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MSc Computaional Architecture - UWE
UBLLV1-15-M - Urban sentience 22sep_1
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Project Portfolio
Group 3

CONTENT

1

PROJECT INTRODUCTION

COMPUTATIONAL ANALYSIS TO IMPROVE OUTDOOR THERMAL COMFORT DEPENDING ON BUILDING FORMS OF RESIDENTIAL BLOCKS IN HOT AND ARID CLIMATE- MASDAR CITY.

1. PROJECT INTRODUCTION

1.1. ABSTRACT:

Urbanization has brought about changes in urban morphology and climate, while urban building parameters have become important ecological factors for evaluating urban development performance.

In this portfolio, study represents an optimization approach using heat radiation simulations using ladybug plugin. This application uses genetic algorithms with Grasshopper tools to study the shape, orientation, layout and configuration of courtyards in urban buildings and their impact on pedestrian streets in the city of Masdar, Abu Dhabi, in different cases.

//results

Keywords: urban form, housing, computational method, genetic algorithm, ladybug, form optimization, outdoor thermal comfort.

1.2. INTRODUCTION:

Theory- Urban design deals with the larger scale of groups of buildings, infrastructure, streets, and public spaces, entire neighbourhoods and districts, and entire cities, with the goal of making urban environments that are equitable, beautiful, performative, and sustainable. [ref.4,5]
Interactions between buildings and outdoor environment variables, such as the sun, wind and precipitation, depend on building parameters such as orientation, colours, materials and forms. Building forms are one of the most important parameters that directly impact the cooling and heating load energy consumption, daylight environment and urban sustainability.[ref.1]
Today, researchers of Arab urban centres will observe a few differences between Arab and Western cities. The Arab city is now westernized; this quality cannot protect it from the hot dominant climate, and obscures the architectural heritage acquired over centuries. Traditional Arab-Islamic urbanism has been ignored for decades, and Arab architects have been unwilling to revive traditional features or complying with the New Urbanism movement, which emerged in the early 1990s.[ref.2] In his classic early book, 'House, Form, and Culture', Rapoport (1969) said that the built form results from a sociocultural system where religion is one of the major cornerstones (41).[ref.2]

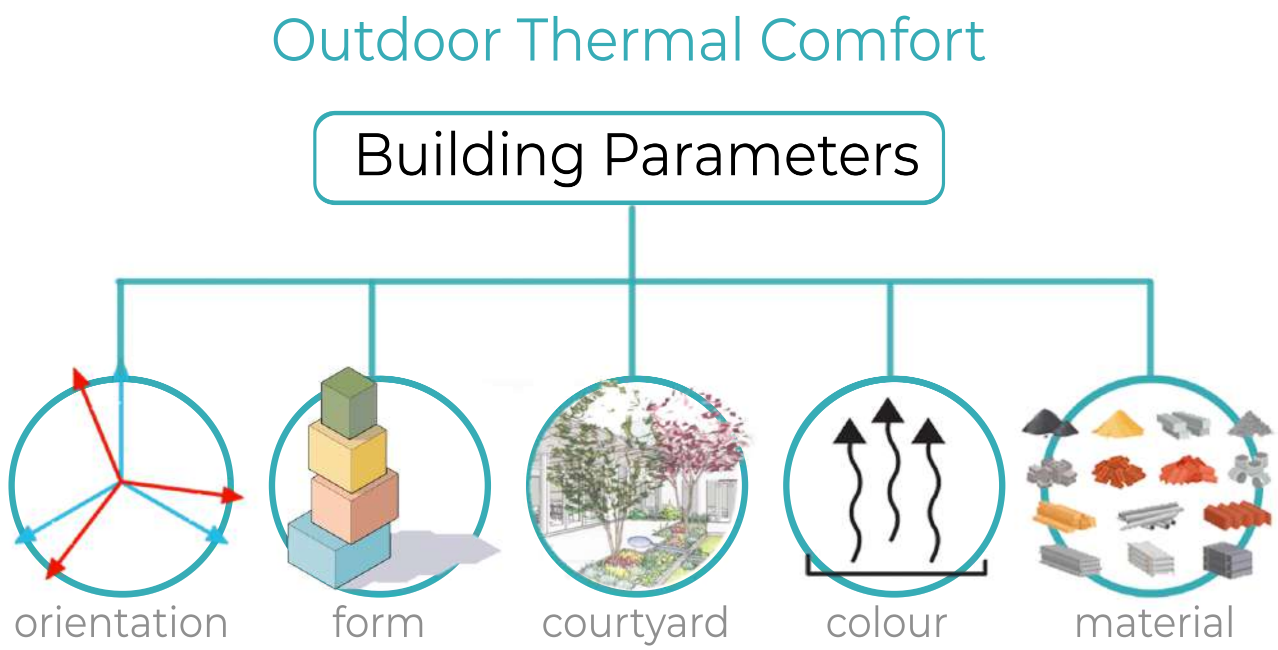


figure 1 : Representation of outdoor thermal comfort building parameters

1.3. BACKGROUD:

The United Arab Emirates (UAE) has witnessed fast growth in urban development in the past four decades. A plan to build 7270 houses by 2021 has been initiated by the local authorities. Different local sustainability guidelines are being implemented, including the Public Realm Manual in Abu Dhabi. These local guidelines are tailored to consider the hot and arid climate of the UAE as well as the applied materials, the inclusion of greenery, shading devices, etc. To understand the effect of these design programs on the outdoor thermal comfort (OTC), further investigations are necessary for each city. In the old local neighbourhoods, Arabic houses were built next to each other to maximize the shading and to ease pedestrians' walkability. [ref.3]

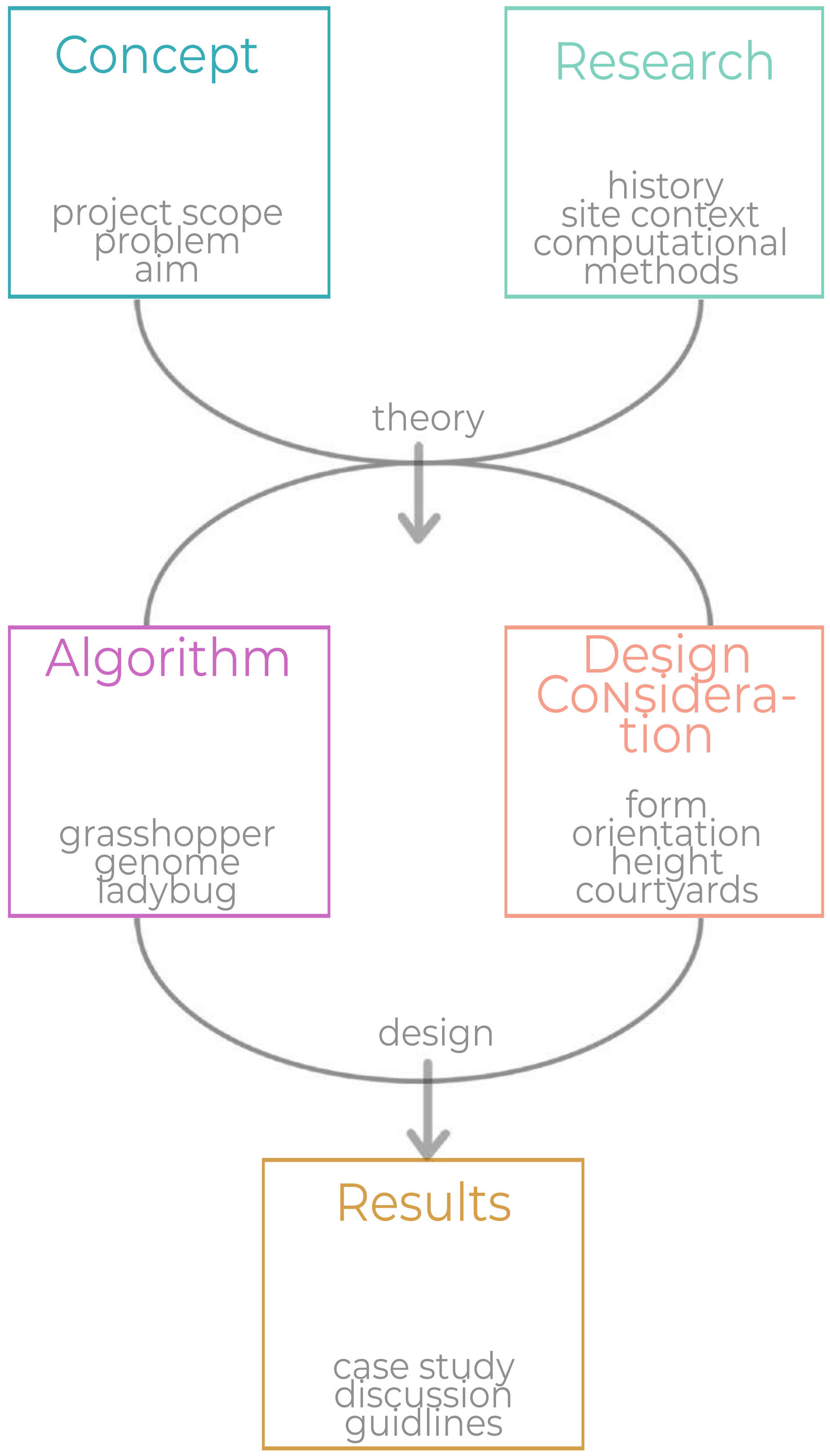
1.4. AIM to examine the Masdar city in Abu Dhabi where the housing programs are applied and to determine the most effective strategy to minimize the heat radiation for pedestrian street and outdoor temperatures and enhance walkability .

1.5. PROBLEM:

Current Masdar city design have grid layout for residential area, the study and design consideration discussed further in this portfolio have potential to improve thermal comfort for pedestrian street of residential block by reconsidering building parameters. For instance street pattern, preveling wind flow, built form and courtyard consideration.

1.6. METHODOLOGY:

The methodology implements the following processes in order:
1) comparative analysis of Medieval Islamic Cairo and Masdar city planning for following parameters:
a] street patterns
b} building heirachy
c] building block shape and orientation
d] green zone/ courtyards
2) case study on building orientation and shape for hot and arid climate zone
3) Design Consideration to improve current masdar proposal for residential blocks.
4) Solar radiation anaylsis for different cases by using Ladybug plug-in in grasshopper



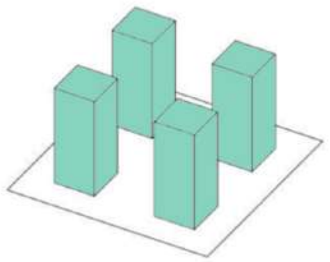
2
RESEARCH

2. RESEARCH

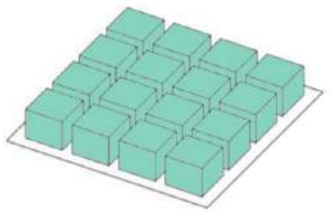
2.1. MODERN URBAN FABRIC AND MEDIEVAL CAIRO URBAN FABRIC

Most Arab countries, especially those who belong to the Organization of Arab Petroleum Exporting Countries (OAPEC), found themselves with a large financial surplus (Awartani and Maghyereh 2013); they used it to change the old landscape and impose a modern, Western style (Rizzo 2014) as shown in Figure 1 [ref.2]

Figure 1. The urban transformation from traditional to modern development in Qatar and the UAE. Tall glass towers have replaced low-rise buildings in a compact urban fabric



MODERN URABAN HIGH RISE HIGH DENSITY



MEDIEVAL CAIRO LOW RISE HIGH DENSITY

2.2. MEDIEVAL CAIRO - BUILDING PARAMETERS

Medieval Cairo is a compact hierarchy of narrow, winding streets that Contribute to the city's aesthetics. Fatimid Cairo had originally an area of 143 ha (Al-Sayyad 1981). According to Warner (2006), about 40,000 people were residing in this area. Therefore, the population density is roughly 280 persons per hectare. The minor streets were so narrow (2–3 m), where as the major ones were ranging between 6 and 7 m (Al-Sayyad 1981). The urban pattern of this historic city offers perspectives on various pathways as shown in Figure 2. The dense arrangement includes the tapered, zigzagging roads around Al-Mu'izz Street in the centre of Fatimid Cairo. Cullen (1961) and Appleyard, Lynch, and Myer (1965) promoted this structure later on. A large number of these roads are dead-end, which helps residents to monitor their neighbourhoods. Furthermore, the dead-ends create semi-public or semi-private spaces that allow children to play under the close watch of their mothers while retaining the social privacy needed in an Arab Muslim community. [ref.2]

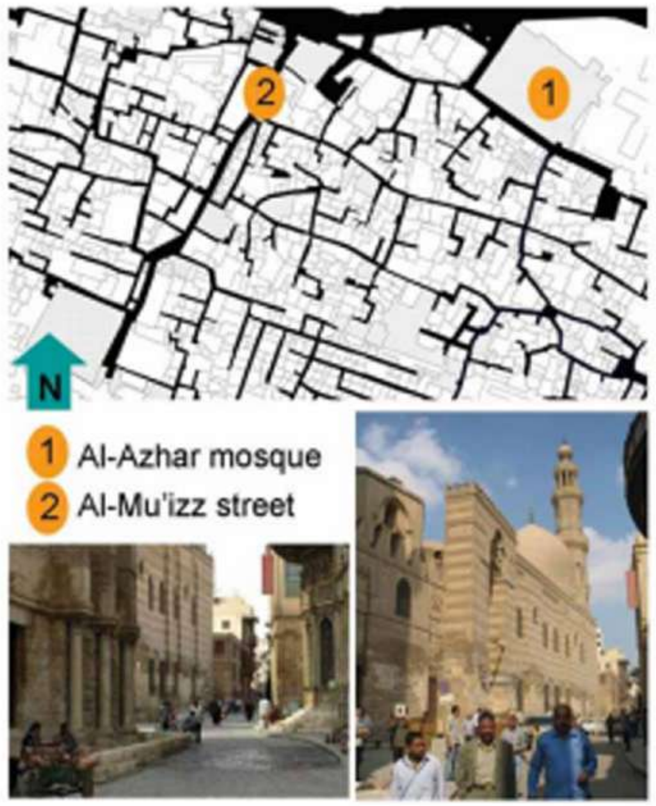
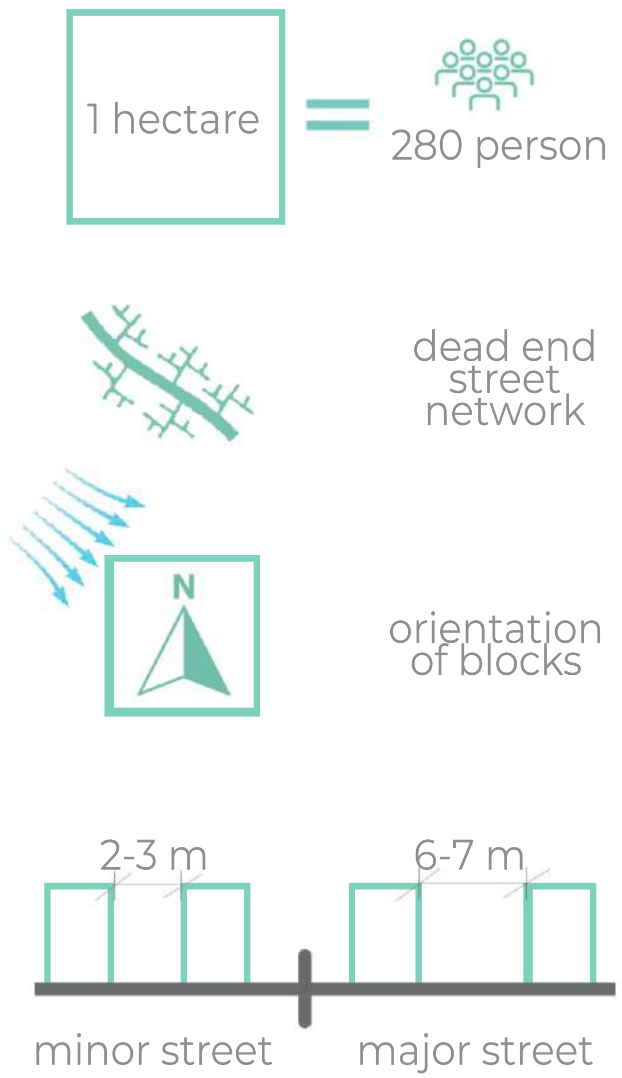
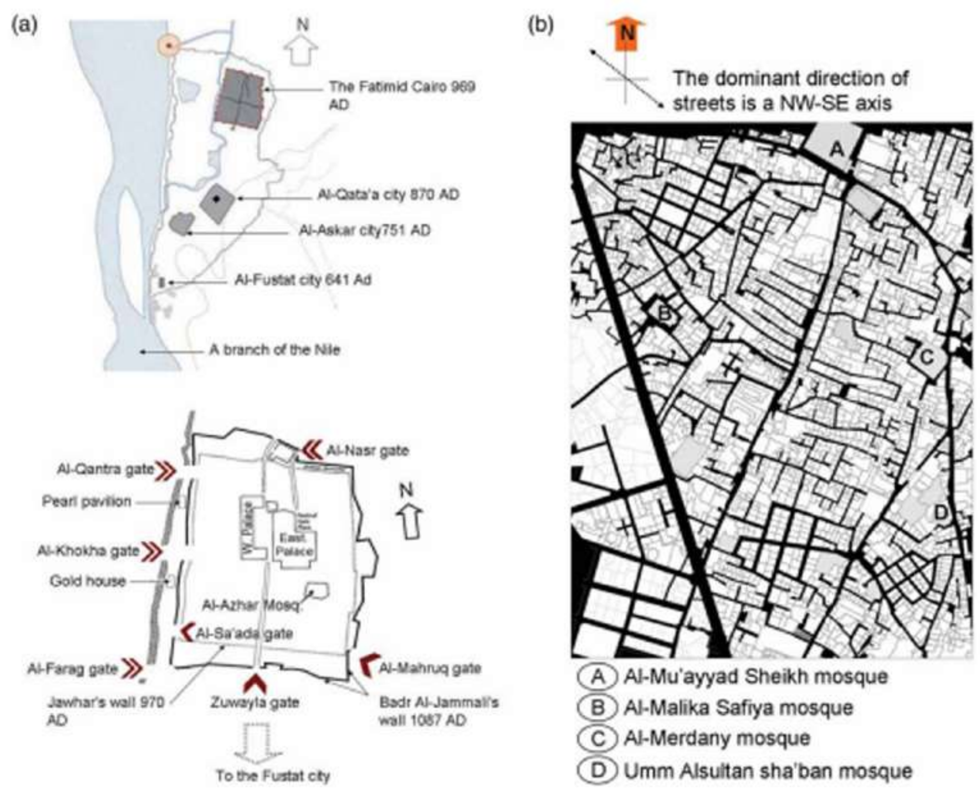


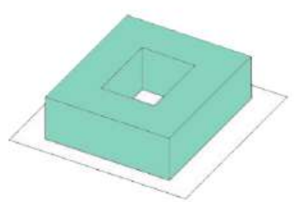
figure 2 . The urban pattern in the neighbourhood of Al-Azhar Mosque and Al-Mu'izz Street, where the dense city structure involves winding, narrow, and dead-end streets.



Al-Maqrizi, a well-known historian of the fifteenth century, said that the Fatimids planned Cairo in the shape of a complete square (Alsayyed 1999). Figure 4(a) shows the layout of Cairo during the Fatimid period, when the city was surrounded by a high wall that followed the square's four edges, each edge having two gates in the beginning. The streets in medieval Cairo might have been angled in the direction of the Kaaba in Mecca (Bonine 1979). Figure (b) shows that most streets were positioned on a southeast– northwest axis and a south–north axis to maximize the flow of cool air from the north and northwest, in addition to increasing the shade provided by buildings, which block solar radiation during the day. [figure a] The general shape of old Cairo (Fatimid Cairo) is almost a square, especially the early territory surrounded by Jawhar's wall (970 AD). [figure b] The common orientation of the streets in medieval Cairo lies on a southeast-northwest axis. [ref.2]

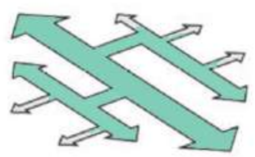


(a) Fatimid Cairo has a square layout. (b) The dominant orientation of the streets lies on a utheast–northwest axis.



SQUARE LAYOUT

ORIENTATION



STREET ORIENTATION
NW-SE AXIS

2.3. MASDAR CITY - BUILDING PARAMETERS

Figure 3 shows the layout, comprises two squares; the grid's dominant orientation lies on a southeast– northwest axis. Masdar City was planned as a compact metropolis with low-rise buildings and a relatively high density (130–160 people per hectare). Because it is a modern city planned at the start of the twenty-first century according to current requirements, the streets are configured in a grid with a limitation on width (14 m as a maximum for main streets and 8.5 m for secondary streets). [ref.2]

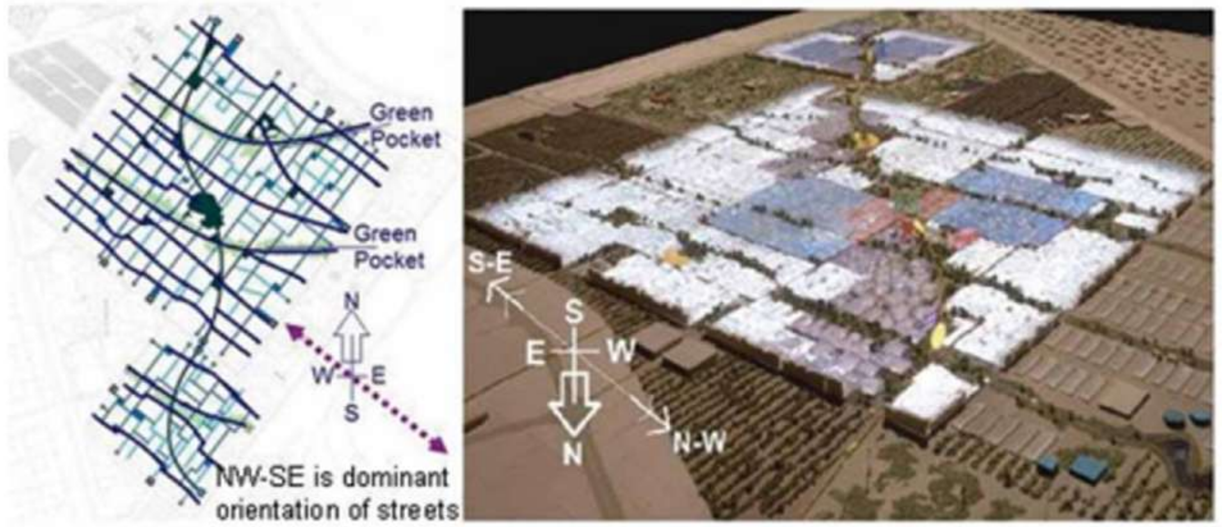
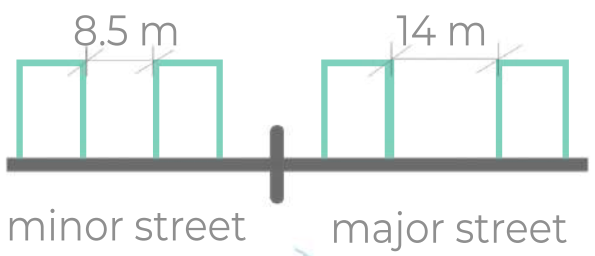
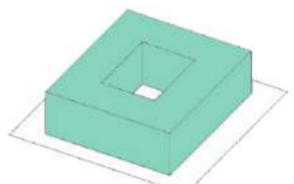


figure 3 . Masdar City consists of two squares. The first is big and the second is small. The dominant orientation of the streets lies on a southeast–northwest axis.



NW-SE is dominant orientation of street



Square planing

orientation of blocks

2.4. MEDIEVAL CAIRO - WIND TOWERS

Wind towers or windcatchers (malqaf in Arabic) capture the preferable, cooler, upper layer of air and force it to pass through the tower shaft, supplying indoor spaceswith cross-ventilation (Roaf 1990). Due to Islamic Cairo's tightly packed form, ancient Arab architects were forced to invent a technique to cool the courtyard. Figure 4 shows the traditional technique for ensuring an active ventilation process throughout indoor areas.[ref.2]

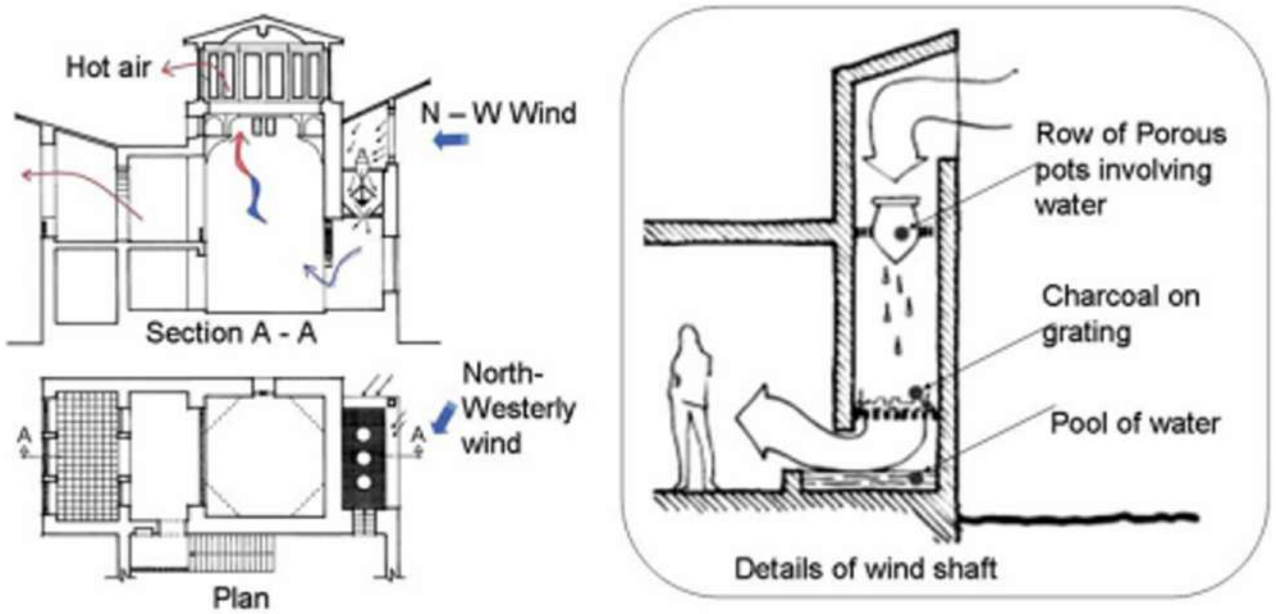


figure 4 . A traditional windcatcher is based on a simple technique. Porous pots of water convert dry air into humid air, and charcoal on a grating increases the flow of air into indoor spaces. Here, indcatchers were only used to affect the inside of buildings

2.5. MASDAR CITY - WIND TOWERS

Masdar City is in a region with little wind. In response, the city's designers employed supersized windcatchers in public squares, rather than private and indoor spaces, so that the wind tower would have a greater effect on more actively used areas. The large urban square at the base of the wind tower is home to cafes and other retail outlets, with seating extending into the open plaza for use in pleasant weather. Figure 5 illustrates the supersized windcatcher's thermal performance in public urban space, which depends on new technologies. The sensible landscaping offers shade and numerous services such as a gym, prayer room, organic grocery store, and bank are located on or near the square to provide recreational and social spaces. A raised platform beneath the windcatcher serves as a performance stage (Masdarconnect 2013).

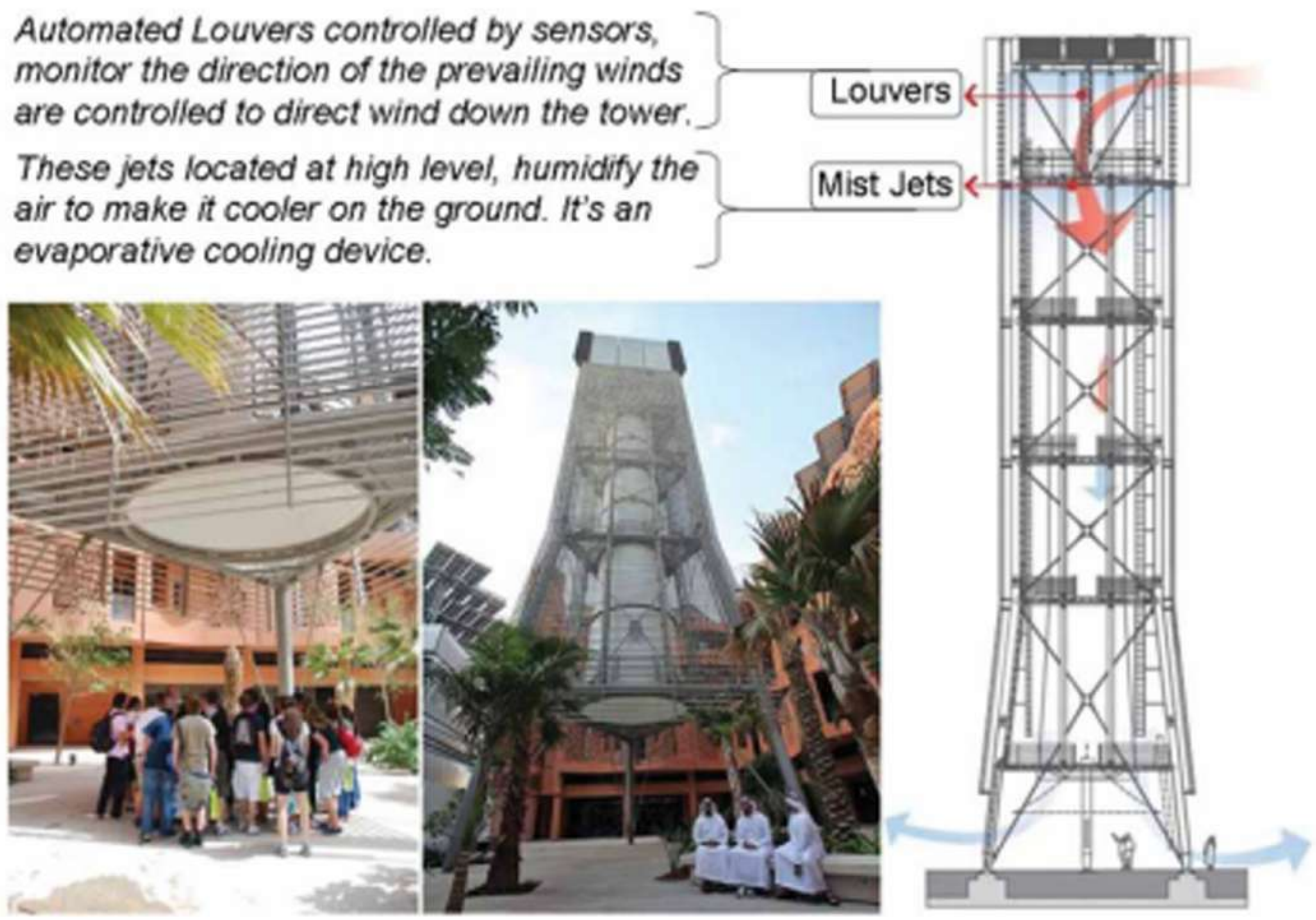


figure 5 . The windcatcher in Masdar City involves complex technology to control the orientation of the wind and the quality of the air. Windcatchers are used in public spaces alongside buildings

2.6. MEDIEVAL CAIRO COURTYARDS

Courtyards characterize the buildings of medieval Cairo and act as a thermal regulator (Hassan and Lee 2014). Homes in Islamic Cairo often encompass two courtyards: a large one and a small one; cool air moves from the small courtyard towards the large one during the day. Circulation is important for thermal comfort in these dry, hot climate because people can adjust the temperature, especially when sweating. Figure 6 shows how cool air moves from a small courtyard to a large one, then passes from the reception area (takhtaboosh in Arabic) to the inner space of Bayt Al-Suhaymi ('House of Suhaymi'), a museum in Cairo that is a house from Ottoman times. Courtyards are a centre for family activities; the fountain, greenery, and privacy make it preferable for women and children (Ratti, Raydan, and Steemers 2003; Roaf 1990). Arab planners showed particular insight using climate control techniques to create the private sphere, where people spend most of their time [ref.2]

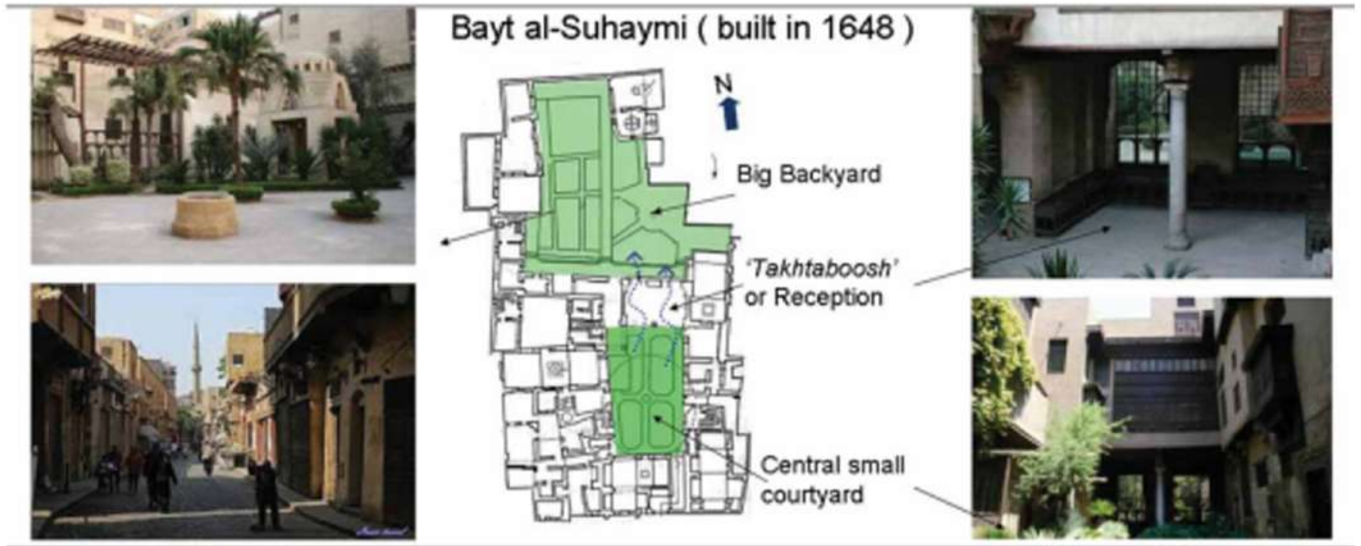
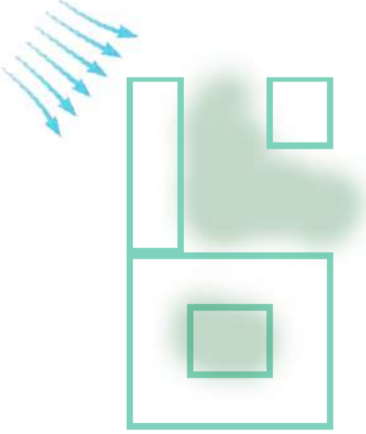
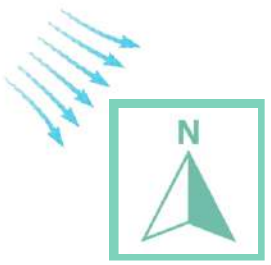


figure 6 . The courtyard is a substantial part of the Arab-Islamic house. Integration between small and big courtyards in Bayt Al-Suhaymi provides a thermal comfort zone through cross-ventilation



big and small courtyard



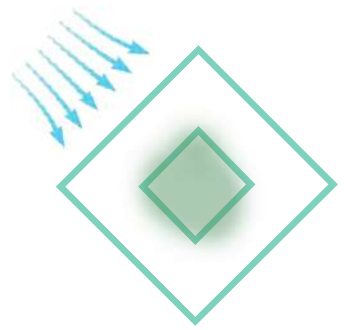
orientation of blocks

2.7. MASDAR CITY SELECTED SITE

masdar city master plan

selected ZONE

street pattern



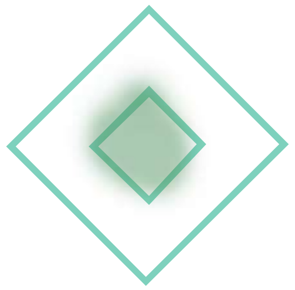
central courtyard

existing proposal

2.8. MASDAR CITY COURTYARDS

In Masdar City, courtyards also regulate thermal performance in hot zones, providing cool air and shade to the surrounding areas, creating assorted spaces of air density that encourage ventilation, and a private environment. The planners created the courtyards based on the arrangement of buildings in the urban design, and included them inside buildings in the architectural design. figure 5 shown how courtyards are use for different urban fabric like around retail corner, academic institute and residentail zone. [ref.2]

figure 5 . Courtyards are an important element in Masdar City's urban fabric. Most buildings include them



urban fabric in residential zone

orientation of blocks

2.9. COLLECTIVE COMPARISION OF BUILDING PARAMETERS FOR MEDIEVAL ISLAMIC CAIRO AND MASDAR CITY:

BUILDING PARAMETERS	MEDIEVAL ISLAMIC CAIRO	MASDAR CITY
PLANNIG FORM	SQUARE LAYOUT	SQUARE LAYOUT
ORIENTATION	N NORTH	N NORTH
STREET NETWORK	DEADEND STREET NETWORK	GRID NETWORK
STREET WIDTH	2-3 m / 6-7 m minor street / major street	8.5 m / 14 m minor street / major street
DENSITY	LOW RISE COMPACT	LOW RISE COMPACT
COURTYARDS	BIG COURTYARD FOLLOW BY CENTRAL COURT YARD	CENTRAL COURTYARD

2.10. ROLE OF BUILDING BLOCK ORIENTATION TO MAXIMIZE WIND DISTRIBUTION

The street grid layouts are comprised of a multitude of variables controlling their design, including orientation, wind direction, height to width ratio and many more. For the sake of narrowing down the results, some variables were assumed at a fixed state, like initial meteorological factors and height to width ratio. The street grid analysis covered the geometrical composition of five designs— containing orthogonal and radial grids, with every grid restricted to exact several properties to ensure all results are calibrated in the same

LAYOUTS	A		B		C		D		E	
ICONS										
NORTH DIRECTION										
WIND DIRECTION										
SCENARIOS	A.1	A.2	B.1	B.2	C.1	C.2	D.1	D.2	E.1	E.2
AREA PERCENTAGE	6%	36%	8%	29%	9%	18%	52%	68%	42%	60%

figure 7.1. Area percentage of the areas thatare receiving less than 0.5m/s of wind speed at 1.5 mheight.

Table 7.1 shows how geometrical layouts distribute wind flow differently. Scenarios 1 with a 45° orientation counter-clockwise of north showed improved results when compared to scenario 2 with no tilt from north. Layout A scenario 1 showed better results across all layouts and scenarios with only 6% of the area having low wind speed of (0- 0.5) m/s, while layout D. showed the worst results across layouts due to its curved streets that obstructed wind flow, with 68% of the area having low wind speeds. [ref.6]

2.11. THE PHYSIOLOGAL EQUIVALENT TEMPERATURE (PET) LEVEL FOR DIFFERENT LAYOUTS

The street grid analysis showed interesting results throughout the different layouts. Wind speed was affected greatly by the change of orientation, where the 45° counter clockwise rotation from North showed a major improvement in wind flow distributions. However, the change in orientation did not play a key part in the PET levels even though the change in orientation changed the shadow patterns. The main reason behind the rise and fall of PET levels was the geometry of the plot, whether it was rotated from the original orientation or not. Understanding the geometry of the site is a key component in determining the thermal

LAYOUTS	A		B		C		D		E	
ICONS										
NORTH DIRECTION										
WIND DIRECTION										
SCENARIOS	A.1	A.2	B.1	B.2	C.1	C.2	D.1	D.2	E.1	E.2
PET	26.1	27.2	26.6	27.7	26.7	28.3	28.2	29.3	28.4	29.6

figure 7.2. Average PET values for all layouts.

An increase in PET values is noticed in all of the layouts in scenario 2, this is caused by the (North-South) orientation streets that receive the highest solar radiation throughout the day The averaged PET values showed in Table 7.2 do not convey how well the layouts present their comfort level, but rather they show how in the same layout the different orientation shifts the comfort levels - scenarios 1 and 2. An increase in PET values is noticed in all of the layouts in scenario 2, this is caused by the (North-South) orientation streets that receive the highest solar radiation throughout the day. [ref.6]

PET	Thermal perception	Grade of physiological stress
	Very cold	Extreme cold stress
4°C	Cold	Strong cold stress
8°C	Cool	Moderate cold stress
13°C	Slightly cool	Slight cold stress
18°C	Comfortable	No thermal stress
23°C	Slightly warm	Slight heat stress
29°C	Warm	Moderate heat stress
35°C	Hot	Strong heat stress
41°C	Very hot	Extreme heat stress

PET Index values

2.12. SHADING AND ISOLATION PERFORMANCE OF INCLINED FACADES

Hemsath and Alagheband Bandhosseini [3] stated that building form and orientation, as early decisions in the design process, could have a great impact on energy consumption, lighting, cooling and heating load. [ref.1]
According to the findings, increasing the inclination angle to up to 30 decreased the cooling load by an average of 15% to 23%. The building forms generated from the optimal inclination angles had a remarkable influence on energy consumption and cooling load. The best performance was exhibited by the buildings with staggered forms, as they provided the most shading to lower floors. The configuration of the south facade had a greater impact on cooling load than the configuration of the north facad . [ref.1]

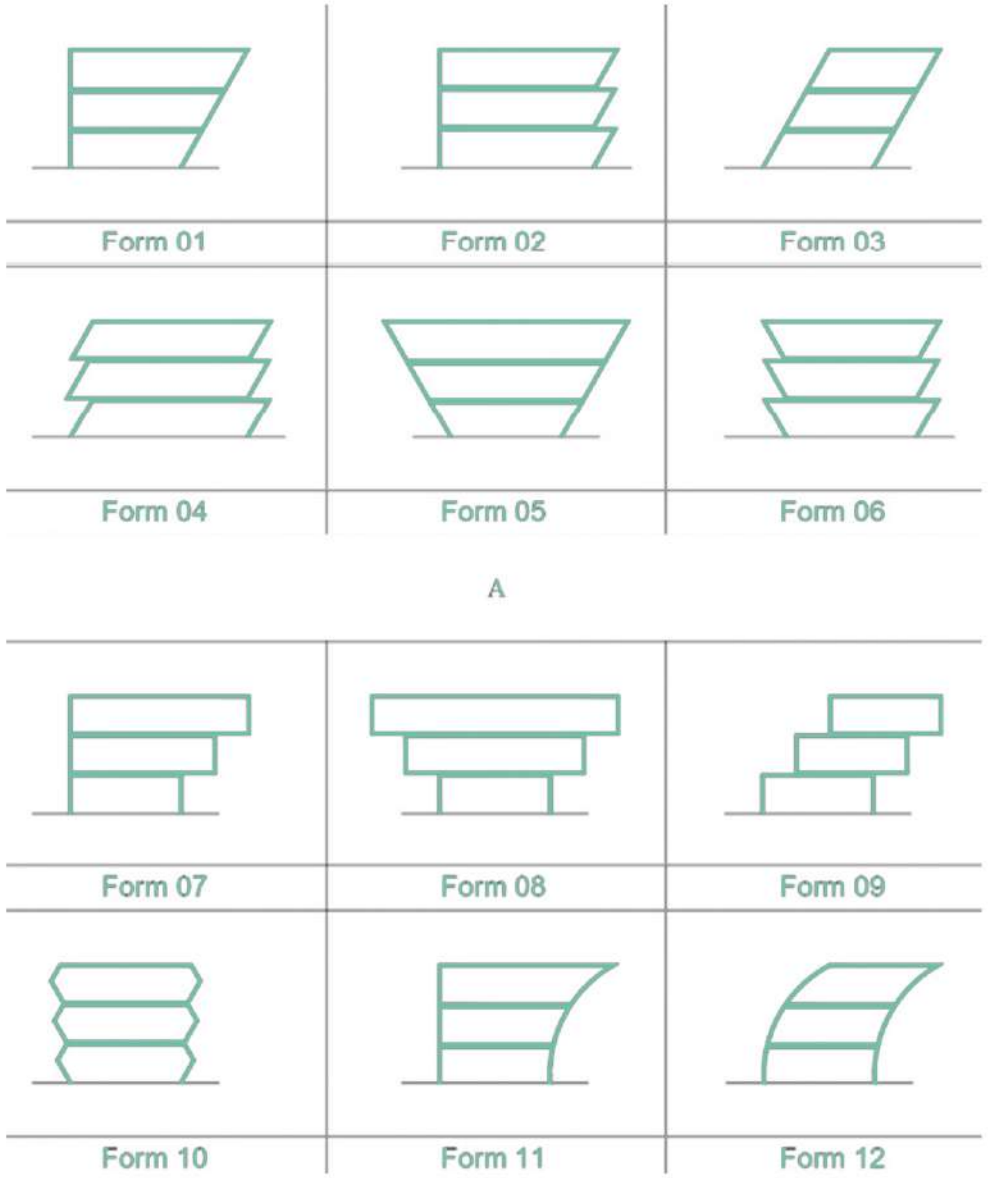


figure 7. . Developed forms: (A) inclined forms (B) staggered forms

2.13. PREVAILING WIND

Usually cooling by ventilation is desired. Buildings should therefore be oriented across the prevailing wind. This direction often does not coincide with the best orientation according to the sun. Here a compromise should be found, paying more attention to the effects of solar radiation, because the direction of the wind can be influenced to a certain extent by structural elements. (Climate Responsive Building: Appropriate Building Construction in Tropical and Subtropical Regions, 1993) In case of multiple buildings on a site, they must be arranged to avoid built forms falling in the wind shadows created by other buildings on the site. [ref.7]

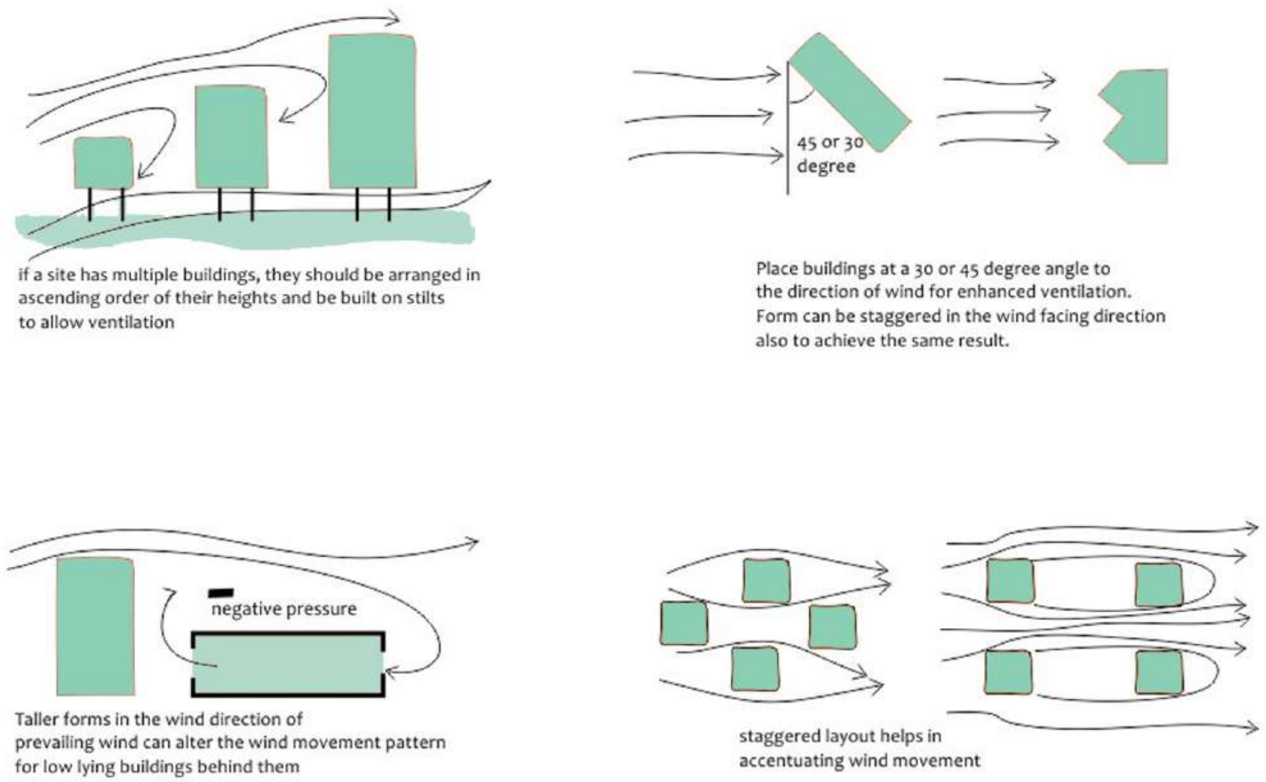
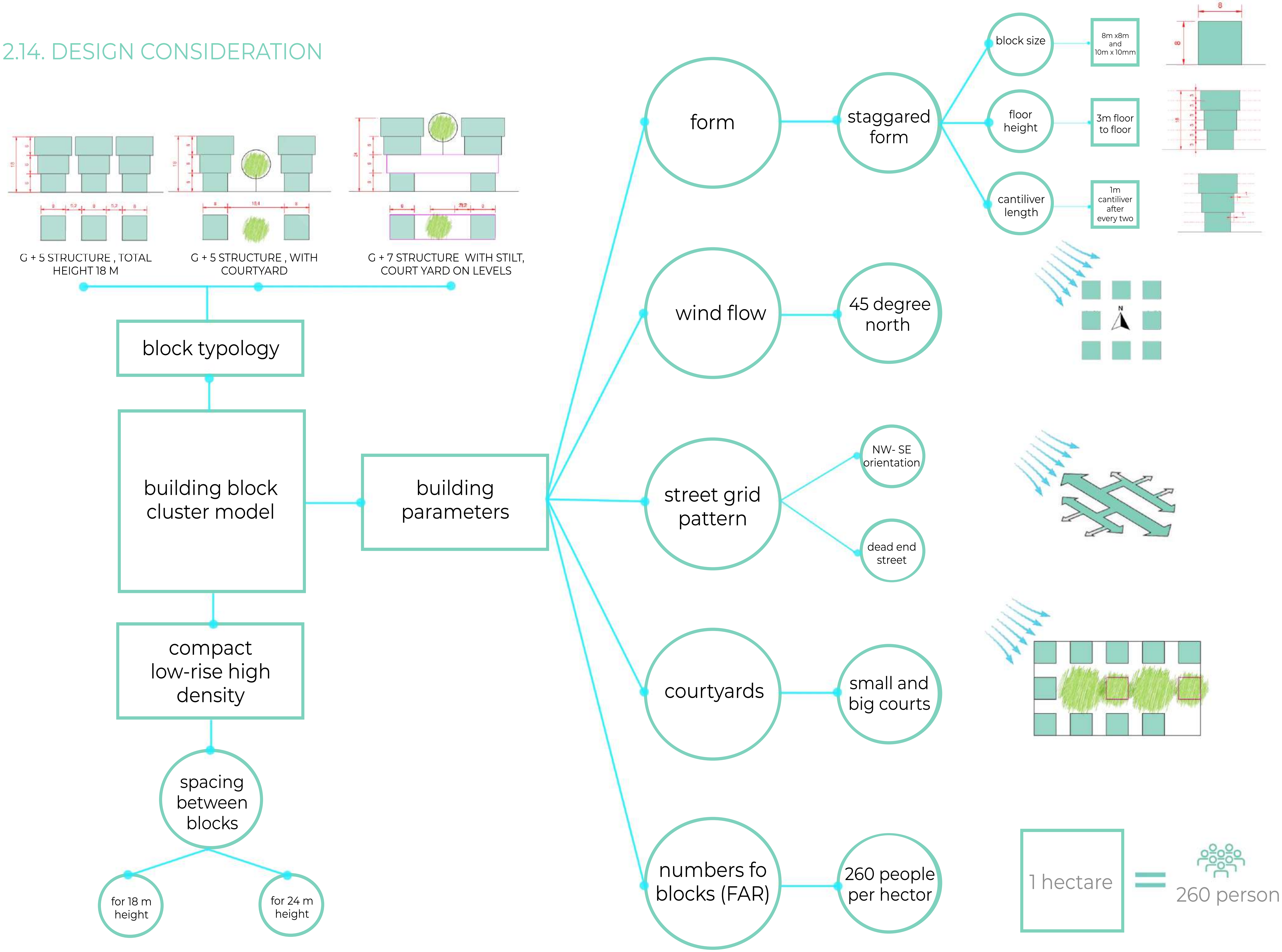


figure 8. . Source: http://www.nzeb.in/knowledge-centre/passive-design/form-orientation

2.14. DESIGN CONSIDERATION

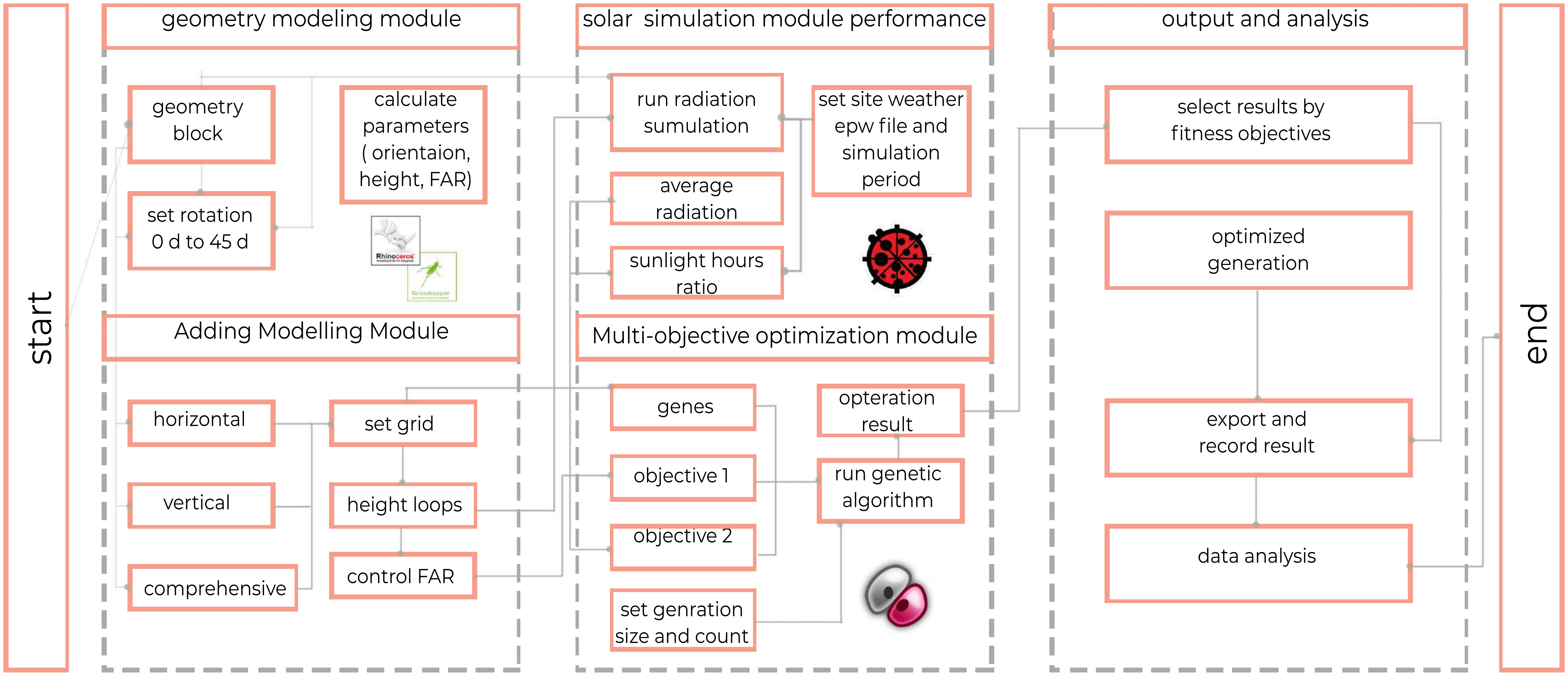


3

COMPUTATIONAL METHOD

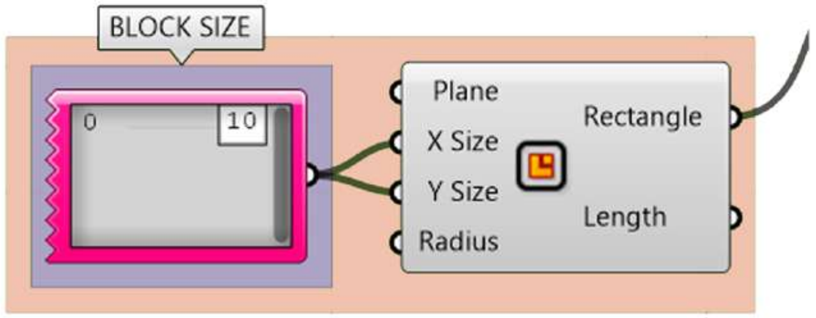
3. COMPUTATIONAL METHOD

3.1. CONCEPT:

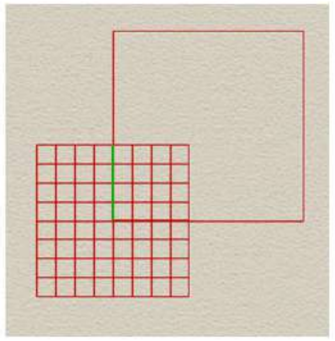


3.2. PROCESS:

STEP 1: set up rectangle component and block size

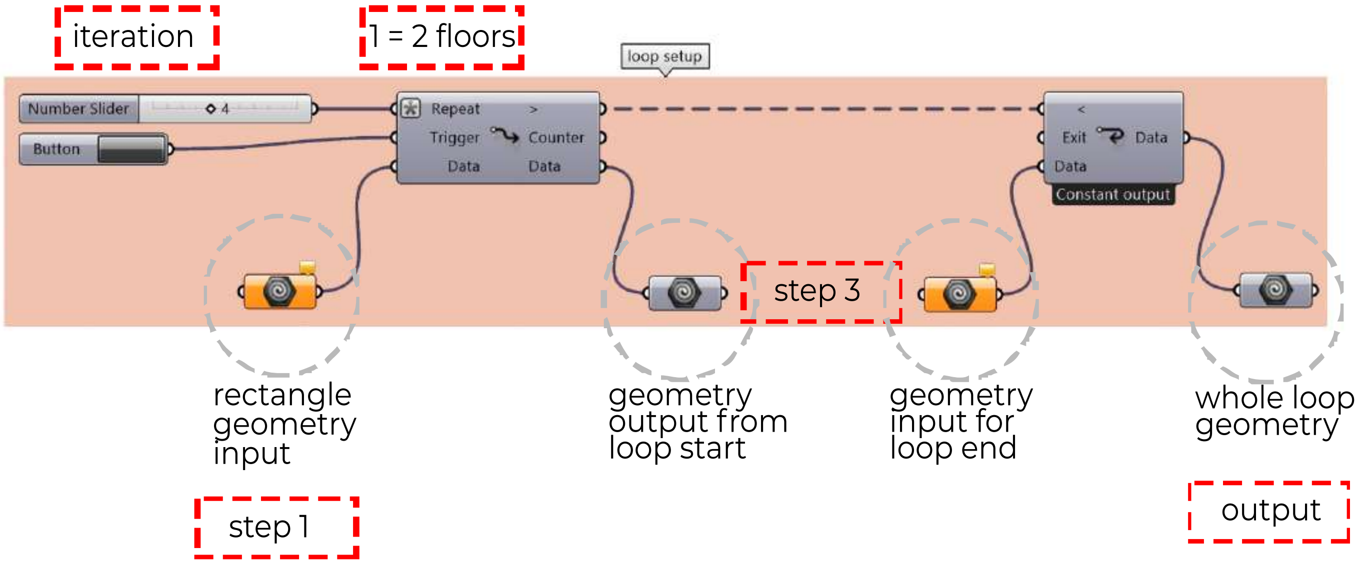


block size range between 8 to 10 meters
(rectangle geometry input)

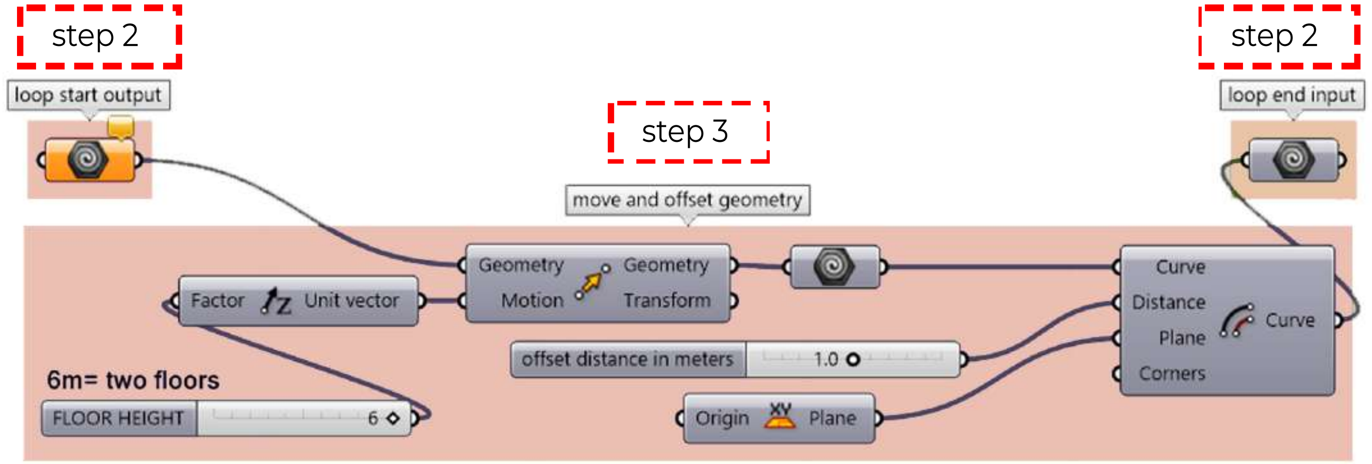


rhino view port plan

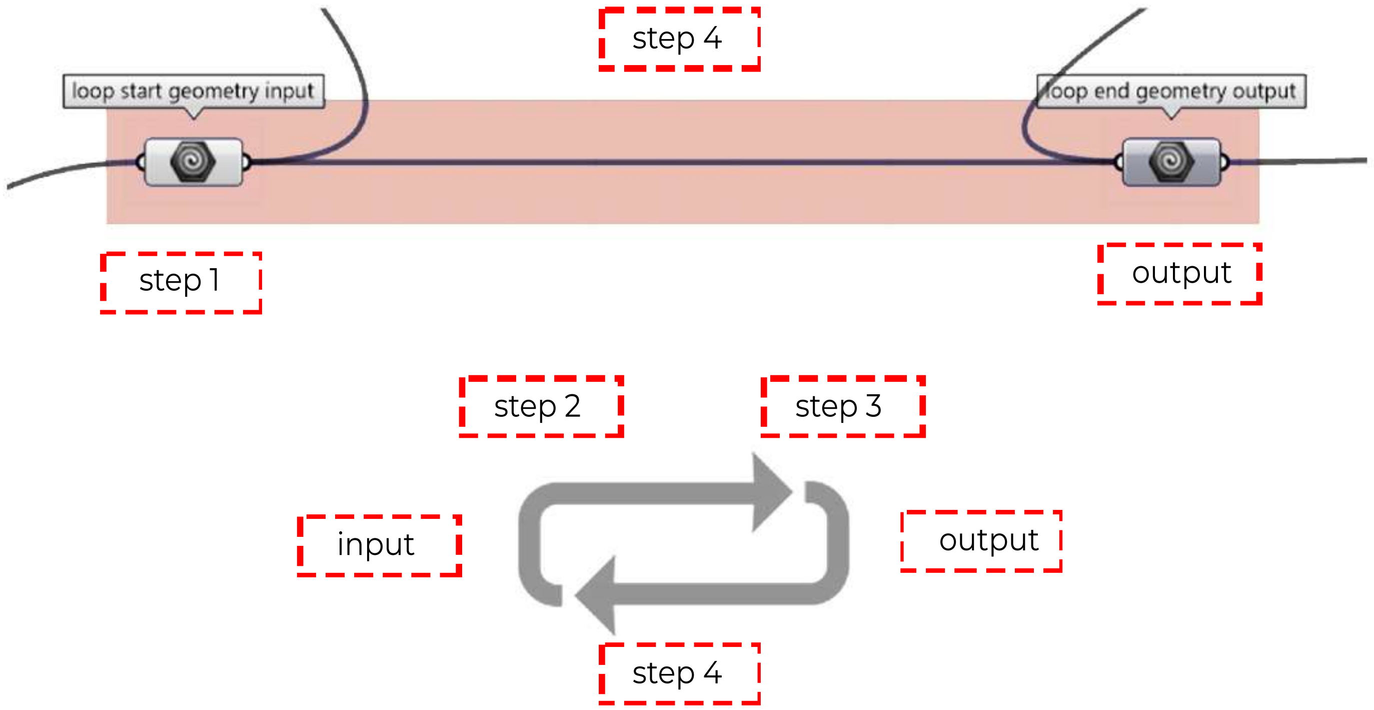
STEP 2: set up loop component for vertical extention



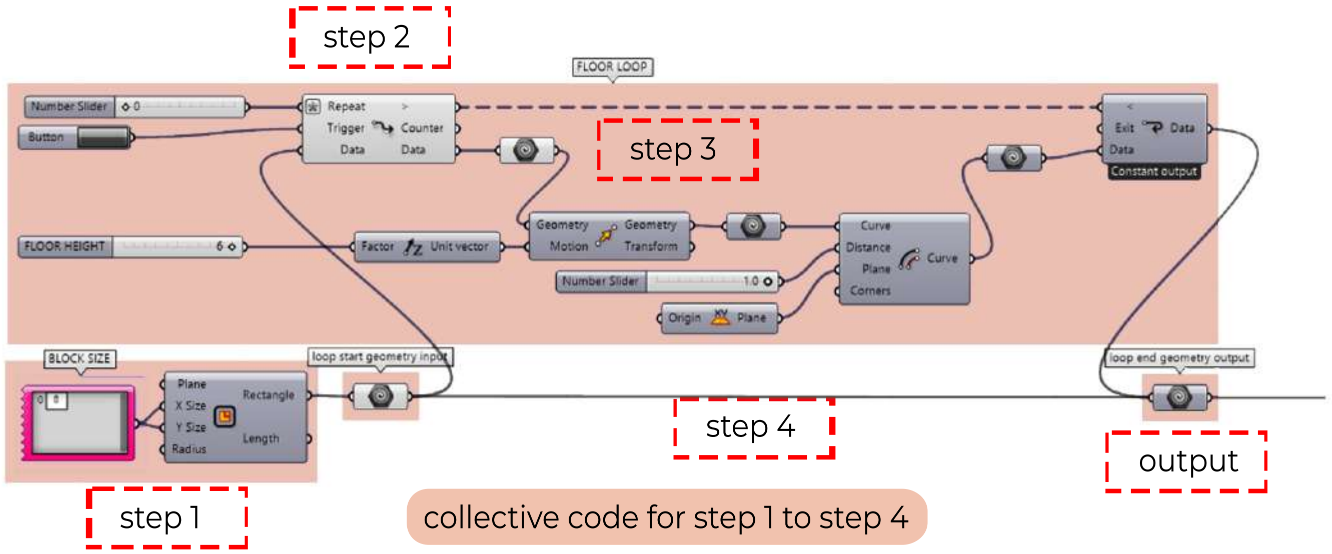
STEP 3: set up move on z axis and offset on xy plan for looping for floors



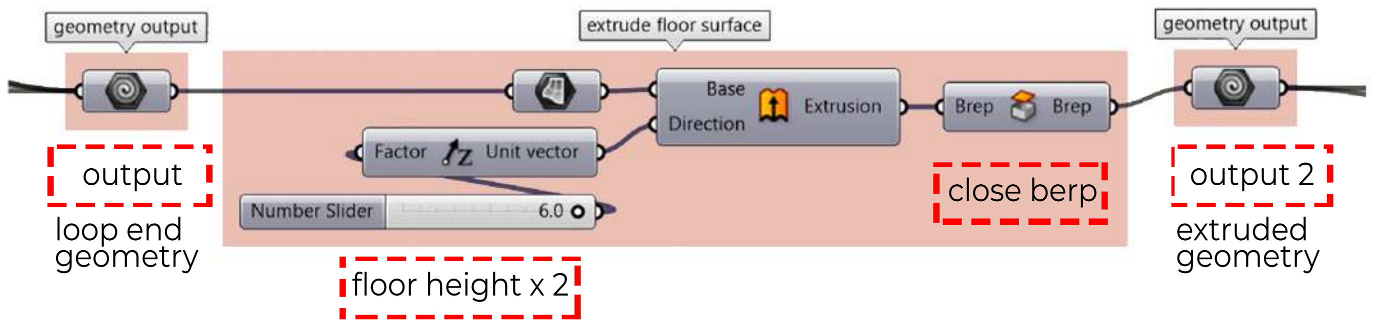
STEP 4 : connect loop geometry input into loop end geometry output to close loop



STEP 1 -STEP 4 SKETCH

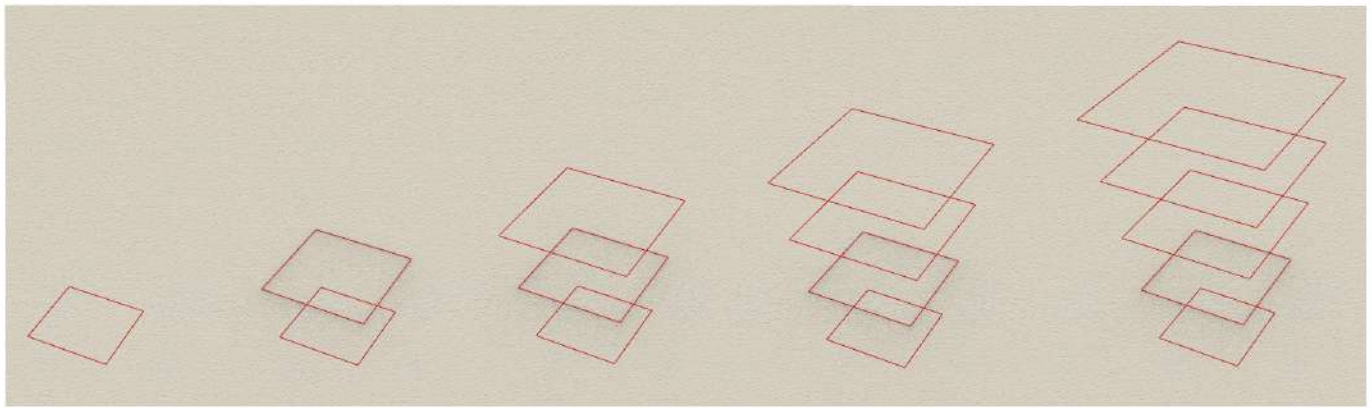


STEP 5: Convert floor curve into surface for extrusion



RHINO VIEW PORT - STEP 4 OUTPUT

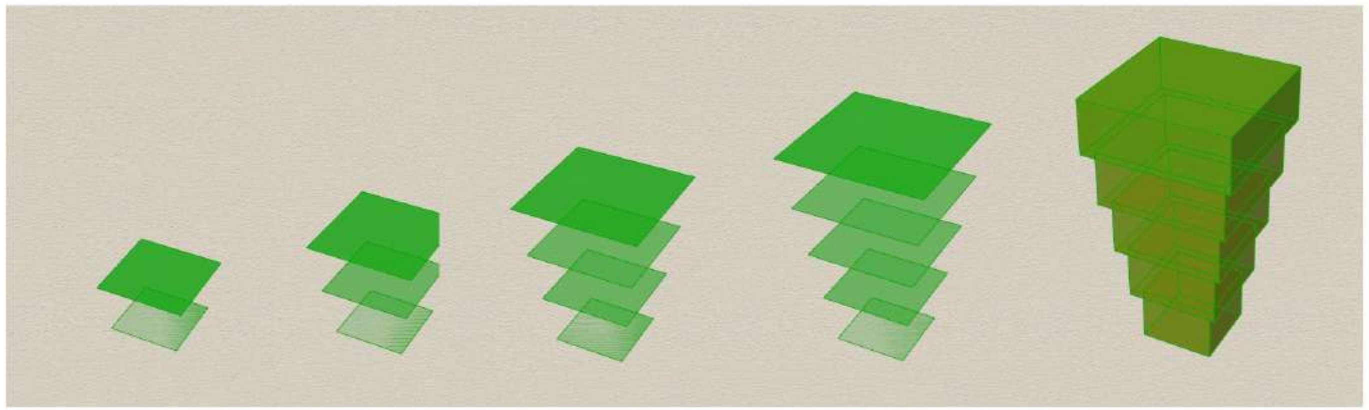
iteration 0 iteration 1 iteration 2 iteration 3 iteration 4



rhino view port prespective

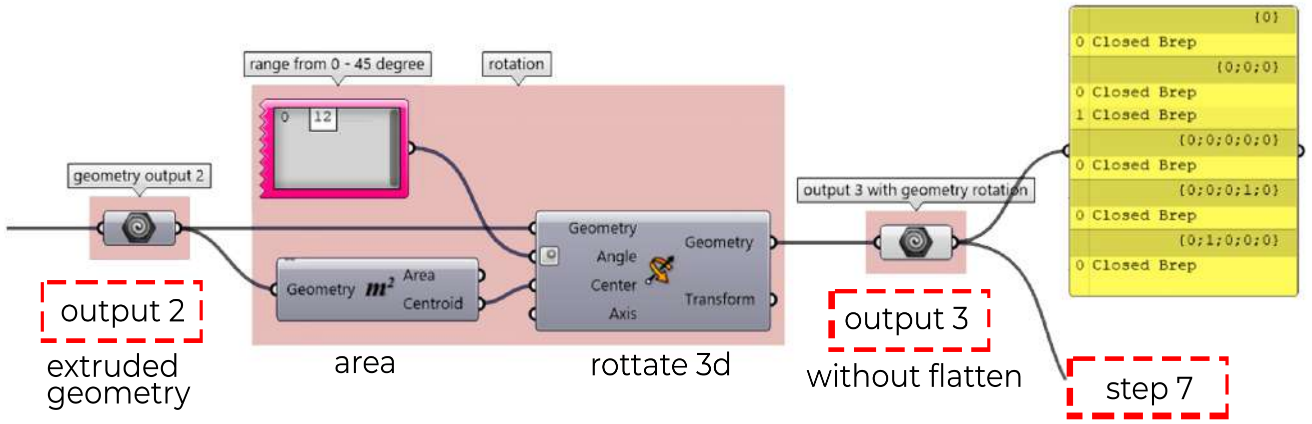
RHINO VIEW PORT - STEP 5 OUTPUT 2

iteration 1 iteration 2 iteration 3 iteration 4 extrusion

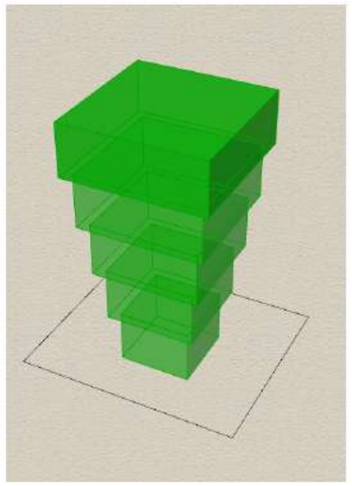


rhino view port prespective

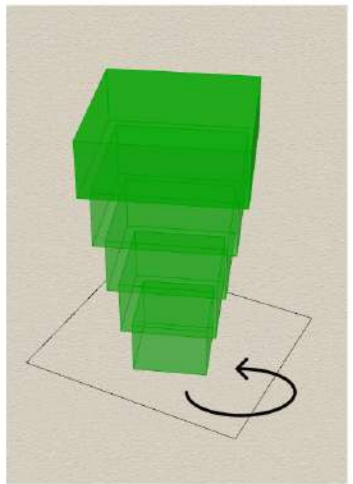
STEP 6: Set Geometry for rotation 3d



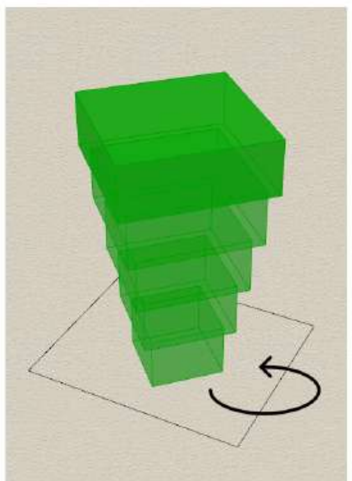
RHINO VIEW PORT - STEP 6



Angle 0 degrees

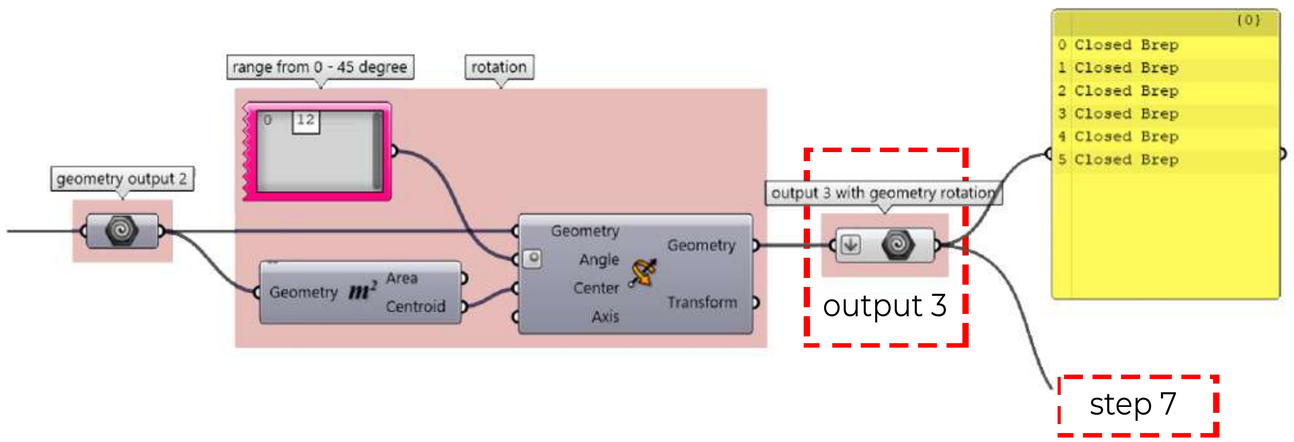


Angle 20 degrees

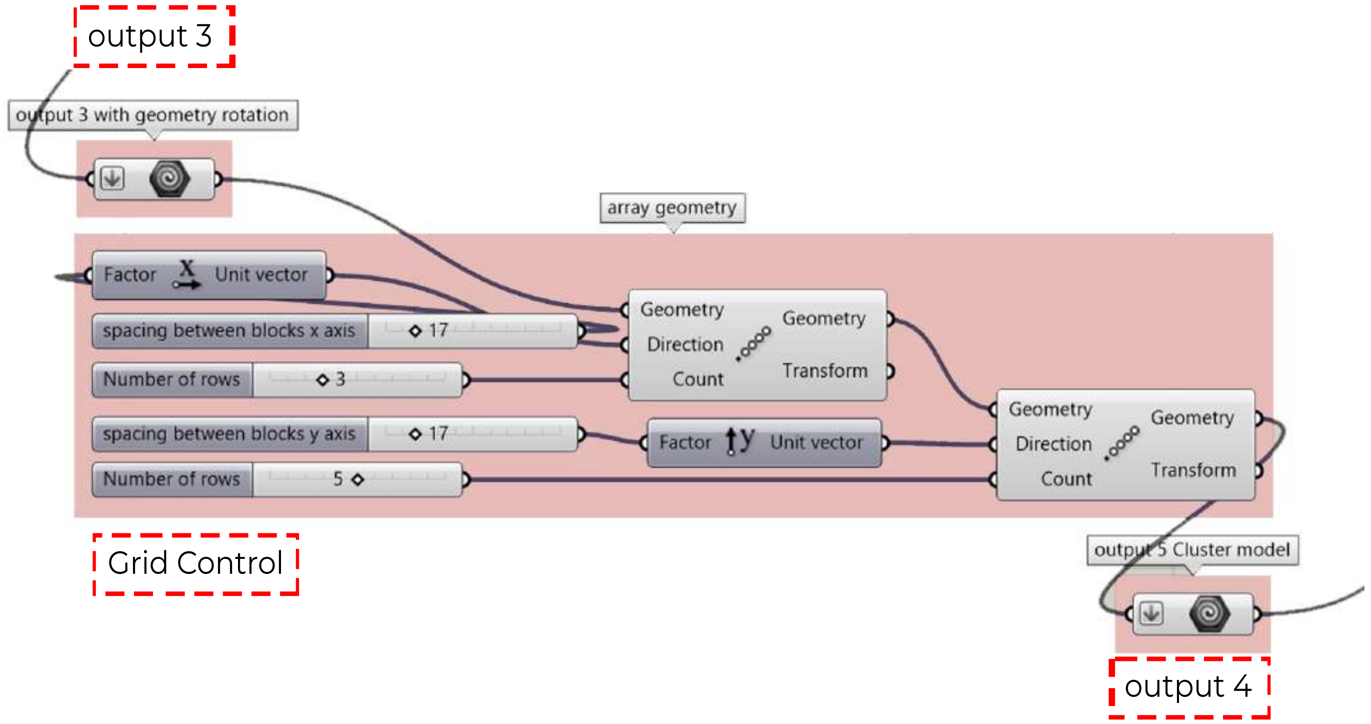


Angle 45 degrees

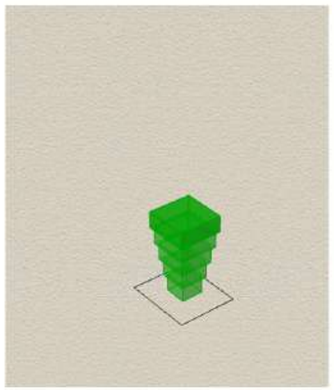
FLATTEN OUTPUT



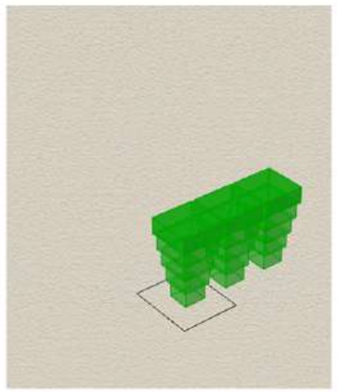
STEP 7: Setup Geomety Cluster module



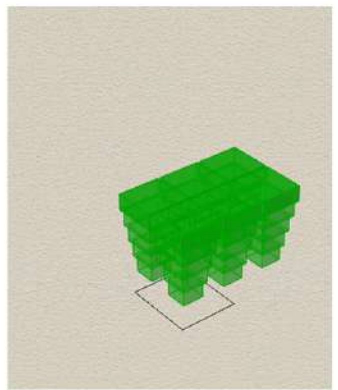
RHINO VIEW PORT - STEP 7



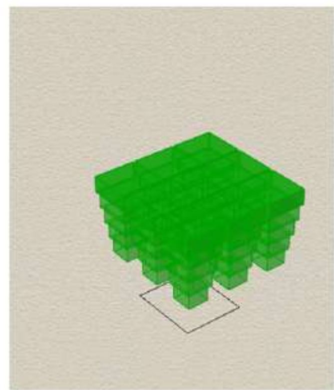
output 3 geometry



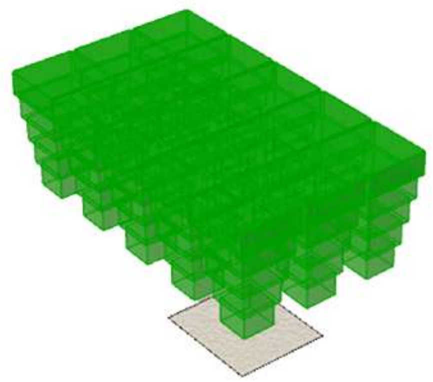
3 rows on x-axis



2 rows on y-axis

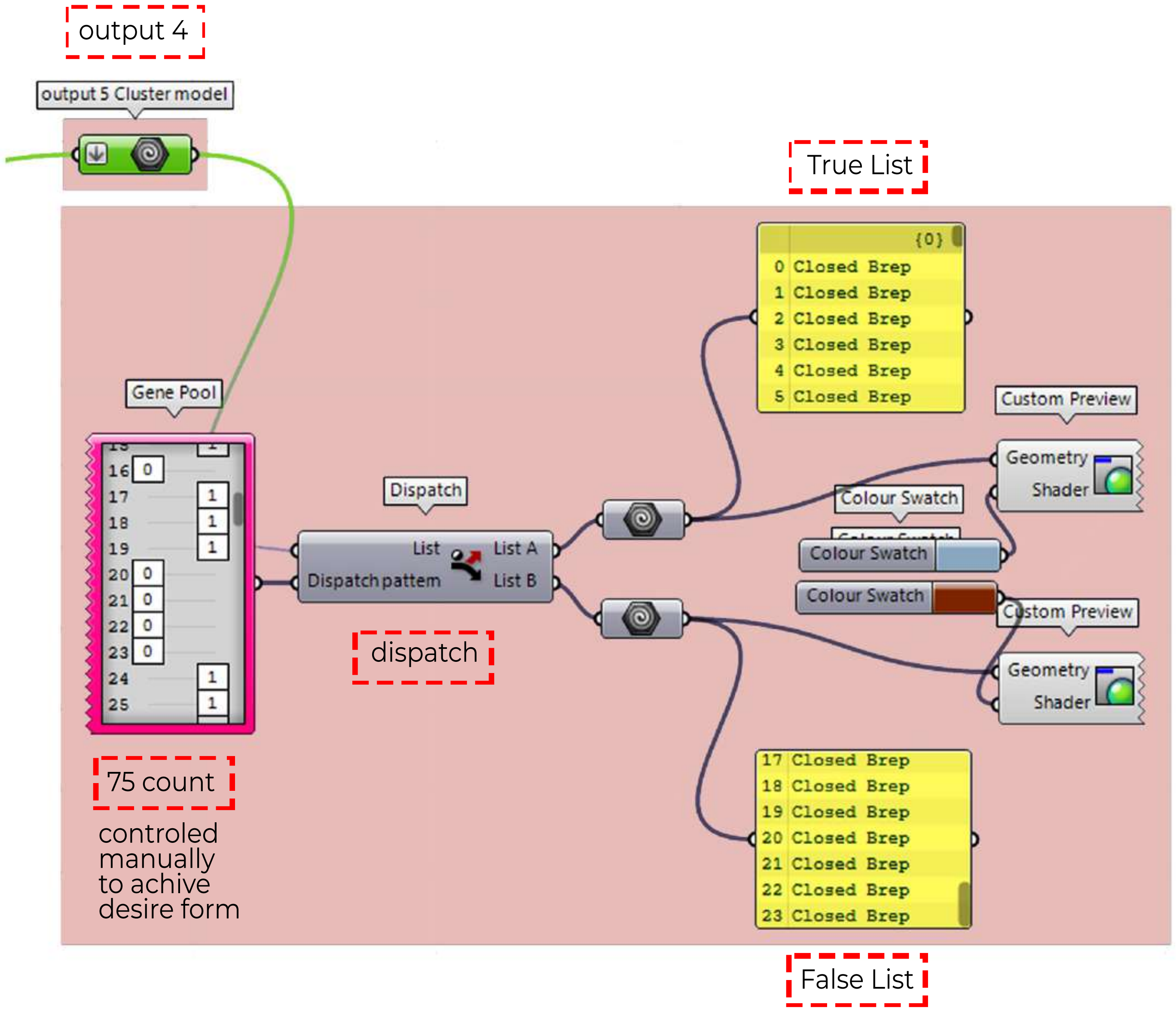


2 rows on y-axis

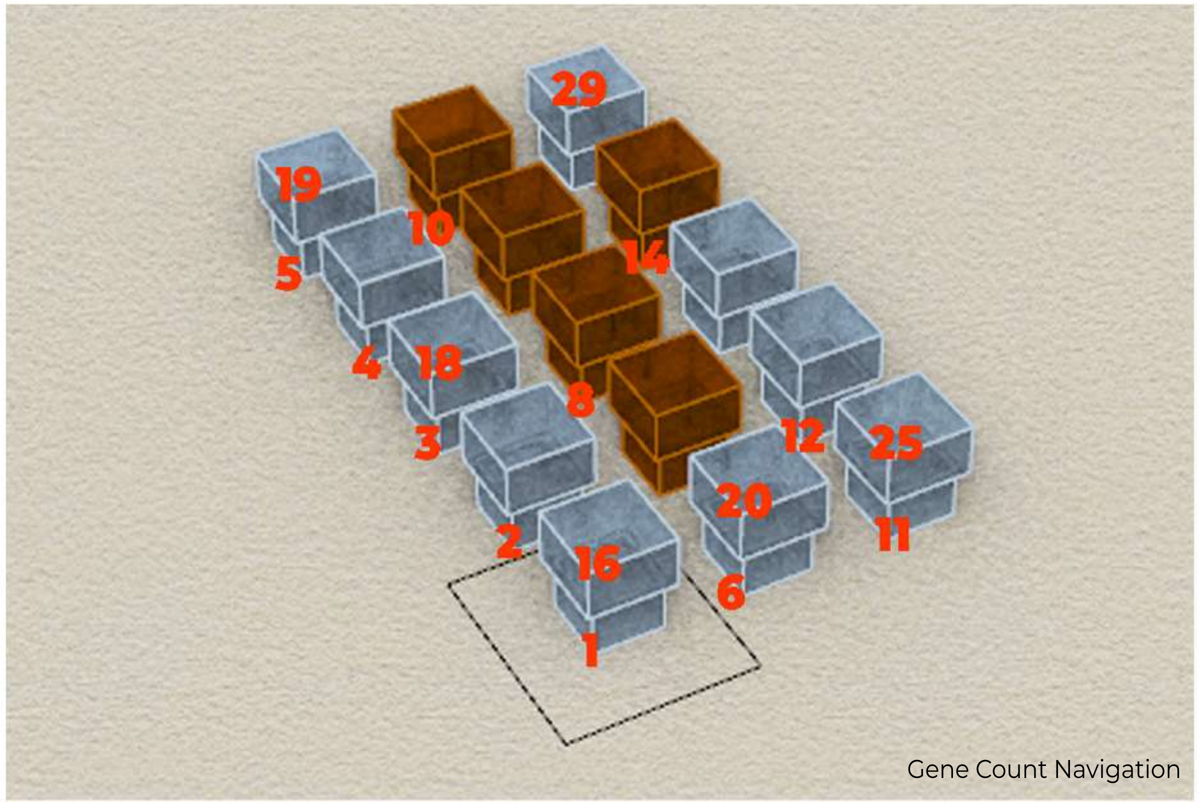


5 rows on y-axis

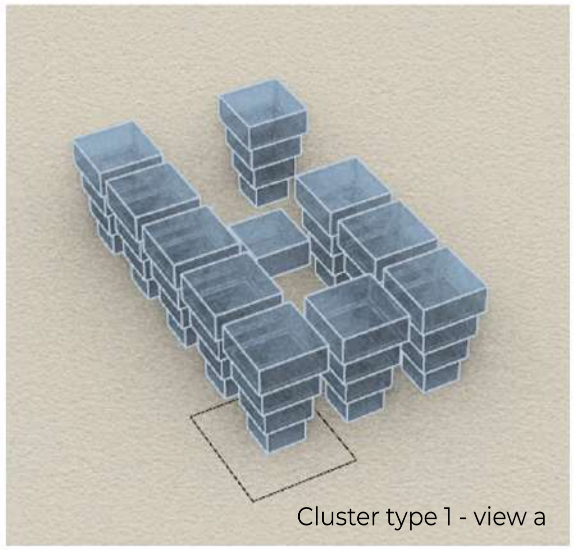
STEP 8: Dispatch Geometry of Cluster Module

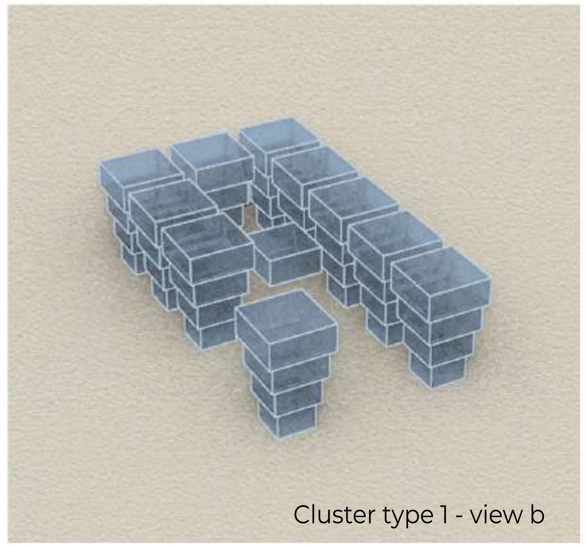


RHINO VIEW PORT - STEP 8



Gene Count Navigation


Cluster type 1 - view a


Cluster type 1 - view b