this book use sophisticated parametric tools in design. The project that is selected for this thesis is called “Open Source Fabric”. This thesis demonstrates non-practicality of that design approach by studying the constructal theory of social dynamics in nature

Wheatley, M. J. (2006). Searching for a simpler way to lead organizations. In *Leadership and the new science: Discovering order in a chaotic world* (pp. 3-15). San Francisco, CA: Berrett-Koehler Publishers.

Wheatley (2006) focuses on living systems and new theories emerging from biology and chemistry. She identifies information as the main resource for generating forms in our self-organized universe. In her view, to create new forms of life there must be new interpretations. Wheatley contrasts Newtonianism with holism and systems thinking .

This research uses holism and systems thinking as a backbone for its research and design development.

Whyte, W. H. (2001). *The social life of small urban spaces.* New York: Project for Public Spaces.

William H. Whyte (2001) discusses the social life in small urban places. He explains his observation and research of the social life in urban public places and mentions that people are attracted to each other in urban places. For instance, people prefer to sit in urban public areas and they enjoy being among other citizens .

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