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BALWANT SHETH
SCHOOL OF ARCHITECTURE

IMPROVING ADEQUACY OF CLUSTER REDEVELOPMENT FOR LOWER INCOME GROUP IN MUMBAI USING GENERATIVE DESIGN METHOD

MASTER OF ARCHITECTURE

SYED MOHAMMAD ASIM

SVKM'S NMIMS Deemed to be UNIVERSITY

BALWANT SHETH SCHOOL OF ARCHITECTURE

CERTIFICATE

This is to certify that the project entitled

"**Improving adequacy of cluster redevelopement for lower income group in Mumbai using generative design method**"

is a bonafide work of

"**Syed Mohammad Asim**"

Roll No. A001

submitted to

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Dr. Kaiwan Mehta
Dean

Aditya Sawant
Mentor

DECLARATION

I declare that this written submission represents my ideas in my own words and where others ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission, I understand that any violation of the above will be cause for disciplinary action by the Institute and can evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Syed Mohammad Asim
Roll No. A001

DATE
19/05/2023

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CONTENT

Definition of terms

Throughout the research the following terms will be used. In order to assure that all readers are interpreting these terms in the same manner that the author intended, the following definitions are offered.

Terms	Definition
Design space	Design possibilities and options created by the designer
Performance space	Designs that are functioning as per requirement
Parametric	A design approach that involves defining a set of parameters or variables that can be adjusted to create different variations of a design.
Computational design	Computational design in architecture refers to the use of computer-based tools, algorithms, and techniques to aid in the design process and generate architectural solutions.
Design parameters	Design parameters include the physical dimensions of the design.
Conditional statements	Conditional statement is the if - else statement in programming that allows the script to make decisions based on the set conditions.
Iteration	Different variations created by changing the design attributes
Iterative design	Iterative design is the process of creating variations in the design and testing them for the best options
Variants	Designs created upon incremental changing of design attributes to reach similar fitness designs
Generation	Generation is a design variation created using algorithms
Generative design	It is the design process in which design options are generated through generative algorithms. These algorithms can be as simple as generating options based on only the physical dimensions, or they can get complex where the options are tested against simulations and fitness criteria.
Fitness	Numeric quantification of defining the performance of the design
Fitness parameter	The quantified factors that affect the performance of design
Fitness criteria	The requirements for the design to be considered optimal
Algorithm	Set of rules
Evaluation	Testing against benchmarks
Optimisation	Improving the previous generated model
Search process	Filtering and selecting the better designs
Exhaustive search	Filtering by testing all of the randomly generated design variants
Heuristic search	Filtration is guided through mathematical algorithms, not all variants are tested thus saving time
Normalisation	Also called "Parameterise" in Grasshopper. It changes the values to fractional values from 0 to 1. This is done by defining the least value as 0, highest value as 1 and all the in-between values are expressed as the fraction of the highest value.
Evolutionary Algorithms (EA)	They are rules that generate a range of design alternatives, evaluate their performance, and iteratively improve them over multiple generations.
Evolutionary Multi-Criteria Optimization (EMO)	EMO deals with the simultaneous evaluation of multiple fitness criteria.
Non - Conflicting EMO	This involves the fitness criteria that are governed by the parameters that are do not create opposite impact upon being changed. Example: maximising number of floors and maximising number of units of the same building.
Conflicting EMO	The fitness criteria are governed by parameters that have the opposite impact on the design when changed. Example: Minimise building height while maximising the FSI

Preference based EMO	It is a method of giving weight to the fitness criteria based on the priority.
Pareto-Front	Set of optimal solutions where no solution can be improved in one objective without degrading another objective.

Definition of terms (DCPR Mumbai 2034)

Following are the definition of terms as outlined in the DCPR of Mumbai. These fall in Part-I Administration - 2. Definitions of terms and expressions - (IV) Definitions.

Sr. No.	Terms	Definition
10	Amenity Space	Amenity Space means a statutory space provided in any layout/ plot to be used for any of the amenities/utilities specified in these regulations.
10	Affordable housing	Affordable Housing means social housing in the nature of housing meant for economically weaker section, lower income group having carpet area of 27.88 sq. mt. (300 sq. ft) or of such area as may be decided by Govt. from time to time.
17-vi-l	Residential building	Residential building means a building in which sleeping accommodation is provided for normal residential purposes, with or without cooking or dining facilities, and includes one or more family dwellings, lodging or rooming houses, hostels, dormitories, apartment houses, flats, and private garages of such buildings.(m) "Semi-detached building" means a building detached on three sides.(n) "Special building" means-
17-vi-q	Unsafe building	Unsafe building means a building which-(i) is structurally unsafe, (ii) is insanitary, (iii)is not provided with adequate means of egress, (iv) constitutes a fire hazard, (v) is dangerous to human life, (vi) in relation to its existing use, constitutes a hazard to safety or health or public welfare by reasons of inadequate maintenance, dilapidation or abandonment.
18	Building line	Building line means the line up to which the plinth of a building extends in any development.
19	Built-up area	Built-up area means the area covered by a building on all floors including cantilevered portion, if any, but excluding cladding and areas specifically exempted under these Regulations for the purpose of computation of FSI.
25	Chowk	Chowk means a fully or partially enclosed space permanently open to the sky within a building at any level; inner chowk being enclosed on all sides and an outer chowk having one unenclosed side.
33	Corridor	Corridor means a common passage or circulation space including a common entrance hall.
34	Courtyard	Courtyard means a space permanently open to the sky within the site around a structure or surrounded by structure and may be paved/concreted.
40	Dwelling Unit/Tenement	Dwelling Unit/Tenement means an independent housing unit with separate facilities for living, cooking and sanitation.
56	Fire Separation	Fire separation means the distance in meters measured from any other building on the site or from another site, or from the opposite side of a street or other public space to the building.
60	Floor	Floor means the lower surface in a storey on which one normally walks in a building, and does not include a mezzanine floor. The floor at ground level with a direct access to a street or open space shall be called the ground floor; the floor above it shall be termed as floor 1, with the next higher floor being termed as floor 2, and so on upwards.

61	Floor Space Index (FSI)	Floor space index (FSI) means the quotient of the ratio of the combined gross floor area of all floors, excepting areas specifically exempted under these Regulations, to the area of the plot, viz. : FSI = (Total covered area on all floors)/(Plot area)
64	Front Open Space	Front Open Space means the space between the boundary line of a plot abutting the means of access/road/street and the building line. Plots facing two or more means of accesses/roads/streets shall be deemed to front on all such means of accesses/roads / streets.
65	Fungible Compensatory Area	Fungible Compensatory Area means any built-up area permitted over and above the admissible FSI by a special permission of the Commissioner in accordance with the Regulation No. 31(3).
73	Height of a building	Height of a building means the vertical distance measured, in the case of flat roofs, from the average level of the ground around and contiguous to the building to the topmost terrace level and, in the case of pitched roofs, upto the point where the external surface of the outer wall intersects the finished surface of the sloping roof, and, in the case of gables facing the road, the mid-point between the eaves level and the ridge.
74	Height of a room	Height of a room means the vertical distance measured, from the finished floor surface to the finished ceiling/soffit of slab. The height of a room with a pitched roof means the average height between the finished floor surface and the bottom of the eaves and the bottom of the ridge.
75	High Rise Building	High Rise Building means a building having height more than 32m above the average surrounding ground level.
83	Marginal Open Space/ Distance	Marginal Open Space/Distance means the minimum distance measured between the front, rear and sides of the building line and the respective plot boundaries
91	Parking Space	Parking space, means an enclosed or unenclosed, covered or open area or area provided by mechanical means sufficient in size to park vehicles. Parking spaces shall be served by a driveway connecting them with a street or alley and permitting ingress or egress of vehicles.
100	Refuge Area	Refuge Area means an area within the building for a temporary use during egress. It generally serves as staging area which is protected from the effect of fire and smoke
102	Road/Street	Road/Street means any highway, street, lane, pathway, alley, stairway, passageway, carriageway, footway, square, place or bridge, tunnel, underpass, elevated road whether a thoroughfare or not, over which the public have a right of passage or access or have passed and had access uninterruptedly for a specified period, whether existing or proposed in any scheme, and includes all bunds channels, ditches, storm-water drains, culverts, sidewalks, traffic islands, road-side trees, hedges, retaining walls, fences, barriers and railings within the street lines.
103	Road/Street level or grade	Road/Street level or grade means the officially established elevation or grade of the centre line of the Street upon which a plot fronts, and if there is no officially established grade, the existing grade of the street at its mid-point.
104	Road/Street line	Road/Street line" means the line defining the side limits of a road/street.

105	Road Width	Road width or “Width of road/street” means the whole extent of space within the boundaries of a road when applied to a new road/street, as laid down in the city survey or development plan or prescribed road lines by any act or law and measured at right angles to the course or intended course of direction of such road.
106	Row Housing	Row housing means a row of houses with only front, rear and interior open spaces..
109	Site/Plot	Site/Plot means a parcel or piece of land enclosed by definite boundaries.
110	Site Corner	Site Corner means a site at the junction of land fronting on two or more roads or streets.
111	Site Depth	Site Depth of means the mean horizontal distance between the front and rear site boundaries.
112	Site with double frontage	Site with double frontage means a site having a frontage on two streets other than a corner plot.
113	Site Interior or Tandem	Site Interior or Tandem means a site access to which is by a passage from a street whether such passage forms part of the site or not.
118	Storey	Storey means the portion of a building included between the surface of any floor and the surface of the floor next above it, or if there be no floor above it, then the space between any floor and the ceiling next above it.
120	Tenement	Tenement means an independent dwelling unit with a kitchen or a cooking alcove.
123	Travel Distance	Travel distance means the distance from the entrance/exit of the remotest Apartment/office/unit/Premises on a floor of a building to a place of safety be it vertical exit or a horizontally exit or an outside exit measured along the line of travel.
124	Volume to plot ratio	Volume to plot ratio (V.P.R.) means the ratio expressed in meters of the volume of a building measured in cubic meters to the areas of the plot measured in square meters.
128	Window	Window means an opening other than a door, to the outside of a building which provides all or part of the required natural light, ventilation or both to an interior space.
129	Wing of a building	Wing of a building means part of a building with independent access, staircase & lift connected to other parts with common basement/stilt/ podium/terrace/common wall/connecting passages.

Ch. 1 Introduction

1.1 Background and motivation for the research

Mumbai, the financial capital of India, is known for its booming real estate market and population density. The city faces numerous challenges, including the inadequate housing conditions for its lower-income population. The existing clusters of old and dilapidated buildings often lack basic amenities, posing safety hazards and hindering the overall well-being of the residents. Cluster redevelopment projects have been initiated to address these issues by demolishing the old structures and constructing modern, sustainable, and affordable housing complexes. However, these projects often fall short in terms of adequacy and fail to meet the specific needs of the lower-income groups.

The motivation behind researching and improving the adequacy of cluster redevelopment for the lower-income group in Mumbai using evolutionary generative design stems from several factors:

Social Equity: Mumbai's lower-income groups often struggle to access safe and adequate housing. By focusing on improving cluster redevelopment, we aim to address the social inequity prevalent in the city. Providing better living conditions for the underprivileged is crucial for their overall well-being and fostering a more inclusive society.

Innovative Solutions: Traditional approaches to cluster redevelopment have fallen short in meeting the needs of the lower-income groups. By incorporating evolutionary generative design, which involves using algorithms inspired by natural selection, we can explore innovative solutions to optimize the massing of the buildings. This approach allows for a more comprehensive exploration of design possibilities and can result in more effective and customized housing solutions.

By focusing on the background and motivation outlined above, the research aims to contribute to the ongoing efforts to improve cluster redevelopment for the lower-income groups in Mumbai. The ultimate goal is to create a more equitable urban environment that caters to the needs of all residents, irrespective of their socioeconomic background.

1.2 Research question and objectives

How can evolutionary generative design algorithms be effectively utilized in architectural form-finding process to generate optimized building geometries?
What criteria should be considered when evaluating the performance and quality of building geometries generated using evolutionary generative design algorithms in the architectural form-finding process?

Objectives:
- Evaluate the potential applications of evolutionary generative design algorithms in architectural form-finding processes.
- Identify and assess the key challenges and limitations associated with the utilization of evolutionary generative design algorithms in architectural form-finding, and propose strategies to overcome these challenges.
- Develop guidelines and recommendations based on the findings to inform policymakers, urban planners, and developers on how to effectively utilize evolutionary generative design algorithms in cluster redevelopment projects for the lower income group in Mumbai.

Ch. 2 Literature Review

2.1 Group Housing

2.1.1 Authorities

Municipal Corporation of Greater Mumbai (MCGM): Municipal Corporation of Greater Mumbai (MCGM), also known as Brihanmumbai Municipal Corporation (BMC), is the governing civic body responsible for the administration of Mumbai. MCGM is responsible for providing a wide range of civic services and infrastructure to the residents of Mumbai. Some of its key functions include urban planning, public health services, water supply and sanitation, solid waste management, roads and bridges, public transportation, education, healthcare, and urban development.

Maharashtra Housing and Area Development Authority (MHADA): The Maharashtra Housing and Area Development Authority (MHADA) is a government organization in the Indian state of Maharashtra. Established in 1977, MHADA's primary objective is to provide affordable housing options to the residents of Maharashtra, particularly those belonging to the lower-income and middle-income groups. MHADA focuses on the development and construction of affordable housing projects, including apartments, houses, and plots. These housing units are allotted to eligible individuals and families through a lottery system.

Mumbai Metropolitan Region Development Authority (MMRDA): MMRDA is responsible for planning and developing the Mumbai Metropolitan Region. MMRDA works towards providing affordable housing options and implementing housing schemes for various income groups in the MMR. It collaborates with developers and stakeholders to create affordable housing projects and ensure equitable access to housing.

Terminology

Group Housing: The DCPR provides guidelines for group housing developments, which are typically defined as housing projects with more than one building. Relevant sections include Section 33(5), which outlines the rules for group housing developments, and Section 33(10), which provides guidelines for amenities in group housing projects.

Cluster Housing: Cluster redevelopment is a process by which a group of old or dilapidated buildings is redeveloped as a single entity. The DCPR provides guidelines for cluster redevelopment projects in Section 33(7), which outlines the rules for the development of such projects.

Redevelopment: The DCPR provides guidelines for redevelopment projects, which involve the demolition and reconstruction of an existing building or buildings. Relevant sections include Section 33(4), which outlines the rules for redevelopment of old buildings, and Section 33(9), which provides guidelines for amenities in redeveloped buildings.

SRA: The Slum Rehabilitation Authority (SRA) is a government body responsible for the rehabilitation of slum dwellers in Mumbai. The DCPR provides guidelines for SRA projects in Section 33(10A), which outlines the rules for the development of slum rehabilitation projects.

2.1.2 Standards for Housing design from DCPR 2034

Cluster Redevopment

Pg 89 of DCPR 2034
17(3) (C)(II) Development of reservation in Reconstruction or redevelopment of Cluster of BDD chawls at Naigaon, Worli, N.M.Joshi Marg and Shivdi under Urban Renewal Scheme(s) under Regulation No. 33(9)(B).

c. If the area under a non-buildable/ open space reservation is more than 500 sq. m, minimum 50% of the area under reservation shall be developed for the same purpose and handed over to MCGM, subject to a minimum of 500 sq. m and the remaining land shall be allowed for development.

f. For other buildable reservations on land, BUA equal to 60% of the Zonal (basic) FSI under such reservations or existing BUA of the amenity(existing) whichever is more, on that plot shall be made available free of FSI and free of cost to the MCGM or the Appropriate Authority. The reservations of compatible nature can be preferably constructed in one or more separate blocks, depending on the area and nature of such reservations and Municipal Commissioner may permit composite development of reservations in case of such reservations. However, if the HPC/Planning Authority requires BUA under any Existing Amenity /reservation in excess of the Zonal (basic) FSI, then such excess area shall be considered as rehabilitation FSI, and incentive FSI as admissible under this Regulation shall be permissible.

h. No premium shall be charged for the fungible compensatory area admissible as per Regulation 31(3) for rehabilitation component of an CDS as sanctioned by HPC and for the tenements to be handed over to MHADA and for the areas of reservation to be handed over to MCGM/Appropriate Authority. This fungible compensatory area admissible to the rehabilitation tenements shall be utilized for rehabilitation component only. Its utilization for Sale Component under the CDS shall not be permissible.

Part-V Floor Space Index

30. Floor Space Indices & Floor space / Built-Up Area (BUA) computation, Tenement Density and Protected Development
(A) Floor Space Indices & Floor space /BUA computation
1) The plots abutting public roads having existing width of minimum 6m but less than 9m which are proposed to be widened to 9.0 m or more then permissible FSI shall be as admissible for 9m road width.
2) The permissible FSI shall be on plot area excluding area under DP roads/roads for which sanctioned Regular line as per MMC Act is prescribed, as per regulation 16,14 (amenity plots), and area of DP Reservation to be surrendered to MCGM/Appropriate Authority under Regulation no 17

31. Exempted from FSI/to be counted in FSI/Fungible Compensatory Area:
(1) Exemption from FSI
(i) Areas of structures permitted in LOS under clause (g) of sub-Regulation (1) of Regulation No 27.
(ii) Areas covered by features permitted in open spaces as listed in Regulation No.42 except for Regulation 42(i) (b), 42(ii)(d),42(ii) (e) (ii) 42(ii) (f) (ii) Areas covered by staircase rooms, lift machine rooms above opmost storey, staircase/lift wells and passages in stilt, basement and floors exclusively used for parking and other ancillary uses as permitted in this Regulation No.31(1)
(iii) Areas covered by staircases/lift wells including lobbies as specified, excluding those covered under DC Regulation No.31 (1) (iii) with special written permission of the Commissioner subject to payment of premium.
(xv) The refuge areas subject to DC Regulation No. 48(8)
(xxiv) Parking floors as specified in Regulation No37(30)

(2) The following shall be counted in FSI.
(iv) Part/Pocket/Covered terraces, for whatever purpose, except open terrace above the top most storey and the part terrace at top most storey due to planning constraints but accessible from common staircase, terraces created due to restriction imposed by the Railway Authority and above shopping/Non-residential/Industrial area at

one level only with a slope of 1:5, in case of esidential/Non- residential/Industrial development on upper floors.
(viii) Area of balconies as provided in sub regulation 20of Regulation No
37.
(xvi) The parking floor in excess of required parking under these
regulation [31(1)(vi)]and for which the premium has been paid. Deck
parking inclusive of car lifts and passages thereto on habitable
floors.

B) Incentive FSI: Incentive FSI admissible against the FSI required for rehabilitation, as calculated in (A) above, shall be based on the ratio (hereinafter referred to as Basic Ratio) of Land Rate (LR) in Rs/sq. m. of the plot under redevelopment as per the Annual Schedule of Rates (ASR) and Rate of Construction (RC)* in Rs/sq. m applicable to the area as per the ASR of the date of approval of plan and shall be as given in the Table B below:-

Table B

Basic Ratio (LR/RC)	Incentive (As % of Admissible Rehabilitation Area)
Above 6.00	40%
Above 4.00 and up to 6.00	50%
Above 2.00 and up to 4.00	60%
Up to 2.00	70%

Appendix
3. Each tenant shall be rehabilitated and given the carpet area occupied by him for residential purpose in the old building subject to the minimum fixed carpet area of 27.88 sq. m (300 sq. ft) and/or maximum carpet area up to 120 sq.m. (1292 sq.ft.) free of cost. In case of non-residential occupier the area to be given free of cost in the reconstructed building shall be equivalent to the area occupied in the old building.
10. For the purpose of calculating the FSI for tenanted building, the entire area of the plot/layout including Development Plan roads and internal roads but excluding the land under the reservation of public amenities shall be considered.

5.Conditions of Rehabilitation:
(i) Each occupant/tenant shall be rehabilitated and given on ownership basis, carpet area equivalent to the area occupied by such occupant/tenant in the old building. However, in case of residential/residential cum commercial occupants, such carpet area shall not be less than 27.88 sq. m.This shall be the “basic area”.

Cluster Development Scheme (CDS)
6. Total Permissible FSI for CDS:
a) The total permissible FSI for an CDS shall be 4.00 on gross plot area, but excluding the reservations/ existing amenity, road set back, area under existing Municipal Roads but including the BUA under reservation/designation, road set back or sum total of the Rehabilitation FSI + Incentive FSI, whichever is more.

13. Relaxation in Building and other requirements:
13.3 Front and marginal open spaces, for a building having height up to 32.0 m. in the rehabilitation component or a composite building, shall be 3.0 and 4.5 m respectively. Provided that for a building having height more than 32.0 m and up to 70 m, open space of the width of 6 m at least on one side at ground level within the plot, accessible from the road side shall have to be maintained for the maneuverability of a fire e gine, unless the building abuts two roads of 6 m or more on two sides, or another access of 6 m to the building is available, apart from the road abutting the building.
13.6 The distance between any two rehabilitation buildings up to 32 m height shall not be less than 6.00 m
13.7 If the height of any building constructed under CDS is more than 32.0 m, marginal open space shall be as per the Regulation No 41(5)

Regulation no. 41(5)
(5) Provisions in open spaces for plots in Reconstruction/Redevelopment Schemes under the Maharashtra Housing and Area Development Authority Act, 1976, Slum Rehabilitation Authority and Redevelopment Scheme of municipal tenanted properties; in case of DCR 33(5),33(6),33(7),33(7)(A),33(7)(B),33(9),33(9)

(A),33(9)(B),33(10),33(10)(A),33(11),33(15)and 33(20)(A).
The following provisions shall only be applicable in case of rehab and composite building. Composite building in Rehab scheme is the building where the rehab component is equal to or more than 50%.
(a) Notwithstanding the provisions contained in sub-Regulations (2) of this Regulation,
(i) For a building up to height 32m the front open space shall be 3.0 m.
(ii) For a building, up to height 32 m, side and rear marginal open spaces may be reduced to 3.0 m.
(iii) for a building with height more than 32 m but upto 70 m the side and rear marginal open spaces shall not be less than 6 m and for a building with height more than 70 m the side and rear marginal open spaces shall not be less than 9 mand 12 m beyond 120 m subject to fulfillment of fire safety requirement as specified in these Regulations.

6. Relaxation in Building and Other Requirements:
6.1 Separate kitchen shall not be necessary. Cooking space (alcove) shall be allowed without any minimum size restrictions. Where a kitchen is provided, the minimum area shall be 5 sq. m provided the width shall be at least 1.5 m.
6.2 There shall be no size restriction for bath or water closet unit. Moreover, for bathroom, water closet or kitchen, there shall be no stipulation of one wall abutting open space, etc. as long as artificial light & ventilation through any means are provided.

Part VIII General Building Requirements

Table No: 14

Minimum size and width of Habitable Rooms

Serial No. (1)	Occupancy (2)	Minimum size in sq.m (3)	Minimum width in m (4)
1	Any habitable room.	----	2.4
2	Rooms in a two-room Kitchen tenement & above		
	one of the rooms.	----	2.4
	other room/rooms	----	2.4
	Kitchen	---	1.8
3	One room Kitchen tenements		
	one room	----	2.4
	Kitchen	----	2.1
4	Multipurpose Room (with provision of alcove)	12.5	2.4
5	Single-bedded room in a hostel.	7.5	2.4
6	Shop	6.0	1.2
7	Vending stalls & kiosks	3.0	1.2
8	Class room in an Educational building	38.0 or area at the rate of 0.8 sq.m. per studentoras decided by Govt. from time to time.	5.5
9	Institutional building (a) special room	9.5	3.0
	(b) general ward	40.0	5.5
10	Bathroom	1.50	1.10
11	Water Closet (W.C.)	1.10	0.90
12	Combined Bathroom and Water Closet (W.C.)	2.20	1.10
13	Cinema hall, theatre, auditorium, assembly hall, etc.	In conformity with the Maharashtra Cinema Rules.	
14	Multiplex/Multiplex theatre complex	In conformity with the Bombay Entertainment Duty Act 1923, Revenue and Forest Dept. Govt. of Maharashtra.	

Table No: 16

Minimum width of common Stairways/Corridors for various occupancies.

Sr. No.	Type of Occupancy	Minimum width of stairway/corridor (in meters) for buildings upto 70.00 m height	Minimum width of stair-way/corridor (in meters) for buildings more than 70.00 m height
1	Residential buildings-		
	(a) General	1.50	2.00
	(b) Row housing (2 storeyed) or internal staircase in duplex flat	0.90	-
	(c) Hotels	1.50	2.0
2	Educational buildings		
	(a) Upto 32 m high	1.50	-
	(b) Over 32 m high	2.0	-
3	Institutional buildings	1.50	2.0
4	Assembly buildings	2.0	2.0
5	Mercantile storage, hazardous buildings	1.50	2.0
6	Industrial Building	2.00	

TableNo: 15

Height of Habitable Room/s

Sr. No.	Occupancy	Minimum height in meters (m)	Maximum height in meters (m)
(1)	(2)	(3)	(4)
1.	Flat roof.		
	(a) Any habitable room	2.75	4.2
	(b) Bathrooms, Water Closets, combined Bath & WC (Measured from the surface of the floor to the lowest point of the ceiling)	2.2	4.2

40. Lighting and Ventilation

(1) Adequacy and manner of provision- All parts of any habitable room shall be adequately lighted and ventilated. For this purpose, every room shall have -
(a) one or more apertures, excluding doors, with area not less than one - sixth of the floor area of the habitable room, with no part of any habitable room being more than7.50 m away from the source of light and ventilation. However, a staircase shall be deemed to be adequately lighted and ventilated, if it has one or more openings , their area taken together measuring not less than 1 sq. m per landing on the external wall;
(b) an opening with a minimum area of 1 sq. m in any habitable room including a kitchen, and 0.3 sq. m with one dimension of 0.3 m for any bathroom, water closet or store;

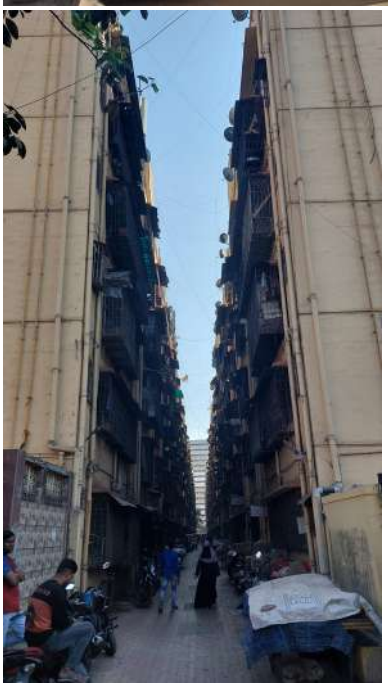
Part IX Urban Safety Requirements
47.Fire Protection Requirements
(a) (i) The refuge area shall be preferably provided within building line at floor level.
(ii) In case of high rise buildings having height more than 32 m, first refuge area shall be provided at 24 m or at 1st habitable floor, whichever is higher. Thereafter, the refuge area shall be provided at every 7th habitable floor. The refuge area shall be 4% of the habitable floor area it serves, and will be free of FSI. With the permission of Commissioner due to planning constraints it may be allowed to be exceeded up to maximum limit of 4.25%. If it exceeds 4.25%, the excess area shall be counted in FSI.
(b) For buildings having height upto 70 m, as an alternate, Refuge areas can be provided as RCC cantilever projections at the alternate mid-landing levels of staircase, free of FSI. Each refuge area at mid-landing shall have a minimum width of 3.0 m, and minimum area of 10.0 sq. m for residential and 15 sq. m for non-residential buildings.
(c) In case of buildings upto 32 m height, the terrace floor of the building shall be treated as the refuge area.

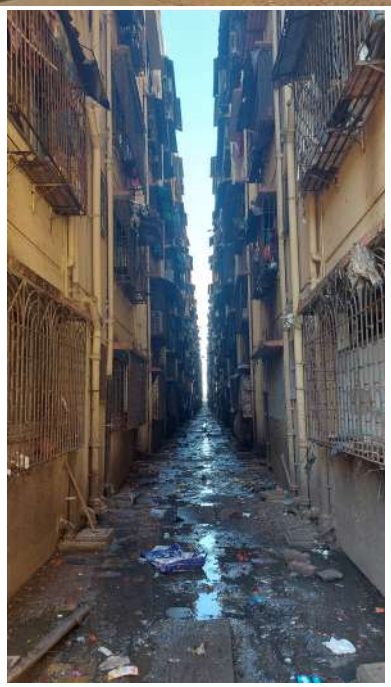
2.2 Conventional approach towards designing group housing for LIG

The existing group housing projects and the upcoming proposals prioritise the profitable sales component of the project thus neglecting the rehabilitation part. in other cases there is the disregard norms. The following cases demonstrate the evaluation of adequacy of the buildings by analysing the incident solar radiation.

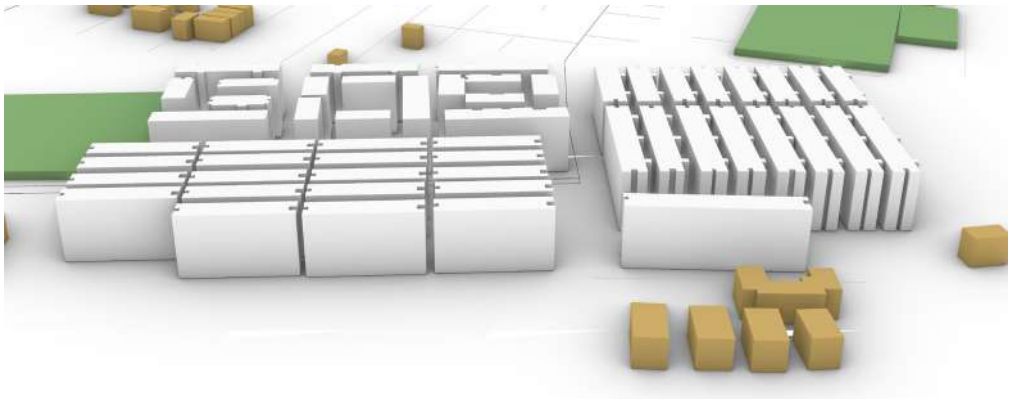
2.2.1 Lallubhai Compound, Mankhurd, Mumbai

- Built in 2007, Lallubhai compound is a cluster of 70 buildings constructed as a part of the MMRDA's free housing scheme for the poor.
- The buildings here are five to seven storeys high with no functional lifts, especially affecting the elderly, disabled persons, those unwell, and children.
- The narrowly packed buildings ignore fire and safety norms.
- The corridors in the building are pitch dark, making it unsafe and unhygienic.
- The distance between buildings is just three metres, making it difficult for ventilation and light in the house.
- A study has found that poor access to natural ventilation and sunlight and dearth of space has resulted in an abnormally high incidence of tuberculosis (TB) among the residents of these complexes. Overall, it establishes a strong correlation between mortality due to TB and housing conditions.

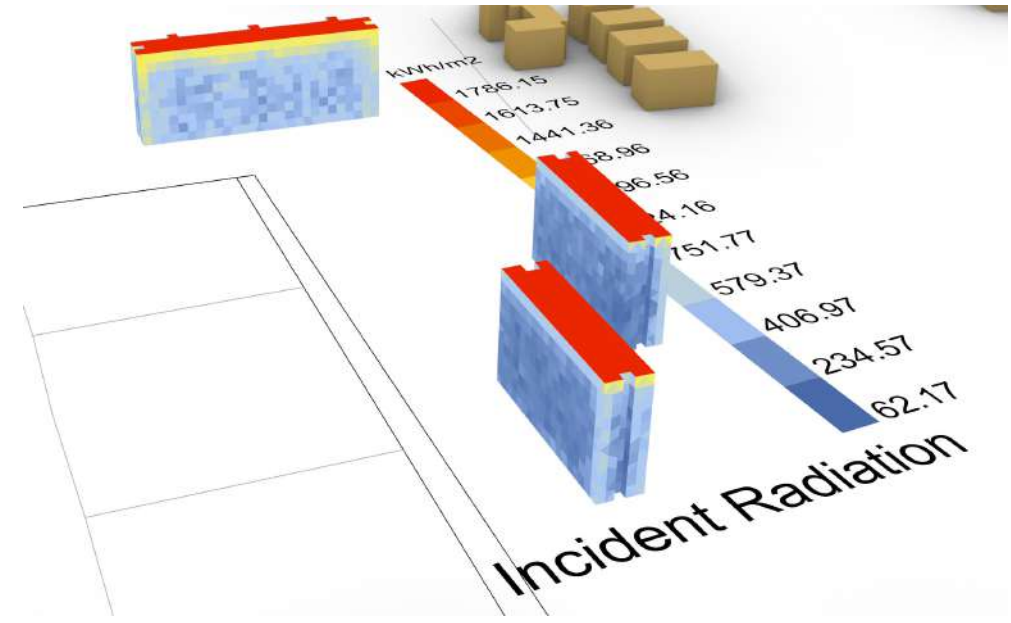




Built in 2007, Lallubhai compound is a cluster of 70 buildings constructed as a part of the MMRDA's free housing scheme for the poor. People from slums in Parel, Elphinston, Prabhadevi, Kurla and CST were rehabilitated here, and promised better living. Survey reveals that life at the compound is a daily struggle for food, water and education for the more than 29,000 residents. Around 50 to 60 per cent of children drop out of school after their families are evicted and rehabilitated to a new area, according to a survey conducted by Youth for Unity and Voluntary Action (YUVA). Unusable playgrounds, narrow unlit lanes, and schools that could only be accessed by crossing the railway tracks. Several children in this area are still enrolled in a school that is about a kilometre away from here. The school can be accessed by walking on railway tracks nearby, this was the preferred option instead of spending on a rickshaw every day. There were no parents accompanying them as taking time off work is not a luxury daily wage workers can afford, and this led to several unfortunate deaths over the years. The buildings here are five to seven storeys high with no functional lifts, especially affecting the elderly, disabled persons, those unwell, and children. The narrowly packed buildings ignore fire and safety norms. Water supply is scarce, and waste management methods are inadequate. The corridors in the building are pitch dark, making it unsafe and unhygienic. The distance between buildings is just three metres, making it difficult for ventilation and light in the house. A new study has found that poor access to natural ventilation and sunlight and dearth of space has resulted in an abnormally high incidence of tuberculosis (TB) among the residents of these complexes. Overall, it establishes a strong correlation between mortality due to TB and housing conditions. The study also found that the incidence of TB was higher among families on the lower floors. The average size of the houses surveyed was 225 sq. feet. According to a report, "there was dirty water around the buildings giving out foul smell, which forced the residents to keep their windows closed. This was aggravated by the fact that a large amount of garbage was thrown off the balconies and windows by the people staying on the upper floors, which accumulated on the open spaces between the buildings." (Bhatkande, 2015)



Lallubhai compound model

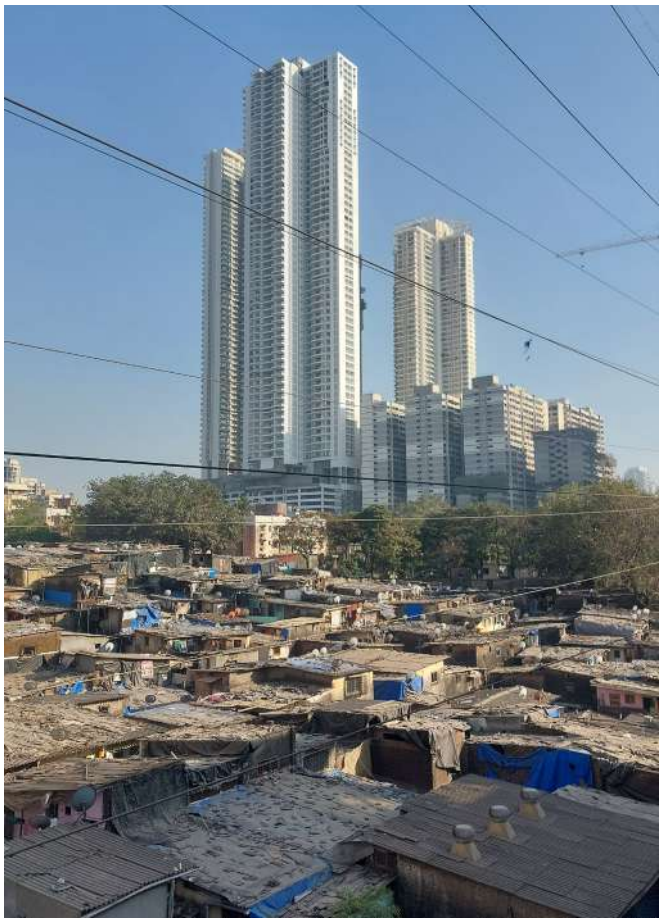


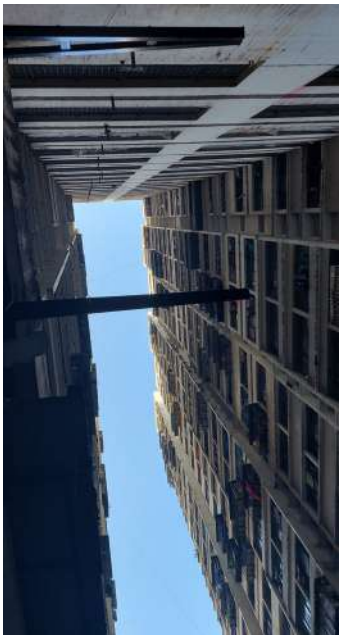
Southwest Solar radiation analysis

The analysis is done using Ladybug plugin of Grasshopper, Rhino. This method quantifies the lack of natural light in kWh/sq.m. The blue portions indicate lack of sunlight incident on the building face.

2.2.2 SRA Sahkari Gruh Sanstha, Omkar Developers

Near the Kurla Metro station, abutting the Western Express Highway lie a cluster of buildings that consist of SRA and residential complexes by the Omkar Developers. The SRA is well spaced out allowing ventilation, however, new residential buildings are being built by the Omkar Developers that do not consider the context of the buildings around them, casting shadows through a major portion of the day. Had there been simulations that could be run to test these parameters of the massing of the new buildings and their impact on the existing structures, such issues might not have emerged. The area consists of either sprawls of slums or high density, high rise structures. This leads to no public open spaces in the area for the people to use. The lack of interactive spaces has always proven to be unhealthy environment for the people to live in.

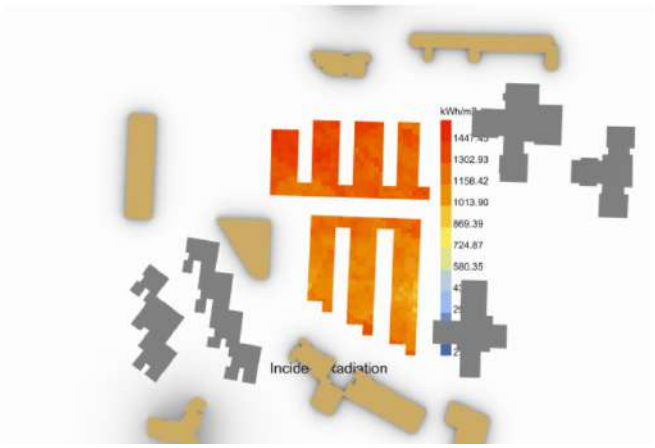




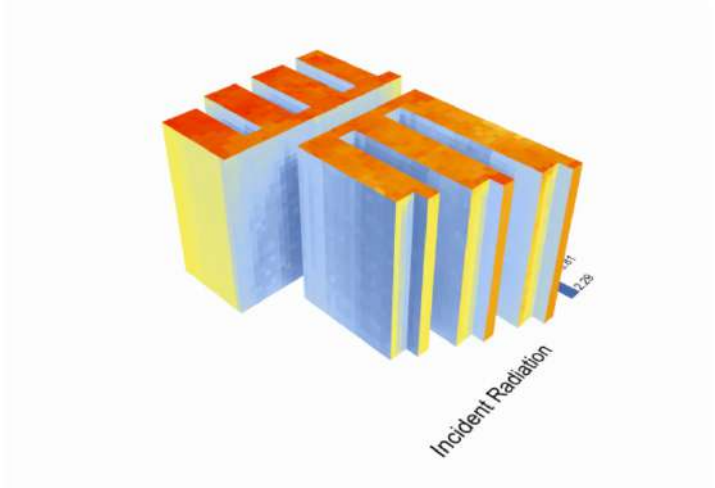
Lack of sunlight in SRA

Om Saidarshan buildings, lack of open spaces

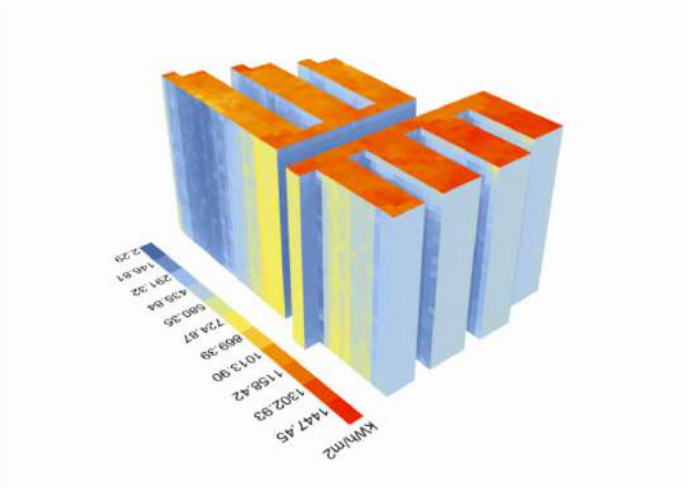
Omkar developers sales and rehab complex



Plan



South west solar radiation analysis

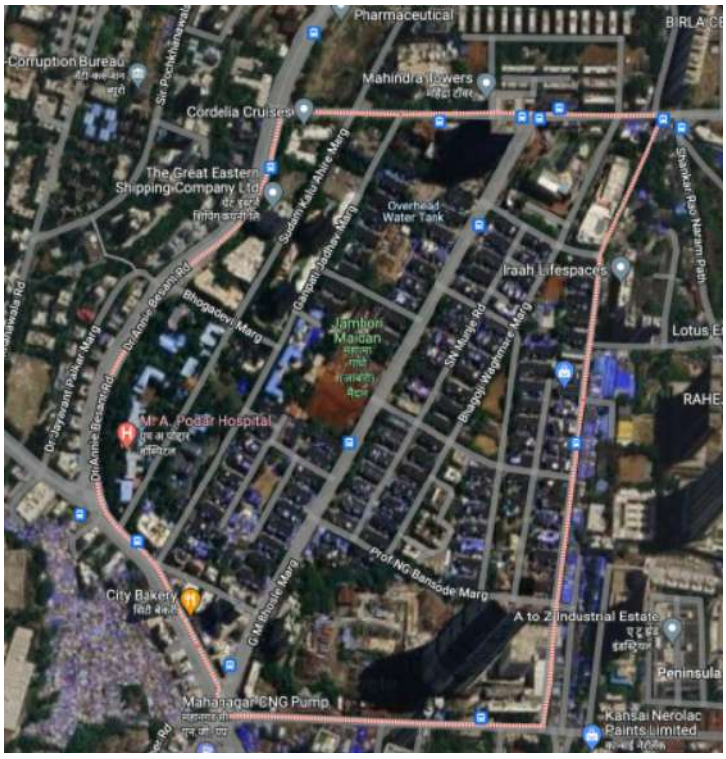


North east solar radiation analysis

2.2.3 BDD Chawls, Worli, Mumbai

The BDD Chawls at Worli, Mumbai consists of 121 Chawls that are G+3, housing 9,680 tenements.. It covers an area of 60 acres. The buildings are 15 m in length and 9 m in depth with 3 m height per floor, surmounting to 12 m of total height. Amidst the buildings there is ample open congregational areas of dimensions 9 x 15 - 20 m. Even though the ratio of built spaces to open spaces is low, yet there is insufficiency of space for the ones residing in the building. This is evident from the fact that there are illegal protrusions coming out of the buildings in upper levels. The reason behind this also lies in the original purpose the Chawls were built for. They were built as dormitory for workers, thus the rooms were not meant for longer occupancy by growing families which is the case of many tenements now. The area per tenement is a meagre 160 sq. ft. of area. Moreover, due to the dormitory configuration, the people have shared toilets that is not maintained leading to an unhygienic environment. New proposal that has been made for the redevelopment of the Chawls has increased space per tenement to 500 sq ft. But the new proposal has increased the number of flats multifold to 40 floors, increasing the density of the place greatly which maintaining the same amount of open spaces. Keeping the spacing between the same while increasing their verticality reduces the sunlight exposure for the buildings which is necessary for healthy livability of the place. (https://memumbai.com/bdd-chawls/)

- 121 chawls
- 60 acres
- 9,680 tenements
- Buildings dimension
- 15 m length, 9 m depth
- 16 steps no landing stairs
- 3 m ceiling height
- 9 x 15-20 m open areas
- Entrance Pathway
- 9.4 m wall to wall
- 1.2 m footpath on one side only

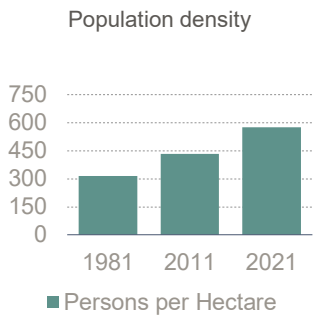


Positive points

- Adequate spacing between buildings
- Open spaces for each complex
- Mixed use buildings

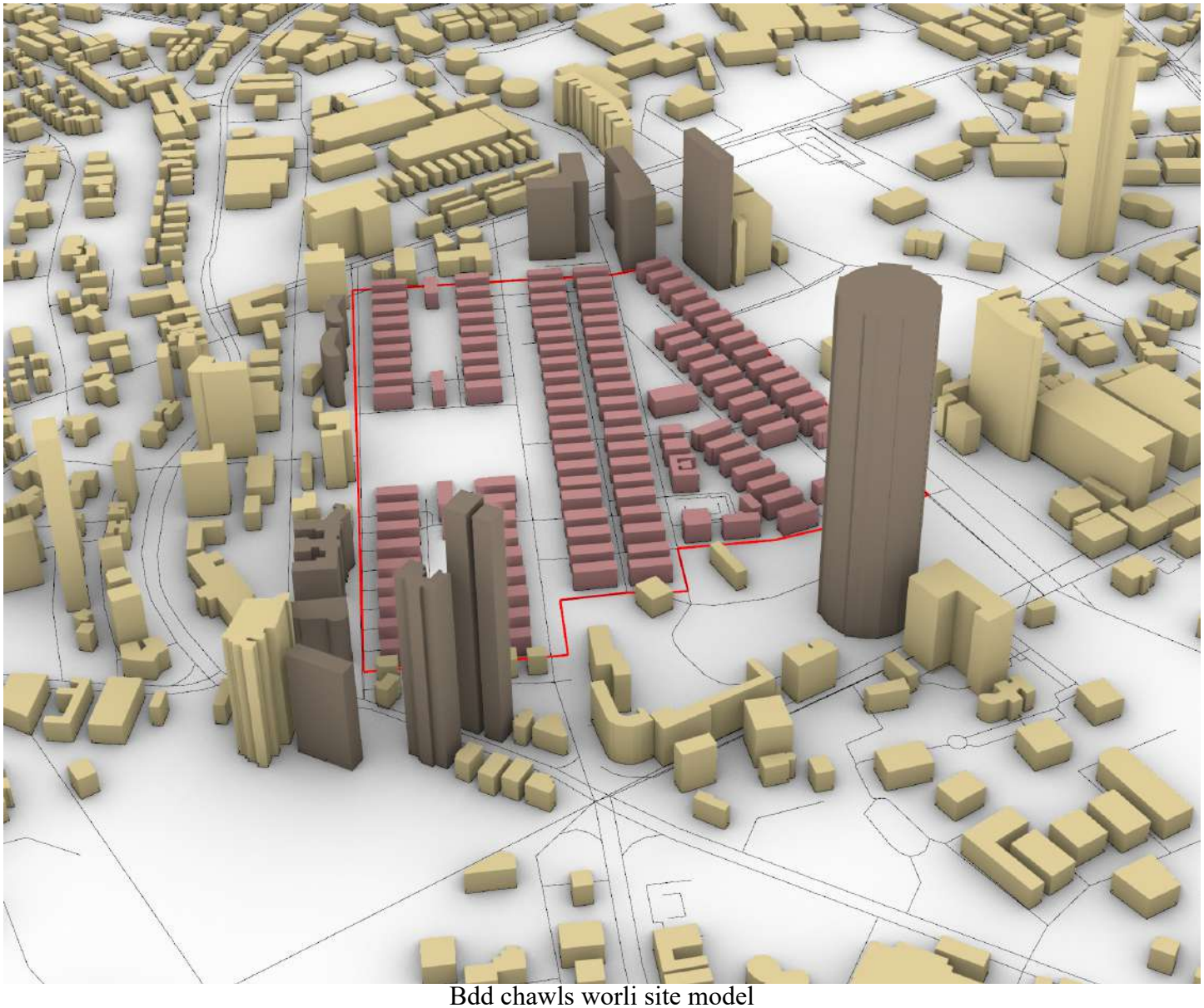
Negative points

- If family size increases, there is no legal scope of expansion
- Common toilets, leads to bad maintenance
- Access point roads are very narrow
- Squares are highly congested due to the traffic, parking and commercial activities
- Design norms are not followed

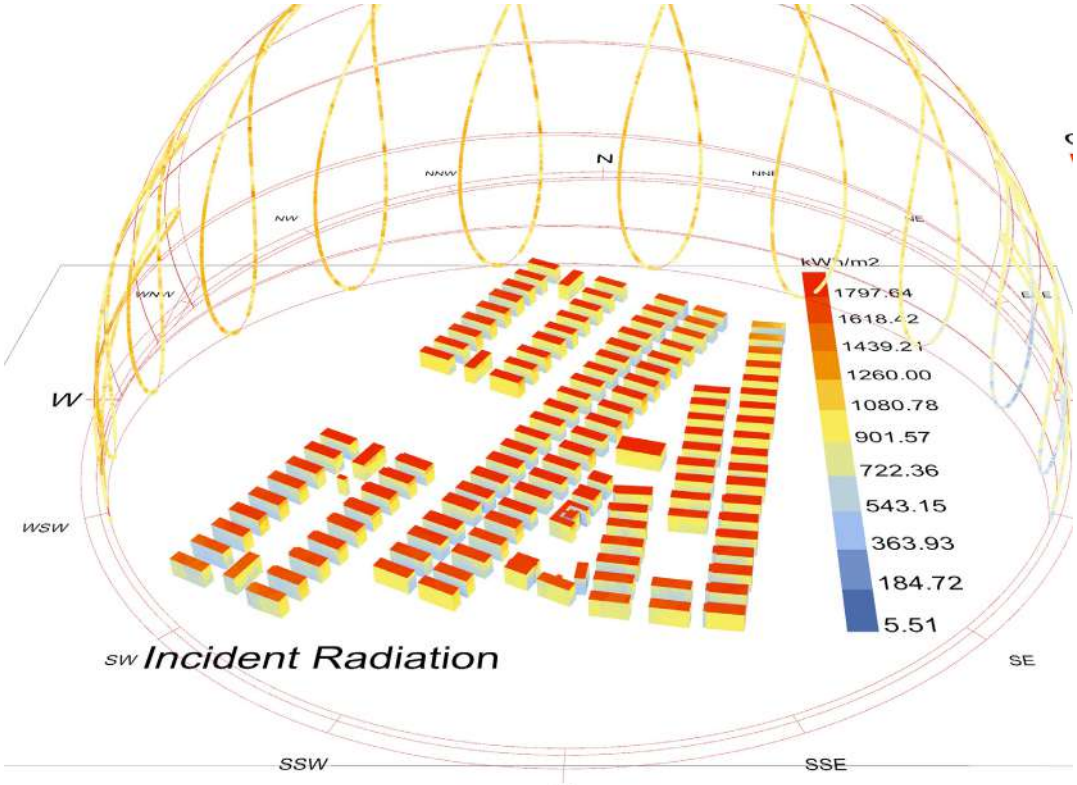


Dilapidated conditions of the chawls

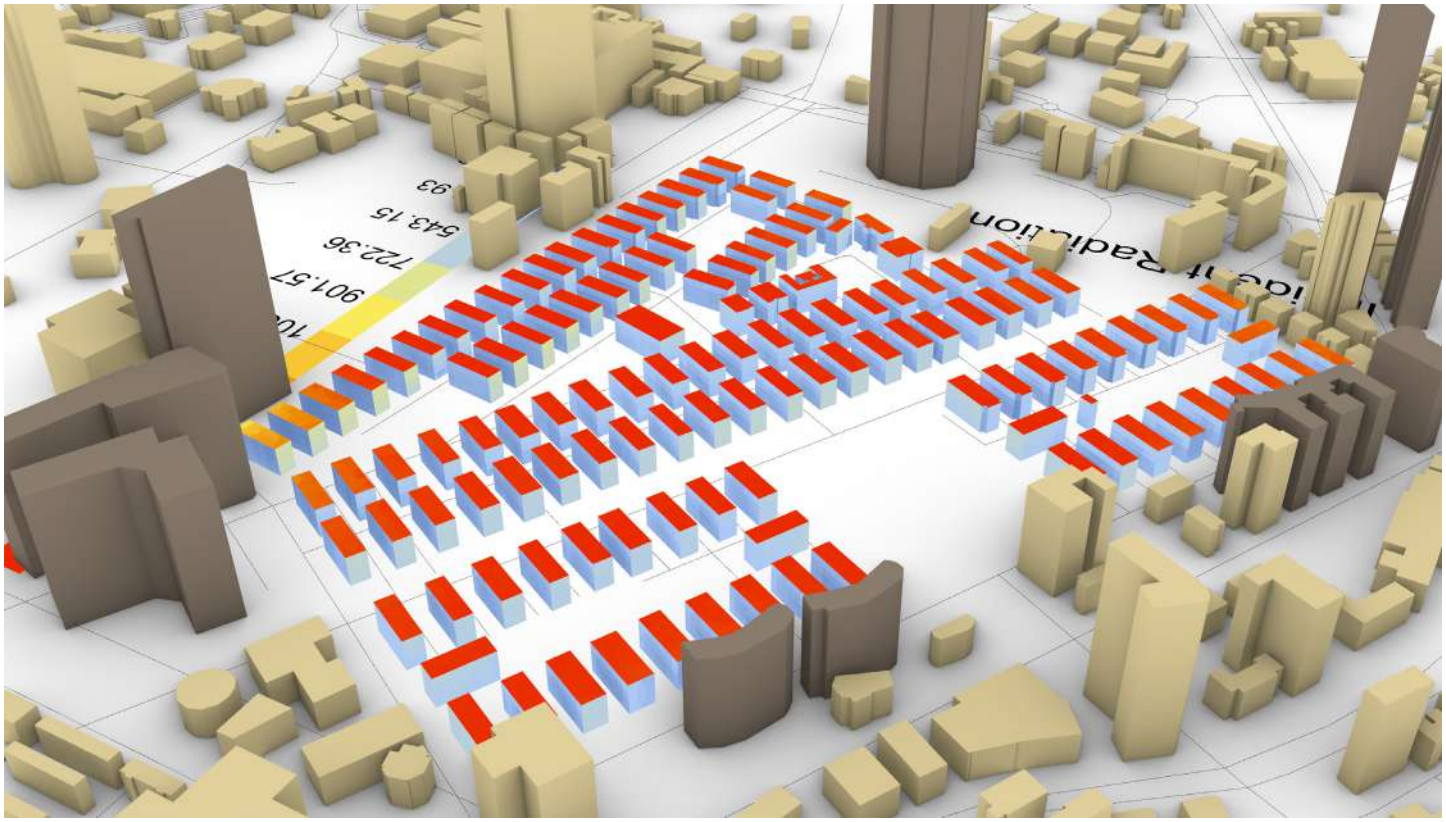
Illegal and unsafe extension being extruded out of the existing chawls due to lack of space for the tenaments



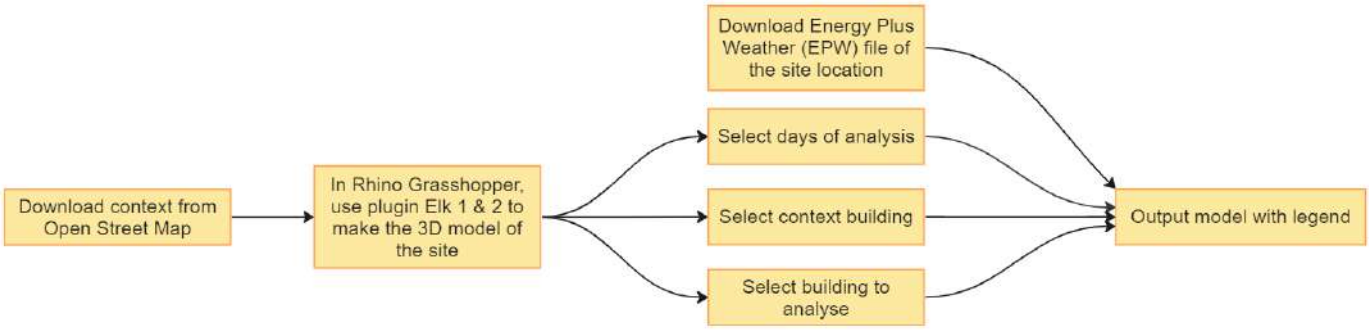
Bdd chawls worli site model



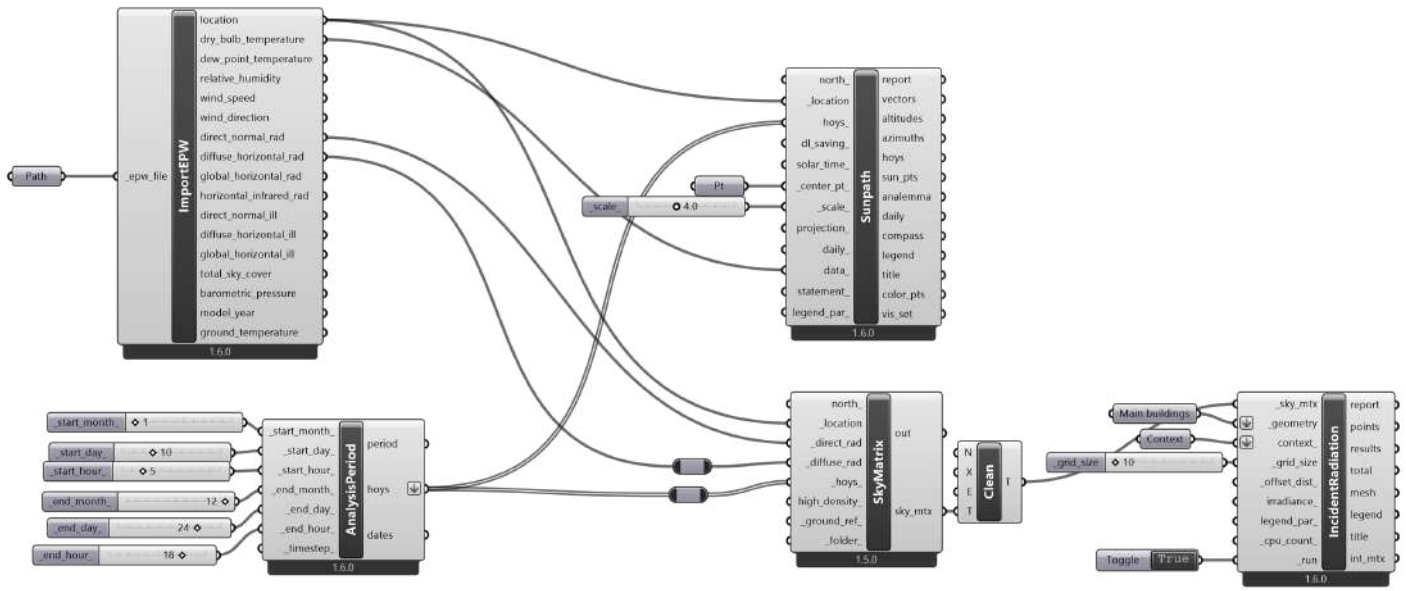
South solar radiation analysis



North west solar radiation analysis



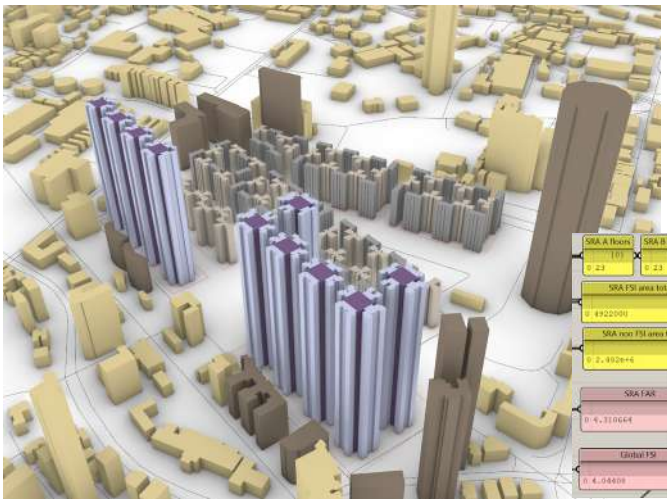
Solar radiation analysis script



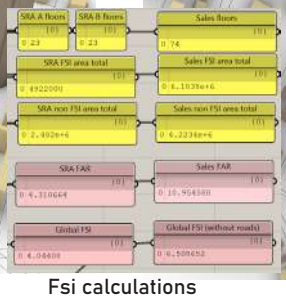
2.2.4 BDD Redevelopment proposal 2017, Worli, Mumbai

2017 proposal plan by Ar. Vivek Bhole

2017 proposal view by Ar. Vivek Bhole



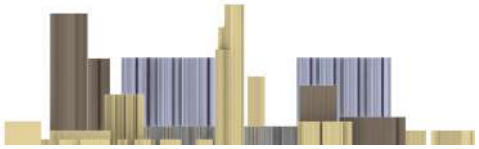
2017 BDD proposal model



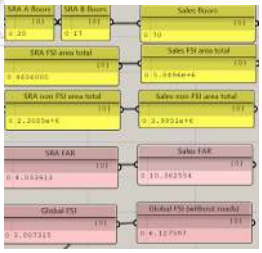
Fsi calculations

Plan

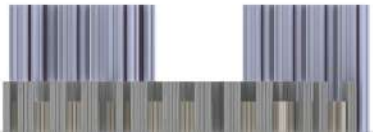
Elevation



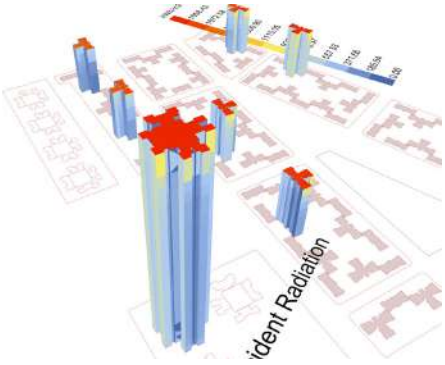
Variation A

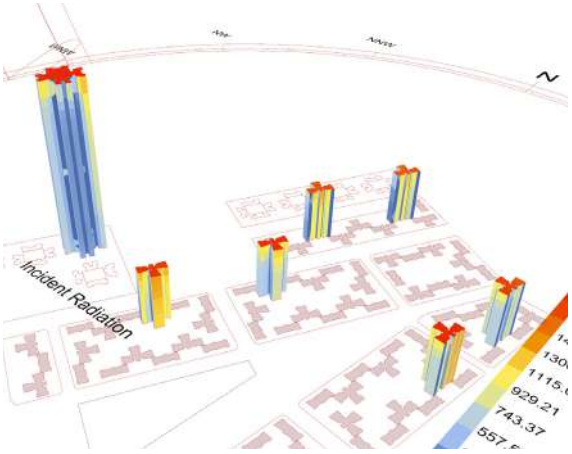


Variation B



Creating a grasshopper model for analysis



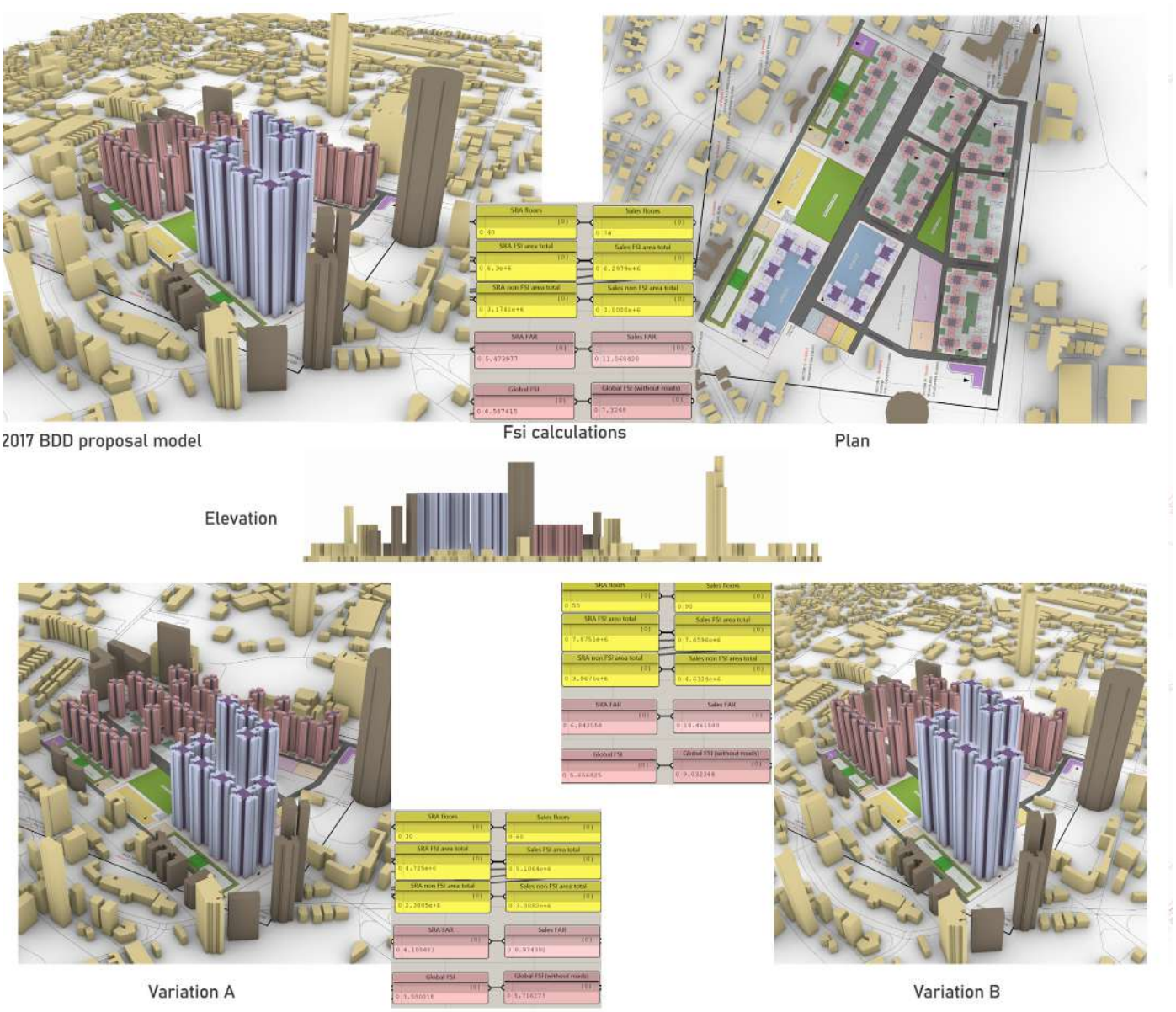


Solar radiation analysis

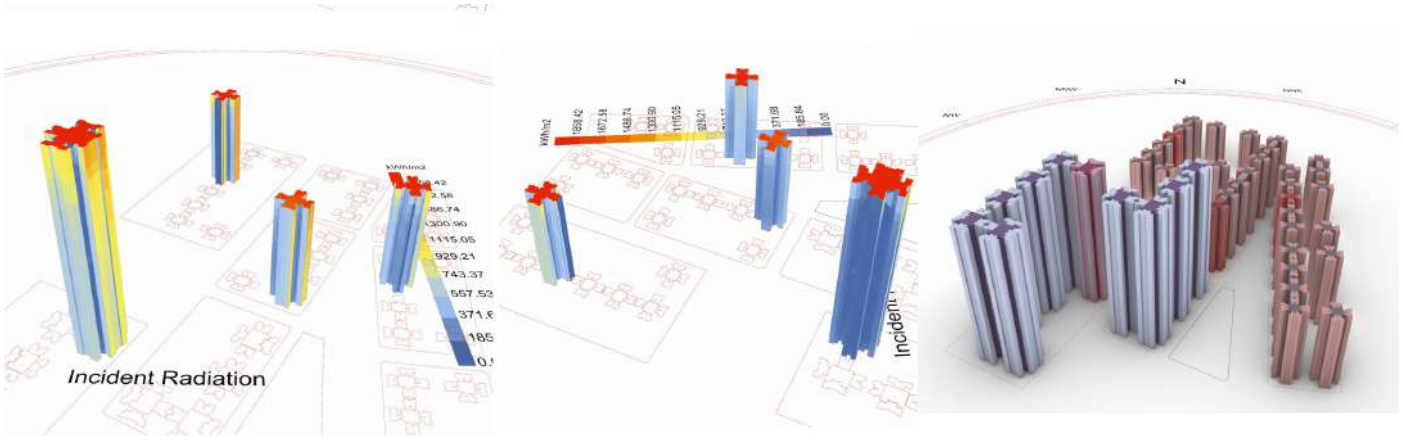
2.2.5 BDD Redevelopment proposal 2021, Worli, Mumbai

2021 proposal plan by Ar. Vivek Bhole

2021 proposal view by Ar. Vivek Bhole



Creating a grasshopper model for analysis



Solar radiation analysis

2.3 Computational design

Computational design is an approach to architecture that uses computer algorithms and tools to generate, analyze, and optimize design solutions.

2.3.1 Parametric design

Parametric design uses mathematical relationships and algorithms to create design models that can be easily manipulated and adjusted based on changing parameters. This approach is particularly useful for designing complex geometries and structures.

2.3.2 Generative design

This type of computational design involves using algorithms to generate a large number of possible design solutions based on specific criteria and constraints. These designs can be evaluated and refined to find the most optimal solution. In generative design, certain attributes of the design are defined as “variables” which can be changed incrementally to create the large number of iterations or variants of the design.

2.3.3 Algorithmic design (Optimisation)

This type of computational design involves using algorithms to optimize a design solution based on specific goals, such as minimizing material usage, maximizing energy efficiency, or reducing construction time and cost. To achieve this, iterative computation is done. Iterations means the generation of a large number of variants or designs that are initially arbitrary and not based on any parameters. These iterations are created by a generative algorithm. The generated iterations are then filtered out according to the evaluating criteria that defines its “fitness”. The fitness of an iteration is a numeric value given to each iteration after evaluating it against the fitness criteria. For example, in the case of BDD Chawls proposal, the parameter would be dirent incident solar radiation levels, and the fitness criteria would be minimise this parameter during summers. This process of filtering and selecting the best iterations is called “searching”. Manually following this process is a very cumbersome process and unfeasible. However, computing it makes it a viable option. In computing the “search”, there are two approaches, “Exhaustive search” and “Heuristic search”. Exhaustive search involves creating a large number of iterations and testing each and every one of them out for the best solution.

2.3.4 Simulation and Analysis

This type of computational design involves using computer simulations and analysis tools to evaluate and test design solutions. This can include simulations of structural performance, energy usage, and environmental factors such as wind and sunlight.

Ch. 3 Methodology

3.1 Research Design and Approach

Initial study was about findingv the relation between the nature and city growth, exploration of examples from nature was done, such as the migratory system of birds, stress priming in plants, survival features of terrestrial animals, scales of fish and forest growth patterns. A research paper modelled the forest growth pattern using the concept of Cellular Automata (CA). To build upon this and contextualise it with architecture due its similarity of networks and interrelation found in cities, the forest growth topic was selected. The codes were understood and CA was studied. This exploration is important in the current times due to the over emphasis on the rigid top down planning which has been practised. The more organic and data driven approaches have not been implemented much because of the previously lack of computation power and available data.

Cellular Automata deals with the interrelation between the cells and its neighbours. This interdependency is similar to the networking seen in the forest growth as well as city growth. In CA, the cells have only two states, either dead or alive. But upon customising its concept, more data can be set in the cells. For example, each cell could hold the data about multiple parameters in the case of forest, the parameters were taken as water, sunlight and nutrients. Moreover, it could be modified such that the data it holds is not only in the form of dead or alive, i.e., binary states. It can hold the value denoting quantity of the parameter available. These quantities can then have an impact on the quantities of the neighbouring cells. In the context of the city, high population density cells affect the resource requirement values of the cell.

In case of the inspiration from the nature, the aspect that was taken into consideration about the forest was how the different types of trees grow together, in what patterns and how their different attributes are related to the parameters such as water availability, nutrient concentrations, sunlight, etc. The parameters were selected based on the level of impact they had on the growth patterns. Thus the micronutrients were left out, which have little impact. Other factors, such as climate, soil types, fauna, etc., were not considered to keep the model simple and workable for experimentation. A script was prepared that had such parameters as the inputs and the tree attributes as the output. The input data was stored in each cell, which was also affecting the neighbouring cells, thus forming a CA where the script would then run on its own simulating the changes in the levels of nutrients and the subsequent changes in the forest. This framework was then taken to the city where the different elements of the buildings, such as the height, orientation, tapering and openings were be governed by the following input parameters: population density, wind, sunlight and temperature. The elements and parameters were selected because of their importance and their simplicity in calculation. Upon given the time and more computing power, more complex parameters such as circulation, landmarks, network of services, etc. could be incorporated.

However this approach was strictly top-down and could not involve in its computation, the elements that fall under the bottom-up approaches, which are highly individualistic and also involve qualitative aspects such as culture. Moreover, the output was highly isolated and non-cohesive in design. To deal with this, a different route of designing is taken. To have a structured beginning, a 3D grid is laid out on the site. The grid is to be populated with habitable spaces which could be done by culling of points according parameters, but this gives rigidity to the form and the process, adding limitations and rigidity to the framework of script.

Other approach is to distort the grid according to the relevant parameters. Morphing the shape, does not fixate the working to a rigid grid. It also allows the application of varying intensities of parameters instead of the stark deleting and placing of elements. These parameters fall under the following categories: Environmental, structural, social integration and demographics. They were selected based on their level of impact and computability, which means, if the data available can be made mathematical and thus, readable by the computer. After the distorting of the grid and the culling of points based on the parameters, the housing design would then emerge. This is done through the software of Rhinoceros which has the plugin of Grasshopper, that has various plugins and provides a good space for running code which was done in the Python language, which is easier to understand and common for interdisciplinary practitioners. The other similar software would be the use of Dynamo plugin in Revit, but it is restrictive to building elements only, whereas Grasshopper gives the flexibility to work with forms in general.

To contextualise and test the design, it is to be applied on a site. The selection of the site was done based on the requirement of housing for the lower income group because these are driven more by authorities and are conventionally highly top-down in their planning, in contrast to that done my medium and high income groups.

Being in Mumbai, slums and chawls fall under the houses for LIG. Slum redevelopment and chawls would come under this category where the housing is to be done for the LIG by the governing authority. The site of BDD chawls at Worli, Mumbai is selected as there have been a large number of redevelopment plans proposed for the same over the past years which could be studied and their documentations referred.

Parametric method is applied by the use of DeCoding Spaces plugin that creates buildings based on the set of parameters. however, due to the lack of control over the script, it was found difficult to incorporate regulations and guidelines.

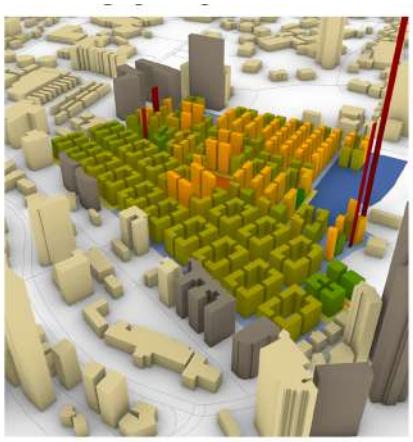
Finally, the method that was selected to be taken forward was Evolutionary Generative design by Multi-Criteria Optimisation using the Wallacei plugin of grasshopper. Galapagos is another common plugin used for the purpose of Evolutionary Generative design, but it is a Single-Criteria Optimisation engine which limits the users in selecting multiple fitness criteria.

3.2 Limitations

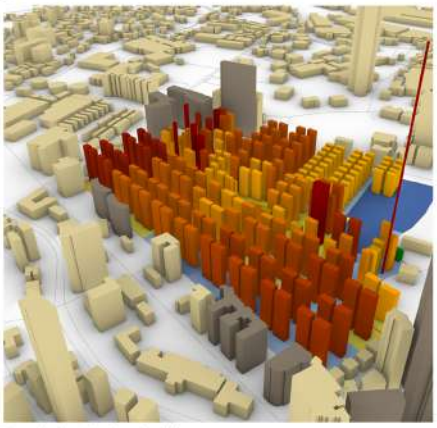
1. Complexity of Design Space: The design space for cluster redevelopment projects is highly complex, involving various factors such as architectural design, infrastructure planning, community needs, and regulatory constraints. Incorporating multiple criteria and objectives into the evolutionary generative design process can further increase this complexity, making it challenging to find optimal solutions that satisfy all criteria simultaneously.
2. Trade-offs and Conflicting Objectives: Different stakeholders involved in cluster redevelopment projects may have diverse and sometimes conflicting objectives. Evolutionary generative design attempts to find a balance between multiple objectives, but there may be instances where trade-offs need to be made. Resolving these trade-offs and reaching consensus among stakeholders can be complex and may require additional negotiation and decision-making processes.
3. Subjectivity and Human Interpretation: The interpretation of design objectives and preferences is inherently subjective and influenced by individual perspectives. While evolutionary generative design can provide data-driven insights, the final design decisions often require human judgment and expertise. The subjectivity and interpretation involved in the design process can introduce biases or limitations in the optimization outcomes.
4. Implementation Challenges: Even if evolutionary generative design yields optimal design solutions on paper, there may be practical implementation challenges. Factors such as cost constraints, regulatory limitations, and logistical considerations can impact the feasibility and realization of the generated designs. It is crucial to assess the practicality and viability of the design outcomes within the specific context of cluster redevelopment projects in Mumbai.

Ch. 4 Proposed Approach of Designing

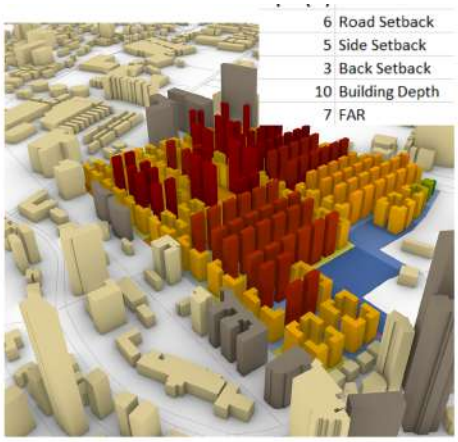
4.1 Parametric approach (DeCoding Spaces)



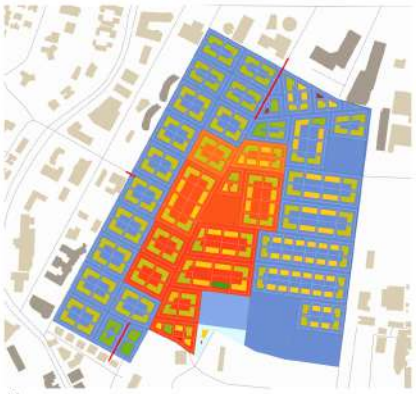
Parcellation a block configuration



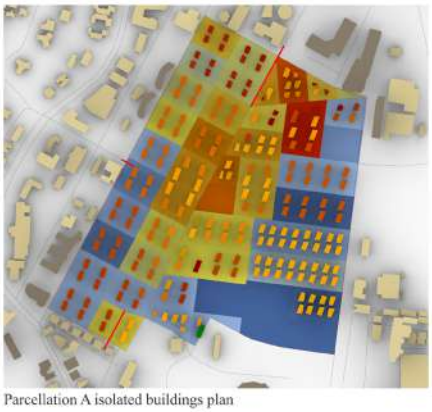
Parcellation A isolated buildings



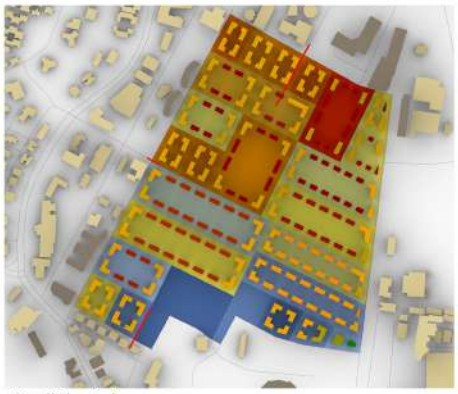
Parcellation B isolated buildings



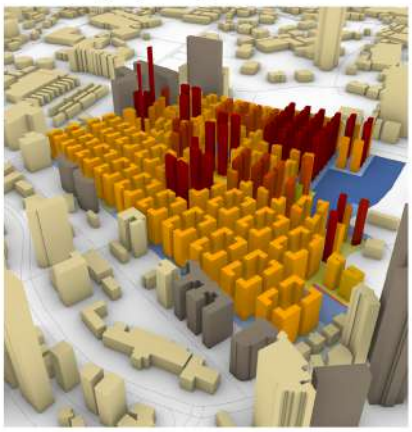
Plan



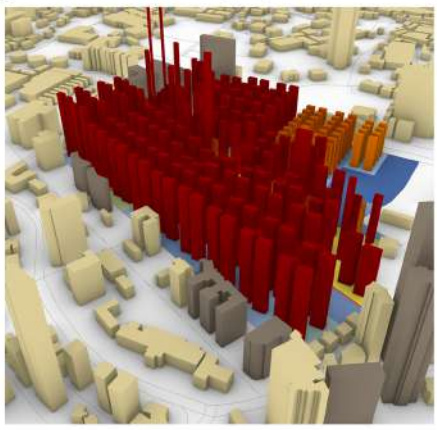
Parcellation A isolated buildings plan



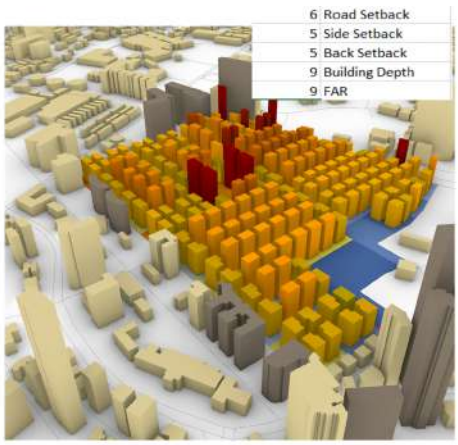
Parcellation B plan



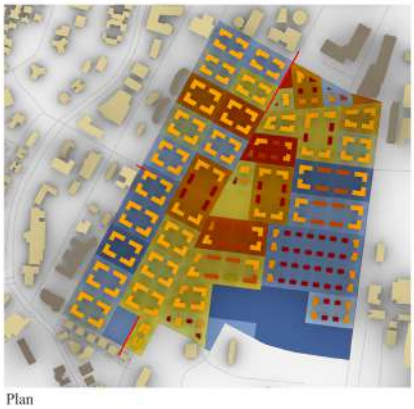
Parcellation a block configuration



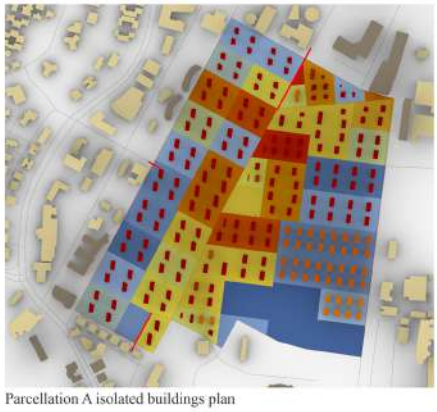
Parcellation A isolated buildings



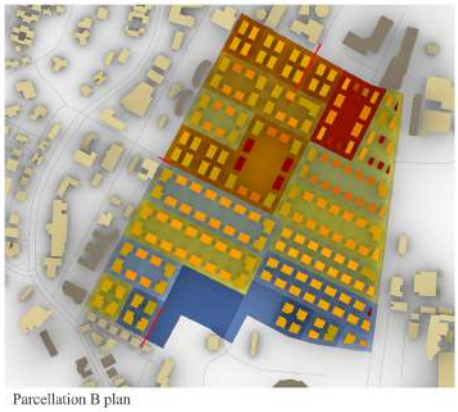
Parcellation B isolated buildings



Plan



Parcellation A isolated buildings plan



Parcellation B plan

The design options are very rigid and do not take into consideration the nuances such as circulation spaces, unit sizes, etc. The structures are not in control of the designer and there is little scope of morphing the forms according to any fitness criteria.

4.2 Evolutionary Generative Multi-Criteria Optimisation method

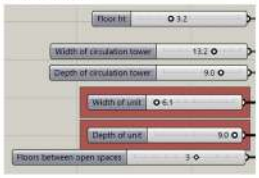
Evolutionary Generative Multi-Criteria Optimisation (EGMCO) is a computational methodology employed in architecture to facilitate the discovery of optimal design solutions that simultaneously satisfy multiple objectives or criteria. This approach leverages evolutionary algorithms, which mimic natural evolution processes, to iteratively generate and refine a diverse set of design alternatives.

In architectural design, there is often a multitude of objectives that need to be considered, including but not limited to sustainability, functionality, aesthetics, cost-effectiveness, and user comfort. These objectives often conflict with each other, making it challenging to identify a single solution that optimally fulfills all requirements. EGMCO addresses this complexity by employing evolutionary algorithms to explore the design space and uncover a range of Pareto-optimal solutions, where no single solution is superior in all criteria compared to others.

The fitness criteria selected for the case of BDD Worli Redevelopment proposal are following the DCPR norms and Sunlight hours requirements, for which the following excerpt is referred and four hours is set as the requirement.
“India does not have mandatory guidelines on the duration of sunlight on neighbouring structures that are dwarfed by construction of a high-rise. In the United Kingdom and South Africa, minimum two hours of direct sunlight is required for any building to survive.”
“Avick Sil, regional director, Electric Power Research Institute, who conducted the study said rampant construction of new tall residential and commercial complexes along with redevelopment of old buildings and rehabilitation of slums into high rises across Mumbai makes it essential to carry out shadow analysis to predict the probable impact of lack of sunlight on human health and the green cover.”

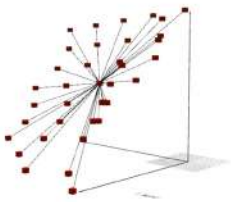
Evolutionary Generative design

Variables:
1. Unit depth
2. Unit length

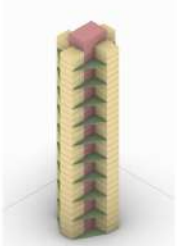


Inputs:
1. Fsi
2. Required unit size (50 sq. M.)
3. Circulation tower dimensions

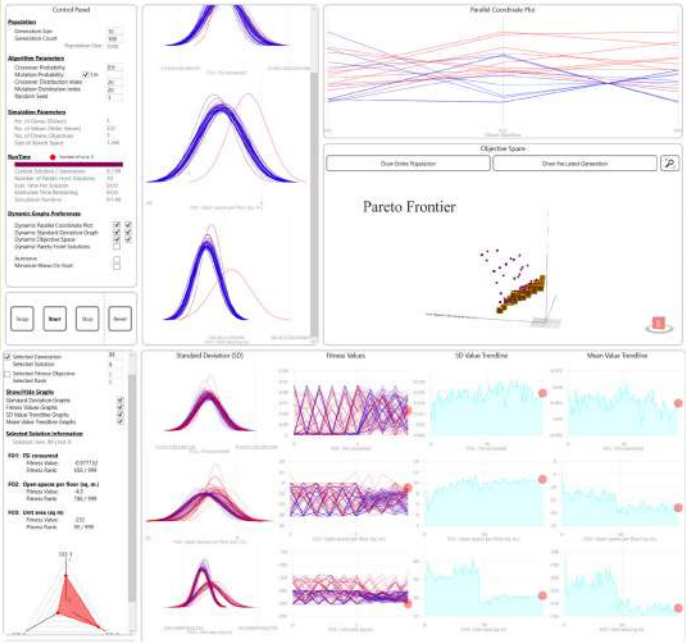
Outputs optimized:
1. FSI consumed maximised
2. Open spaces in building maximised
3. Unit size as close to the required value



Cluster graph



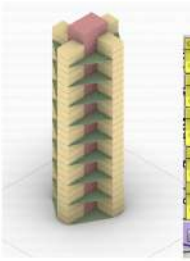
Fitness objective 1 optimized (FSI)

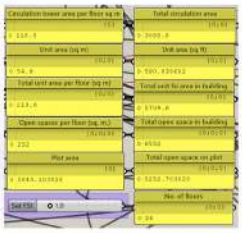


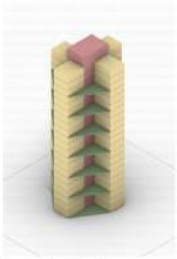
Multi-criteria generative optimization allows us to find the best set of solutions that take into consideration all the fitness criteria that we need.

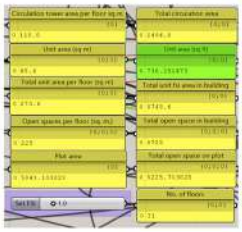
A new method of designing emerges where the designer no longer designs the final outcome, but designs a base model that can be morphed by the generative algorithm to generate iterations.

These iterations are then tested against the fitness criteria set by the designer.





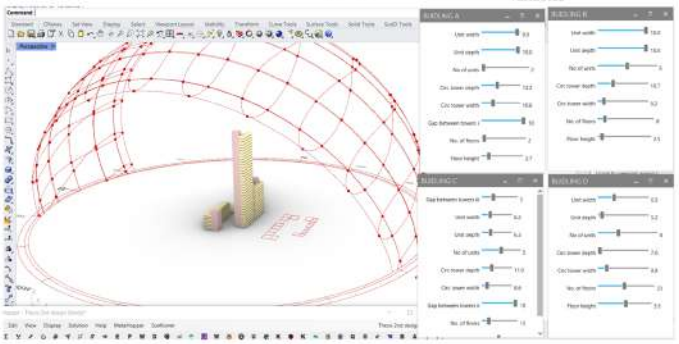




Generation 99 cluster average

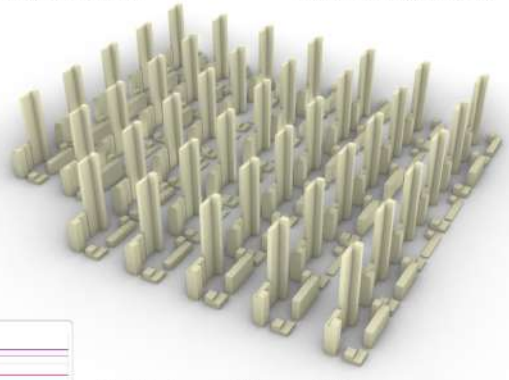
Evolutionary Generative design (Block)

Variables

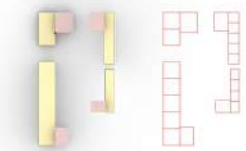


Outputs optimized:
1. FSI consumed maximised
2. Unit size optimised to 50 sq. m.
3. Minimise surfaces that lack direct sunlight

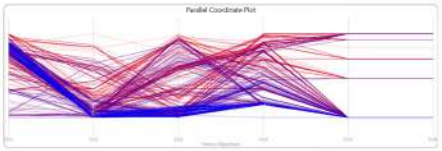
Inputs:
1. Plot boundary
2. Required FSI
3. Required unit size (50 sq. m.)



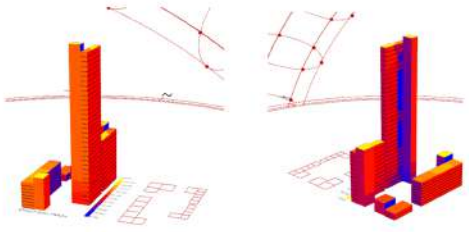
Top 40 designs out of 1000 generated forms



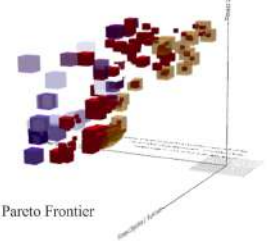
Plan



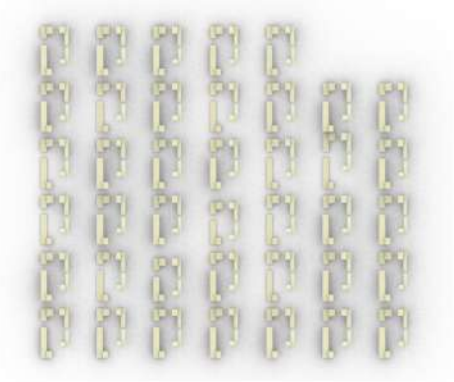
Parallel Coordinate Plot



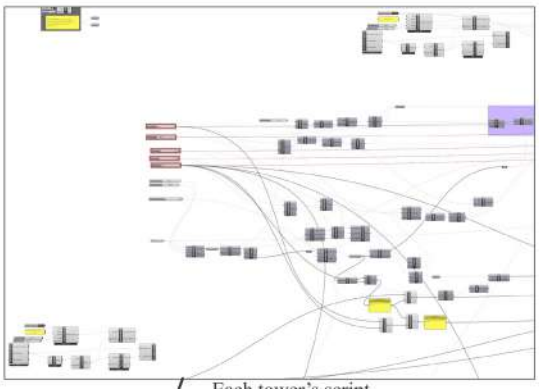
Sunlight hour analysis



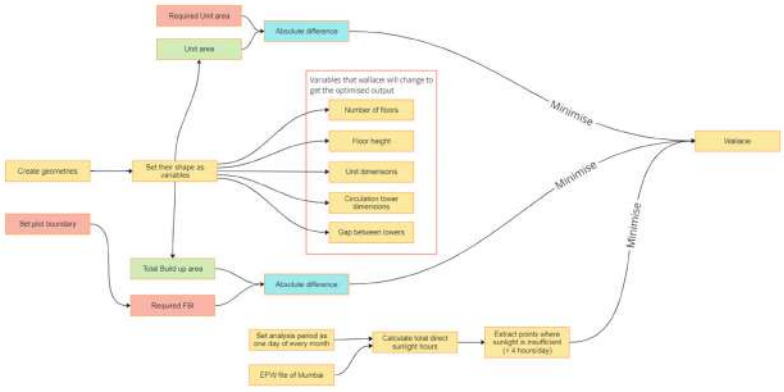
Pareto Frontier



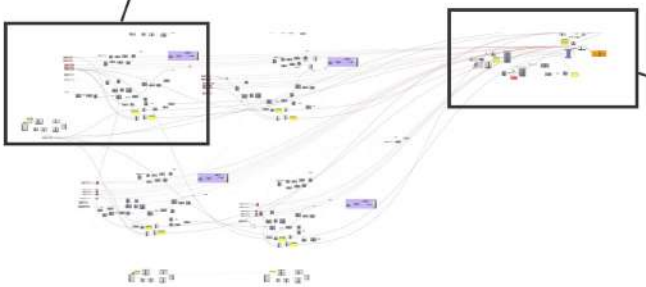
Evolutionary Generative design (Block) script

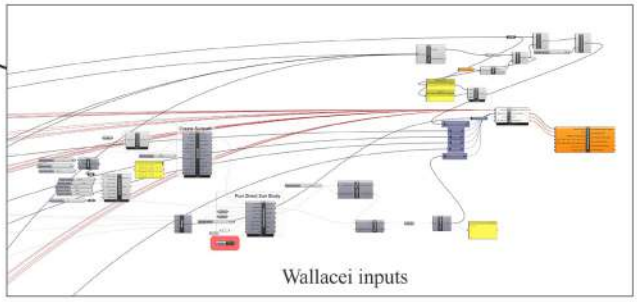


Each tower's script



Pseudo-script





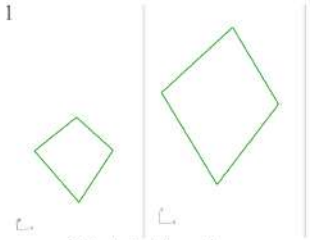
Wallacei inputs

For buildings of ht 24 to 70 m	2 lifts								
	Steps	Tread	Riser	Width	Area	Ht.	No.		
Stairs flight	24	0.3	0.15	1.5	10.8	3.6	1		
	Dimension		Number		Area				
Landing	1.5	1.5	3		6.75				Total area
									65.55
Lift Shaft	Dimension		Number		Area				
	2	3	2		12				
Corridors	Width	Length			Area				
(Length = Perimeter of circulation tower)	1.5	40			27				
Service and vent shaft					9				
For buildings of ht more than 70 m									
	Steps	Tread	Riser	Width	Area	Ht.	No.		
Stairs flight	24	0.3	0.15	2	28.8	3.6	2	(fire stairs/chute)	
	Dimension		Number		Area				
Landing	1.5	1.5	3		13.5				Total area
									187.3
Lift Shaft	Dimension		Number		Area				
	2	3	6		36				
Corridors	Width	Length			Area				
(Length = Perimeter of circulation tower)	2	50			100				
Service and vent shaft					9				

Circulation tower area requirement calculation

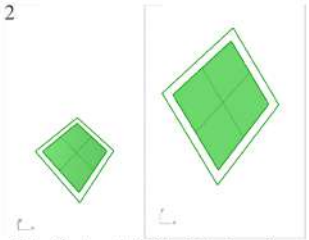
Evolutionary Generative design (Finalised approach)

1



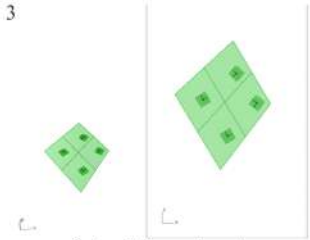
Select plot boundary

2



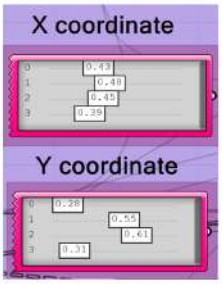
Set offset and divide into 4 regions

3



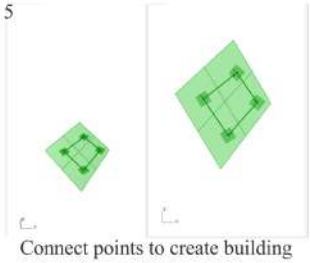
Set point in each part

4



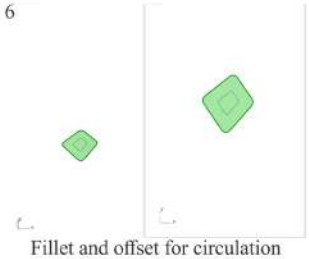
Sliders for setting the points

5



Connect points to create building line

6



Fillet and offset for circulation tower

7

```
if (HtOfBuilding < 24)
{
  A = less24;
}
else if (HtOfBuilding < 70 && HtOfBuilding >= 24)
{
  A = m24to70;
}
else
{
  A = more70;
}
```

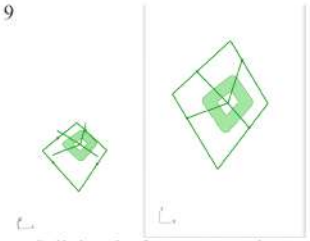
The script reads excel sheet to find the optimum area according to the building height

8

```
if (AreaOfTower > RequiredArea)
{
  A = OffsetFromBoundary + Accuracy;
}
else
{
  A = OffsetFromBoundary - Accuracy;
}
```

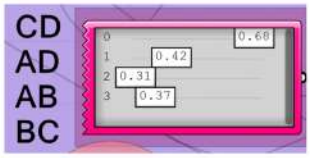
The script finds the offset needed for the circulation tower to achieve the required area

9



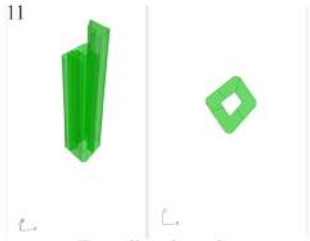
Splitting the form to get units

10



Sliders controlling the splitting lines

11

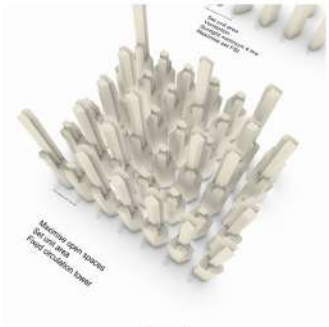


Extruding the units

12

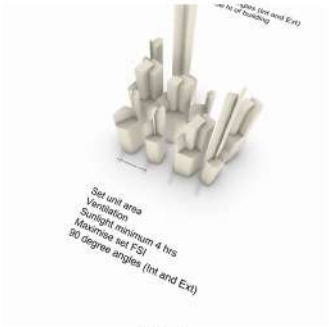
Sliders controlling the number of floors

Evolutionary Generative design (Finalised approach)



Setup 1

Setup 2



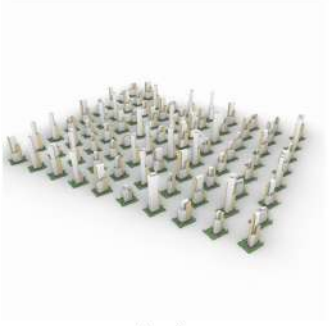
Setup 3

Setup 4

Setup 5

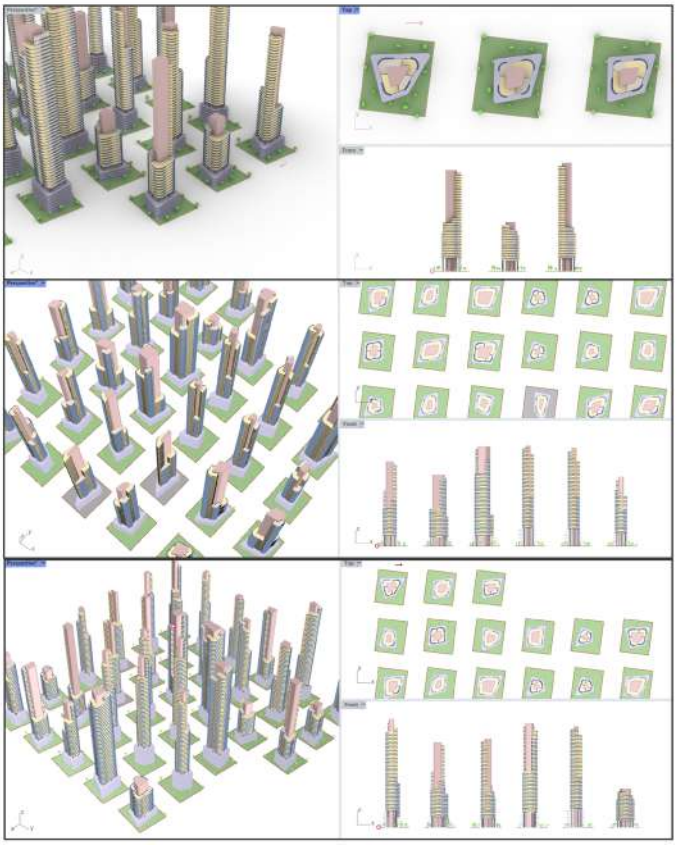
Setup 6

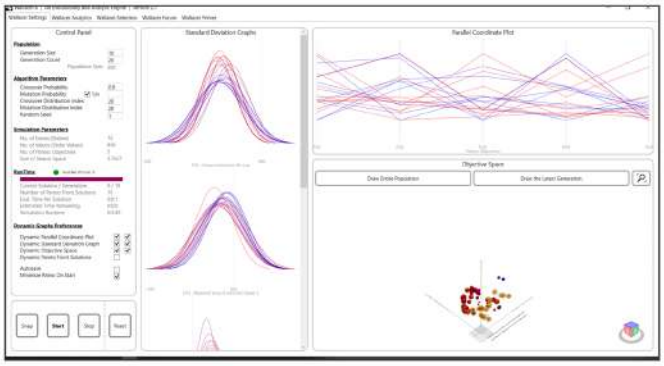
Setup 7

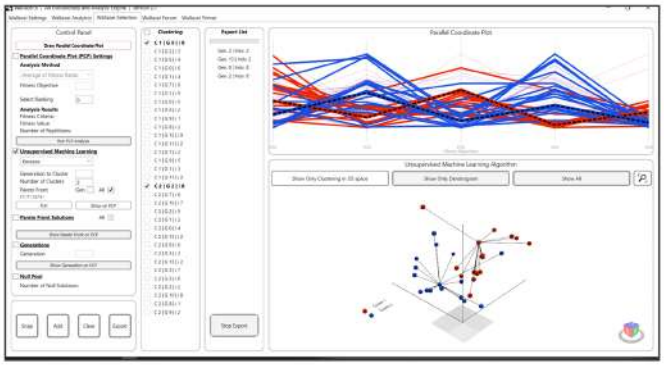


Setup 8

Finalised setup

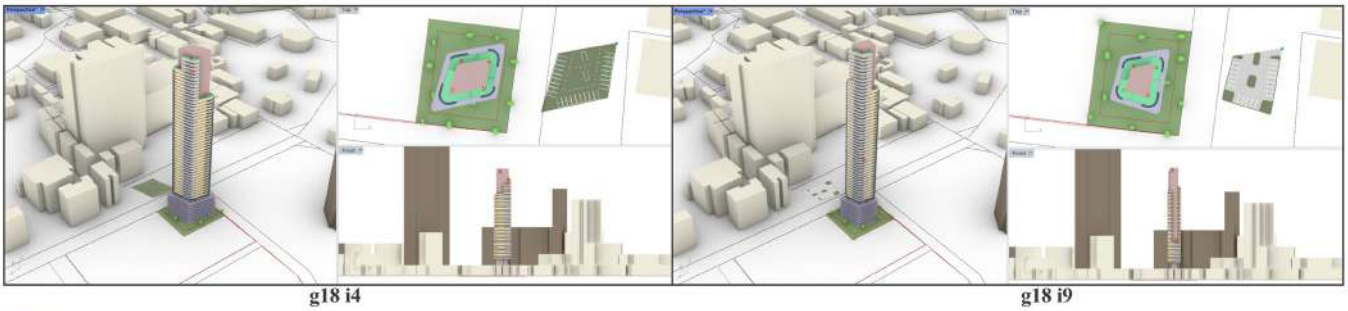






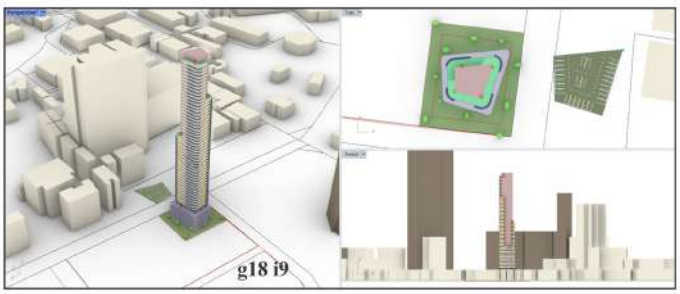
Most optimal sunlight criteria (g0 i4)

g18 i3

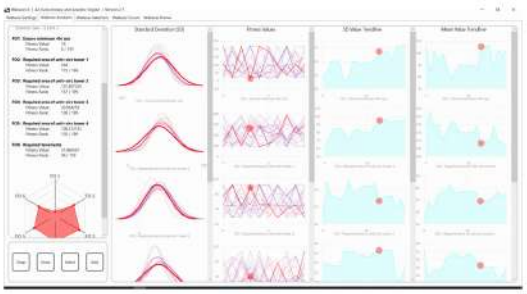


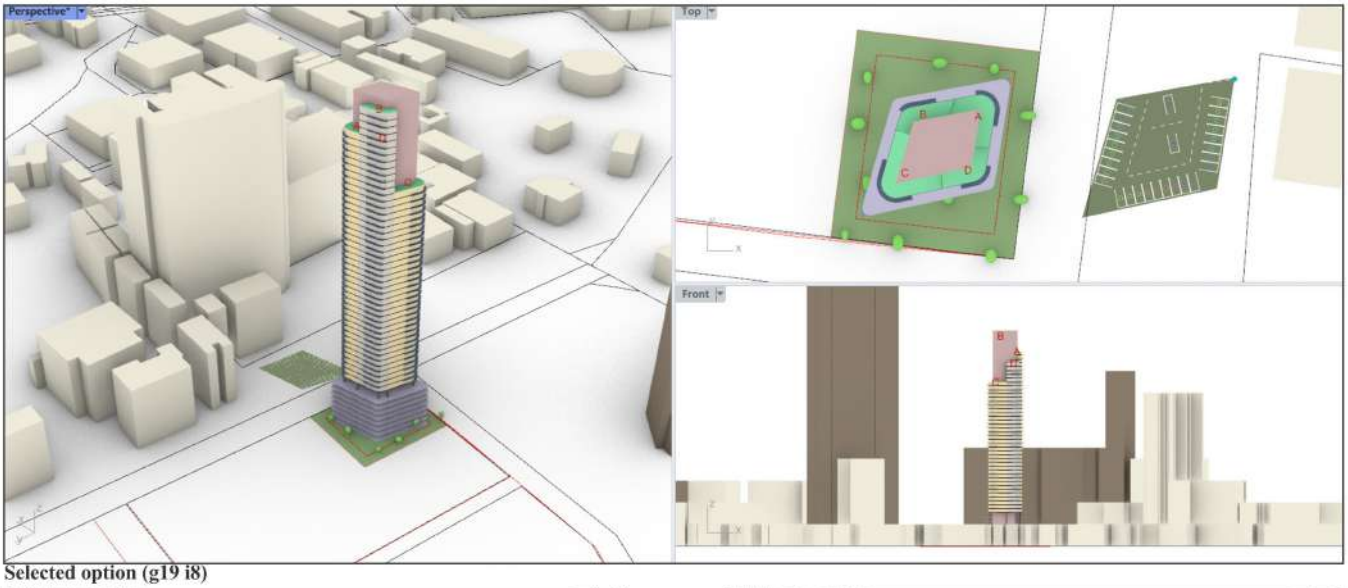
g18 i4

g18 i9

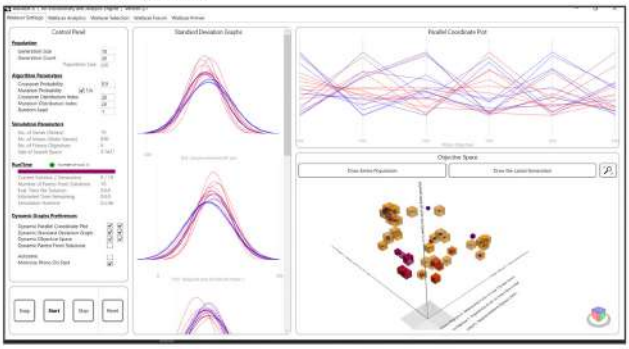


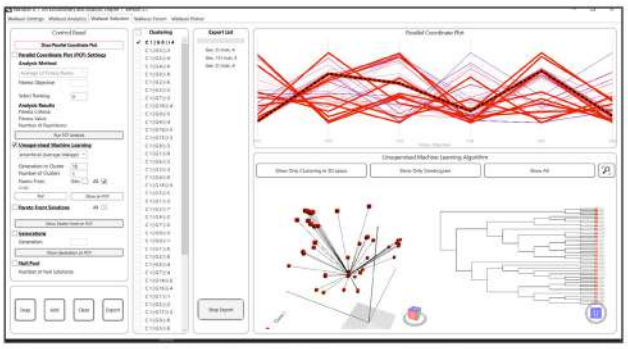
g18 i9

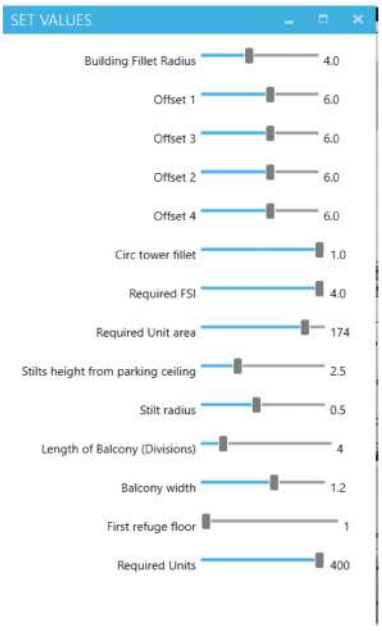


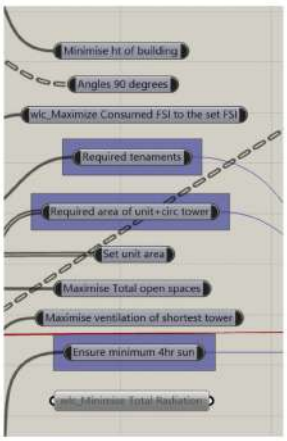


Selected option (g19 i8)





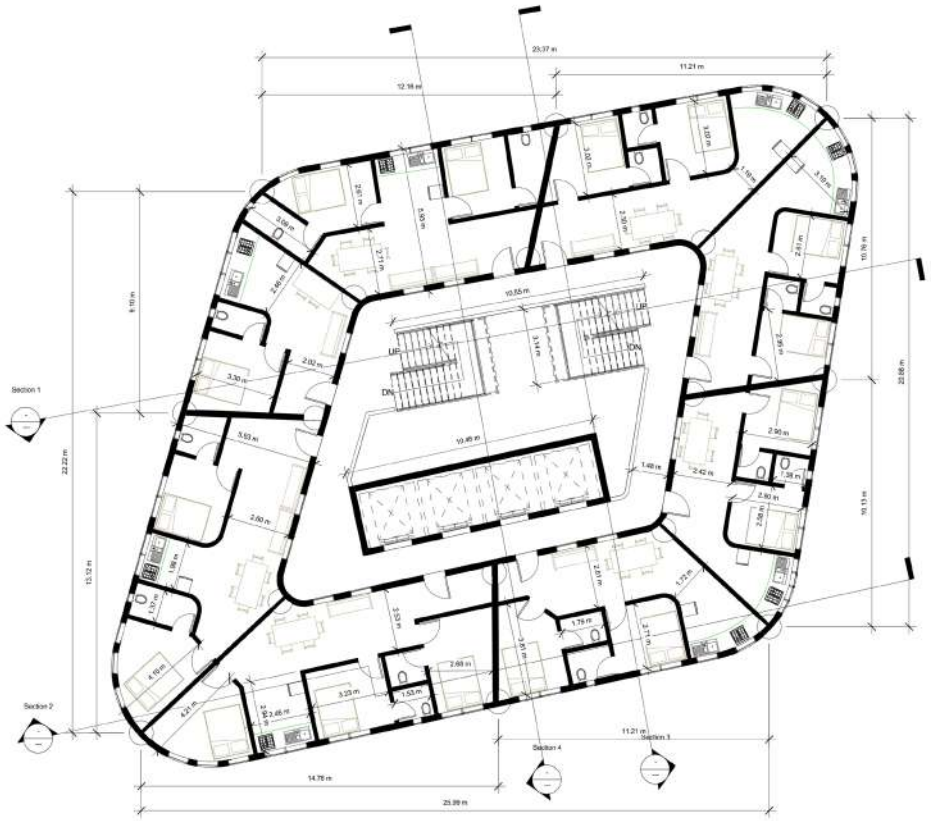




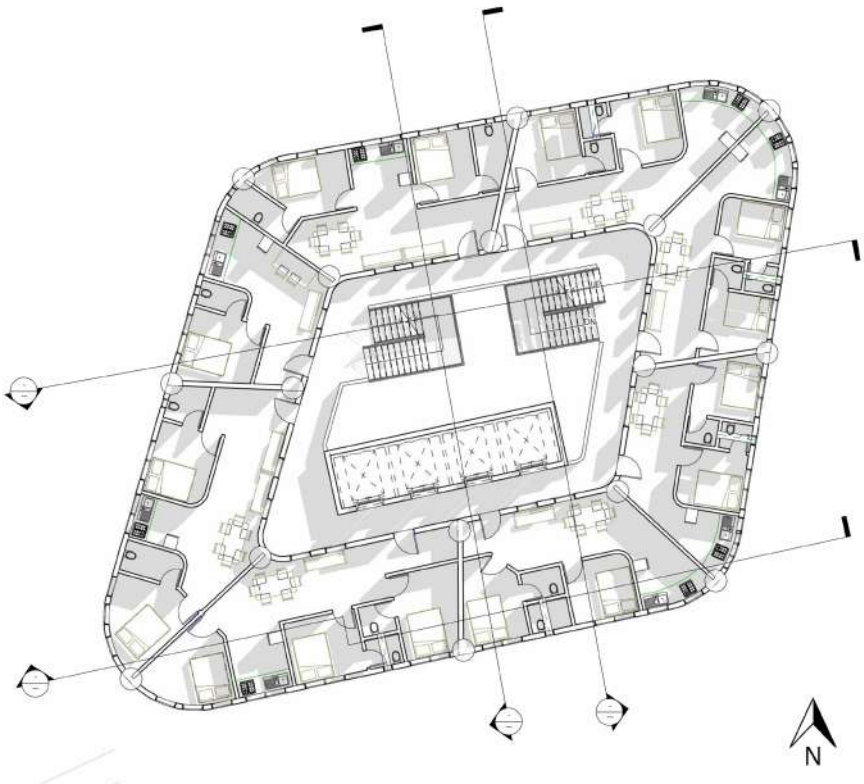
Sr. no.	Name	Tower	Values	Unit
1	Area of plot		2788	sq m
2	Total BUA		15557	sq m
3	FSI Consumed		6.36	
4	Total units		282	
5	Unit Areas	A	109	sq m
6		B	98	sq m
7		C	138	sq m
8		D	100	sq m
9	No. of units	A	42	
10		B	46	
11		C	34	
12		D	39	
13	Ht of building		161	m
14	Refuge floors	A	5	
15		B	6	
16		C	4	
17		D	5	
18	Total refuge area		2194	sq m
19	Area of Circulation tower		180	sq m
20	Terrace open spaces		446.8	sq m
21	Open spaces around building		1787	sq m
22	% of open space		64	
23	Balcony lengths	A	11	m
24		B	11	m
25		C	14	m
26		D	11	m
27	Ht of parking tower		25.9	m
28	Unit depth		6	m

Parking needed	176.25
Parking provided	178

Level 1 plan



Toilet duct section from section 1



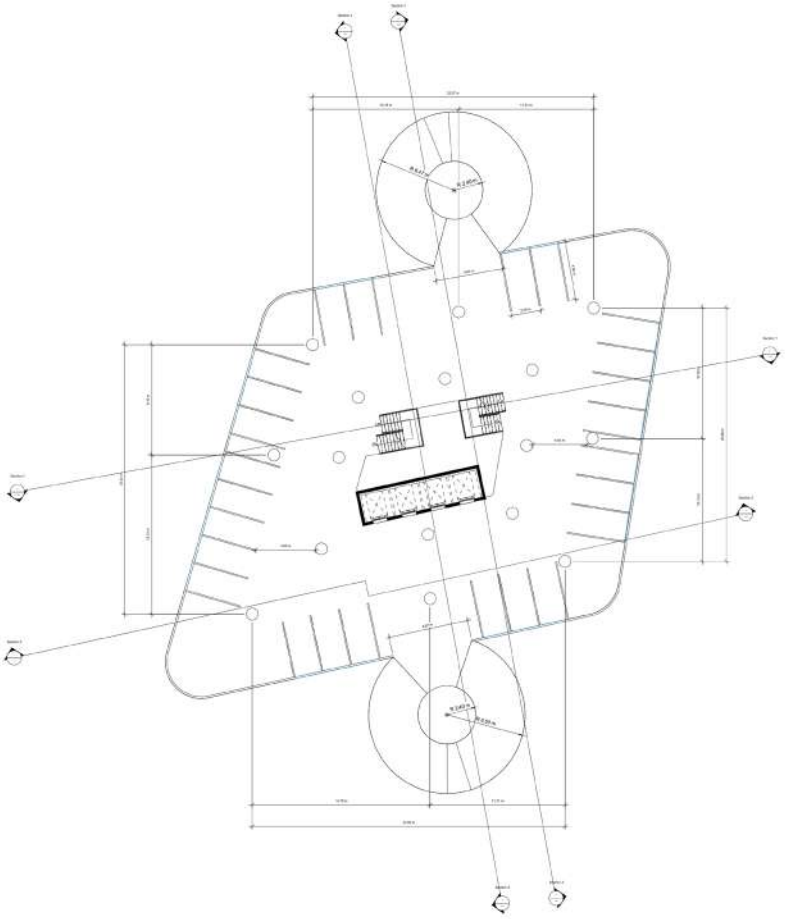
Level 1 plan

Level 35 plan

Level 40 plan

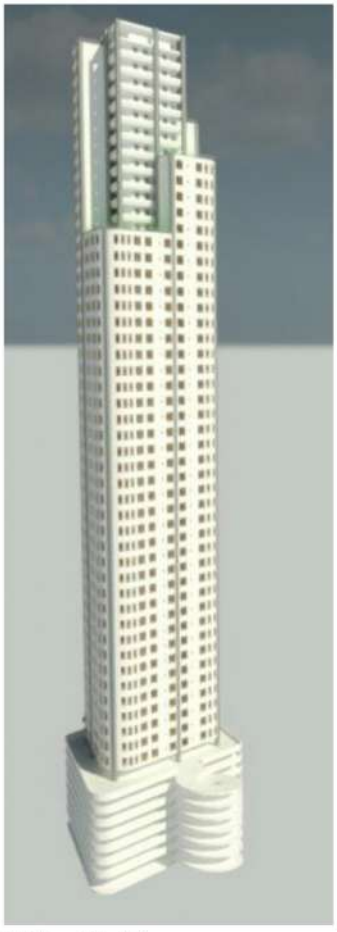
Level 43 plan

Parking level 1 plan



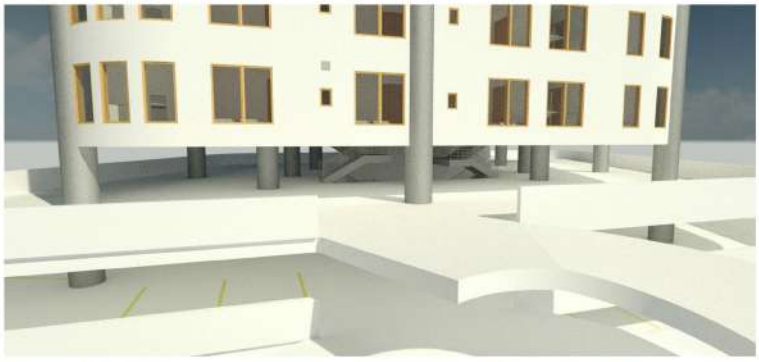
Scale 1:200

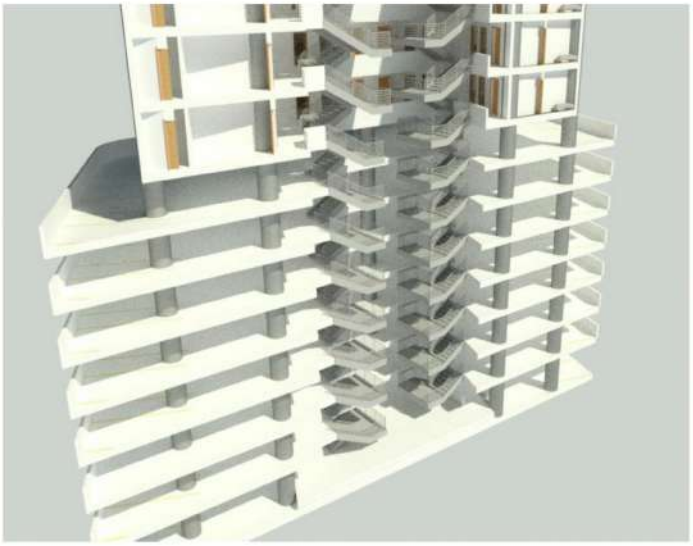
N



Facilitation

Parking views

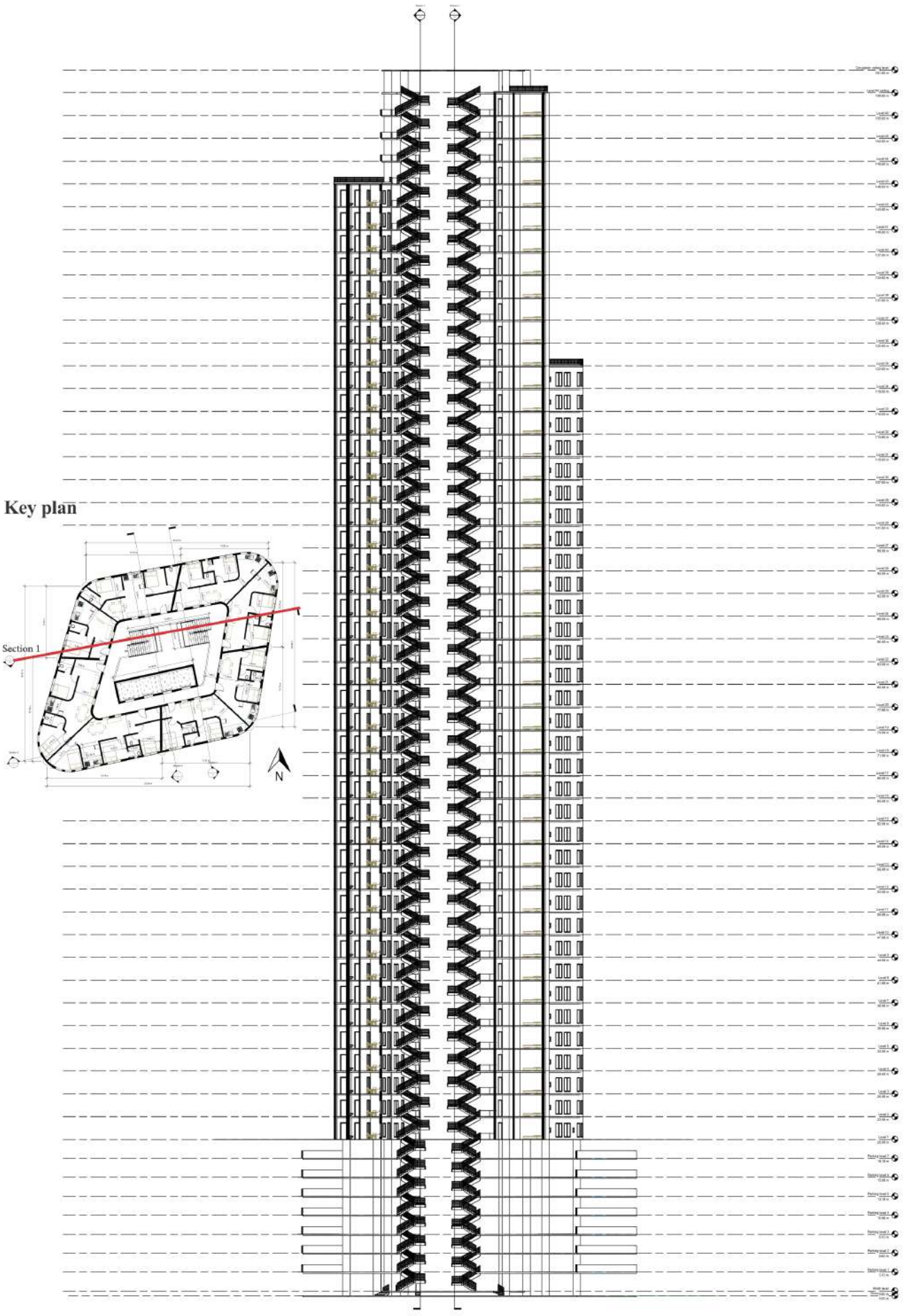




Corridor section view

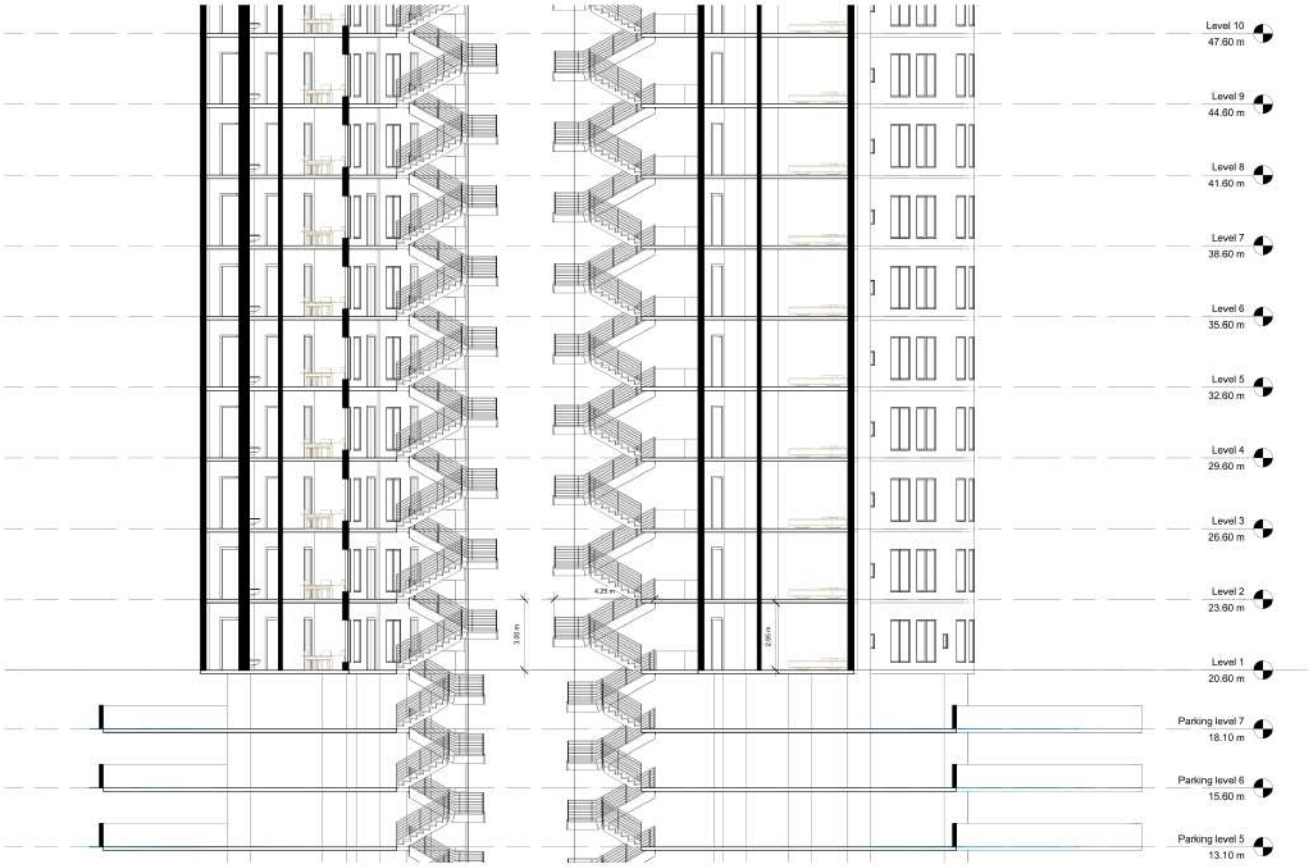
Terrace views

Section 1



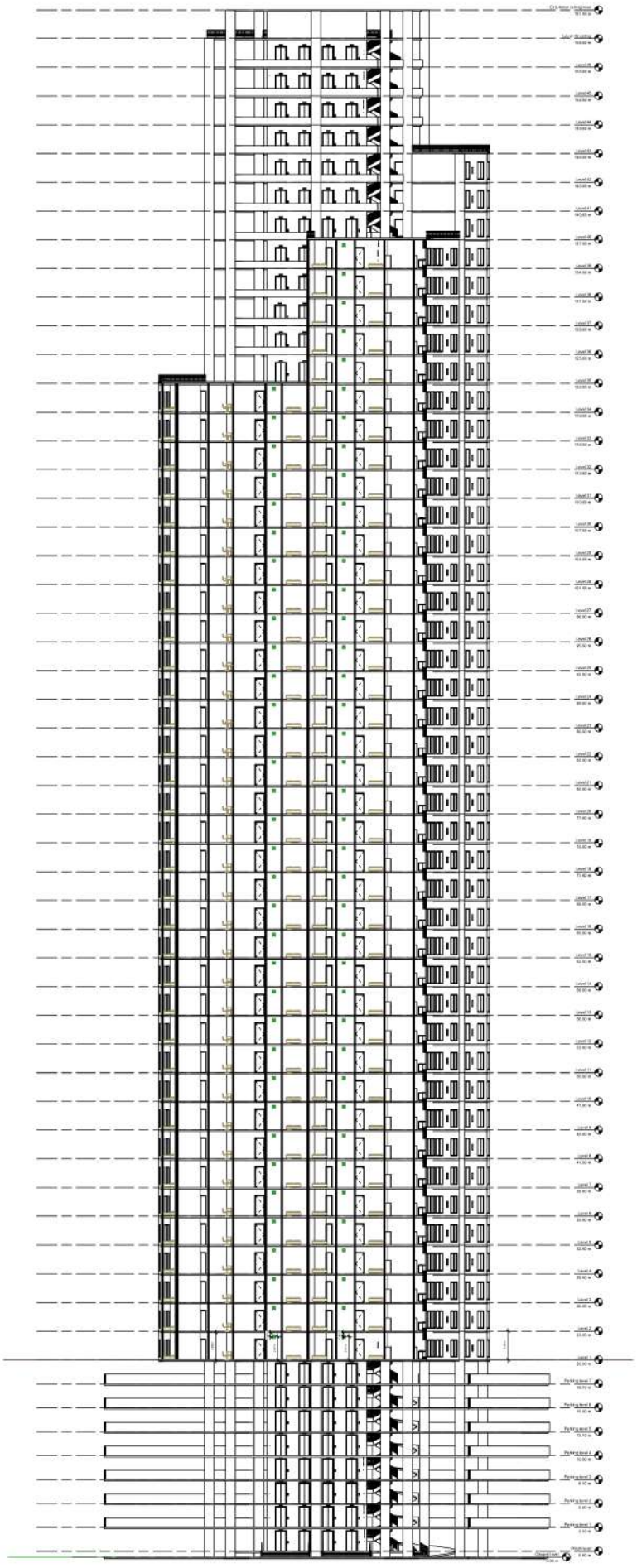
Key plan

Section 1 detail

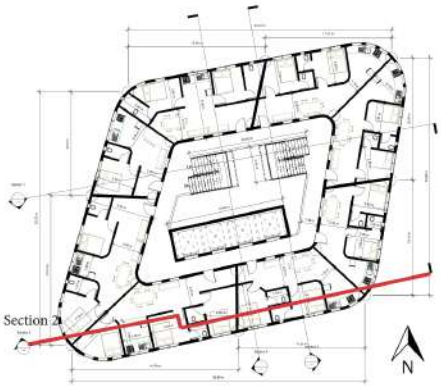


Section 1 parking detail

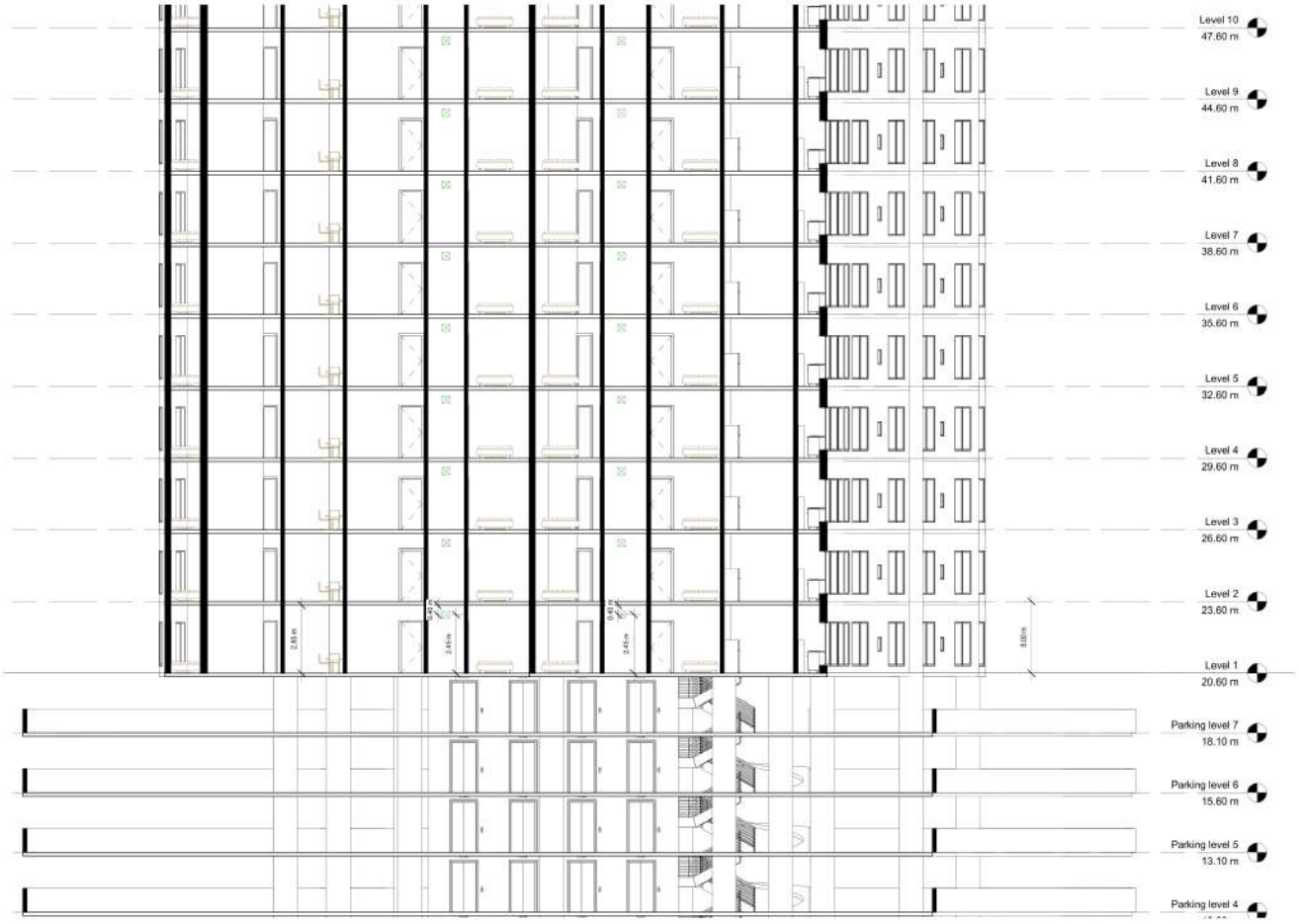
Section 2



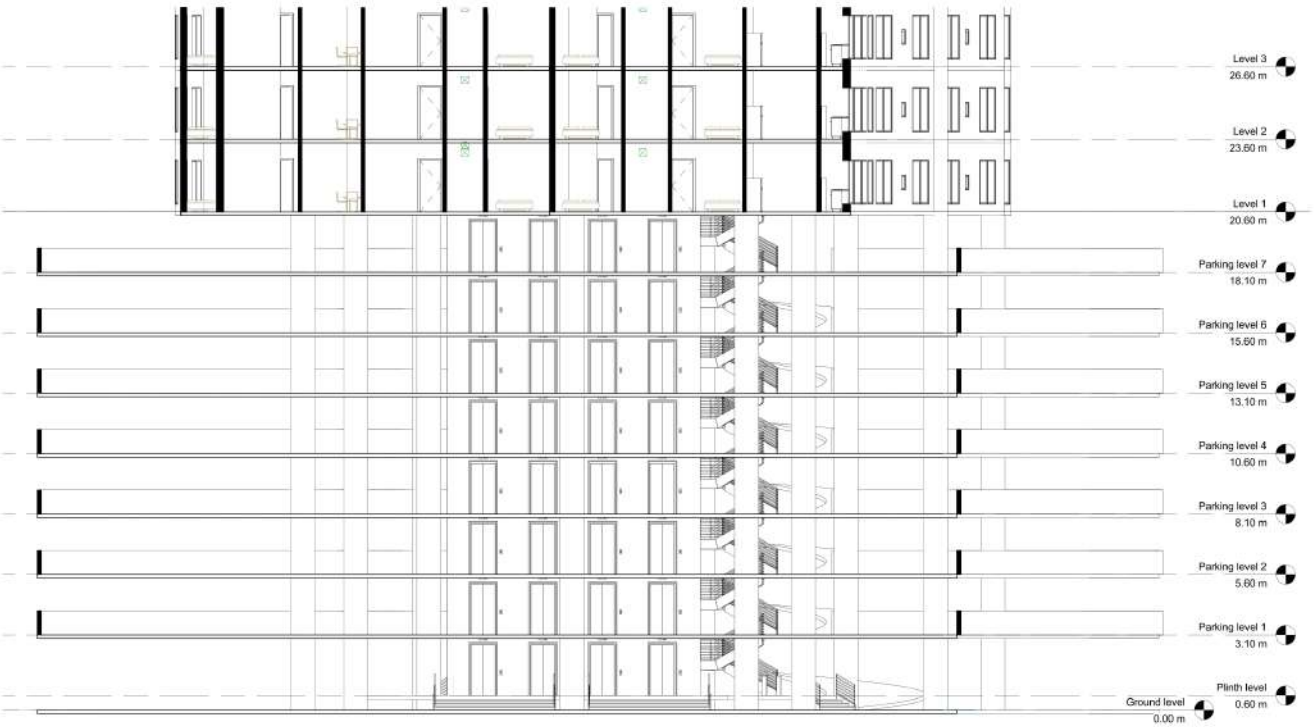
Key plan



Section 2 detail

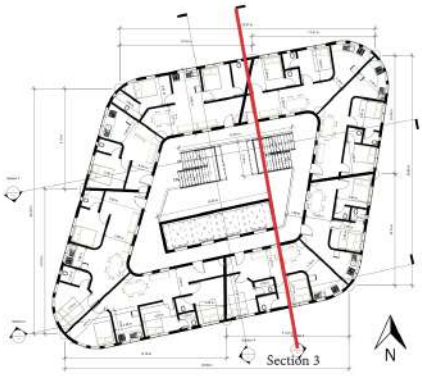


Section 2 parking detail



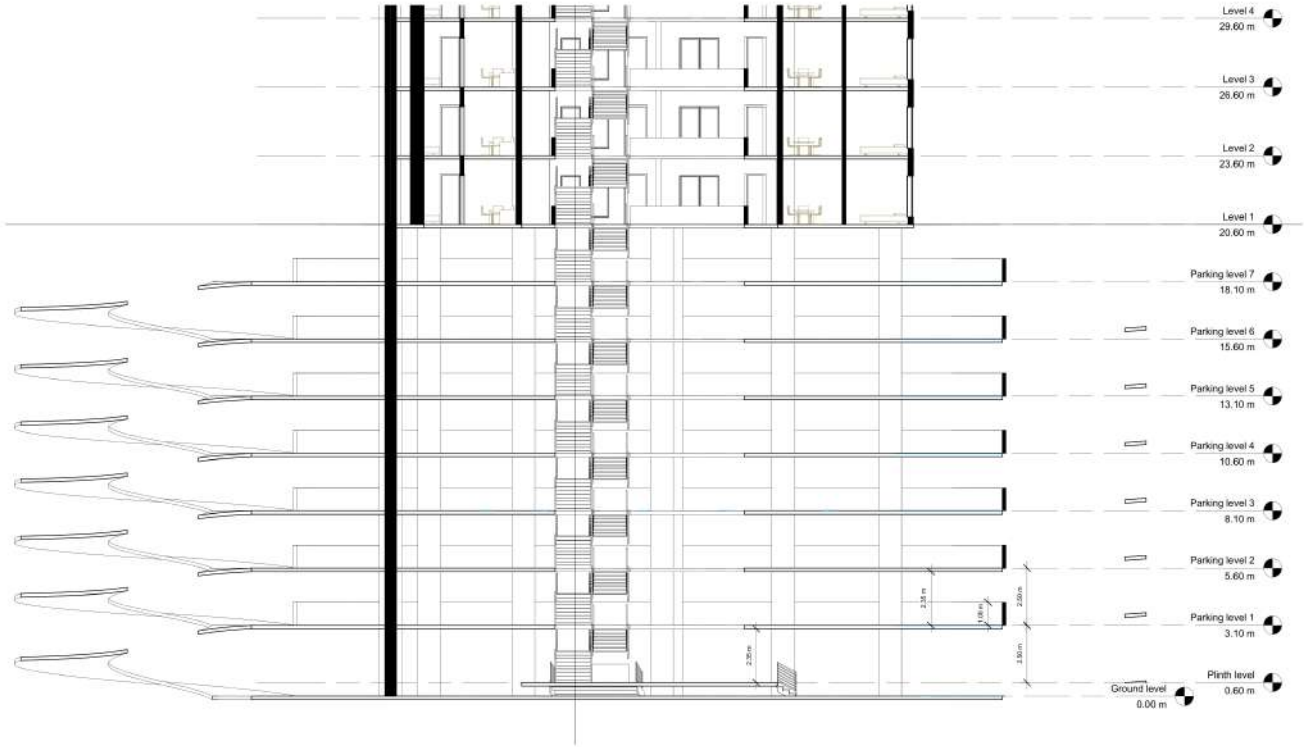
Section 3

Key plan

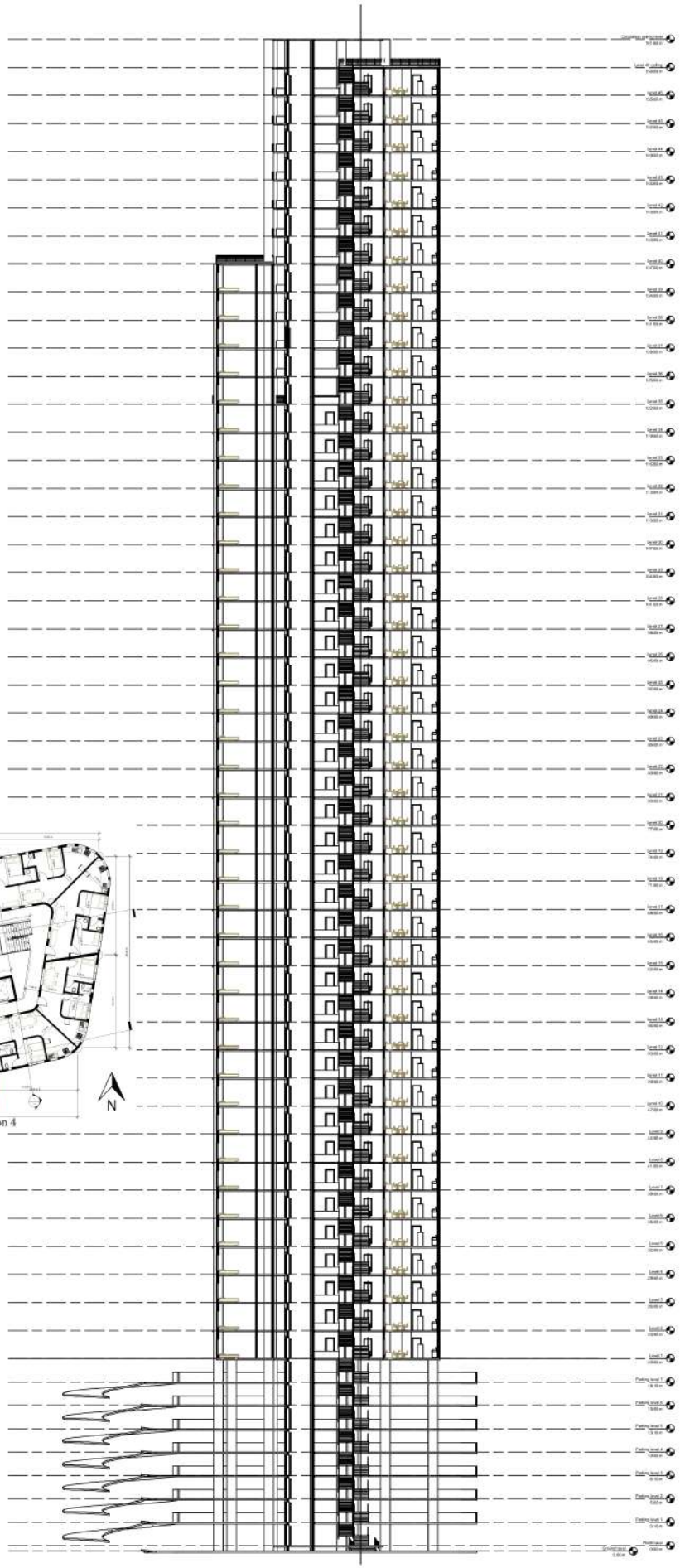


Section 3 detail

Section 3 parking detail

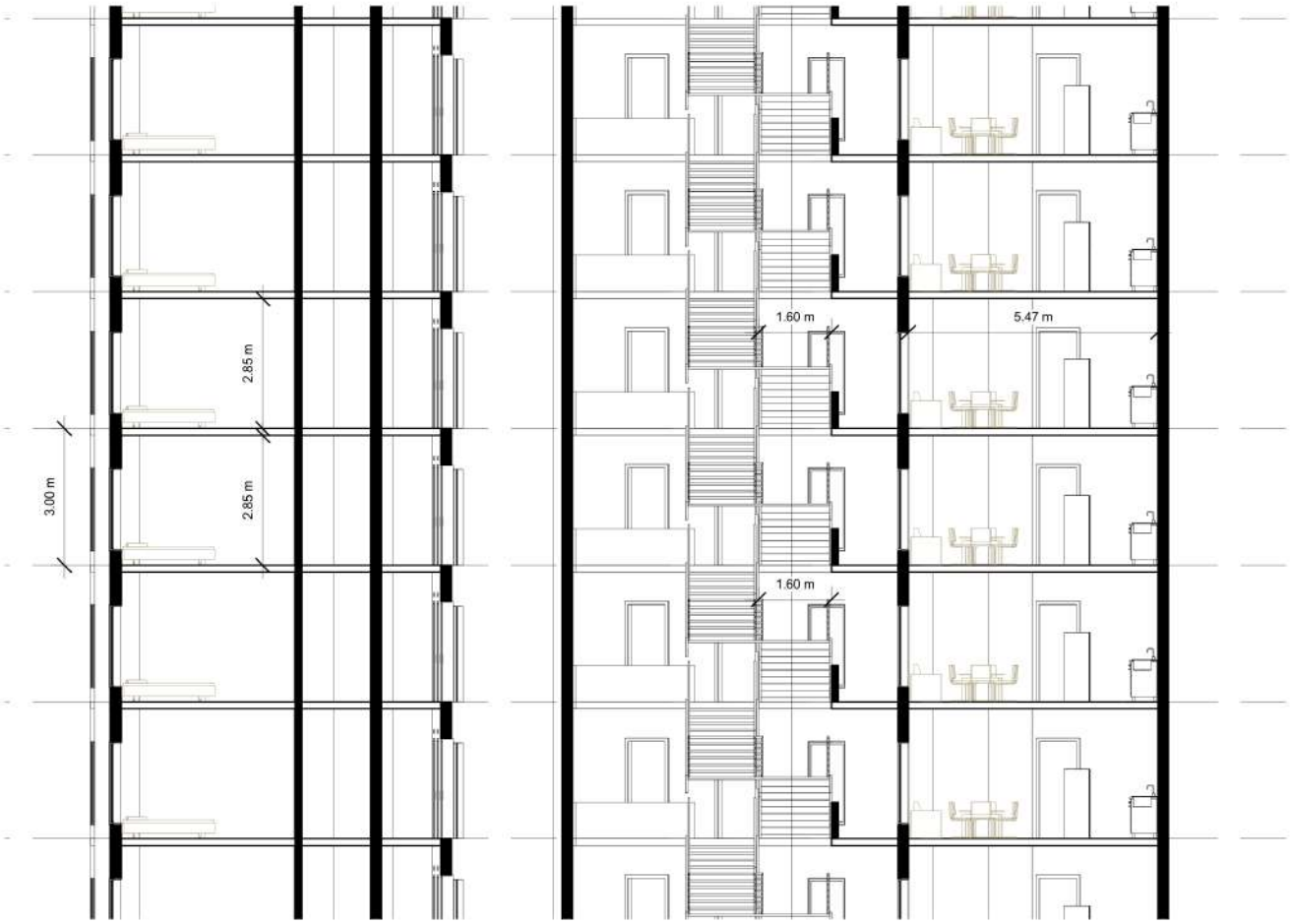


Section 4

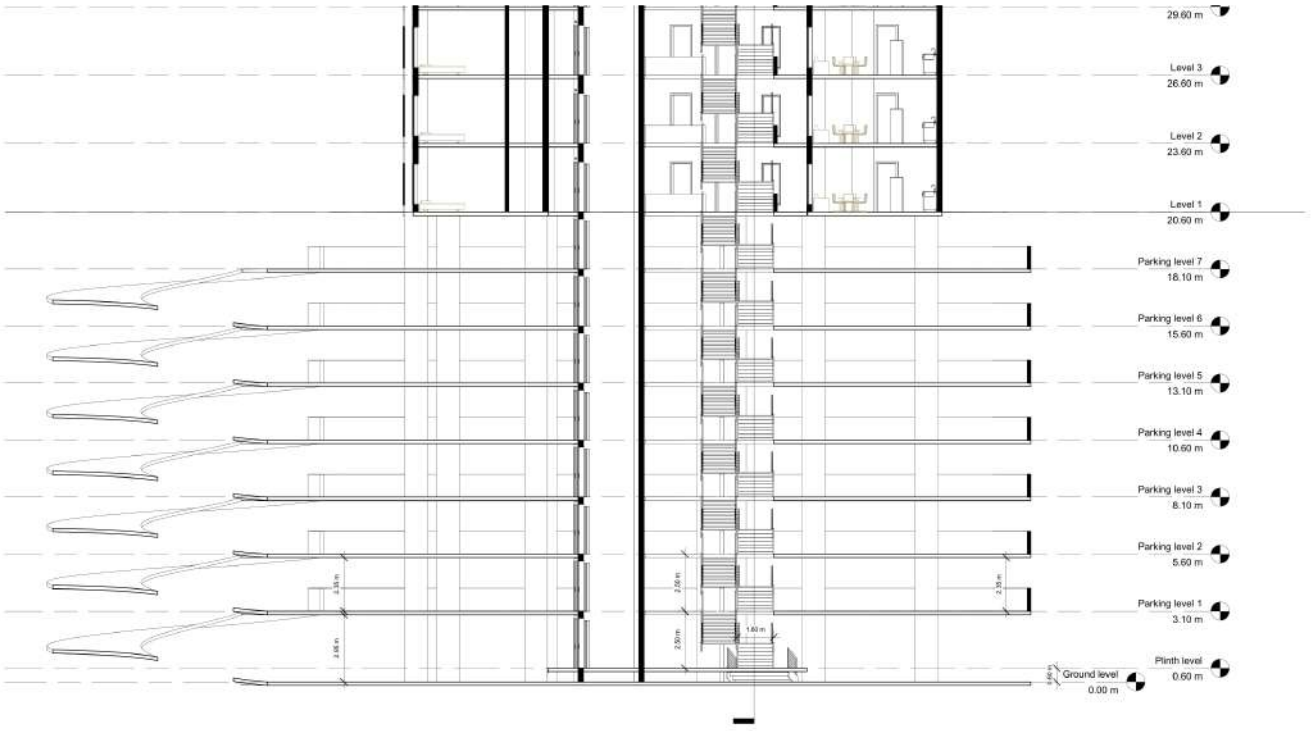


Key plan

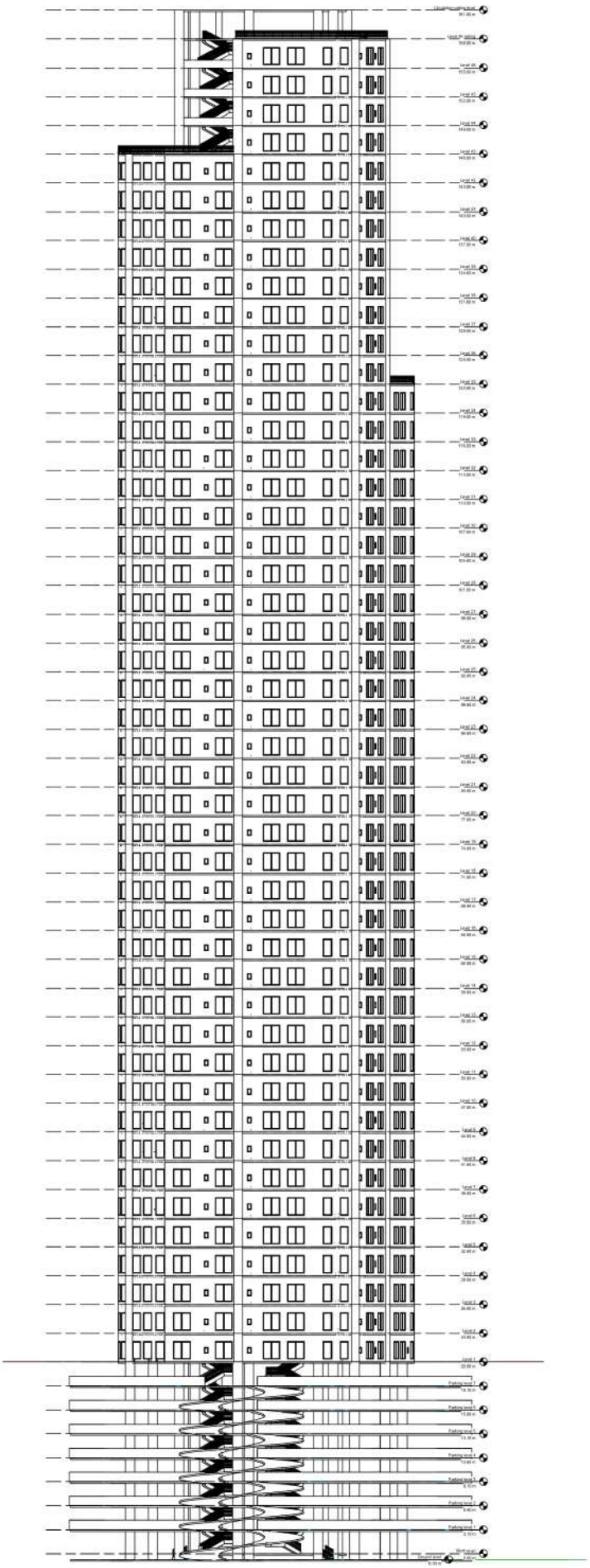
Section 4 detail



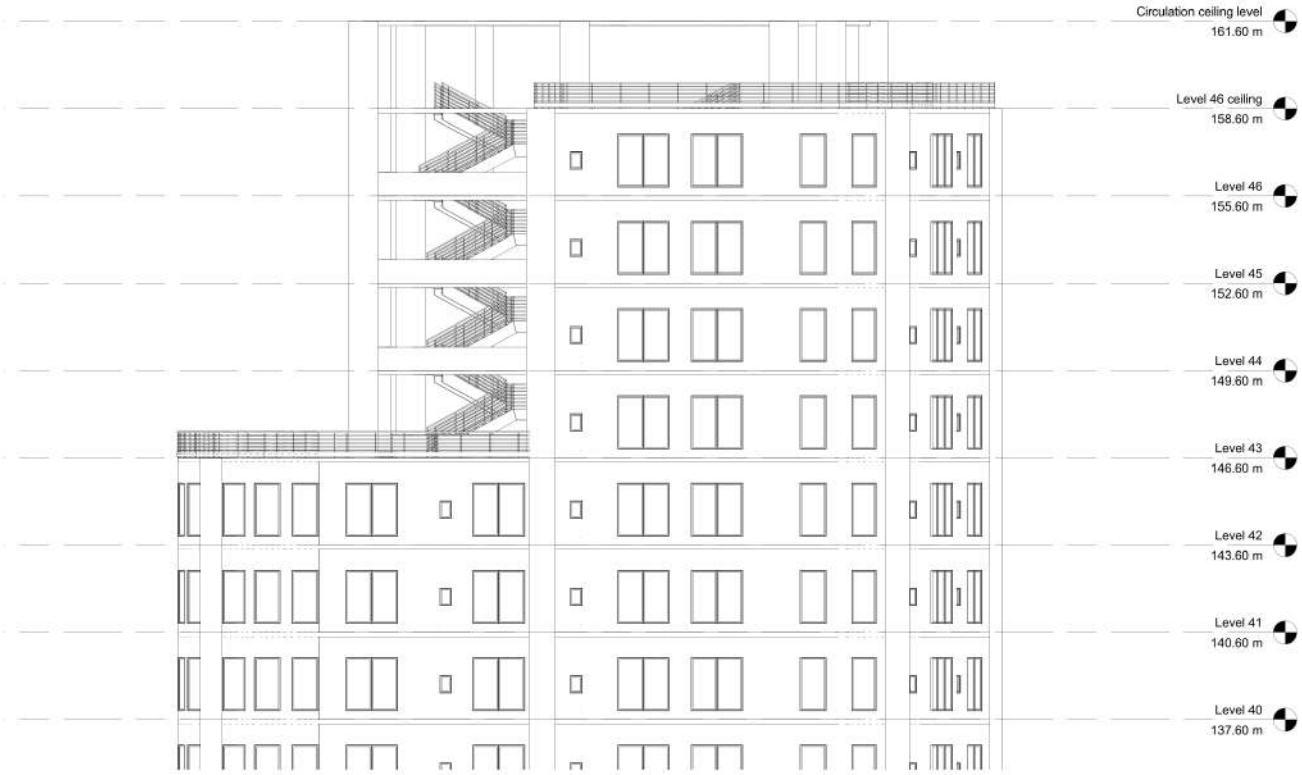
Section 4 parking detail



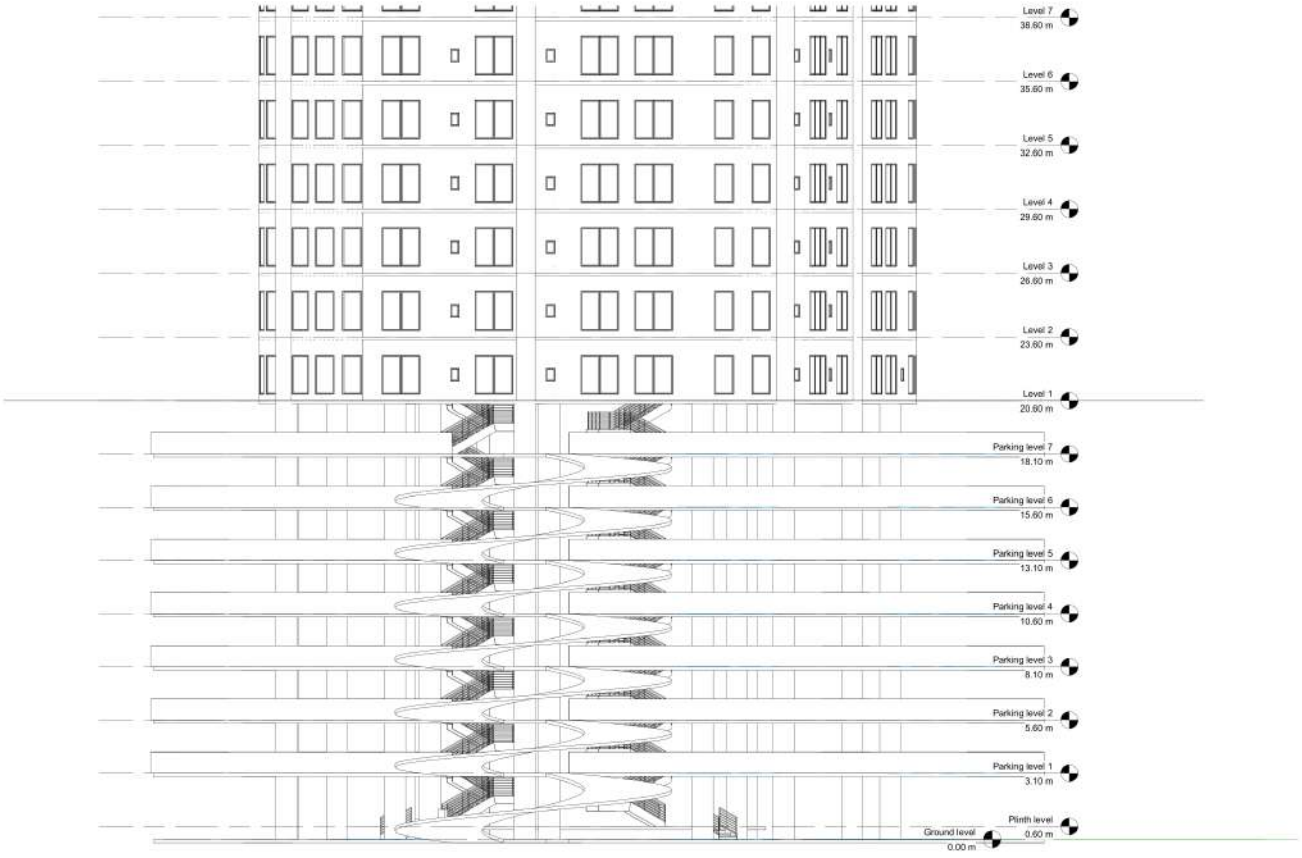
North elevation



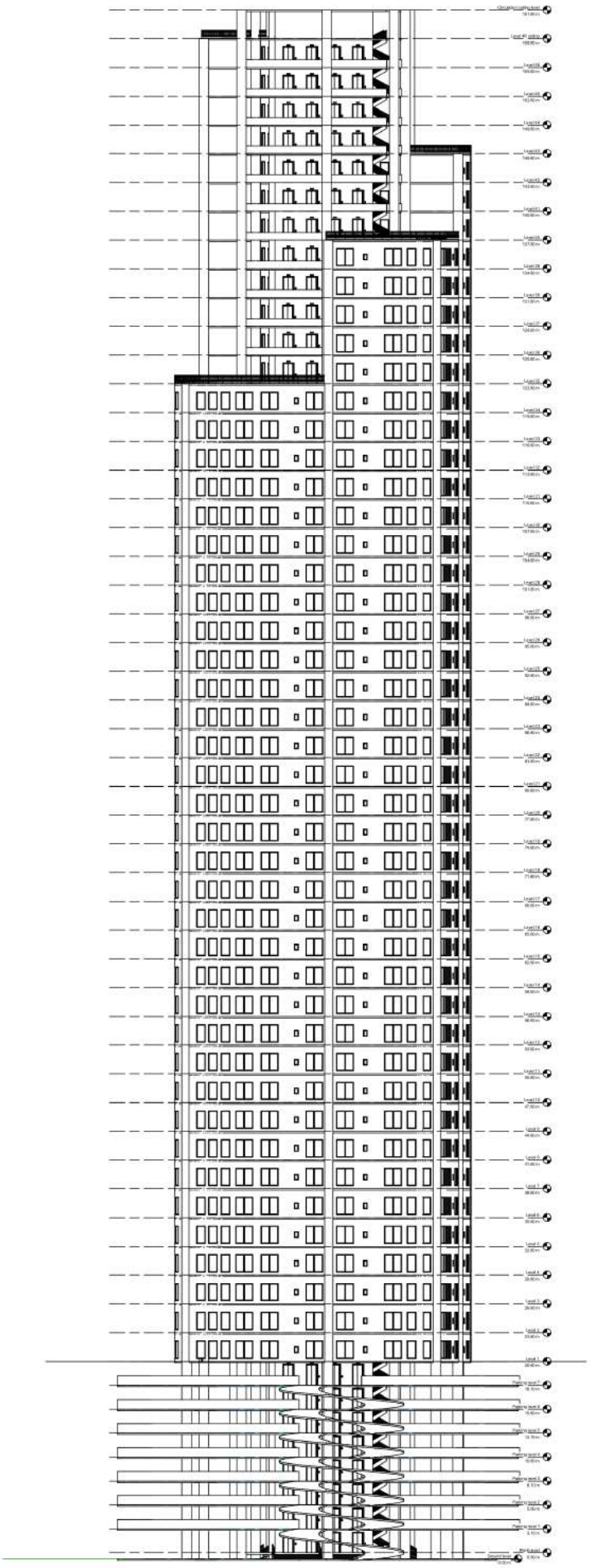
North terrace elevation



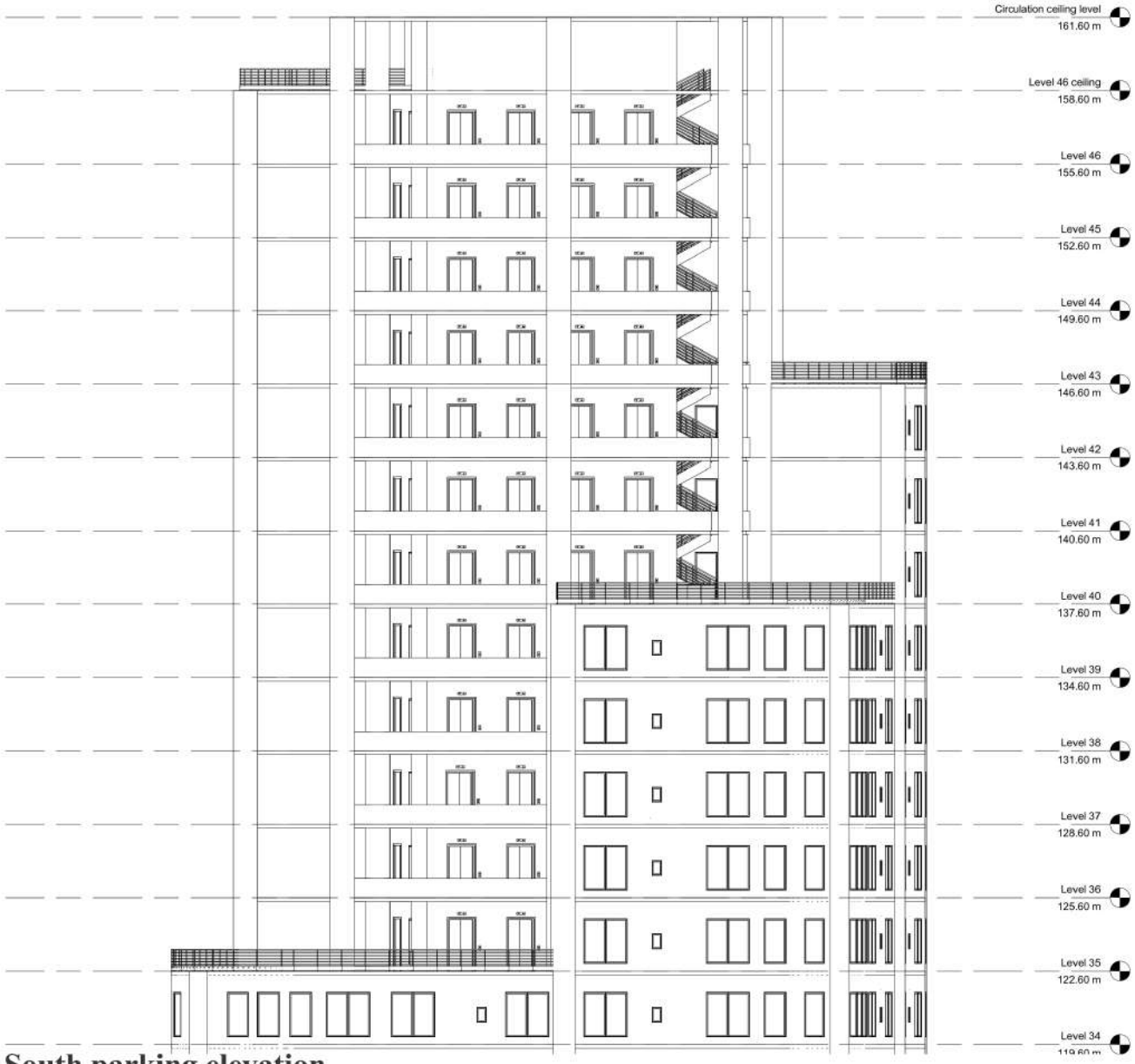
North parking elevation



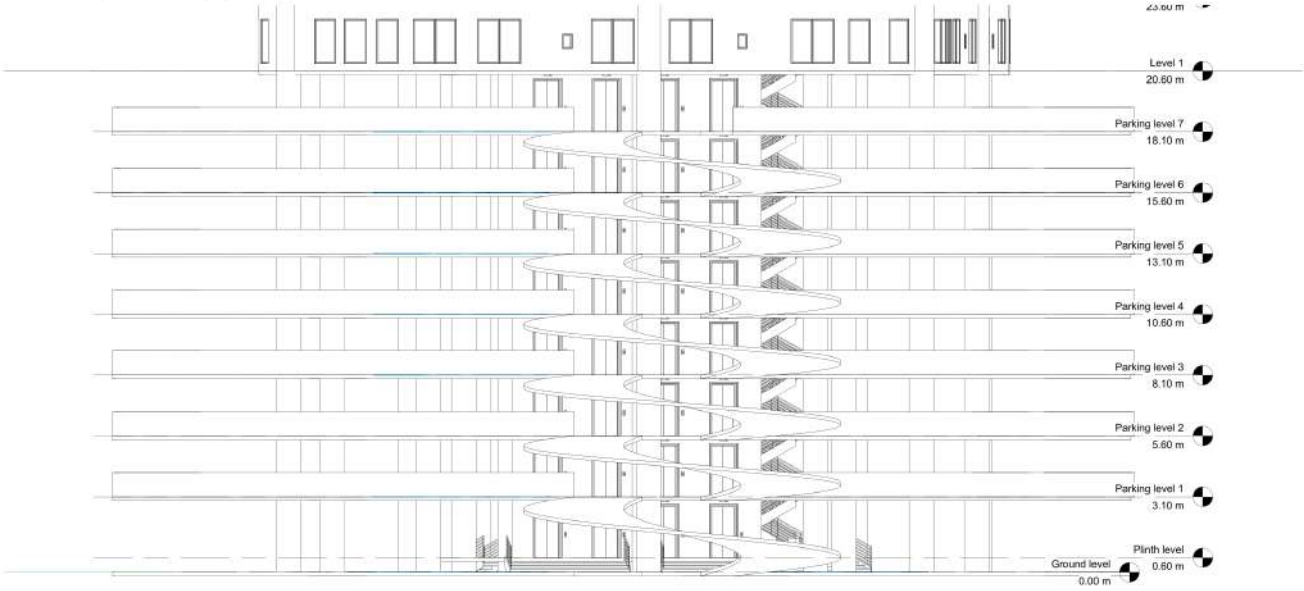
South elevation



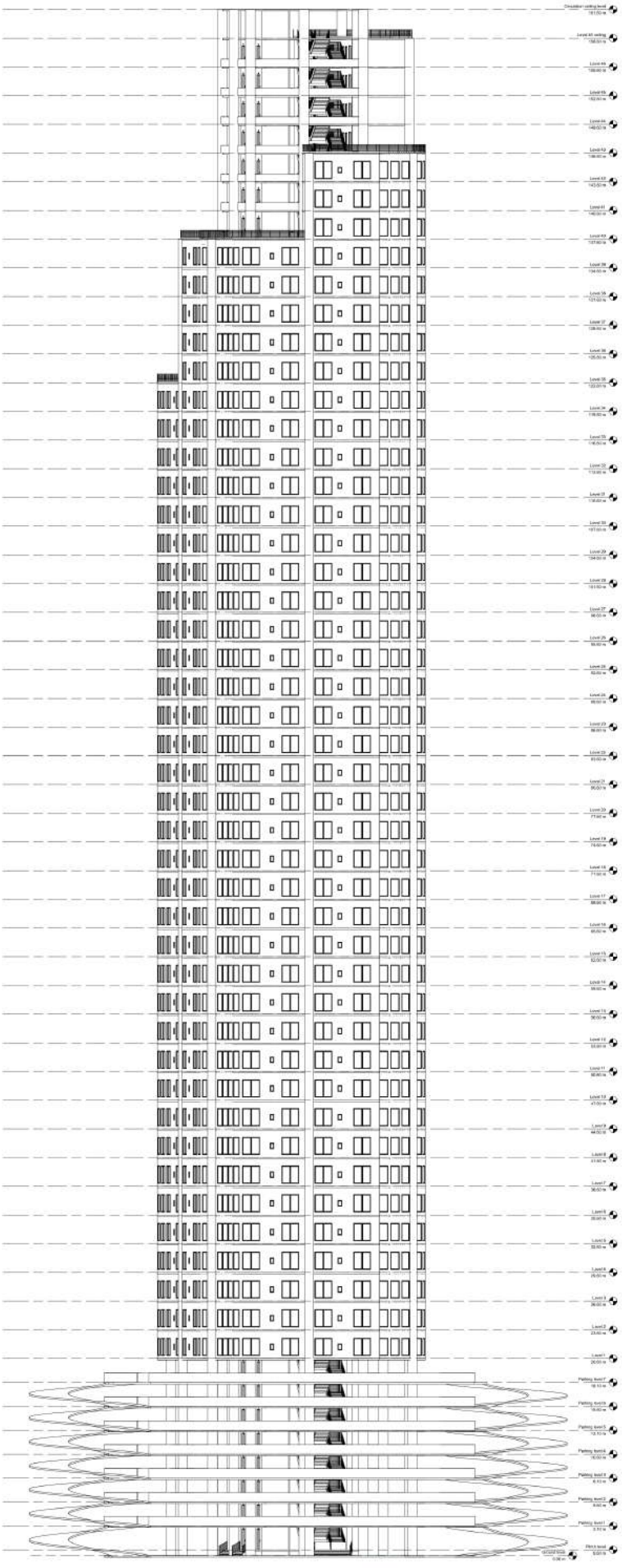
South terrace elevation



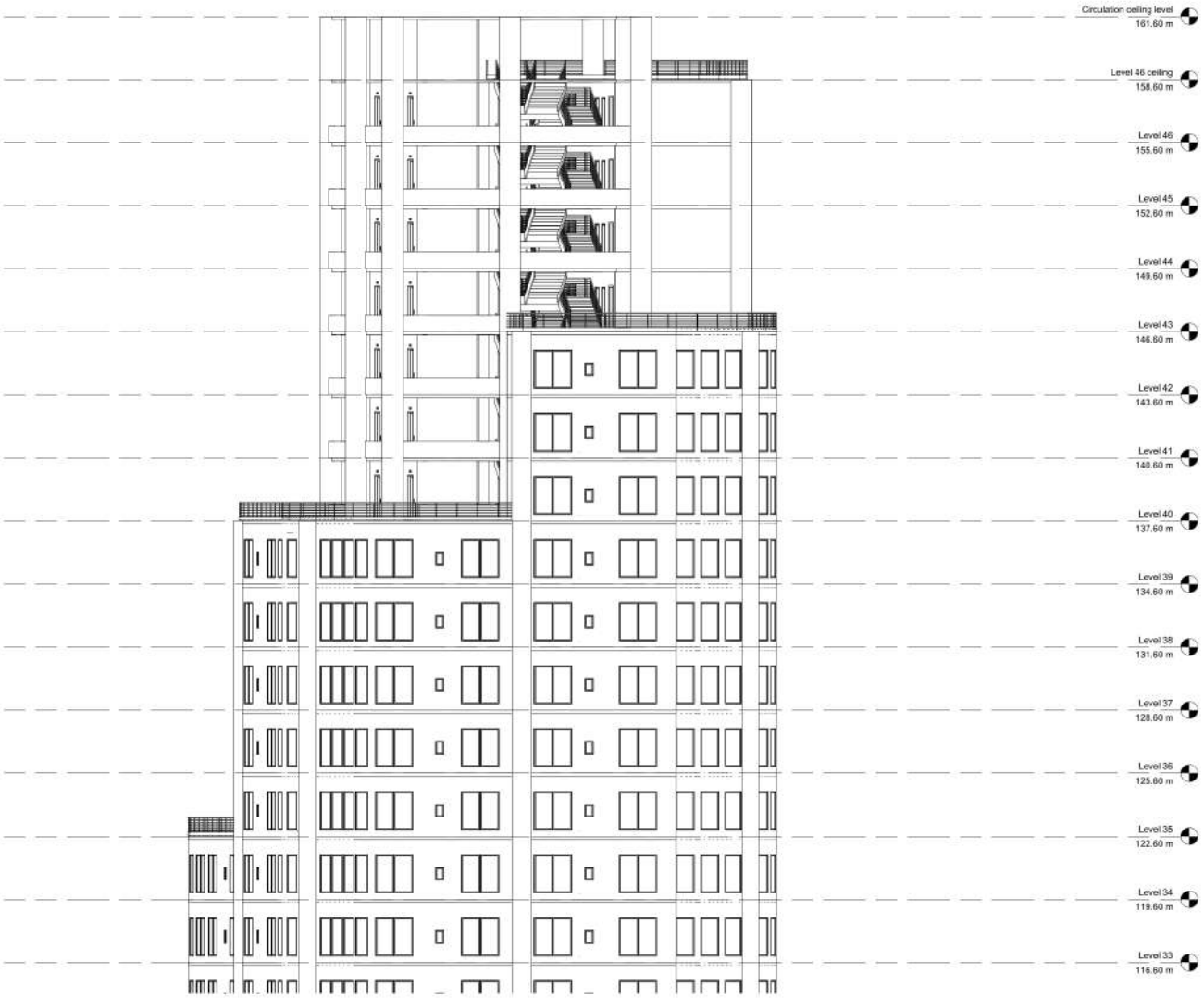
South parking elevation



East elevation

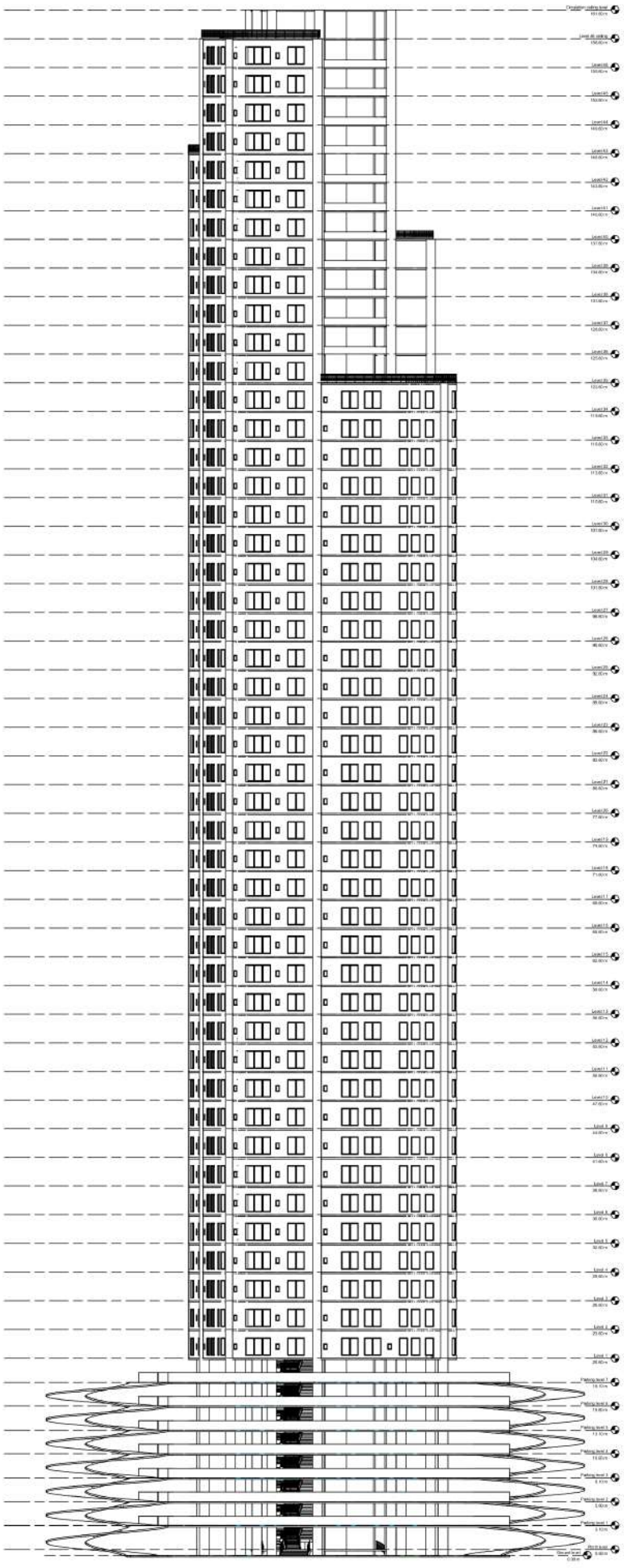


East terrace elevation



East parking elevation

West elevation



West terrace elevation

West parking elevation

Ch. 5 Findings and Discussion

5.1 Summary of proposed approach

The proposed approach of Evolutionary Generative Multi-Criteria Optimisation allows the designer to create forms that are governed by the defined fitness criteria such as sunlight requirements, DCPR norms and requirements of the project. The proposed model generates the massing of residential towers that encorporates the said fitness criteria. The script is designed in a way that it can be made functional by users with limited software knowledge. It generates options after having assigned a plot of land and being given the requirements to achieve. The best options that constitute the Pareto Frontier solutions is from where the designer selects the optimal form based on his or her expertise. This form is further corrected to be able to house the interior units and facilitation of the building structure.

5.2 Discussion

The application of multi-criteria evolutionary generative design for lower-income group cluster redevelopment in Mumbai holds significant potential for addressing the pressing urban challenges faced by this marginalized population. This study aimed to investigate the effectiveness of this approach in improving the adequacy of cluster redevelopment projects in Mumbai. The design outcome demonstrates that th evolutionary generative design framework offers valuable insights and benefits for the redevelopment process. By considering multiple objectives such as design brief, DCPR norms, the approach enables the exploration of design solutions that strike a balance between these often conflicting criteria.

The design outcome reveals that the use of evolutionary algorithms facilitated the discovery of a diverse set of Pareto-optimal design solutions. These solutions offered trade-offs between different criteria, providing decision-makers with a range of options to choose from based on their priorities and preferences. However, it is important to acknowledge certain limitations and challenges associated with this approach. The complexity of the design space, including factors such as budget limitations pose practical constraints on the implementation of the generated design solutions.

These limitations can be dealt with by the involvement of architects throughout the process of scripting and selection of desing options.

Ch. 6 Conclusion

In conclusion, the research findings suggest that multi-criteria evolutionary generative design holds promise as a methodology for improving the adequacy and inclusivity of cluster redevelopment projects for lower-income groups in Mumbai. By considering multiple objectives, integrating community engagement, and leveraging the power of evolutionary algorithms, this approach enables architects and urban planners to navigate the complex trade-offs and create design solutions that are adequate and better aligned with the needs and requirements of the marginalised communities. Further research and collaborative efforts are warranted to address the identified limitations and refine the methodology for wider application and impact in practice.

Future scope

The script serves as a foundation for more objectives to be added to it for better solutions.
There needs to be more research done on quantification of architectural objectives so that they can be incorporated as fitness criteria in the evolutionary generative design approach. Examples of such objectives are:
- Thermal comfort
- Quality of spaces
- Incorporating spatial preferences of the residents such as room layout, proximity to amenities, etc.

Some of the objectives that can be added to the design framework at present are:
- Wind and ventilation detailed analysis by Computational Fluid Dynamics
- Feasability studies
- Energy calculations to make the structure more sustainable
- Structural integrity
- Amenities, walkability
- Mixed use buildings

References

Beirão, J. N., Nourian, P., & Mashhoodi, B. (2011). Parametric urban design: An interactive sketching system for shaping neighborhoods.

CAMPELL, S. and FAINSTEIN, S. (eds.), Readings in Planning Theory, Massachusetts: Black-well Publishers (originally published in 1992 in Town Planning Review, 63 (2), pp. 143–162).

Chigara, Benviolent & Magwaro-Ndiweni, Linda & Mudzengerere, Fungai Hamilton & Mudzengerere, Anastance & Ncube,. (2013). An Analysis Of The Effects Of Piecemeal Planning On Development Of Small Urban Centres In Zimbabwe: Case Study Of Plumtree. 15. 27-40.

Clark, Molly R., "Equitable Housing Generation Through Cellular Automata" (2022). Masters Theses. 1177. https://doi.org/10.7275/28874765 https://scholarworks.umass.edu/masters_theses_2/1177

DCPR Development Control and Promotion Regulation 2034

Deb, K. (2001). Multi-objective optimization using evolutionary algorithms. John Wiley & Sons.

Fink, T., & Koenig, R. (2019). Integrated Parametric Urban Design in Grasshopper/Rhinoceros 3D-Demonstrated on a Master Plan in Vienna.

HEALEY, P. (1996), 'Planning Through Debate: The Communicative Turn in Planning Theory'
Islam, Syful. (2011). Traditional Urban Planning Approaches and Sustainable City. Open House International. 36. 15-23. 10.1108/OHI-02-2011-B0003.

Hernández Falagán, D., & Ziaiebigdeli, M. (2022). Parametric Architecture beyond Form—Klein and Price: Pioneers in Computing the Quality of Life in Housing. Architecture, 2(1), 1–17. MDPI AG. Retrieved from http://dx.doi.org/10.3390/architecture2010001

Ineˆs Caetano, Luı´s Santos, Anto´nio Leita˜o. Computational design in architecture: Defining parametric, generative, and algorithmic design

Klosterman, Richard. (2001). Urban Planning: Methods and Technologies. International Encyclopedia of the Social & Behavioral Sciences. 16055-16058. 10.1016/B0-08-043076-7/04435-1.

Makki M, Showkatbakhsh M, Tabony A, Weinstock M. Evolutionary algorithms for generating urban morphology: Variations and multiple objectives. International Journal of Architectural Computing. 2019;17(1):5-35. doi:10.1177/1478077118777236

MURRAY, M., GREER, J., HOUSTON, D., MCKAY, S. and MURTAGH, B. (2009), 'Bridging Top down and Bottom up: Modelling Community Preferences for a Dispersed Rural Settlement Pattern', European Planning Studies, 17 (3), pp. 441–462.

Navarro-Mateu, D., Makki, M., & Cocho-Bermejo, A. (2018). Urban-Tissue Optimization through Evolutionary Computation. Mathematics, 6(10), 189. https://doi.org/10.3390/math6100189

Naveen K. M. et al. Combining AI and BIM in the design and construction of a Mars habitat.

Pak, Burak. (2017). Strategies and Tools for Enabling Bottom-up Practices in Architecture and Urban Design Studios. Knowledge Cultures. 5. 0-12. 10.22381/KC5220176.

Poh-Chin Lai, et. al., Risk of tuberculosis in high-rise and high density dwellings: An exploratory spatial analysis, Environmental Pollution, Volume 183, 2013, Pages 40-45, ISSN 0269-7491, https://doi.org/10.1016/j.envpol.2012.11.025.

Steinø, Nicolai and Niels Einar Veirum. "A Parametric Approach to Urban Design Tentative formulations of a methodology." (2005).

Tiwari, P., & Rao, J. (2016). Housing markets and housing policies in India.

Newspaper articles

Ankita Bhatkhande, 2015. "Our slums were better, say rehabilitated families." https://mumbaimirror.indiatimes.com/mumbai/civic/bmc-chief-to-pull-up-staff-for-absence-during-blaze/articleshow/47228579.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

BMC begins process to create virtual model of entire Mumbai city. July 25, 2022. Eeshanpriya MS, Mumbai. https://indianexpress.com/article/cities/mumbai/bmc-create-virtual-model-mumbai-8051205/

Indian cities can have intelligent growth, not become urban horrors like Gurugram, Mumbai. 17 March, 2021. Meeta Rajivlochan. https://theprint.in/opinion/indian-cities-can-have-intelligent-growth-not-become-urban-horrors-like-gurugram-mumbai/623056/

Urban Development: Bottom-up approach is the key: PM Narendra Modi. June 26, 2015. Shalini Nair. https://indianexpress.com/article/business/business-others/urban-development-bottom-up-approach-is-the-key-pm-narendra-modi/

Access to decent housing to make Mumbai global city: Fadnavis. December 1, 2018. Press Trust of India. https://www.business-standard.com/article/pti-stories/access-to-decent-housing-to-make-mumbai-global-city-fadnavis-118120100586_1.html

Mumbai's development plan should make adequate provisions for affordable housing: Experts. Apr 22, 2015. Nauzer Bharucha. https://timesofindia.indiatimes.com/city/mumbai/mumbais-development-plan-should-make-adequate-provisions-for-affordable-housing-experts/articleshow/47019290.cms

Scant hope for 'housing for all' within Mumbai city. February 27, 2020. Hepzi Anthony. https://citizenmatters.in/pm-awas-yojana-brings-little-hope-for-housing-for-all-within-mumbai-city-16097

BDD chawl redevelopment plan: Experts suggest alternative to CM Eknath Shinde. July 22, 2022. Express News Service. https://indianexpress.com/article/cities/mumbai/bdd-chawl-redevelopment-plan-experts-suggest-alternative-to-cm-eknath-shinde-8044444/

Smart cities must begin with citizens, not from above: Industry. 20 Feb, 2018. https://economictimes.indiatimes.com/news/economy/policy/smart-cities-must-begin-with-citizens-not-from-aboveindustry/articleshow/62988179.cms?from=mdr

UPA's 'top-down' approach in urban planning resulted in 'design flaws': Venkaiah Naidu. February 15, 2015. Press Trust of India. https://indianexpress.com/article/india/upas-top-down-approach-in-urban-planning-not-desirable-says-naidu/