MASTER THESIS

TANJONG PAGAR

Parametric Master Planning of the Waterfront Tanjong Pagar District in Singapore

IULIIA OSINTSEVA

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Bauhaus-Universität Weimar
Fakuktät Architektur und Urbanistik
Masterstudiengang Architektur

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Iuliia Osintseva
Matriculation Nr 116048
juliia.osintseva@gmail.com

1. Referee: Jun.-Prof. Dr. Reinhard Koenig
2. Referee: Vertr. Prof. Dr. Sven Schneider
3. Referee: Teaching Assistant Abdumalik Abdumawla

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1. INTRODUCTION

This project addresses the problem of interactively modeling large-scale urban districts. This task is a very comprehensive one because designing a vivid contemporary quarter of such scale demands interdisciplinary approach and possibility to link the investigations from different fields. It also needs to be iterative in order to react to evaluation results and optimize the unsatisfying issues.

Therefore, computational methods can be a great help for rapid switch between different variants, as well as for evaluation of multiple performance criteria and adapting the solutions after receiving the feedback.

Such a computational model is designed to achieve a certain outcome, but because it operates with a range of input parameters, the outcome is not a sole solution but the range of them. Varying input parameters allows comparison of possible solutions based on performance evaluation.

In this project the case study for developing a computer-based urban model became Tanjong Pagar Waterfront Area with a demand of creating a new mix-use quarter of a high density at the place of current container terminal.

The aim of the project was to achieve a context-specific outcome through the certain conceptual decisions taken in course of the work. Therefore the outcome is the parametric model of a city district which is only applicable to this very area of Singapore.

However, the methodology developed during this project might be implemented at various spots of the world to answer the challenge of rapid sustainable developments.

2. STATE OF THE ART

Urban projects of a large scale are increasingly occurring around the globe. Their outcomes as high-density developments of mixed character are continuously seen as positive for economic, social and environmental perspective on cities. Those projects are very complex because of their scale. Their design and implementation are putting many challenges for the urban planners as they need to include economic, social and spatial parameters to create livable environments (Grand Projet, 2016).

In such projects the competence of an urban planner is reaching its limits hence he needs to cooperate with energy planners, transport experts, environmental engineers, etc. But in a traditional working process this cooperation is very slow and sometimes difficult in terms of searching the common solution space, because first urban planners create the spatial model, which is then analyzed by experts from other fields including recommendations on changes, which need to be incorporated by urban planners. After they correct the project, the second "iteration" starts and there are many to follow. There are also public and governmental reviews which might lead to the changes in the project which would start the loop again.

Parametric urban planning allows performing urban design as a process. First of all this means that one is operating with a range of input parameters , so in case of changes it might be enough to change one or several parameters within the model which don't change the process logic and therefore the outcome automatically adjusts to the new input data.

The second advantage is that in such a model of the process each part (module) has an input from previous part and output to serve for the next part. So exchanging one part of the algorithm with a completely different one can be done without destroying other working modules, because they automatically adjust to the new data and this may save a lot of time.

But parametric approach does not only provide advantages in means of time saving and interdisciplinarity, it also completely changes the way how an urban cloth is being developed because all the data is incorporated within the model which enables quick and precise evaluations and simulations of different kind. Whereas in a standard urban project the urban planner may develop the spatial layout he finds optimal in terms of qualitative characteristics like livability, well-mixed environment and diversity, after completing the layout it may appear that the buildings are not reaching the expected amount of GFA or another demand, which throws him back to the first step. In a parametric model designer can see this data at each step of layout-making and react quicker with rearrangements.

So, from this perspective a parametric model can first provide a perfect instrument for data-driven rapid prototyping and afterwards turn to be a platform of cooperation of multiple experts for achieving a holistic and sustainable approach for a big urban area.

PROTOTYPES

At the moment parametric approach is rather used for various analysis, evaluations and estimations during the design process, as well as for solving particular urban tasks and is less incorporated into case study designs.

One of the widely used tools is Space Syntax that is used for the analysis of spatial configurations and is currently being implemented in multiple research areas and design applications (Hillier, Leaman, Stansall, & Bedford, 1976).

Fig. 1. Integration analysis, source: malmo.yimby.se

Decoding Spaces components are linking the Space Syntax to the Grasshopper extension for Rhino to run a graph analysis on parametric line structures and use its results for further form generation (Bielik, Schneider and Koenig, 2012)

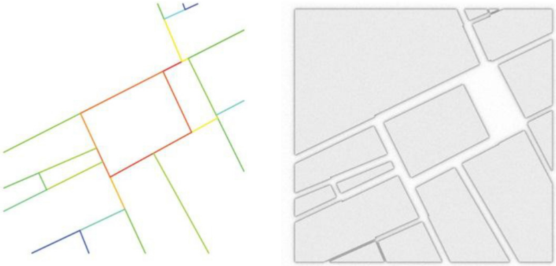


Fig. 2. Left: Analysis of street network, right: parametric pattern. Source: Bielik, Schneider and Koenig 2012

City Engine may serve as an example of existing solution for generative modeling. It is used for automatic generation of models through sets of predefined rules, based on shape grammar system.

Fig. 3. Source: Wikipedia

However, this tool is difficult to use at early stages of design because the rules for algorithms are "...technical, abstract and not related to a planning problem" (Parish & Müller, 2001).

In contrast to this approach, Decoding Spaces includes components of Synthesis, which enable fast prototyping of urban design proposals. They generate spatial layouts for street network, parcels and building volumes. The generated form is controlled by the input parameters (Koenig, Miao, Knecht, Buš, & Mei-chih, 2017).

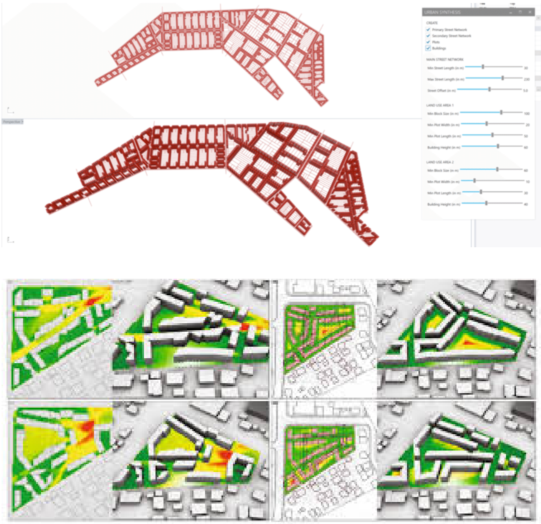


Fig. 4. Urban fabric synthesis in case study.
Source: Research gate, City Afforastation.

Another parametric tool for procedural urban planning is Modelur, plug in for Sketch Up. It works as a tool for quick 3d drawing, simultaneously providing information about control parameters (GFA, Built-Up area, site coverage, etc).(http://modelur.eu)

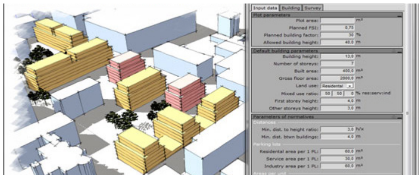


Fig. 5. Modelur interface, Source: Sketchup3dConstruction.com

The tools listed above aim to solve specific problems throughout different contexts and scenarios. There are also existing case-study applications, for example Parametric Urban Design Model/ QURM by Aurel VR, Carlos Ramos da Silva and Sergei Mikhailenko. In this project a tool was created "to interpret environmental data to generate urban design according to rules governed by climatic fitness criteria" (aurelvr.com).

Fig. 6. Parametric Urban Design Model/ QURM .
Source: aurelvr.com

Projects of such kind provide excellent examples of solving complex urban tasks and providing great flexibility of the end solution. Unfortunately, there still seems to be several skeptisicm concerning compatibility of procedural modelling with urban context-specific concepts, which might occur because parametric projects are rather focused on solving specific tasks then on linking them to conceptual input.

This project is composed of linear procedural steps: streets, land use, parcels with buildings, yet each of them is context-based. Such approach aimed combining the advantages and efficiency of procedural design with qualitative urban criteria.

Fig. 7. Own image based on snazzymaps.com

3. PROJECT AREA

Tanjong Pagar Waterfront area is a container port terminal to the South of Singapore. Its planned relocation will free up to 400 ha of land for creating a high-dense mix-use quarter. The site is situated in a direct neighbourhood of the Central Business District and has a quick connection to Jurong East Business district from the other side. It consists of a mainland part and Brani island (Fig. 7) and is surrounding by meaningful recreation zones: Gardens by the Bay to the East, Mount Faber Park to the West and Sentosa island to the South (Fig. 8).

Tanjong Pagar area is particularly interesting because it is one the very few places in Singapore, where one can see that he is on the island. Most of the ocean waterfronts accesses are restricted. Available ones like Sentosa island is not a representing a city cloth but rather a recreation area. Though a very famous Marina Bay area is a splendid waterfront area, it is not facing the ocean. Tanjong Pagar therefore has a potential for developing a strong and unique urban character.

Because of such a prominent location the programme for the site demands construction of 12 mln m^2 of GFA in this area. It should provide around 70.000 residential units and at least 500.000 m^2 of retail area.

Tanjong Pagar area


Mount Faber park


Gardens by he Bay


CBD at Marina Bay

Fig. 8. Ares Photos. Sources: right top: Yale-NUS, middle left: tripadvisor, middle right and down: flickr Artle Ng.

4. METHOD

group work

The goal of this project was to develop an instrument allowing the transition from a basic sketch to a detailed model in a much shorter time compared to standard drafting methods.

As this was a case study linked to a specific area, first a concept for this area's development was created in order to set up a context-specific spatial layout corresponding to the surroundings yet still generating several additional value due to its design. For turning the concept to a computational model a system of procedural tools was developed.

These tools are organized as separate modules, dividing a very complex task into a sequence of smaller challenges solvable on their own. The modules are ordered in a linear sequence, so that each previous module provides input data for each next one. This framework promotes efficient workflow separation with later integration of the achievements into one holistic approach, as shown in Fig. 9.

The process of area layout generation is semi-automated, but designer can control the behaviour of the algorithms by changing their input parameters at each step. Within the computed range of solutions multiple concepts can be tested and compared in a short time.

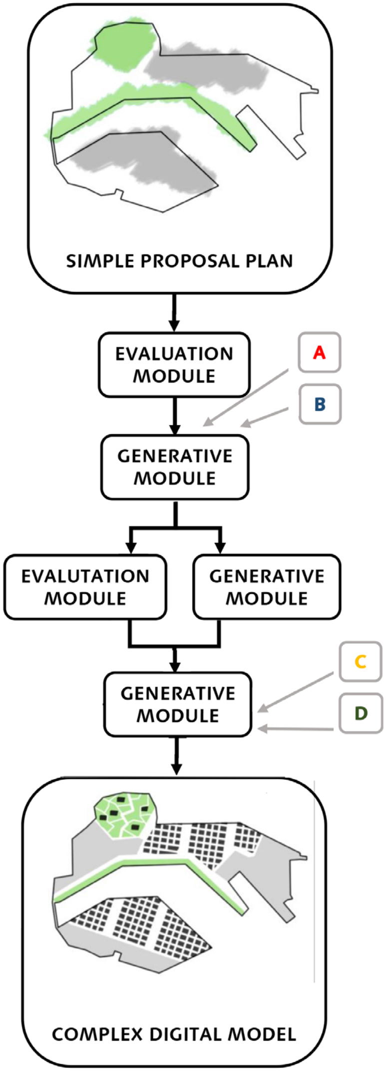


Fig. 9. Scheme of the method (image: Ondrej Vesely)

5. CONCEPT

group work

In the beginning of the generation the scenario (concept) is being defined. Each scenario needs to go through several steps manually as the key input for the further generation algorithm (Fig. 10):

- drawing the shoreline (part of the terminal area is on pilotis that could not resist the load from buildings, so the new outline will need to be reclaimed, providing decision freedom)
- connections to the site (marking the entrances of external streets into the area, which are then used for street network generation).
- layout of built-up areas versus greenery (drawing the neighbourhood outlines)
- main streets (exceptional connections which from a designer's perspective need to be provided)
- landmarks placement (setting the points manually to be able to have a finer control over territory character)

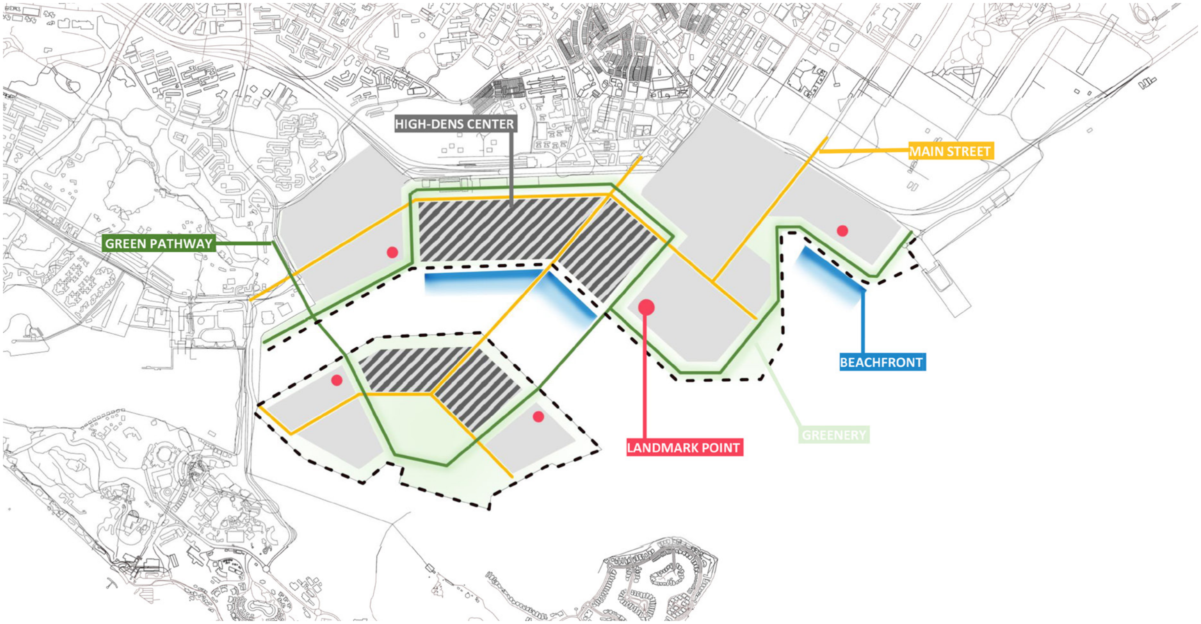


Fig. 10. Sketch of the concept (image: Ondrej Vesely)

6. PROCESS

Part of Ondrej Vesely

MODULE: STREET NETWORK

The module of street network aims to split neighbourhoods into street blocks creating secondary streets (Fig. 12). For the streets layout the rectangular grid was chosen because of the flat terrain. The usage of an algorithm for streets generation simplifies the process greatly and several parameters ensure producing the desired result.

The algorithm is designed to set up the right orientation of the grid, it provides manual control over the size of the street blocks in different neighbourhoods and avoids T-junctions for the easy transportation and encouragement of the wind transition in the city (Fig. 11).

MODULE: SHORELINE/FJORDS

The next module finalizes the street grid by creating channels (fjords) along the alleys at the waterfront. This was a conceptual decision for emphasizing waterfront access and channeling wind into the city.

As such elements might be a big topic for later discussions with investors and government because of their cost, this module is designed to enable quick rearrangement of fjords position by manually drawing a segment near the shore where the fjords should appear. After this step the street network is completed.

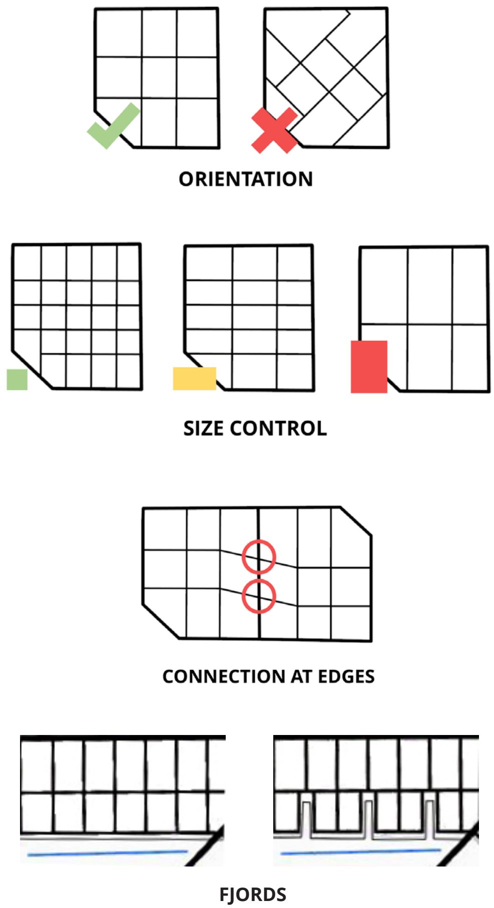
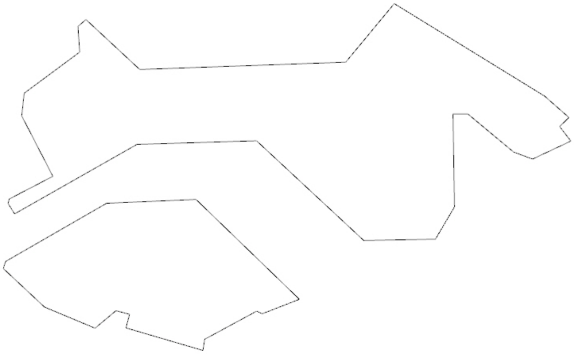
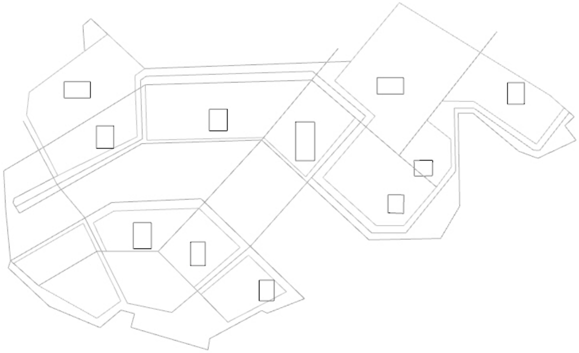


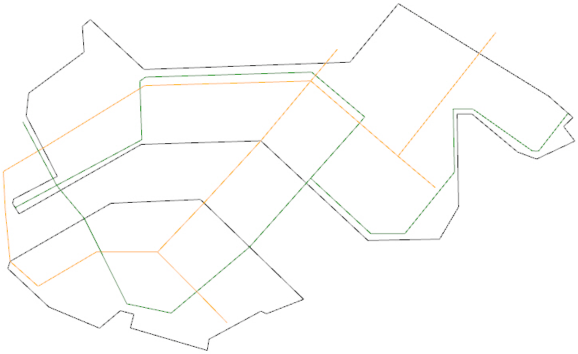
Fig. 11 Illustration: Ondrej Vesely



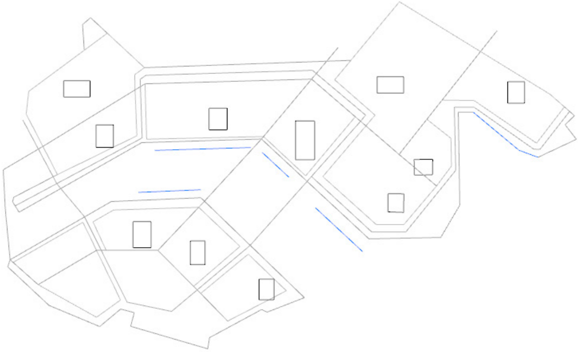
Shore outline (manual)



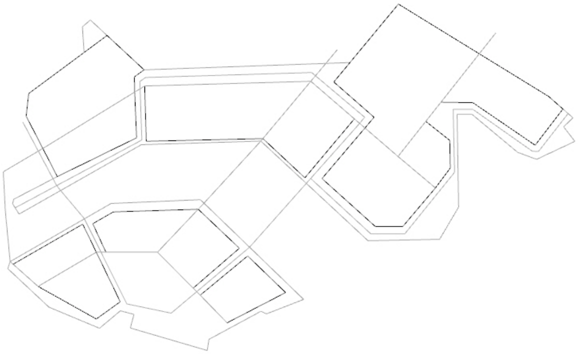
Wished blocks size (manual)



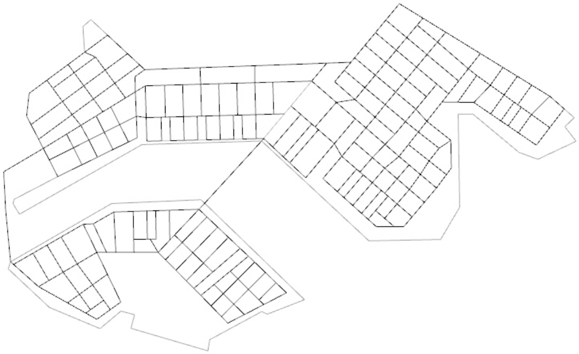
Main street axes (manual)



Wished fjords placement



Outlines of neighbourhoods (manual)



Generated street network

Fig. 12. Stages of street generation. Own images

MODULE: FUNCTIONS

This module distributes functions across the area based on a site programme, created after research on demography statistics of the place. (Population Trends, 2016)

First, specific criteria are defined for each function's reasonable placement, then according to different patterns the corresponding points are placed throughout the site. Depending on the flexibility of a particular function, radius is assigned. Most flexible functions have the biggest radius and therefore intersect with multiple street blocks (Fig. 15). To assign them to a certain block, the energy performance statistics are taken into consideration to define complementary functions for energy profile optimization. (MuSES, FCL). Afterwards the precise programme of functions for each street block is defined (Fig. 16).

MODULE: TRANSPORTATION

In current planning transportation and road system are often designed separately from the other design elements which is rarely beneficial, therefore this module attempts embedding traffic planning estimations in early design phaze (Engaging Mobility, FCL). Street network, functions map and density layout as inputs for this module allow calculation of trip numbers per hour. These trips are then adjusted after Space Syntax centrality analysis and assigned to street segments.

First, the estimation runs with 2 lanes in total for each segment, if the evaluation shows the lacking capacity for traffic at several segments, they get additional lane and the new iteration of the simulation starts.

After offsetting the roads according to the lanes number (Fig. 13), the street blocks map is generated (Fig. 14). The last step of the module is bus stops distribution including accessibility analysis.

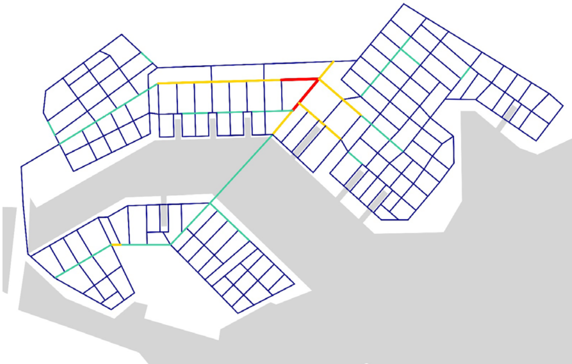


Fig. 13. Map of traffic lanes after Level of Service(image: Kateryna Konieva)

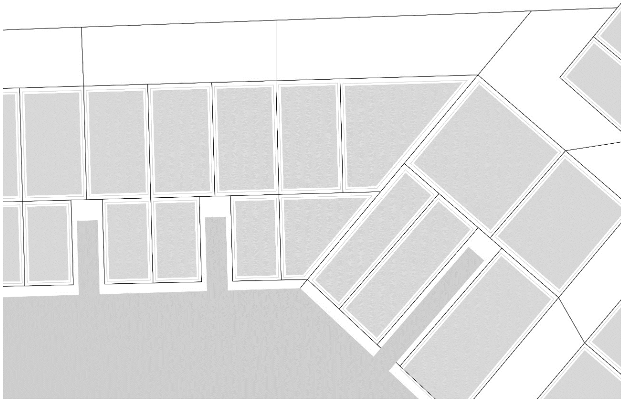


Fig. 14. Fragment of the final streetblocks layout (image: Kateryna Konieva)

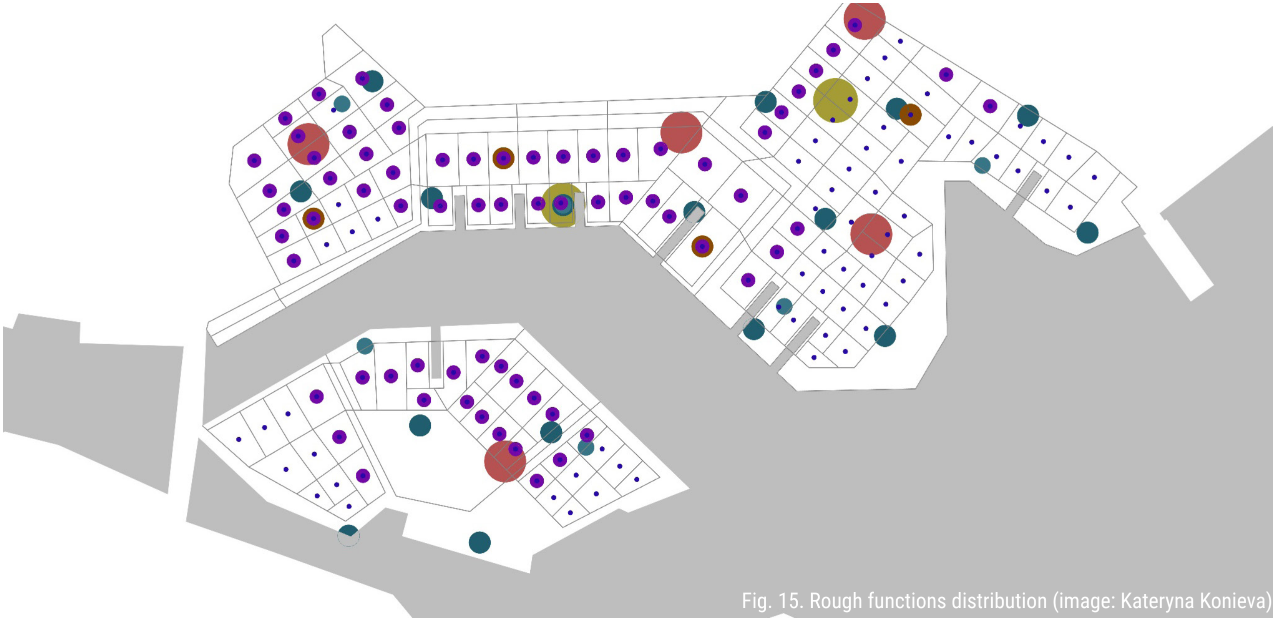


Fig. 15. Rough functions distribution (image: Kateryna Konieva)

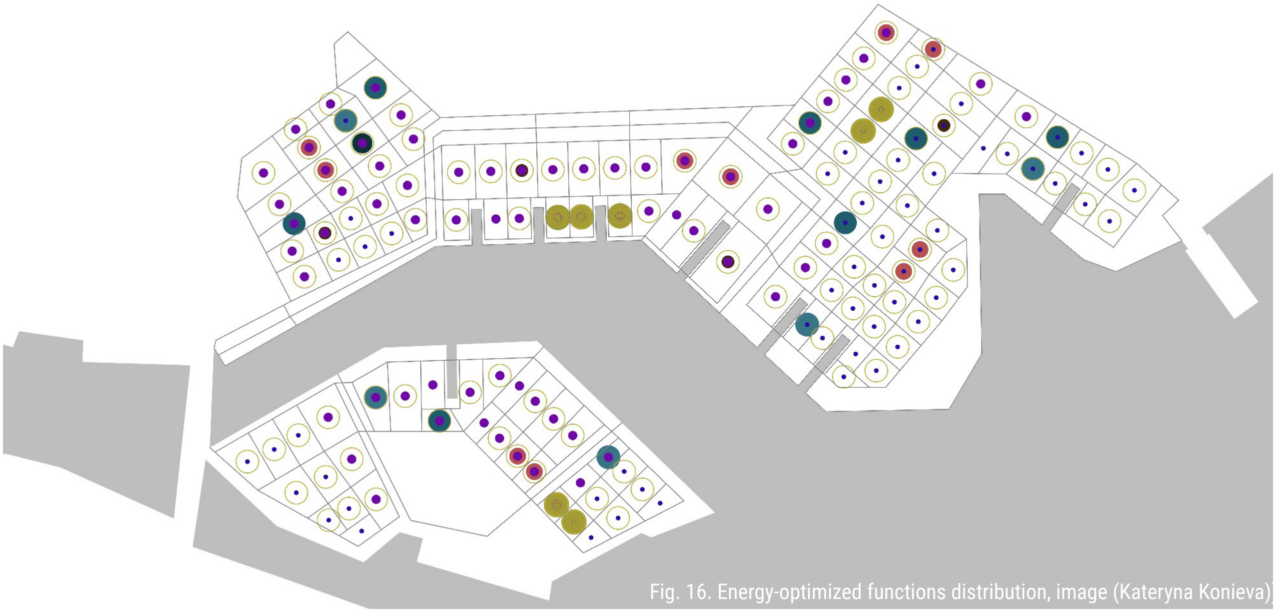


Fig. 16. Energy-optimized functions distribution, image (Kateryna Konieva)

MODULE: BUILDINGS

This modules is developed for filling street blocks with the buildings according to the functions list. The inputs for this module are offsetted street blocks (Fig. 17), functions list (Fig. 18) and density map (Fig. 19). Density was roughly estimated at the conceptual stage by manually defining high density area, afterwards the lowest density is assigned to the coastal blocks and the rest of the site has the moderate density.

Fig. 17. Streetblocks (own image).

Fig. 18. Functions layout: list of functions per stree block (own

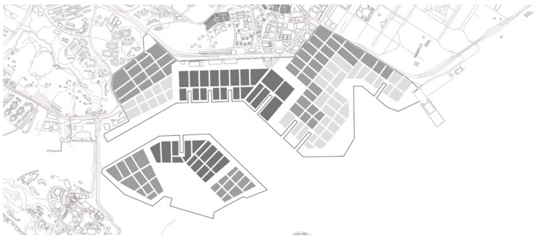


Fig. 19. Density map (own image).

First of all blocks with assigned public typologies (under those are hospitals, primary schools, secondary schools, university, religion, culture, etc. as shown in Fig. 20) are chosen from the general list.

Those functions are combined with residential or other functions, therefore first the public functions is placed, cutting the required amount of the block away, and the rest of block area serves for accommodation of their functions in the list.

The algorithm creates a simplified building form for each separate function, total amount of the GFA per particular function (if estimated in the "Functions" module) is then divided with the number of this function's facilities to get the floor area of each separate one (if there is no data from the "Functions" module, the average number of m^2 is taken based on comparison on several examples in Singapore). Depending on the plot area, floor number per facility might vary. This is a very simplified representation, yet it is enough to estimate the achieved building volume in a final masterplan (Fig. 21).

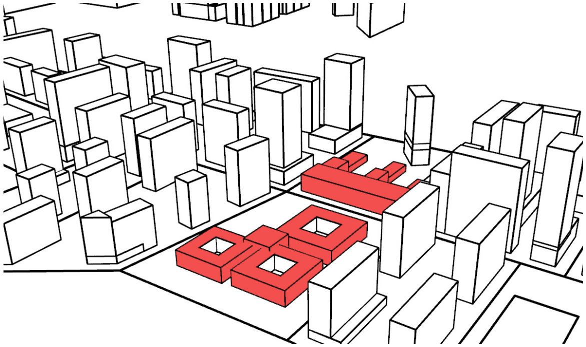


Fig. 20. Primary and secondary school buildings in residential neighbourhood

Fig. 21. Map of public functions distribution (own image).

RESIDENTIAL TYPOLOGIES

As one of the demands to the area was its mix-use character, there should not be purely residential neighbourhoods, instead of it living function should be combined with commercial and offices both for energy profile optimization and creating more sustainable community where each neighbourhood is multifunctional. Therefore, there are three modes for residential blocks: only living ones (very rare), residential+commerce, residential+commerce+offices. From the module of "Functions" living blocks get the modes assigned and therefore typologies include variations in the geometry for each of the mode. This in turns helps avoiding monotonous neighbourhouds development.

Residential typologies depend on density map (p.18). Density map was set up after a research on typical Singapore residential typologies in combination with the project's concept for the area, in this way 3 density zones were defined.

HIGH DENSITY AREA

High-density area is defined manually by drawing a rough outline (Fig. 22).

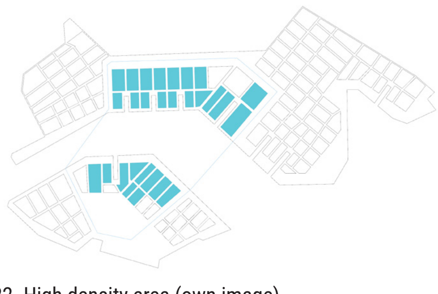


Fig. 22. High density area (own image).

In this area each block has commercial facilities, residential and offices assigned, because such area would be seen as an extension of the CBD and would be too valuable to make it overwhelmingly residential. At the same time, the area should not exclude residential completely, because traditional unmixed business districts are deserted after office hours (Marina Bay Case Study, NUS).

To achieve the high density each block is filled with skyscrapers on podiums to maximize GFA. As in local context public life is often not only on the streets, but to a big extent within the block, towers are placed at the perimeter of the block, thus living an opportunity to transfer public life inside of the block by directing alleys from street corners towards the block middle. (Fig. 23)

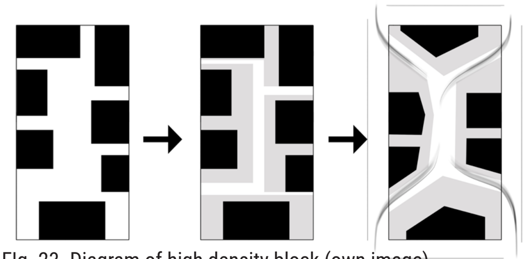


FIg. 23. Diagram of high density block (own image).

Distribution of the buildings is done with the Voronoi algorithm. First, the range of parcel's lengths is selected (50 to 90m), then algorithm splits each block's perimeter into the segments of the length, randomly picked up from this range, and applies Voronoi to create cells. As the edges of those cells are then used to create streets, algorithm makes sure to connect them if they are situated then several reasonable distance.

In such way the base for a sub-system of paths in the quarter is created, as shown in Fig. 24.

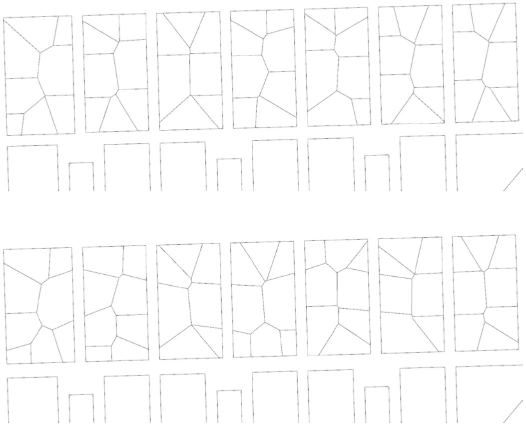


Fig. 24. Matching the pathes between the blocks (own image).

Afterwards block's sides are sorted according to their orientation in the area (coast edge, city edge, side edges). Cells are sorted according to their proximity to one of the sides of the block perimeter, so that four cell clusters are formed. After the form of the clusters is simplified, their inner edges (edges not attached to the block perimeter) get offsetted to create the four passes inside of the block and some amount of public space in the middle. The amount of the public space depends on the block's position: blocks at the waterfront have smaller free area because public life should be emphasized at the waterfront promenade, but blocks in the second raw or further get bigger space, promoting diverse activities in the area. Of course, these are just two modes of sizes set-up, there might be a more sophisticated rule to define these inner areas at the more detailed stage of work.

Those cells clusters serve as podiums (Fig. 25) for further towers distribution.

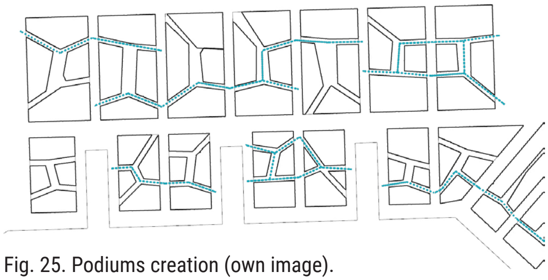


Fig. 25. Podiums creation (own image).

To place the towers in a reasonable way and correspondingly finalize the area's geometry, functions distribution is taken into consideration.

There are three new MRT stations planned around Tanjong Pagar Waterfront (Circle line 6, LTA, 2017) to close the line 6 into a full circle (Fig. 26). The middle one (cantonment) is situated right over the high density area.

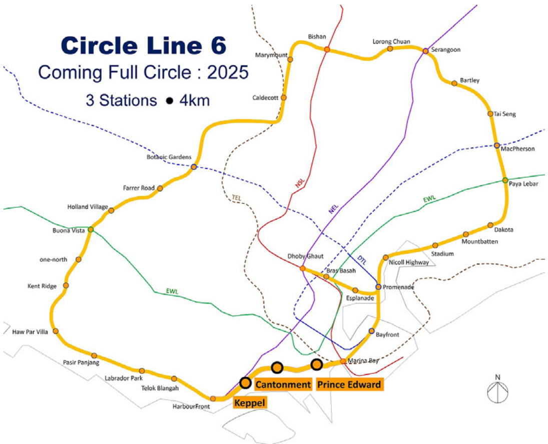


Fig. 26. Source: www.ita.gov.se/public transport

Most of external visitors of this area would use MRT for transportation. To assure high accessibility of the facilities for the visitors, commerce and offices are placed at the longer streets to provide a continuous uninterrupted walkway and easy orientation. Residential towers and small-scale commerce would in response to it find place at the shorter alleys, guiding people to the waterfront and providing a greater variety of public activities (Fig. 27).

To differentiate the functions, podiums for commerce are higher, then those for small-scale retail and are terraced to provide public space at different levels.

To create office towers, first area of the podiums underneath is measured. If it is smaller than a certain value, the form of the podium is just scaled and extruded. If it is larger, Voronoi algorithm divides surface into 3 ones, and from the center of the largest one a rectangle is generated and extruded. It orients towards the longest podium side, which is normally facing the commercial street. Such orientation is as well aimed to promote downwash effect (p.23) for catching ocean wind and guiding it into the block.

Residential towers should be narrower than the offices, therefore their podiums are cut at the random distances from the certain range and offsetted to form buildings.

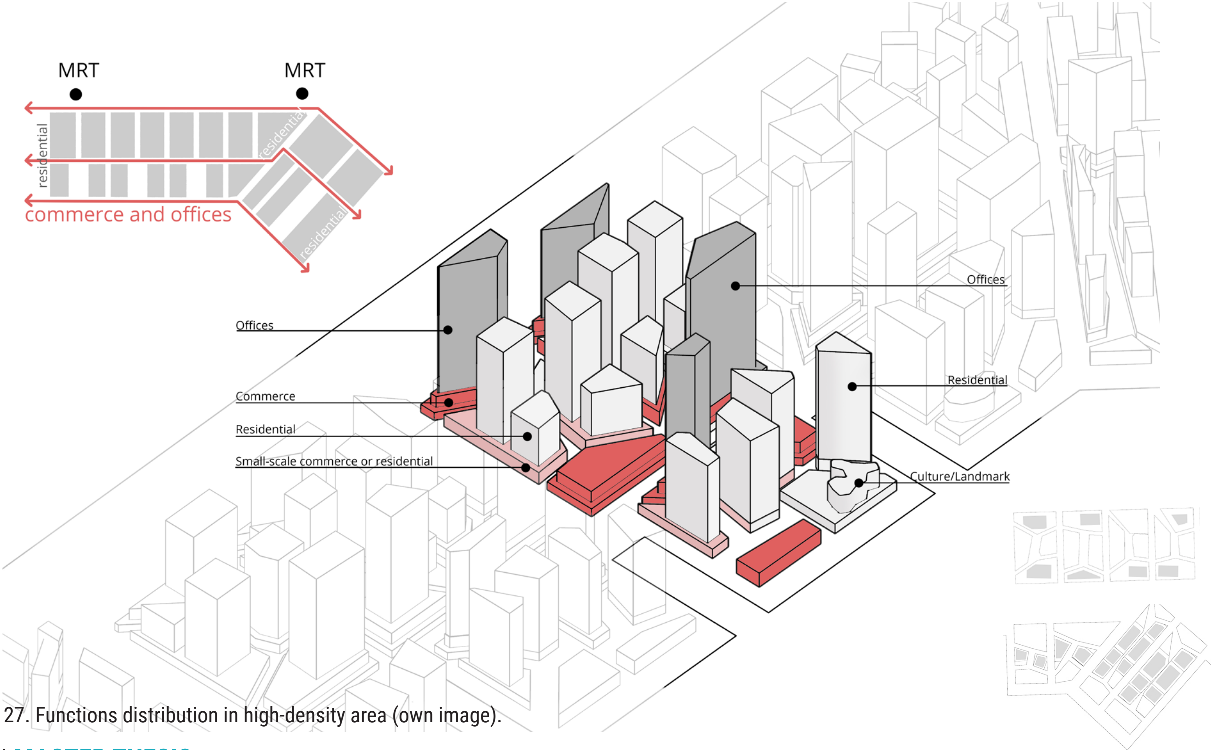


Fig. 27. Functions distribution in high-density area (own image).

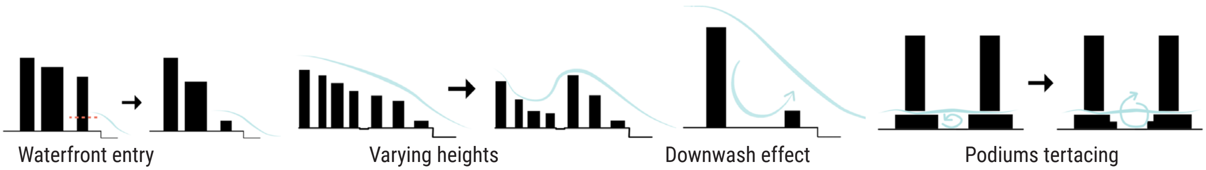
In dense tropical and subtropical cities the urban climate has a significant influence on public life in the area. As dense areas increase urban heat islands and decrease evaporation, urban ventilation can be of a great help, reducing heat stress. Therefore height distribution in the blocks aimed to promote wind in the city (Fig. 28), following several advices from case studies (Edward Ng, 2010).

1. If the parcel is at the waterfront, no high-rise is generated.

2. Heights of the towers within the block are varying not gradually to let the wind inside of the block and not let it fly over.

3. Offices become the tallest buildings to promote downwash effect (as they stand perpendicular to the wind direction.

4. Podiums are terraced to increase wind circulation at the street level.



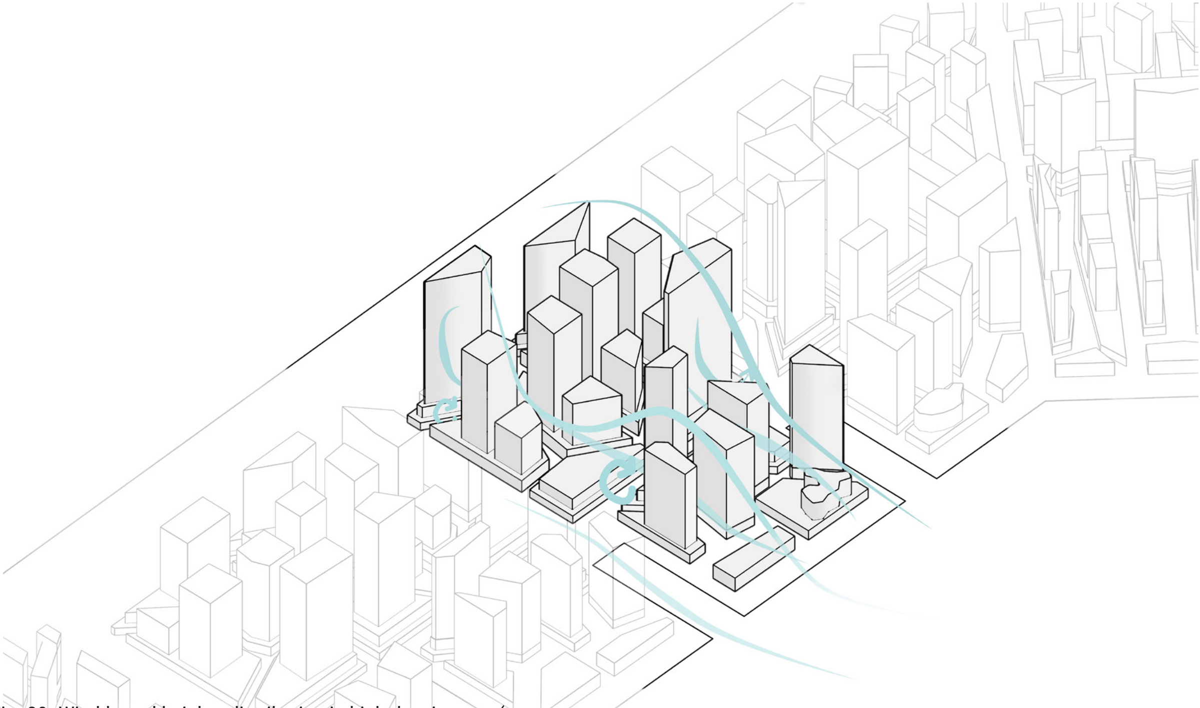


Fig. 28. Wind-based heights distribution in high-density area (own

The last step of the algorithm here is defining the skyline. The overall height distribution is adjusted after a cultural facility as an attractor point. The nearer to it - the higher the building (Fig. 29)

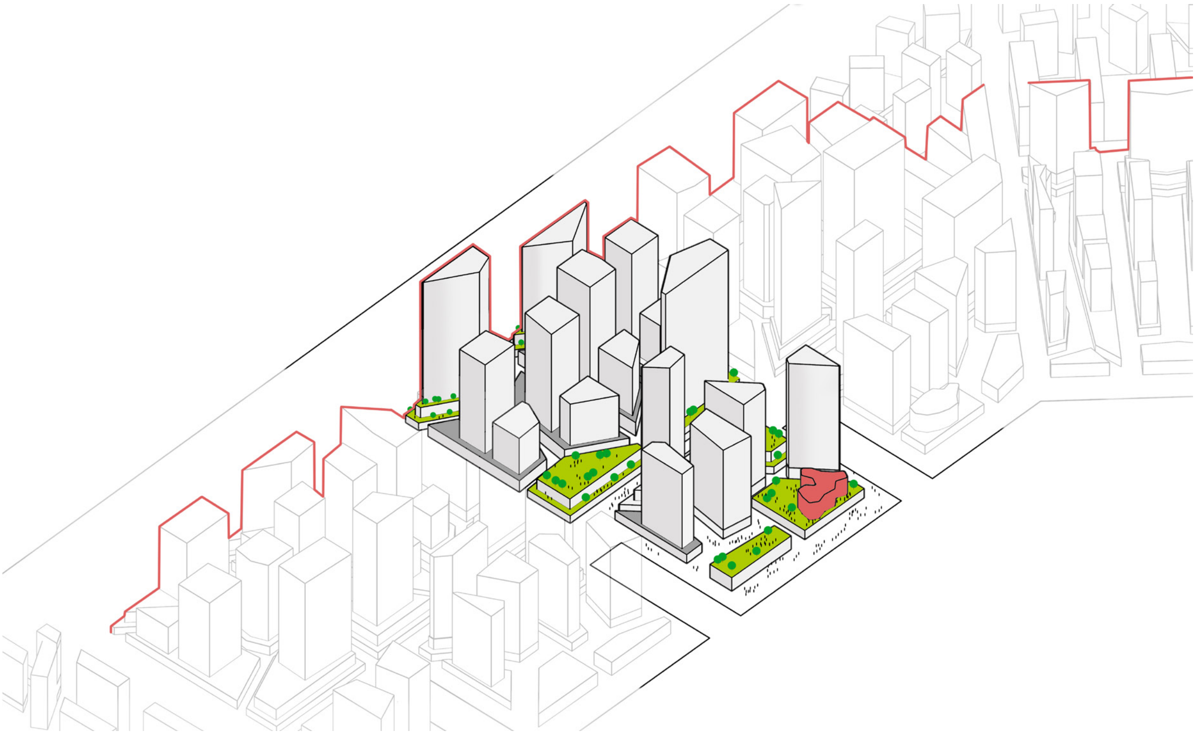


Fig. 29. Skyline-forming and public spaces in high-density area (own image).

COASTAL AREA

The next part of algorithm chooses blocks that are within a certain distance to the waterfront and applies coastal typology to them. Main goal of this typology was to promote wind penetrate through the area and by no means block it. Therefore it fills blocks with prolonged buildings, placed perpendicularly to the coastline. The alignment of the buildings along the axis increases wind velocity, creating Venturi effect (Fig. 30)

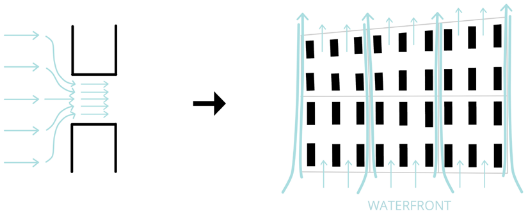


Fig. 30. Venturi effect at coastal typology (on image).

Because of the absence of perpendicular elements the heights can be distributing gradually, reducing towards the waterfront (Fig. 31).

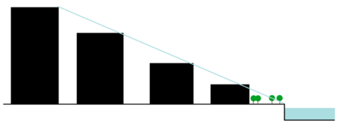


Fig. 31. Gradual heights distribution (own image).

Depending on the width of the blocks, they are automatically divided into number of parcels (based on setting up the max parcel width, Fig. 32).

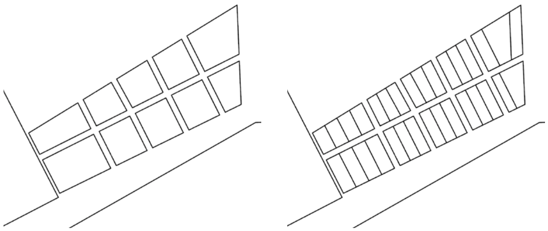


Fig. 32. Division into parels (own image).

The next subdivision is done by setting up the max distance of the parcel's length. Because the street blocks have different sizes, parcel's subdivision differs as well (Fig. 33)

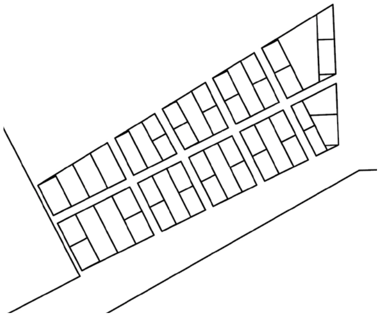


Fig. 33. Subdivision of the parcels (own image).

With this basic parceling set-up the algorithm proceeds to assigning the functions mode, because depending on it typologies slightly change. There is also a differentiation according to spatial position: blocks at the waterfront look different than further ones.

Waterfront, except of the high-density area, is treated as a natural recreational zone. But to fill it with life, it must be accompanied with commercial units. Therefore a part of the middle parcel is cut at the waterfront blocks to create a chain of public squares along the promenade. Commerce appears as podiums in the middle parcel and at one of the edge parcels (at the more integrated edge after space syntax analysis), so that public spaces is "framed" by commercial units. If the block should include offices as well, then the middle parcel is split in two parts: office, facing the public square and residential behind.

In the further blocks commercial units are formed as podiums at one side edge (chosen after space syntax analysis). The middle parcel in those blocks is split into 3 parts, the central one reserved for the public space. The smaller of the rest two parcels gets commerce podium as well. If there are offices assigned, they are placed over the commercial podiums.

Normally, integrated streets in space syntax analysis are building continuous paths to several extent, therefore such functions distribution should create commercial arteries through the area (Fig. 34)

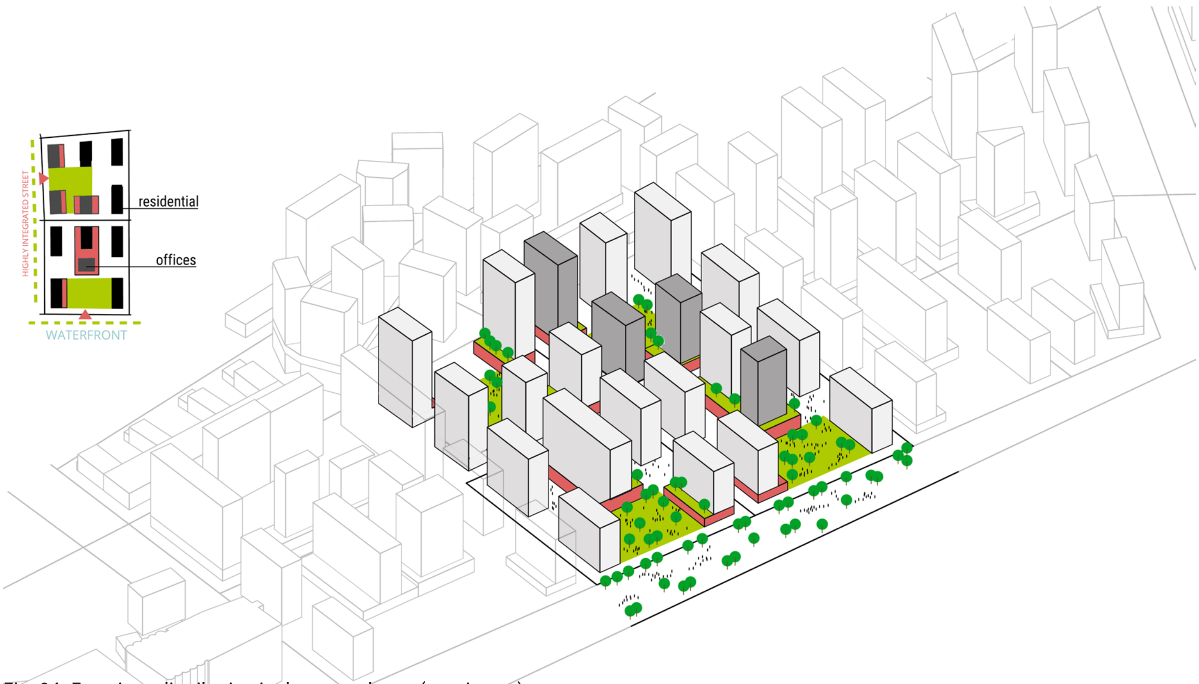


Fig. 34. Functions distribution in the coastal area (own image).

HINTERLAND AREA

The rest of the area should have middle density. The typical Singaporean HDB block analysis showed that the developments always have a more complicated hierarchy than just placing the buildings around the block's edge (Fig. 37). At the same time, those types of structures often do not frame the streets and despite the very high density in the neighbourhood public life at the streets does not really reflect it (Fig. 35).

Fig. 35. Source: ita.gov.sv

The typical European typologies that work so well for mix-use areas - the block structures - would not work in Singapore because of the climate issues. Therefore a hybrid typology was proposed - a block with breaks for the air paths (Fig. 36).

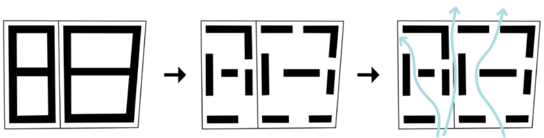


Fig. 36. Hinterland typology (own illus-

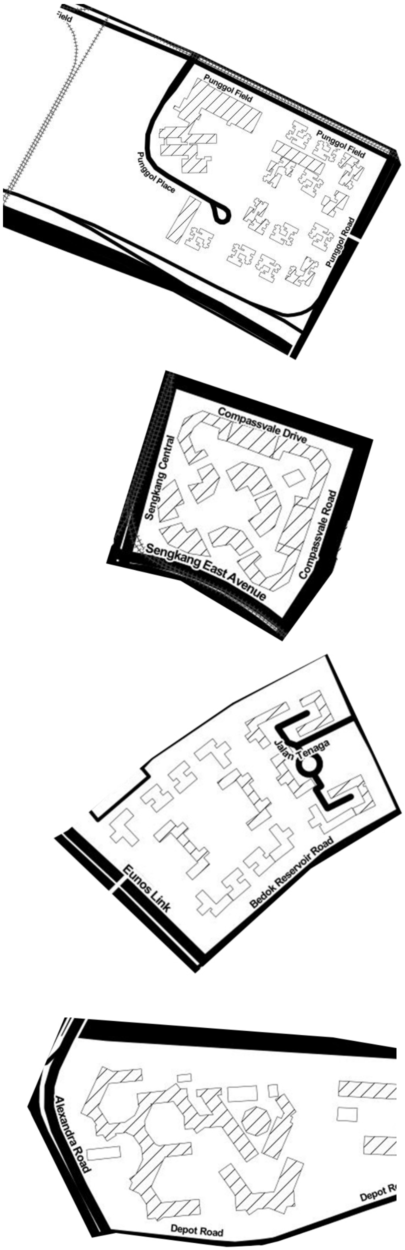


Fig. 37. Examples of HDB blocks.Source: maps.

This typology is constructed by offsetting the block and creating gaps at the perimeter. In the middle of the block algorithm installs a building, splitting the block into two parts. The part, oriented to the more integrated street of the block, gets the gaps organized in such way, that those breaks build a go-through axis. (Fig. 38)

The assigned commerce is generated in this half of the block. If there should be only retail as additional function, then an edge of the block is cut away to arrange a public square. Such square would then be a buffer zone, letting the public life from the street partially penetrate into block.

If there are offices as well, they are generated as a gate set up at the block edges, making this half of the block an extraverted space. (Fig. 39)

Because of such distribution, block is clearly split into private and public zones. (Fig. 41)

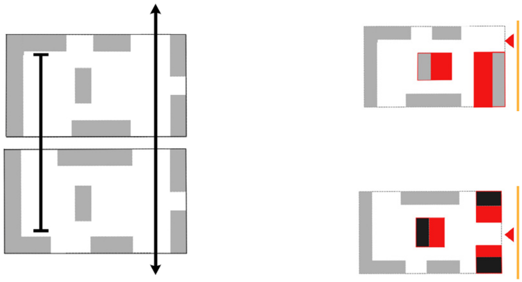


Fig. 38. Diagram of the blocks modes (own image).

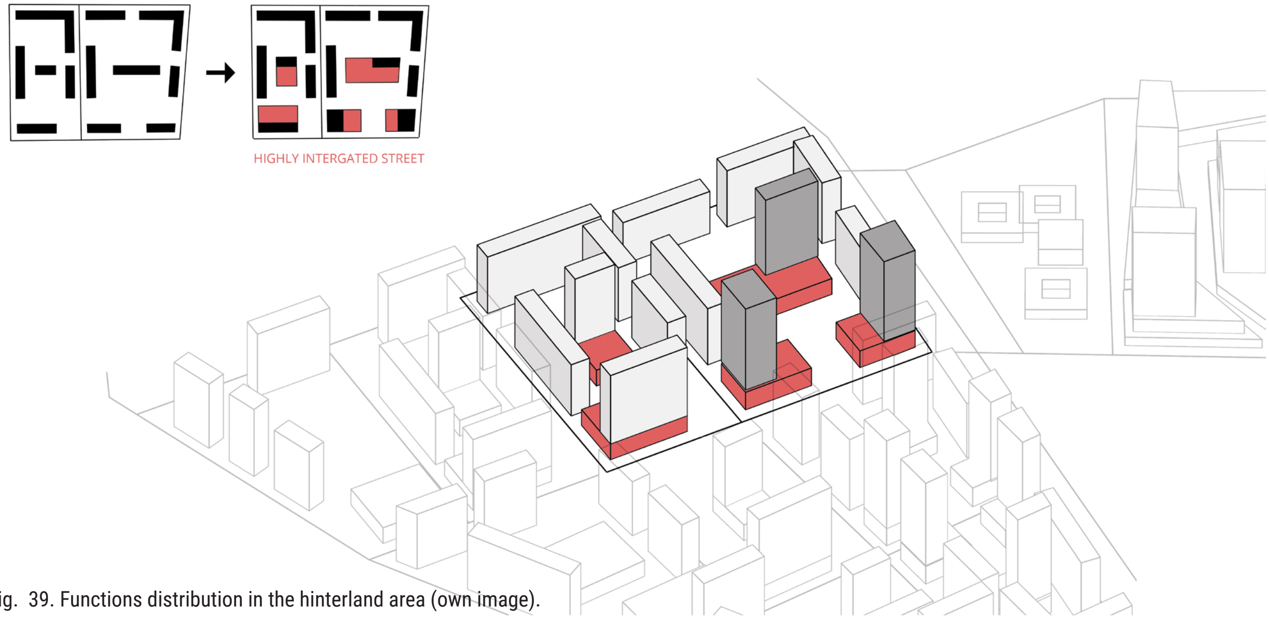


Fig. 39. Functions distribution in the hinterland area (own image).

To distribute the heights for this typology, neighbourhood parks are manually defined and serve as attractor points (Fig. 40).

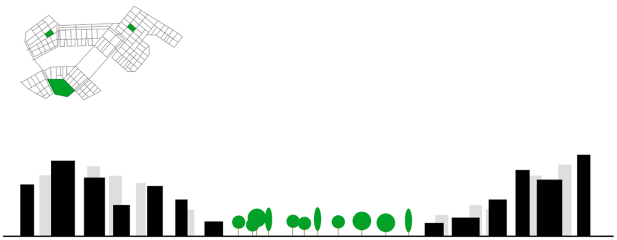


Fig. 40. Heights desitibution in the hinterland area (own image).

The alternative typology for hinterland area is a set of randomly turned buildings, reminding more of a traditional HDB. It is generated near the neighbourhood parks as a modus for purely residential function or at the block where public functions need to be accompanied with residential, commerce and offices (Fig. 42).

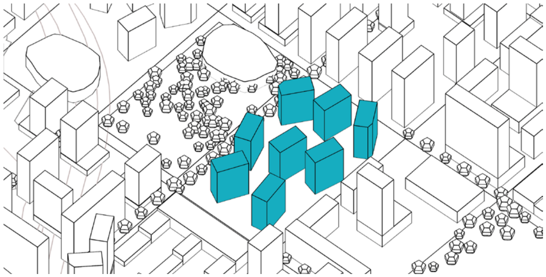


Fig. 42. Additional typology (own image).

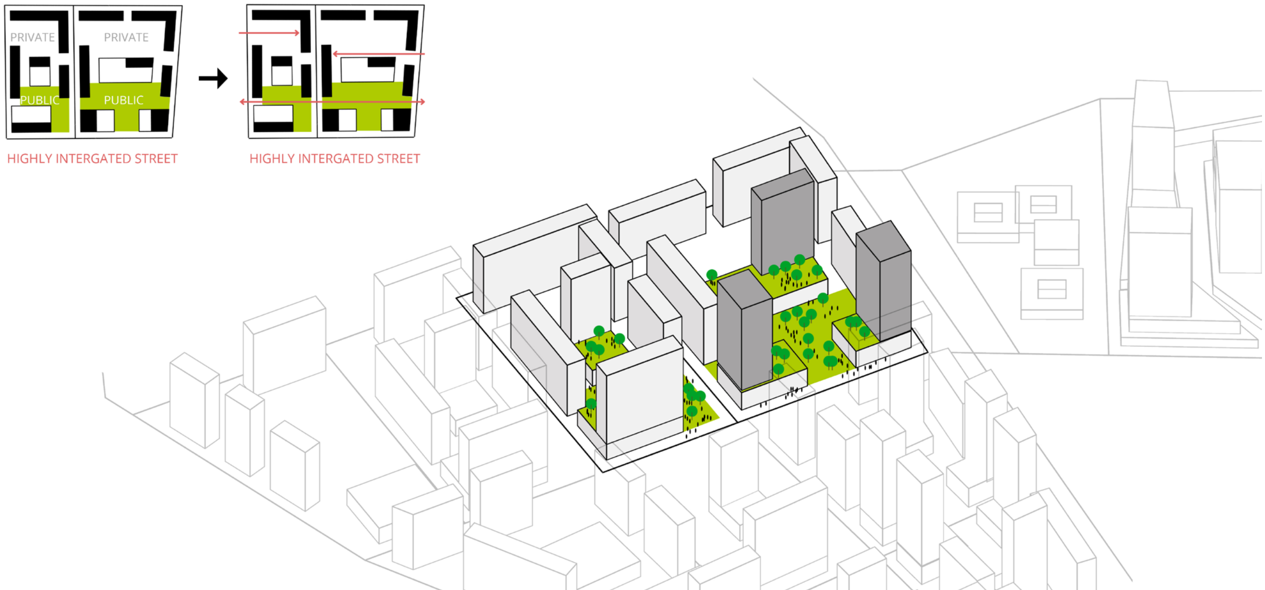


Fig. 41. Public spaces in the hinterland area (own image).

7. OUTCOME

group work

The algorithm creation evolved during the implementation of the initial concept, yet to test the adaptability of the algorithm three scenarios were created.

SCENARIO 1

The main idea of the initial scenario was creating a continious green connection between Mount Faber park and Gardens by the Bay along the coast from East to West. Mount Faber is one of five parks united in one walkway, so using site to connect it to the greatest public space of Singapore - Marina Bay - would enrich the recreational layout of the island. In the middle of the area this green axis splits into North - to connect to the old railway green corridor- and South - to include the existing park on Brani island- and then unites again, creating a green loop in the center. Within this "loop" the high-dense district is placed, giving the area unique character, and serving as a uniting element for the land and the island. By this we provide the waterfront with two different characters: broad recreational area versus highly urbanized public space at the ocean edge. The waterfront promenade is prolonged by adding the fjords (Fig. 44)

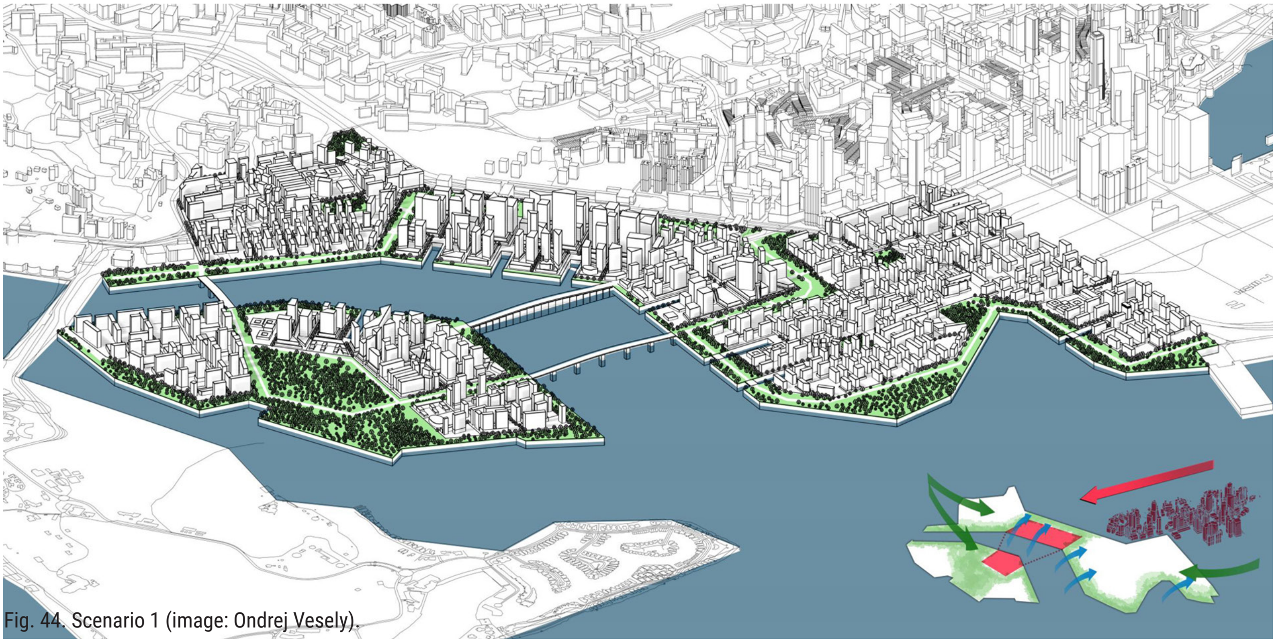


Fig. 44. Scenario 1 (image: Ondrej Vesely).

SCENARIO 2

In the second scenario the concept was based on the Singapore advertisement image of the "City in the garden", pushing the ration between green and built-up area to its limits.

In this concept the dense core of the neighbourhoods is surrounded by a huge green area, which should benefit from the density of the quarter in terms of being filled by activities generated by the area inhabitants.

In this layout minimal area is used for construction, cutting a part of the site for deepening the channel between the island and the land.

High density area was placed to the East of the site closer to the existing CBD development and by enlargening its outline the required amount of GFA was still achieved (Fig. 45).

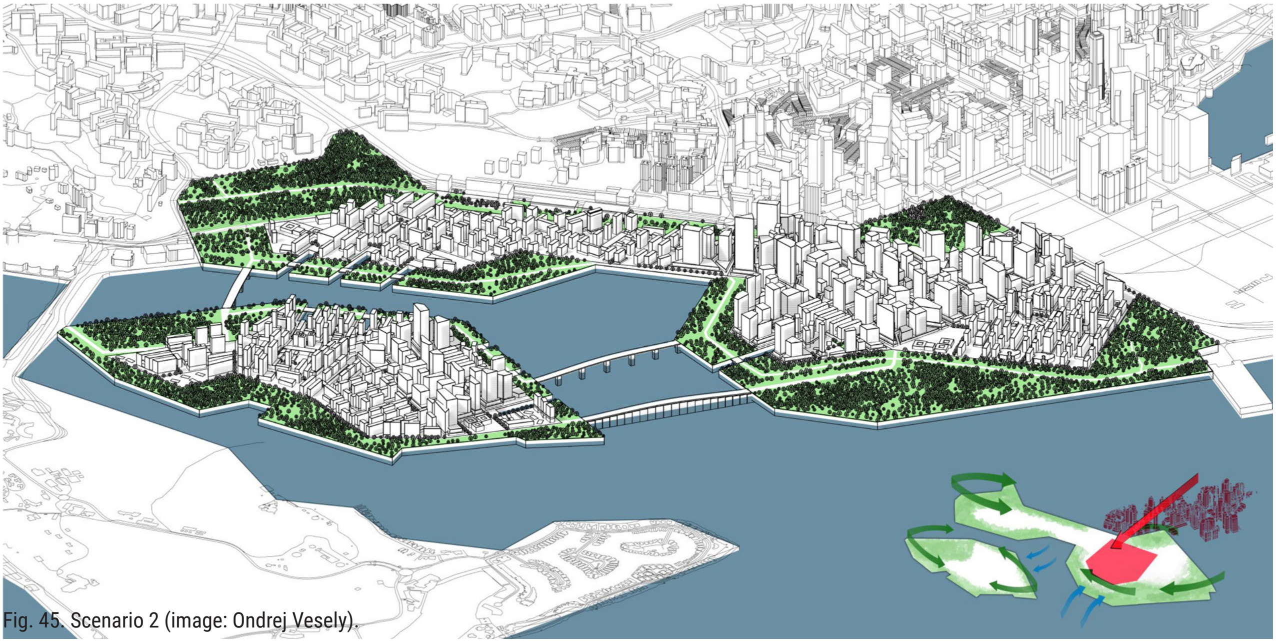


Fig. 45. Scenario 2 (image: Ondrej Vesely).

SCENARIO 3

The last scenario increased the shore outline to gain more area and prolong the waterfront walking zone. For this purpose an artificial island was created by splitting a part of site from main land by a newly created channel. The high-density area is then placed right next to it, being a straight axial extension of the existing CBD.

Following the Marina Bay example, sweet water reservoir could be constructed in the extensions of the channels, providing the city with the much needed reserves. The Fjord typology was applied at the shoreline to a greater extend, to create an impression of a dock or marina, which would be appropriate for a site, serving as the shipping dock today (Fig. 46).

After creating the conecptual input (p.12), the algorithm runs automatically. To generate a complete quarter model (Fig. 47) from drawing sketches the needed amount of time is approximately three to four hours.

Depending on the concept goal, parameters within the algorithm may be adjusted to better correspond to the aim.

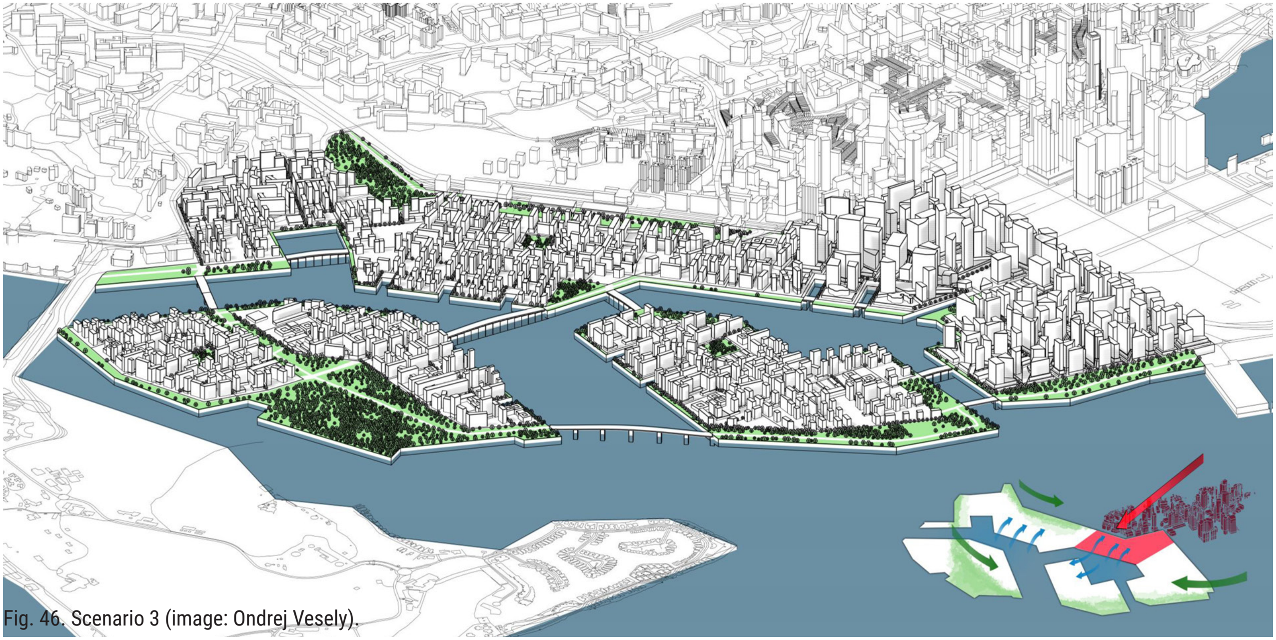
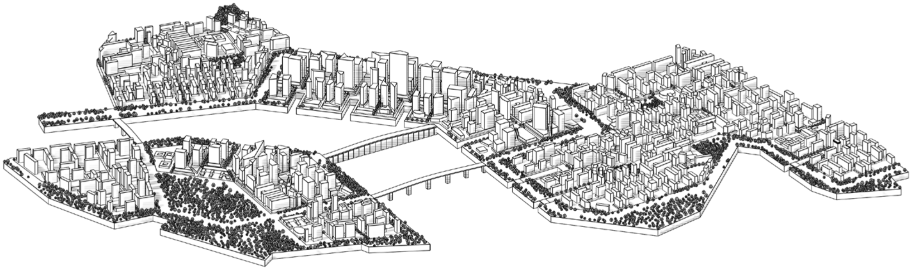
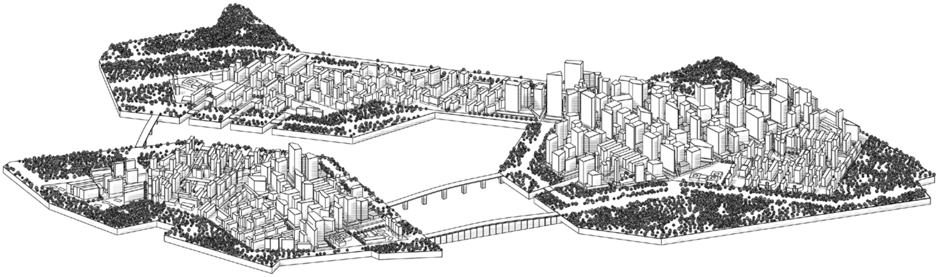


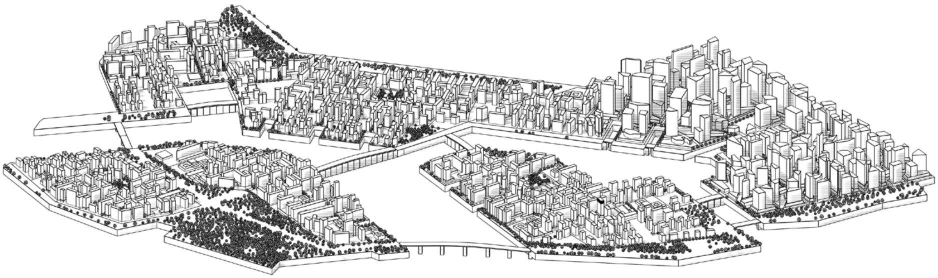
Fig. 46. Scenario 3 (image: Ondrej Vesely).



Scenario 1



Scenario 2



Scenario 3

Fig. 47. Scenarios comparison (image: Ondrej Vesely).

8. STREET LEVEL

Building typologies were created within street blocks. Although such an approach is reasonable for developing various structures with complex hierarchies as well as parceling land for administrative goals, it does not pay enough attention to a street as an element. Therefore this chapter of the thesis focuses on street design as both spatial layout and public space. Four types of streets are considered, using the geometry of the first scenario as an input to define a strong character. Designing the streets requires high level of detail and shapes the character of the particular area, therefore the algorithm does not need to be tested on the other two scenarios.

COMMERCIAL STREET

To make an example of a commercial street, the long street in high density area was picked by drawing a segment manually (Fig. 48).

Fig. 48. Street segment for commercial street (own image).

To define the street profile, combination of parameters is set up. (Fig. 49)

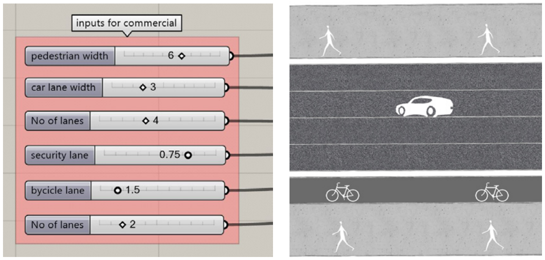


Fig. 49. Parameters for commercial street, example (own

If the new street is broader than the initial one, street blocks are cut with the street's outline and the Module of Buildings rearranges the geometry of the street blocks. Afterwards the road intersections along the street are defined. (Fig. 50)

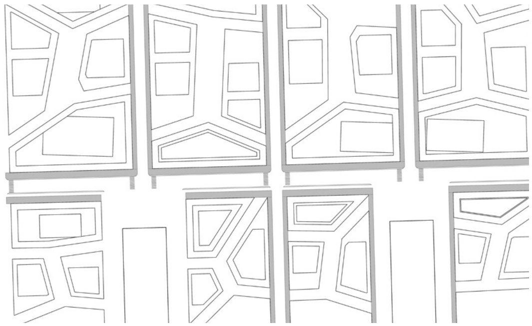


Fig. 50. Comercial street layout (own image).

From the map of solar radiation the overheated parts of the street are defined (Fig. 51, 52).

The alignment of facades depends on this heat map. At the areas with lower temperature commercial podiums stay terraced as before and islands of greenery appear along the pedestrian part. If the temperature is higher than a certain number, the upper floors of the podiums are adjusted to create arcades to provide better thermal comfort. At such walkways the trees are aligned into continuous stripes to provide maximal shading (Fig. 53)

Taking into consideration climatic issues, the attendance of such a commercial street might depend a lot on the ability to walk it through without going outdoors. Orchard Road, one of the most successfull commercial streets in Singapore, promotes seamless connections between the unit, thus becoming a mega-mall (Fig. 54)

Such linkways can occur in form of underground passages and sky bridges. To distribute both types of connections the algorithm checks the distance to the fjords: near to the water sky bridges between the buildings are arranged, further away underground passways link four buildings around each street intersection,

In this way all of the commercial units along the street are interconnected. (Fig. 55).

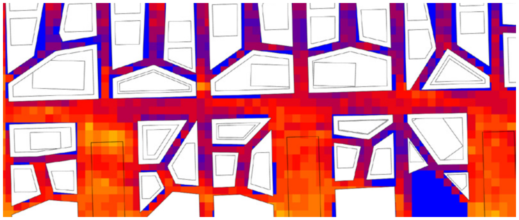


Fig. 51. Solar radiation map (own image).

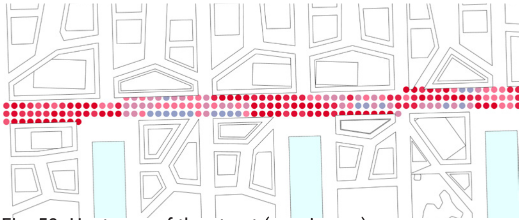


Fig. 52. Heat map of the street (own image).

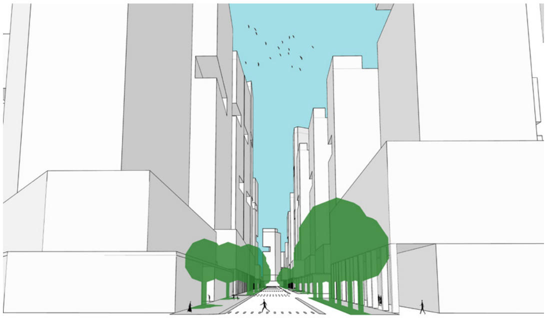


Fig. 53. Facades reaction on solar radiation map (own image).

Fig. 54. Linkways at the Orchard Road. Source: asiaone.com

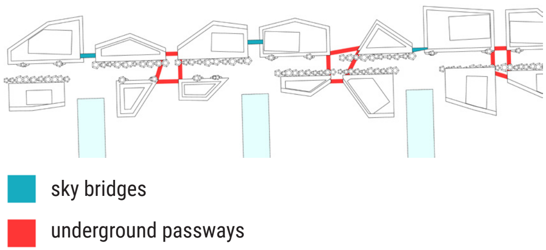


Fig. 55. Linkways at the commercial street (own image).

ALLEY

Short alleys in the high density area are streets with small-scale retail units and residential towers on top. Those streets should guide people towards the waterfront (Fig. 56) and therefore serve as public venues.

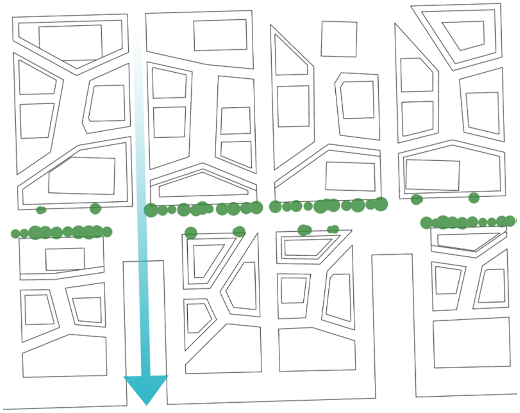


Fig. 56. Picking the alley (own image).

The alley has a narrow part, which gets wider when it comes to a fjord after crossing the commercial street. The narrow part of the alley has a shared street mode, so the algorithm defines pedestrian spaces and creates parking islands for trucks at retail facades (Fig. 57, 59).

Alleys provide access to courtyards through covered passages. Courtyards are covered as well and serve as public spaces (Fig. 60). Public space for residents can be arranged at the tops of the podiums. (Fig. 58).

Fig. 58. Public space for inhabitants (own image).

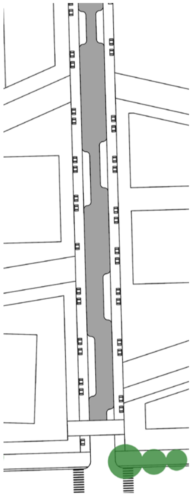


Fig. 57. Alley layout, narrow part (own image).

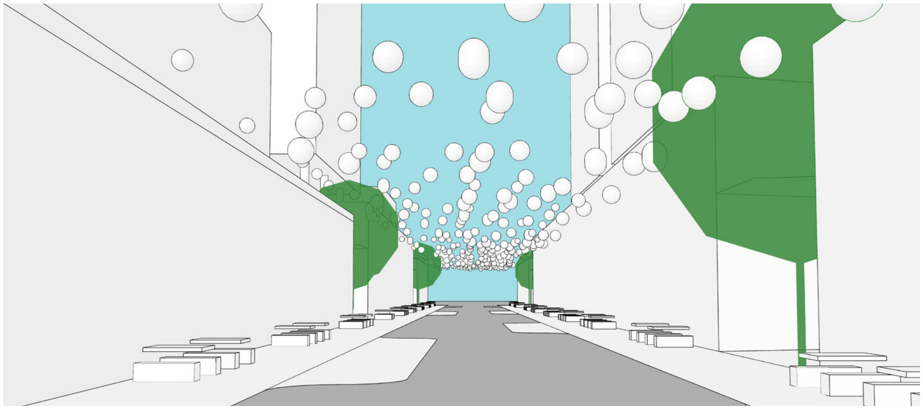


Fig. 59. Alley perspective (own image).

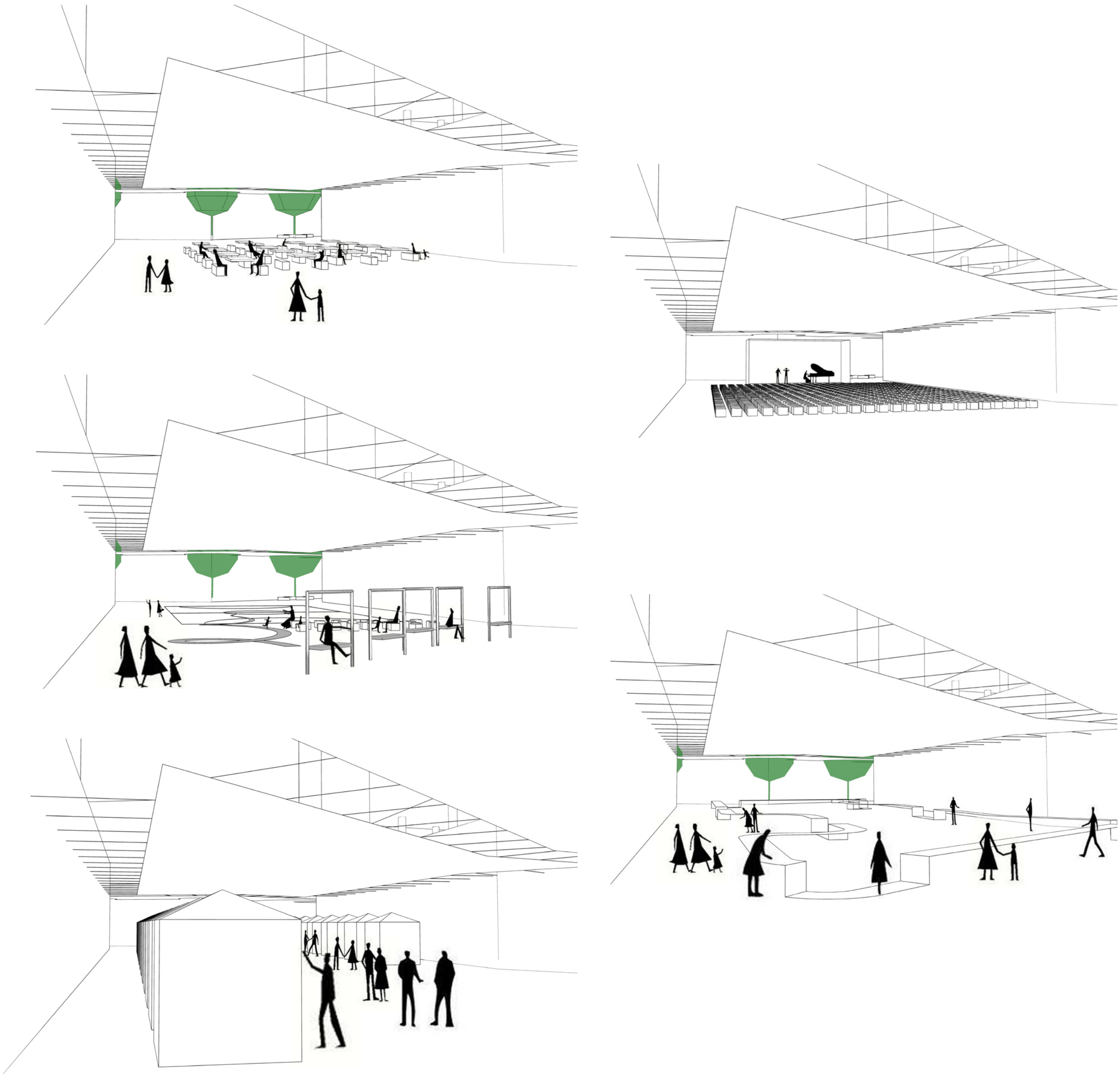


Fig. 60. Scenarios for cortyard usage (own image).

The broader part of the alley is a public space around the fjord. To promote urban life there the area should be pedestrian-only (Fig. 61)

To mark the intersection area and emphasize entrance to a public space, a square is arranged next to the fjord. At the narrow fjord side algorithm generates stairs to offer place for leisure activities (Fig. 62).

Alley splits into two around the fjord. The algorithm defines, which edge has larger summe of facades and generates there a restaurant street under pergola (Fig. 63). The other edge is then automatically defined as recreation zone. (Fig. 64).

Fig. 61. Alley layout near fjord (own image).

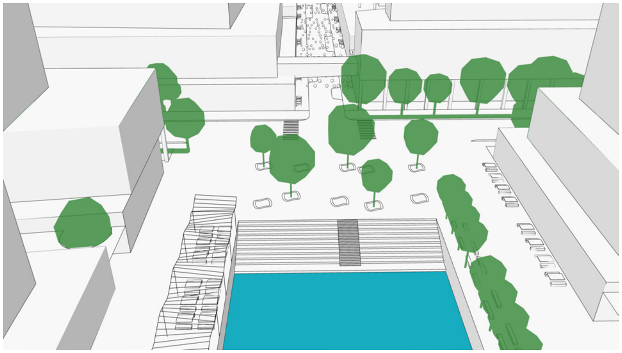


Fig. 62. Transition to the fjord (own image)

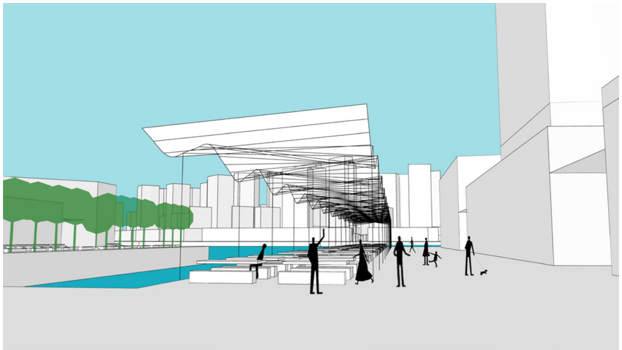


Fig. 63. Restaurant zone (own image)

Fig. 64. Recreational zone (own image)

WATERFRONT

Waterfront area has a different character depending on its spatial position. In the high density area it is another space for public life to take place, whereas attached to the residential neighbourhoods it is generated as a recreational zone (Fig. 68)

Algorithm splits urban waterfront in two levels: the upper one along the facades of retail and gastronomy (Fig. 66) and the lower one, making place for different activities (Fig. 67)

The recreational trail is generated as freeform ways in a park (Fig. 65). Traffic lanes are generated between the park and the neighbourhood (Fig. 68).

Fig. 66. Lower promenade level (own image).

Fig. 65. Nature trail (own image).

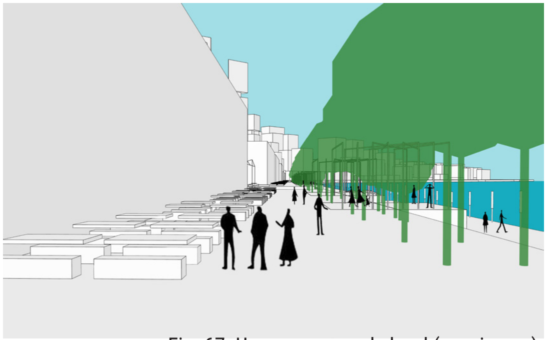


Fig. 67. Upper promenade level (own image).

Fig. 68. Waterfront (own image).

NEIGHBOURHOOD STREET

Because of the complex structure of Singaporean typical street block (Fig. 36) public life often trnasfers inside of the-block. Therefore for this area algorithm defines both the street and the block area.

The streets were generated in order to conduct wind through, serving as air paths with the help of buildings' alignment. However, the air path only works as such if the width of the street is not less then 1/3 of the height of the buildings which frame it. (Edward Ng, 2010)

To ensure correct set-up algorithm check each pair of buildings at both sides of the street. If W/H is less than 1/3, the higher of both buildings is being moved further from the street edge (Fig. 69).

Fig. 69. Arrangement of buildings for providing air pth (own image).

Afterwards the street layout is generated by placing tables along commercial units and greenery stripes in front of residential buildings (Fig. 70).

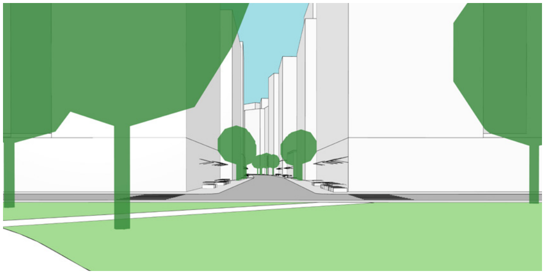


Fig. 70. Neighbourhood street view from natural trail (own image).

To combine both public life and quite space for residents, each block has a square at one of the edges to encourage a walk inside. Around a square commercial podiums are generated (p.23), whereas the opposite part of the block contains residential buildings only and green recreational zone. Because commercial units are generated at the most inegrated street segment of the block, they appear aligned, so the public space within several blocks follows an axis and creates an alternative walk-through.

Let's regard such a route on example of two blocks at the waterfront.

The block at the natural trail is set up to have a middle parcel at the "trail edge" free, thus generating a chain of public squares along the waterfront (p.24). Further, the block is divided in two halfs by the middle building, so the square has to guide visitors into direction of the more "public" path. To do this, algorithm creates a commercial corner at one edge, whereas the other edge is closed by trees raw. Commercial unit in the middle of the square is generated to emphasize the "public" path and leave place for public activities. (Fig. 71, 72 and 73)

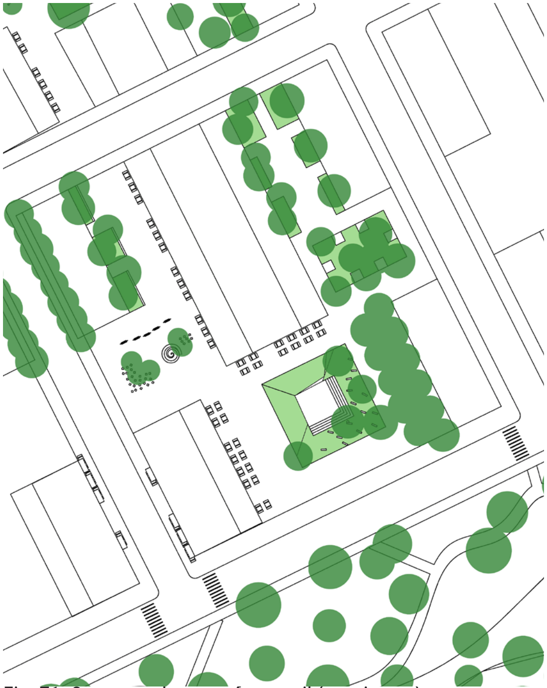


Fig. 71. Square at the waterfront trail (own image).

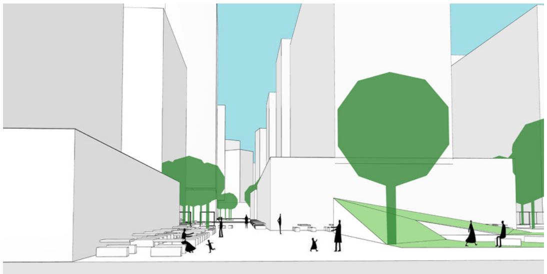


Fig. 72. Square at the waterfront trail, direction public path (own image).

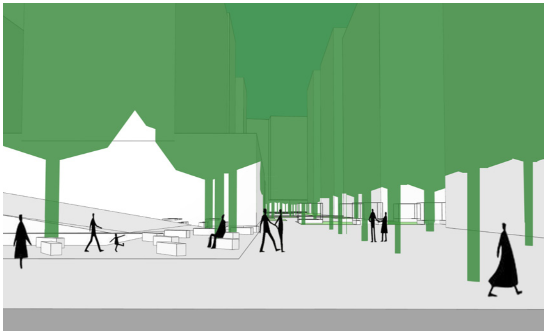


Fig. 73. Square at the waterfront trail, direction quite zone (own image).

In the block from the second raw the distribution of zones appears in a similar way (Fig. 74)

Fig. 74. Zoning in the second-raw block (own image).

The URA vision for mobility in future promotes public transport usage and to encourage it the programme Walk2Ride is launched, which provides covered walkways for a big radius from transport stops. (WALK2RIDE scheme,2015)

To implement this in the neighbourhood, the algorithm creates a walkway in the block, depending on the position of the bus stop (Fig. 75, 77). It aims to provide a rain-protected access to each building (Fig. 76).

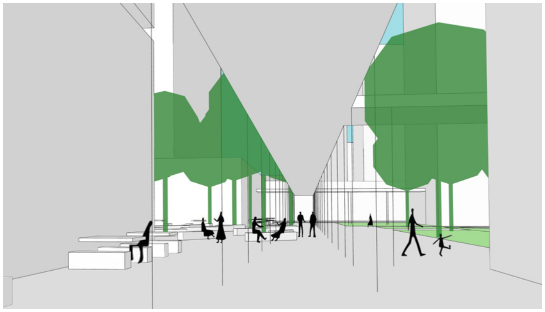


Fig. 76. Covered passway in the street block (own image).

Fig. 75. Generation of covered pass 1 (own image).

Fig. 77. Generation of covered pass 2 (own image).

Fig. 78. Perspective view (own image).

9. EVALUATIONS

One of the most significant advantages of the parametric design is possibility of running different analysis and evaluations of the computational model within the algorithm, which may further be used for embedding evaluation and further optimization into iterations of model generation, thus ensuring the fulfillment of requirements.

In case of multiple solutions evaluations might be a great help for informed decision taking as well as an instrument during negotiations with different stakeholders.

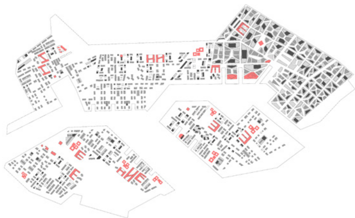
In this chapter some examples of evaluations of the three produced scenarios are shown, though there are definitely much more possible.

FUNCTIONS DISTRIBUTION

The GFA data about each function is directly stored in the model, which provides a direct estimation of the functions layout in the area (Fig. 79). For example, the second scenario provides 12,1 mln m^2 of total GFA, among which Residential units take 43%, Retail - 13%, Offices - 27%, Public functions - 13%. If the character of the area should not remind CBD area but rather create a cultural quarter, parameters in the modules of Functions and Buildings should be adjusted to rearrange the final distribution.

12,5 mln m2; 52/16/19/13

12,1 mln m2; 43/17/27/13

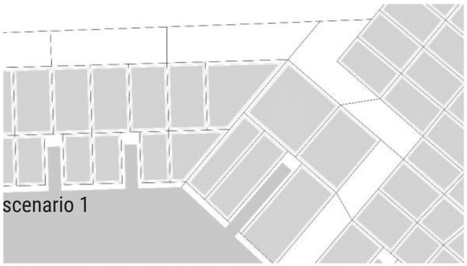


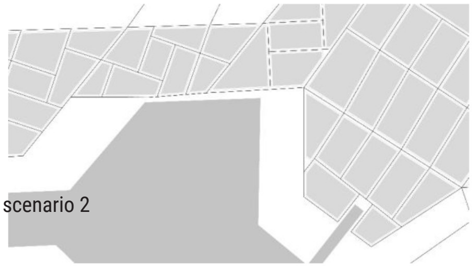
15,2 mln m2; 50/15/26/9

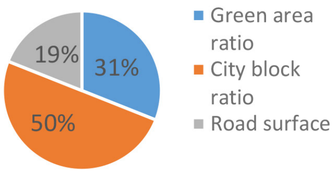
Fig. 79. GFA and Functions proportions, in %: Residential/Retail/Offices/Public (own image).

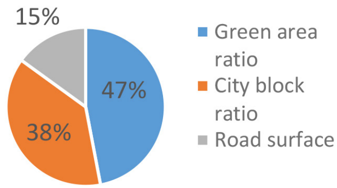
Land use ratio

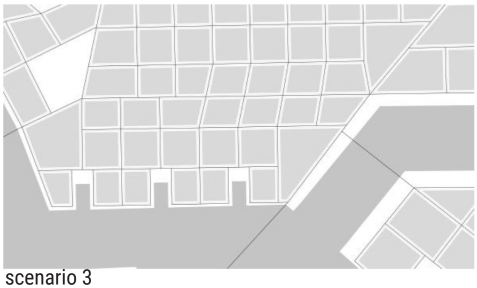
Part of Kateryna Konieva











scenario 3

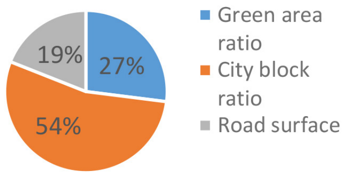


Fig. 80. Land use ratio (images: Kateryna Konieva).

ACCESSIBILITY

Part of Kateryna Konieva

Accessibility is another important criteria for evaluating diversity, mix-use character and walkability of the developed quarter.

The issue of accessibility also refers to the usability of the geographical territory and the mobility of the users. As pedestrians are constantly more seen as main actors in the urban space, city should be planned to meet their needs (Steffan, 2006).

To estimate the placement of functions, accessibility analysis based on City Graph (Fuchkina, 2017) is run. The algorithm estimates the accessability of a particular function (Fig. 81). There is no optimization loop in the algorithm, but comparison of different scenarios can be helpful for estimating the optimal one.

% within 500m

% within 200m

Average distance, m

Fig. 81. Accessability analysis, scenario 1 (image: Kateryna Konieva).

PHYSICAL SIMULATIONS

Group work

Having a complete three dimensional model generated at the end, we can test our design using various physical simulations (Fig 82,83).

The results of such analysis can be useful for evaluating level of climate comfort at various spots, which is very important in terms of tropical climate of Singapore.

Combining physical simulations and approximating them, a heat map (Fig. 84) for each scenario can be produces. Such map displays overheated spots (Fig. 85)and those having higher thermal comfort (Fig. 86), thus helping for design decisions on public spaces placement and character.

Such a heat map might as well work in combination with energy consumption models for optimizing energy demand of buildings or blocks.

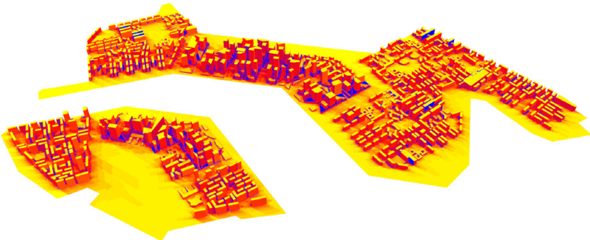


Fig. 82. Solar radiation effect on the area layout (own image).

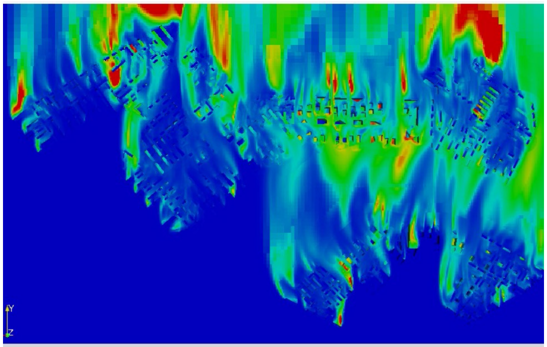


Fig. 83. Average wind flows simulation (image: Ondrej Vesely).

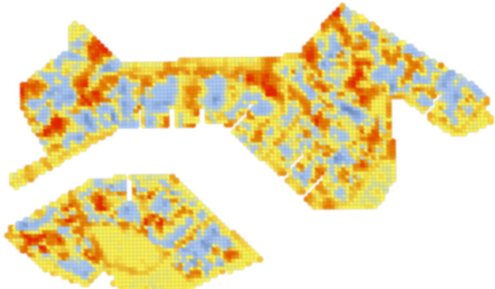


Fig. 84. Heat map (image: Ondrej Vesely).

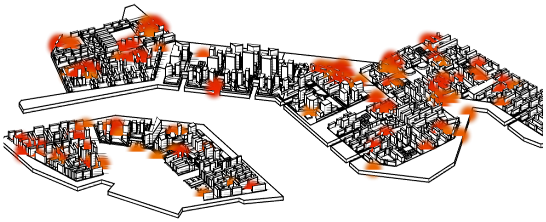


Fig. 85. Overheated spots (image: Ondrej Vesely).

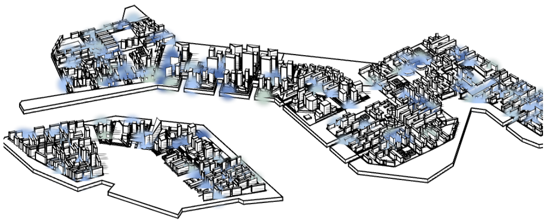


Fig. 86. Comfort spots (image: Ondrej Vesely).

10. CONCLUSIONS

The very evident benefit from the usage of parametric tools is caused by their nature: a range of input parameters leads to a range of outcome solutions, which still respond to the criteria set up by a designer. This was demonstrated on the example of 3 scenarios, where different outcome models were achieved in a short time by changing the input data. This also means that parametric approach simplifies the process of decisions taking greatly: the three scenarios prove as well that this tool is well applicable for quick prototyping and can save an immense amount work, providing feedback loops at early design stages.

When it comes to the interaction with stakeholders, investors and citizens, each of them has a certain solution idea and reaching common ground is a difficult process. Because parametric design is representing a solution space, negotiation is much easier to achieve, as shown in Fig. 87.

The framework that is proposed for the area is site specific and refers to the current characteristics of the area. However, the methodology developed for this project can be implemented for other big scale urban projects around the globe. Its advantage lies in splitting the working process into separated modules with defined interconnections. This allows uniting different expertises in one project and at the same time there may exist feedback loops from the end modules to the earlier ones which ensure that the final output will be corresponding to all of the requirements.

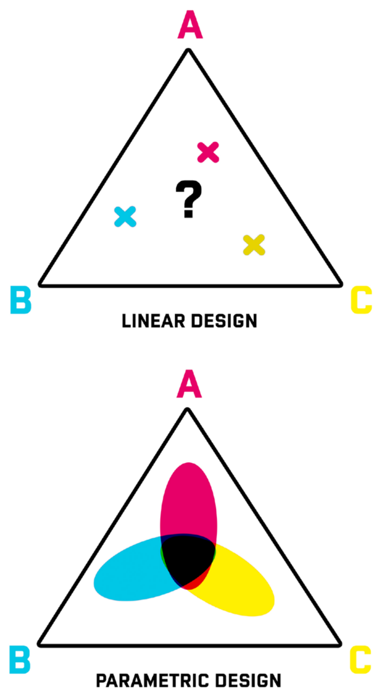


Fig. 87. Solution space in parametric design (image: Ondrej Vesely).

LIMITATIONS

An approach used in this thesis is based on qualitative aspects, which is normally a great concern of traditional urban planning specialists when it comes to procedural design. Qualitative aspects (conceptual cognitive decisions) were involved in the framework at each step. For each module some assumptions were taken, according to which the tool was created to achieve certain goals.

However, such an approach is very limited in terms of searching for the optimal solution, because the solution range is set by a designer when creating an algorithm. The designer's decisions may be excellent after evaluating them, still there is no guarantee that there was no better solution.

To overcome this limitation, an evolutionary algorithm might be a proper solution. It works by setting up constrains and thus creating design space to run the algorithm. Then performance criteria are set and the algorithm evaluates all the possible generated solutions from the perspective of the defined criteria. If the criteria are contradicting, the algorithm shows compromising area. The measurements for such a multi-criteria optimization can only include quantitative figures, which generates the next limitation: qualitative parameters can only be evaluated cognitively.

Another difficulty in the optimization process is that the design process cannot be described as a linear sequence. When creating a new project, an architect needs to take into consideration the site, climate, available materials, budget, aesthetical aspects and so on. This decisions are influencing each other and restricting the solution space during the whole design process and all of them matter for the final outcome. One model that would incorporate all of the criteria for evaluation of the best performance at the time is not possible to achieve (at least now), because so many steps are dependent on the previous ones and cannot be generated before the previous ones are complete. Let's regard the street network and buildings generation. Buildings rarely can be designed without the street network (if only there is a solitary house in a wood or at the top of the mountain). Let's say, a street network was optimized based on connectivity measures and traffic analysis. In the next step the buildings are generated and optimized to reach certain performance. It may appear, that several building blocks do not satisfy the desired outcome, yet not because of the failed optimization, but because the street network created a bad input at some points. At this moment one needs to do another iteration for the street network to optimize it for the buildings, but it will not be the best solution for connectivity aspect anymore.

CONCLUSIONS ON THE MODULES OF THE "BUIDINGS" AND "STREETS"

In the module of "Buildings" the assumptions for design of particular typologies were made after considering the existing tradition and climate, demands on density, global movement in urban design and the concept for the area. In this module different typologies are assigned to different zones (based on the density distribution concept). The functions layout serves as an input for the street blocks. Based on this layout a set up of fitting geometries for each block is generated. Such a distribution scheme is quite convenient as long as the density concept makes sense. It allows to create diversity within the area while still leaving a clear perspective on how each block will be generated because the "reactions" to different input parameters are all programmed by a designer.

The advantage of this method is that it allows to create "organized chaos", implementing a certain set up which responds to different conditions by changing the form to fit the new requirements. This generates diversity that is still organized after precise rules.

The disadvantage is that most of the blocks are generated simultaneously, they dont have any impact on each other. This is especially noticeable at the borders between density zones where both street sides have different typologies that are not interconnected.

Concerning the inner layout of the blocks, rules for building arrangements are quite flexible, allowing change of proportions and spatial configuration in frames of predefined typologies. The disadvantage being that currently most of the rules are not sophisticated enough. For example, the height of the buildings in the "hinterland" typology is distributed using the neighbourhood park as attractor and ignoring which place does a block take in the overall spatial configuration. However, improvement for the rules can be undertaken at any further step of the project. A more problematic feature is that those inner geometries were set up based on assumptions whereas an evolutionary process for different typologies to define rough geometries might be more beneficial.

The third major disadvantage is that the street blocks define the layout within the block and the street pattern is then composed randomly. To solve this issue, the module of "streets" was investigated to explore to which extend the generated buildings can be optimized from the streets' perspective. This module revealed that moderate changes are easy to implement, for example by offseting facades towards or away from the street, modifying heights, moving the building or turning it. Larger changes would be still possible but this would mean the complete change of the block layout and therefore change its functionality. It seems that the major changes to the buildings´ layout would only be needed for those streets that are between different density zones. Maybe such streets need to be treated separately from the rest of the geometry set up.

However, the module of "Streets" shows that work with the qualitative input, where street design belongs, is easy to implement in a parametric model, because the initial geometries can be corrected if the current step requires changes.

RECOMMENDATIONS

This project aimes to show the potential of parametric approach as a method of solving urban design problems. It can be a very useful tool in the early design stages, when many conceptual ideas are proposed but the lack of resources does not allow to test them all and to extract the quantitative proof about the better option.

To use parametric approach to a full extend in other projects, one should think about combining the cognitive design approach described here with evolutionary algorithms.

The generation steps described in the project can be repeated for any other area if the concepual input is changed respectively.

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