Modifying and Extending the Geodesign Framework for Eco Campus Design Project

Applied Research Paper
By
Yanlin Wu

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Advisor: Dr. Perry Yang

Contents

Abstract

Geodesign is a theory proposed by Carl Steinitz in 2012 to integrate the scientific complexity and the participation of stakeholders into design profession in different types of projects. The framework of geodesign is a prototype methodology, so applying the framework to specific types of project requires to modify or extend to the framework since the characteristics of the project and the application of the new techniques. This paper reviews the geodesign theory and modifies and extends the framework for the eco college campus design project. This paper recognizes the design and research in the 2018 GT Shenzhen Campus workshop, which is to design a net-zero energy college campus, as a case and provide research outcome of the campus design project. The paper studies the application of the implementation of the representation, process, evaluation, change, and impact models in the geodesign framework and the interaction between each model. By studying the anticipatory, participatory, and constraining models in the workshop, the paper demonstrates the differentiation of the interaction between change models and the other models and recommends two modifications for the geodesign framework: changing the role of the traditional geospatial and specifying the research based on the change model applied. The first modification is for all the change models, while the second modification is for the models with certainty. The paper also discusses the introduction of the new model—parametric model. By indicating the benefits and pitfalls of the parametric model, the paper specifies it from the community level to the campus level, also proposes to integrate the model with the energy modeling after researching the energy consumption preliminarily. The modification and the extension proposed by the paper can be applied to design projects similar to the scenario of eco college campus design.

1. Background Introduction

Geodesign is a concept introduced by Carl Steinitz in 2012. It is comprehensive design method that incorporates professional design, geographic science, planning system, and information technology. Scholars explain it as "systems-oriented planning and design for complex projects by interdisciplinary teams and public participation using GIS, CAD, BIM and other algorithmic techniques including timely modeling and impact assessment" (Ervin, 2016). The framework off geodesign include six types of models: representation models, process models, evaluation models, change models, impact models, and decision models (Steinitz, 2012). The six models are implemented in three iterations to firstly, to understand the context; secondly to develop the methodology for the project, and thirdly to implement the methodology.

In the six models, change models are the significant models that form a substantial nexus between the three preceding models in the assessment process and the following models in the intervention process. Steinitz (2012) provide nine options for the change models: anticipatory, participatory, sequential, constraining, combinatorial, rule-based, optimized, agent-based, and mixed. These models are suitable for different scale projects or different types of stakeholders. However, since geodesign is a general framework that can be widely applied to projects from block-scale to global scale, the change models provided concern more on the generic collaboration mode between stakeholders, designers, and geo-scientists, but less on the specific techniques and the collaboration based on those techniques. The techniques appropriate the project are an open answer, while the collaboration based on the application of techniques should be established specifically based on the techniques selected. This paper aims at studying the interaction between different models in geodesign, especially how to change model implements and interacts with the evaluation and impact models in geodesign in the college campus design project. The paper will regard the GT-TJU Shenzhen Campus design workshop as a case of the collaborative process between design, geography science, and information technology to study the practice of geodesign framework and how to innovate geodesign framework in the scenario of campus urban design project.

The paper will firstly introduce the concept and general workflow of geodesign and the context of Shenzhen campus design in literature review; illustrate the process in the case and the method to study the case in methodology; demonstrate and analyze the collaboration process between different models in geodesign; finally make a conclusion about how to extend and modify the geodesign framework for campus design project.

2. Literature Review and Research Question

1) Concept and Framework of Geodesign

Geodesign is a concept introduced by Carl Steinitz in 2012. It is "a design and planning method which tightly couples the creation of design proposals with impact simulations influenced by geographic contexts, system thinking, and digital technology" (Carl Steinitz, 2012). In his book, design and geodesign are a wide concept including multiple scales from global to regional, city and local. On the one hand, the traditional designers are generalists with broad but simple knowledge and concern on the future, while the geographical scientists are specialists who focus on studying the past and current with specific, profound, but cares less about the future. (Steinitz, 2012) Without collaboration, it is difficult for designers to address the emerging challenges like biodiversity, urban microclimate, and urban information network. The framework of geodesign involves the collaboration between the designers, the sciences, as well as the stakeholders to promote the integration between the scientific complexity, design, and local understanding in the design and implementation process. Steinitz outlines the framework of geodesign into six models and three iterations with the interaction between the multiple-disciplinary design group and the stakeholders:

The representation models to describe the study area and the history and context; the process models to study how currently the system in the study area is operating; the evaluation models to test how well the current system operates; the change model to provide alternatives for the study area; the impact model to assess the possible changes which are provided by the change models; and the decision model to select the change for the future by the design teams and stakeholders(Steinitz, 2012). The framework runs through these sixes models in three interactions: in the first iteration, the design group study from the first (representation) models to the sixth (decision) models to understand the study area; the sequence of the models in the second iteration is reverse from the decision models to representation model to figure out most appropriate study and design methodology for the study area; the final iteration runs the model from first to sixth again to implement the methodology which is decided in the second iteration and generate the study and design outcome. In each iteration, the design group can make three possible decisions on the outcome of that phase: "Yes", "No", or "Maybe". "Yes" means they can move forward to the next step; "No" means that the design group needs more feedback from the stakeholders; and "Maybe" means that they need to change the scale, timing, or the study issue of the site. The design group also interacts with the stakeholders by the question "Yes", "No", or "Maybe" to decide their next actions. (Steinitz, 2012)

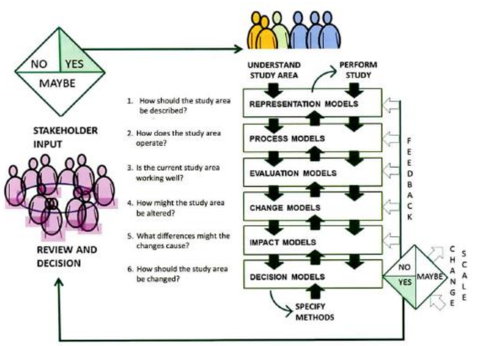
The purpose of the framework of geodesign is to integrate the design, science complexity local understanding in two levels. The top level is the "three iterations" working flow involving the design group and the stakeholders, and the bottom level is the integration of scientific complexity and design in each model in the iterations. To facilitate the integration between design, science, and public understanding, an appropriate framework should be developed in the second iteration. Steinitz states eight independent change models and one mixed model for different types of projects:

The anticipatory model: a confident design team to develop the project based on status quo with a deductive logic to fulfill each requirement. The participatory model incorporates two or more confident designers and combines the designs with maintaining the characteristics of each. The workflow of each design is similar to the anticipatory model. Sequential model: the designers or the stakeholders make choices among the requirements of the design from the status quo with an abductive logic. Anticipatory, participatory, and sequential models are appropriate to small-scale projects, or to the condition that the designers and the stakeholder have certain vision and goals for the future. Constraining model and combinatorial model are developed for the uncertain situations. Constraining model is to rank the issues in Zipf's law pattern and to solve following the degree of priority, while combinatorial model is to combine certain substantial requirements at first and solve the combination of those issues as priority. When the designers or decision makers know the rules: there are rule-based, optimized, and agent-based model. Rule-based is to firstly set up a series of design rule to guide the design. The principle is similar to the overlapping map method of Ian McHarg (1975), but more complicated rules can be introduced by implementing computer algorithms. The agent-based model is to design based on the interaction among different agents which could be stakeholders, people, or policies. The optimized model might be the most difficult one (Steinitz, 2012) because it requires that the stakeholders and designers are clean about the importance of the requirements and the standards to make the choice. The design is to implement the clear understanding of designers and decision makers. Finally, there is mixed model that includes more than one method stated above. (Steinitz, 2012) This paper will study the change models that are applied in the case of Shenzhen Campus workshop.

Geodesign is not simply overlapping maps in design. (Batty, 2013). Instead, it provides a systematic and complex way for the integration between science and design. It not only introduces "science in design" but also "design in science" in the framework (Batty, 2013). The geodesign framework goes beyond the traditional planning support system (Yang, et al., 2017) because it fills the gap between planning support system and urban design: the design dimension and the adaptability. Geodesign invites the collaborate between professions to form a more design-driven method, and it uses the interventional approaches within the designers, scientists, and stakeholders, which might change or even interrupt the current system, while planning support system only expects a future with the given conditions and visible trends in the past and the present (Yang, et al., 2017).

To achieve this goal, geodesign should firstly develop specific ways to meet various situations in different types of projects based on the framework and secondly introduce more data sources and new techniques to represent, measure, and evaluates the study objects. However, the geodesign framework provided by Steinitz is a prototype, which means that it can be broadly applied in different types of design project, but it is not the detailed enough for geodesign framework to support various study areas and different social and cultural background. In the practices of geodesign, the integration between techniques and design is significant, but what techniques should be introduced into the geodesign framework is an open answer based on situation is different in terms of scales, stakeholders, types of projects, and sites. In the small-scale level (block, neighborhood, or campus level), designers will face challenges which are different from the city or regional level, e.g. the issues in 3D. The geographic science complexity might be weaker, but there are other science complexities that need to be noticed in this level. In additional, the traditional geospatial analysis for planning tends to develop "scientific indicator" or "comprehensive index" to guide design, such as the land adaptability index, but whether this method is able to address the issue in small-scale urban design project is questionable. The basic understanding in geospatial techniques might be challenged in the urban design professions, such as the characters of settlements and their distribution in the watershed. (Fisher, et al., 2017)

When geodesign framework is introduced to energy ecological design, there are more specific topics such as the microclimate in the urban environment and the ecological performance of urban space in urban ecological design. Therefore, the GIS techniques might be not enough to address those challenges, and new techniques should be introduced into the design in small level and in specific type of design. However, because the techniques are from different disciplines, so there may be mismatch of the understandings and practices within those technotes causing the impedance in the collaboration. Therefore, as more new techniques and technologies are introduced, the framework of geodesign needs to be extended or modified for integrating the new techniques with the traditional geospatial analysis and the design profession. The next section will review the precedents of introducing new technique into the geodesign framework in the small-scale urban eco design.



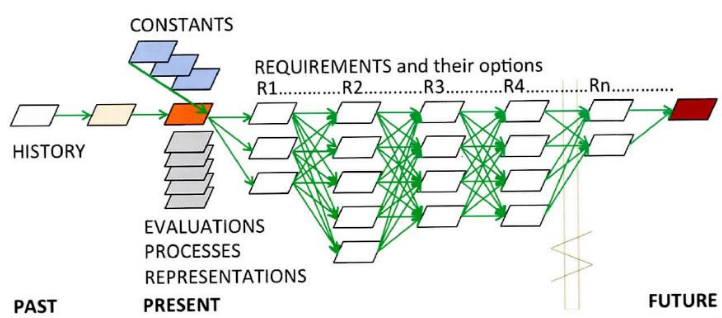


Figure 1 (left), the original framework of geodesign, source: Steinitz, 2012
Figure 2 (right), the template of change models in geodesign framework, source: Steinitz, 2012

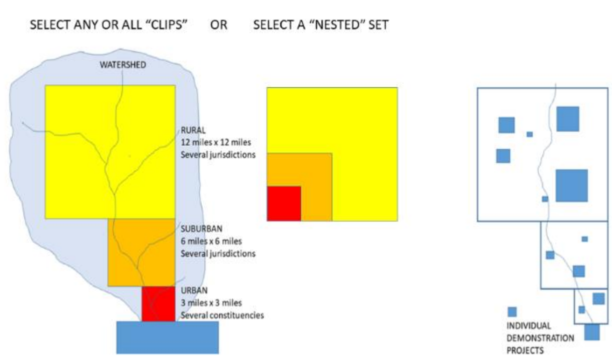


Figure 3, watershed and rural, suburban, and urban settlements, source: Fisher, et al., 2017

2) Extending Geodesign Framework in Urban Eco Design Projects

Geodesign project or study cases in smaller scale are relatively fewer than those in large scale. Compared to the large-scale projects. The urban resilient research and design of Georgia Institute of Technology coordinated by Yang introduce new energy calculation and simulation tools in the neighborhood and block levels. (GT, 2011; Yang 2014). The project focuses on studying the energy performance of downtown area in 13 cities around the world and seeking design solutions for improving the carbon reduction in urban space, which means there are innovations in the evaluation models (performative models) and the change models. For evaluation models, the study group applies eQuest to simulate the energy consumption and Ecotect to analyze the building level solar radiation. The result in building level would be aggregated into urban level in the GIS platform for studying the overall energy performance. For the change model, the study group design low carbon blocks based on the understanding of existing condition provided the performative model. (Yang 2014) The change model is driven by design instead of only following the rules and index. Thus, it is categorized as an anticipatory or a participatory model rather than a rule-based model. The whole project provides a clear example of how new techniques can be applied in the evaluation and change models of the geodesign framework. Moreover, it demonstrates "science in design"—considering science analysis as organization principles for urban design—and "design in science"—taking design as a tool for integrating complicated factors in changing the urban spaces.

A more complex case about energy resilient urban design can be seen in the Shanghai Disney near Zero Energy District (Urban Eco Lab 2016; Yang et al, 2018). The project proposes an extended and experimental geodesign framework for near zero urban design to address the challenges of implementing geodesign in urban ecological design project. The framework includes more parameters different models: social, economic, environmental index in the process and evaluation model; the human experience index, e.g. view factor, human comfort, and wind velocity, and energy performance metrics, e.g. solar energy harvest, land use energy performance, building energy consumption in the impact model. Moreover, the researchers develop a new parametric design model. The evaluation model, impact model, and the parametric design model together interact with the change model to produce to achieve multi-objective optimization. The design team innovates the impact model after they generate two design proposals in the geospatial planform by introducing multiple factors to examine the energy performance. Overall, the project shows how to integrates different professions related to the vision and organizes and evaluates the design based on the inter-disciplinary science complexity.

The project urban energy resilient research and design in global cities and the near Zero Energy District design in Shanghai Disney illustrate about how to apply new techniques into urban ecological design and how to organize those techniques in evaluation, change, and impact models in the geodesign framework. The global city project aggregates the building level data into blocks and neighborhood level in studying the building energy consumption and uses a tool different to simulate the energy production which is from that in large levels. The result in energy simulation is aggregated to link to GIS platform and design guideline is develop based on the result to improve the energy performance of the design in the change model. This method provides a simple but powerful method for embedding new technology to the change model. The change model, in this case, is the combination of rule-based and anticipatory. Compared to the global cities project, the Shenzhen campus workshop has a more specified situation—campus design, so the design can consider more details e.g. programming and placemaking. Moreover, more techniques will be incorporate in the Shenzhen campus to deal with issues for different realms. The Disney project is more complicated: it adopts advanced techniques in different professions and integrates the study result of those professions at a larger level. In this project, the whole geodesign framework is extended by adding new metrics in existing models and creating new models. The way that Disney project adopts to specify and extend the geodesign framework is holistic—to innovate models by proposing new techniques.

Compared to the Disney project, this paper will develop in a more bottom-up way: to start from studying the practical cross-model integration techniques and design and from comparing the implementation of different change models to come up with extension and modification for the geodesign framework. This paper takes a specific urban eco-design case to study—the GT-TJU Shenzhen Campus project. It is a campus design project contains the goal of energy net-zero. Therefore, besides the area or urban eco-design, there is one more scenario in this paper—campus design. The outcome of this paper can also be applied in the urban eco-design projects that are similar to the campus design project in the case.

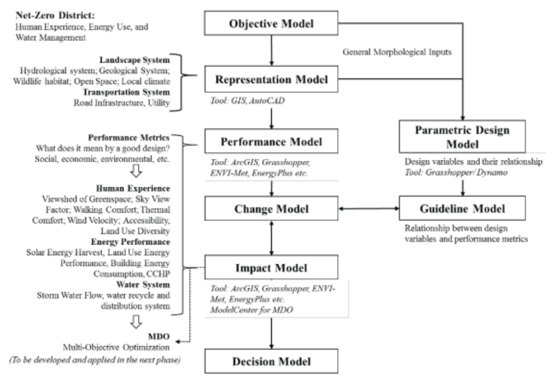


Figure 4 (left), geodesign evaluation model in urban eco design, source: Georgia Tech & Yang, 2014
Figure 5 (right), an innovated geodesign framework in Disney project, source: Yang, et al., 2018

3) Research Question

The research question of this paper is:

How to extend and modify the geodesign framework to optimize the feasibility of campus ecological design project?

To address this question, the paper should study: the relationship between different models in the geodesign framework in the situation of urban eco-design; how to apply the new techniques and to adjust the traditional techniques; what additional model should be introduced into the framework; and what is the difficulties and the solutions in the practices of geodesign framework in urban eco-design.

3. Introduction to Shenzhen College Town and Shenzhen Campus

Located in the east wing of the Pearl River Delta metropolitan area, Shenzhen is one of the largest cities in China which was famous for manufacturing and now earns a new reputation from booming information technology industry. It is the youngest large city in China with a 40-year history. Because of the short history, the higher education in the city left behind other Chinese large cities such as Beijing, Shanghai, and Guangzhou. Thus, the government planned the Shenzhen College Town in 2000 to improve the higher education in the city.

Shenzhen College Town is in the North East of Nanshan District between Tanglang Hill and the Xili Reservoir. The town can be divided into the west (initial phase) and the east (later phase). The initial phase was in 2003 with the area about 1.54 square kilometers. The initial phase implements the "national" strategies that invite national high-ranking universities to establish a campus for graduate programs. The 1.54 square kilometers initial town include three colleges: Tsing Hua University, Peking University, and Harbin Institute of Technology. The later phase (east part) adopts a "local" strategy. It mainly includes two campuses: the largest campus in the town, Southern University of Science and Technology, and a campus of the University of Shenzhen.

After the "national" and "local" strategies, the city government implements a "global-national" strategy in the college town—inviting famous foreign colleges and high-ranking national colleges to form a joint campus in the college town. The joined campus of Georgia Institute of Technology and Tianjin University is one of the anchor projects for this strategy. Georgia Tech will establish graduated programs in the campus, while Tianjin University will hold under-graduate programs. The site of the campus is about 16 hectares. The future campus will accommodate 3,000 students, half of which are foreigners. The stakeholders in this project are clearly identified: the Shenzhen city government, Georgia Tech, and Tianjin

University. The relationship between stakeholders are collaborative: the city government intends to attract high-quality education sources; the two colleges plan to expand their influence in one of the most rapid-growing tech-hubs in Asia. The vision for the project is to build a world-class ecological campus. Under the vision, the stakeholders share two common goals for the campus: a net-zero carbon campus and a stimulating learning environment. The GT Shenzhen campus workshop is an urban design workshop in Georgia Tech from Jan 2018 to Apr 2018. The students in the workshop consider the GT-TJU Shenzhen campus as a case and a design project to produce research outcome and design proposals. The workshop does not go through the whole three-iteration process of the geodesign framework, but the research and design groups in the workshop form the interaction between the representation, process, evaluation, change, and impact models. The next chapter will introduce the process of the workshop.

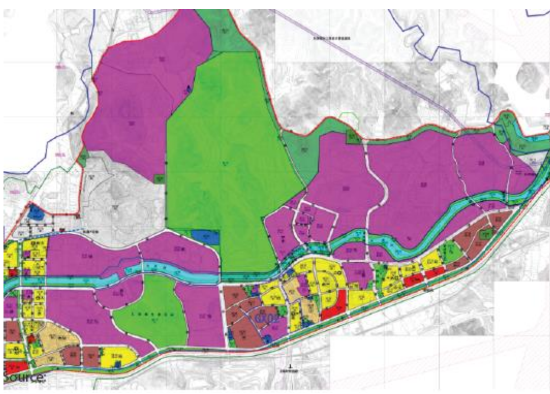



Figure 6 (left), Planning of Shenzhen College Town
Figure 7 (right), Site of Shenzhen Campus

4. Methodology

1) Workflow of the Shenzhen Campus Workshop

The process of geodesign requires a cooperation between designers, geographic researchers, and other professions. Therefore, the author will study geodesign framework in the case of the Shenzhen GT campus workshop. The workshop includes three design groups who will produce three design schemes and one analysis groups to provide support of GIS and other techniques for the design groups as the representation, process, evaluation, and impact models. The author will also participate in the research group, so this paper will also include the research result produced by the author.

Firstly, after a background study and basic site introduction in representation, the first iteration in the workshop starts. It is notable that this “first iteration” is the iteration of the workshop, not the geodesign framework. The three design groups will develop the preliminary schemes. Meanwhile, the analysis team will provide basic GIS study for the site, such as information about flooding, solar radiation, locations, and context as the process and evaluation models in the geodesign framework. The result of the study will inform the designers to enhance their design in the next phase. Sequentially, there is an integration between design and research to provide feedback to each other for further develop the change model and evaluation model. In the first iteration, most of the techniques are traditional geospatial analysis, but the new model and new techniques will also be discussed in this phase.

In the second iteration, the design groups will further develop their design schemes with the support from the analysts. In this iteration, the research group will study the preliminary result of the design groups instead of the status quo as the evaluation model. The network created by the designers will be analyzed, while the research group will also provide instructional guidance for the network by generating the lowest cost trail. Moreover, based on the baseline developed from the preliminary design, a parametric model will run for the three schemes to provide multiple options for further optimization. To achieve the net-zero goal of the project, a preliminary building energy consumption modeling will be implemented as a part of the impact model. The GIS analysis and the energy modeling will compile to assess the outcomes of the change models in the second iteration, and the outcome of the parametric model will help to further develop the outcome. After the second integration, the design group will produce final schemes.

2) The Methodology of the Research Paper

In the lower part of Figure 8, the pink part shows the methodology of this paper. The author will study the process of the implementation of the geodesign framework in the workshop. Firstly, the author will study the design groups to summarizes a specific change model based on their actions in the design process. They are using the anticipatory, participatory, and constraining models. Secondly, as what has been mentioned above, the author will participate in the research in the process, evaluation model in the first iteration and as the impact model in the second iteration. The research outcome will be included in this paper. The study of the change models and the participation in the research occur in both iterations in the workshop.

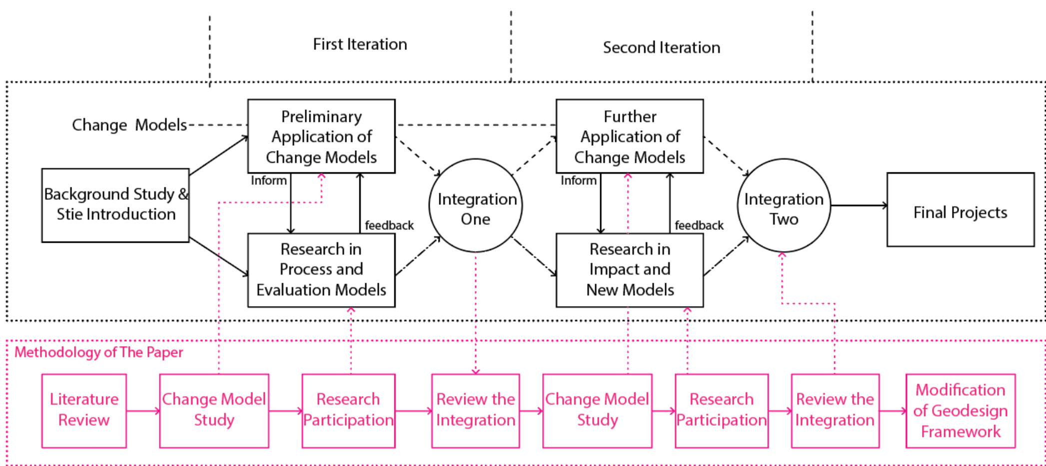


Figure 8, the workflow of Shenzhen workshop and the methodology of the research paper

This paper is not only a comprehensive site analysis and design research to support the design outcome but also a case study of the practice of change models in an urban design project. Therefore, after each iteration, the author will provide a qualitative study about the integration between design and research, and the application of each change models: Are the current techniques adopted in the evaluation or impact models of the analysis team capable and compatible enough for the design? How can those techniques reorganize or adjust to improve the integration? What new technique should be introduced?

What is the difficulty in applying those change models in the practice of campus design? How will the design group improve their change models?

Finally, the paper will develop a modification for extending and specifying the geodesign framework to suit the campus urban design project by concluding the studies mentioned above. The modification includes the reorganization and transformation of the traditional techniques, the collaboration modes between the evaluation, change, and impact models, and the participation of the new parametric model.

3) Tools Data in the Research

Since the author participates in the research in the process, evaluation, and impact models. The tools adopted by the author in geodesign include the ArcGIS: spatial analyst and network analyst in ArcMap are the two main toolsets adopted. In addition, there is an energy consumption simulation in the impact model. The tools of the simulation are Rhino, Grasshopper, ArchSim, and EnergyPlus. It is notable that in the workshop, the members use more tools in the geodesign process for analysis and design.

The DEM data which is the foundation of the GIS analysis is from the database of China Geospatial Data Cloud (http://www.gscloud.cn/). The resolution is 30 meters. The data of the energy modeling in Chapter 9 is generated by the simulation of ArchSim.

5.Preliminary Application of Change Models

The three design groups adopt different change models and produce the preliminary outcomes. The outcomes of the design are to conceive the potential concept for further design and to develop the project. According to the geodesign change models, the author summarizes three different change models for the groups by studying their design logic and practices. Group A adopts an anticipatory model to develop the scheme by specific design theory and deductive logic. Group B applies an approach similar to the constraining model. Group C applies the participatory model to design compiling two scenarios for the future.

Figure 9, preliminary design of Group A, source: 2018 Shenzhen campus workshop

Group A adopts the anticipatory model, a model appropriate to the small-scale project. They are influenced by the landscape urbanism concept which proposes to leverage the landscape as a driver for the urbanization to organize the human activities and ecological system (Corner, 2010). The designers called them the "flows" of space and activities. They conceive a future scenario considering the whole site as a large "playground" with a thorough distribution of landscape and a high degree interaction between landscape and activities to provide plural green spaces for the students and staff on campus. According to the future scenario of "playground", they develop a decentralized scheme: The design concerns on transfer the challenge of the complicated topography into the opportunities of multiple types of landscape. The massing programs, which are located dispersedly in the site, interact with the landscapes in various ways. The circulation system of the campus is developed based on the topography of connects different types of landscape. The interaction between landscape and massing is the main approach for the further design to achieve the purpose of "playground".

Figure 10, preliminary design of Group B, source: 2018 Shenzhen campus workshop

Compared to Group A and Group C, the model of Group B is not concretely identified. Although there are two specific goals, net zero and stimulating learning environment, the design team also concerns other requirements. Facing the complicated landform and the rainy climate, the group identify land adaptability as the first and stormwater management as the second priority for the design. Therefore, the change model of this team is a quasi-constraining model: they are ranking the most important two issues and try to solve them in the design, but in this stage, they do not have a clear ranking for the other issues. In the design, the Group B allocates the programs in three different areas in the site and maintain a large area of open space instead of developing the whole site for the adaptability purpose. They choose the flat area in the east, the middle area along the road, and the flat west corner as the exploitable zones and proposes programs on those zones. Two ponds are designed to store stormwater in the area vulnerable to flooding. The three zones are connected by a loop path with bike-lane and shuttle bus line. Except for the two challenges they identify, the group lacks approaches to address other issues such as programming, and traffic. To become a real constraining model, the team needs to firstly provide a more solid argument for their priority, and secondly incorporates other requirements in the change model.

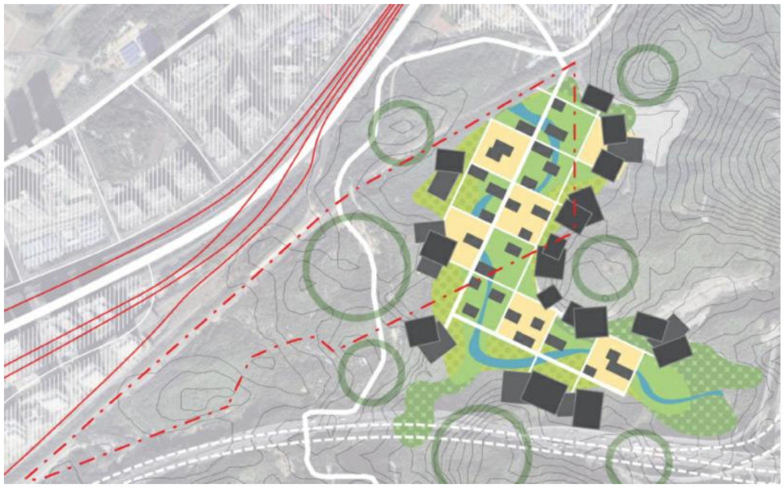


Figure 11, preliminary design of Group C, source: 2018 Shenzhen campus workshop

The schemes of group C combines a mega-structure from case study and a design based on geographic analysis. A designer is inspired by the mat urbanism case of Saitama Prefectural University in Japan: linking two long educational buildings with a gridiron complex with rooftop gardens, open corridors, and different types of programs. The corridors can provide shading and ventilation for adapting the hot, humid climate in Shenzhen, and the separation of two buildings is can is consistent with the condition that there are two main separated headquarters in the campus: undergraduate department of TJU and graduate department of Georgia Tech. Another Design is based on the study of topography and hydrology. Instead of designing within the site boundary, the designer considers that the east flat area is more suitable for locating the campus, so the design incorporates more area in the west and reserves the trees in hilly areas. The designer also proposes a new waterway in the middle of the site to control stormwater. In the combination, buildings are located adjacent to the hills to reinforce the massing of the hill, and green roof of the buildings can bind the hills and the buildings compactly. The gridiron mega-structure links the buildings to shape broad open space, and green space and built area are interlacing with each other in the mega-structure.

The design teams provide three concepts to the project: entirely decentralized, agglomerating in adaptive areas, and introducing mega-structure in mat urbanism. More importantly, the design team practices in three different change models: an anticipatory model which introduces a universal urban design theory in the project and attempts to address the issues by the design theory; a participatory model incorporates a "global" approach and a "local" maneuver; a quasi-constraining model ranking the issues. Because of the differentiation of the change models, the interaction between the change models and the research in the process and evaluation models varies and forms different situations. The situations will be discussed and analyzed in Chapter 7.

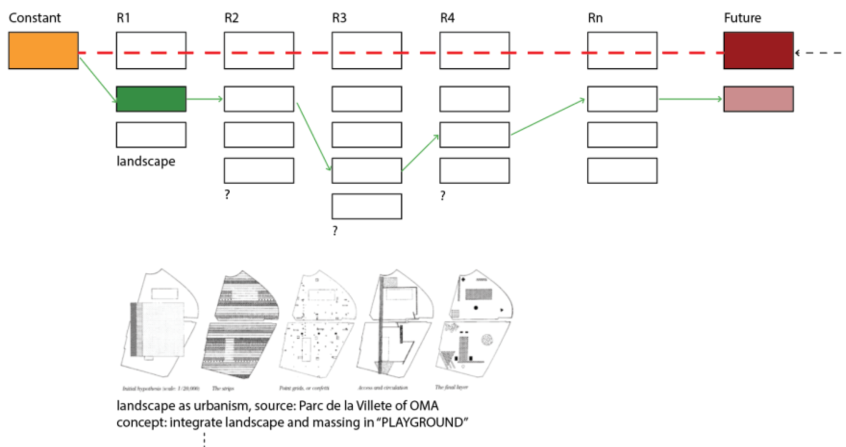


Figure 12, the anticipatory change model of Group A

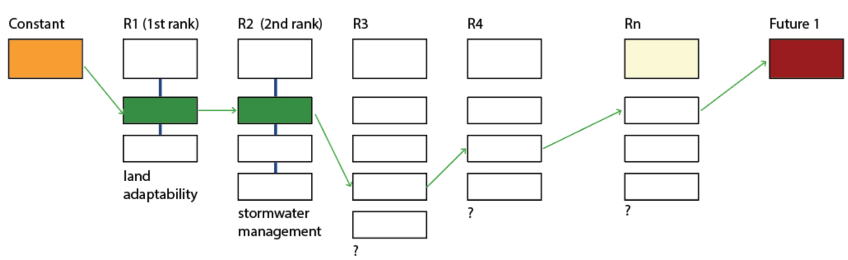


Figure 13, the quasi-constraining change model of Group B

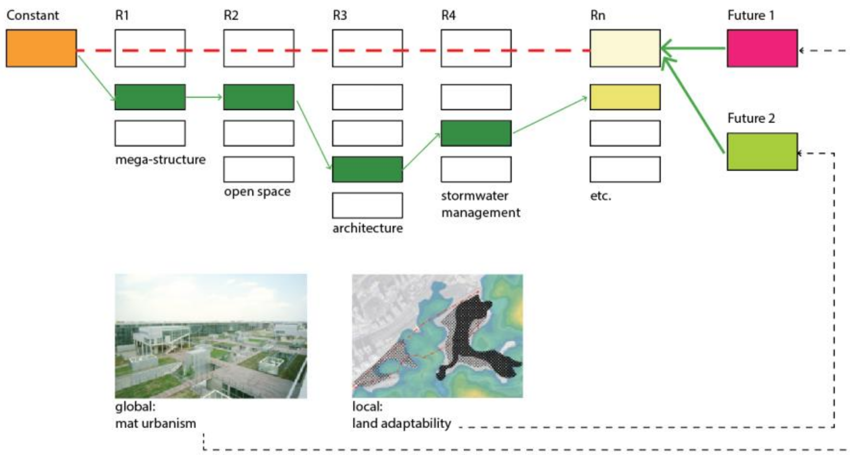


Figure 14, the participatory change model of Group C

6. Research in Iteration One

Geospatial analysis in regional, city, neighborhood, and site level are produced in the workshop in the representation, process, and evaluation models. This paper will not include all the Geospatial analysis. Instead, this chapter will incorporate the analysis at the site level which has direct interaction with the change models for studying the integration of the research and the change models.

1) Basic Geospatial Analysis

The topography of the site is complicated. The degree of slope low in two areas: the east former industrial site and the top of the hill in the middle of the site with a road crossing. However, the zone between these two areas are steep: the slope is generally over 10 degrees. To the west of the top of the hill, there are three small flat areas, but they are all separated by steep slopes. Moreover, there are hills to the east of the former industrial site, so this large flat area is surrounded by hills in an L shape.

Figure 15, landcover of the site, source: author

Slope

The topography of the site is complicated. The degree of slope low in two areas: the east former industrial site and the top of the hill in the middle of the site with a road crossing. However, the zone between these two areas are steep: the slope is generally over 10 degrees. To the west of the top of the hill, there are three small flat areas, but they are all separated by steep slopes. Moreover, there are hills to the east of the former industrial site, so this large flat area is surrounded by hills in an L shape.

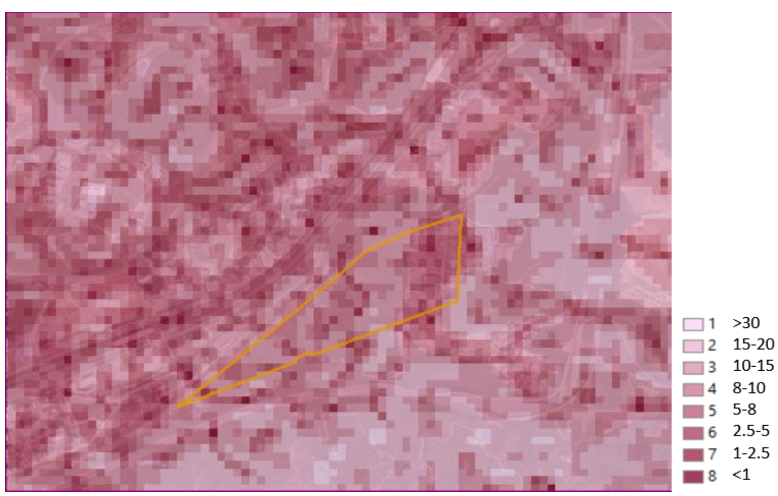


Figure 16, slope analysis, source: author

Flow Accumulated Area

Figure 17 shows two flow accumulated area: the area of the one square kilometer zone shown in dark blue, and that of the quarter square kilometer zone in light blue. The dark blue area can be considered as the vulnerable area for usual stormwater or floods, while the light blue area can be recognized as the vulnerable area for extreme floods. The map indicates that the main flow accumulated area is located in the flat zone in the east of the site, which is currently concrete. Their southwest corner of the zone might be vulnerable for extreme floods.

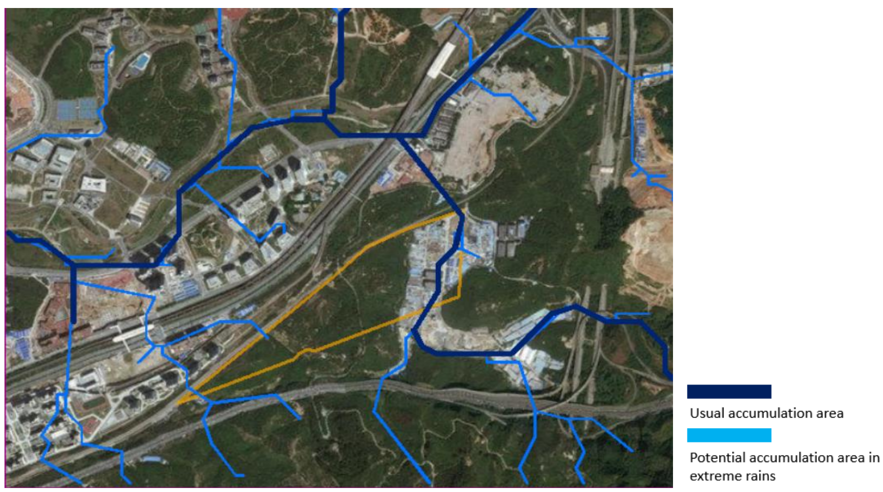


Figure 17, accumulation area for 1km^2 and 0.25km^2, source: author

Euclidean Distance

Figures 18-20 shows the distance from the local roads, highways, and railways. The curvy road and the future entrance in the southeast corner can become opportunities for future campus development. The north edge of the site is threatened by the railroad, while the south edge is exposed to the highway. Therefore, the southwest corner is closed to both the railroad and the highway.

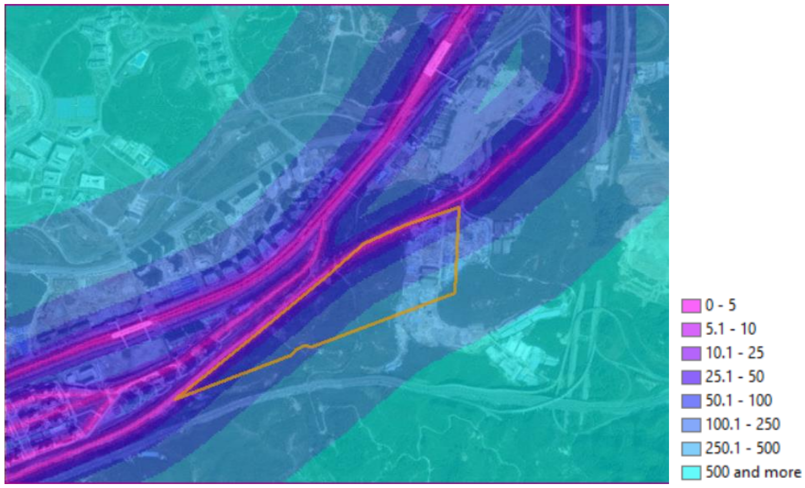


Figure 18, Euclidean distance to railroads on the ground, source: author

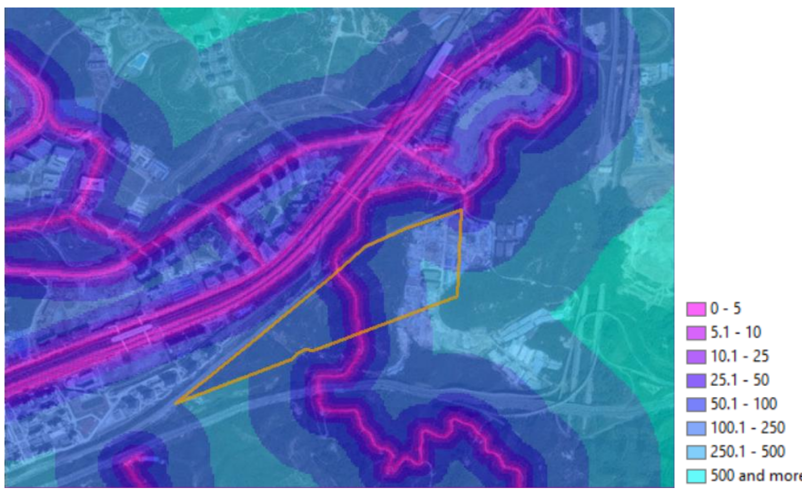


Figure 19, Euclidean distance to local roads, source: author

Figure 20, Euclidean distance to highways, source: author

Waterways

The site is closed to the Dasha River and the Changlingpi reservoir. A canal in the site which separates the hilly and flat area links to the Dasha river. It is notable that this canal is not consistent with the flow accumulated area. Future research and design can concern about the water flow between the current canal and the theoretical accumulated area

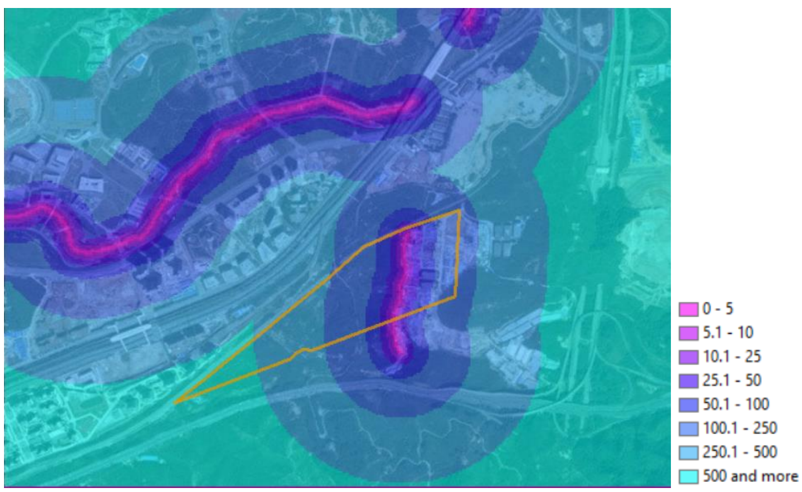


Figure 21, Euclidean distance to existing waterways, source: author

Flooding

Figure 22 shows the flooding potential of the site. The flooding index is a weighted index involving accumulation area, slope, and elevation. The result shows that most of the flat area of the site has a high potential for flooding. This finding provides a solid argument for the constraining model of group B which taking stormwater management as the second ranking issue. However, the result also shows that some location Group B selects has high flooding potential. Group B needs to further clarify or to develop their design strategy for addressing the issue.

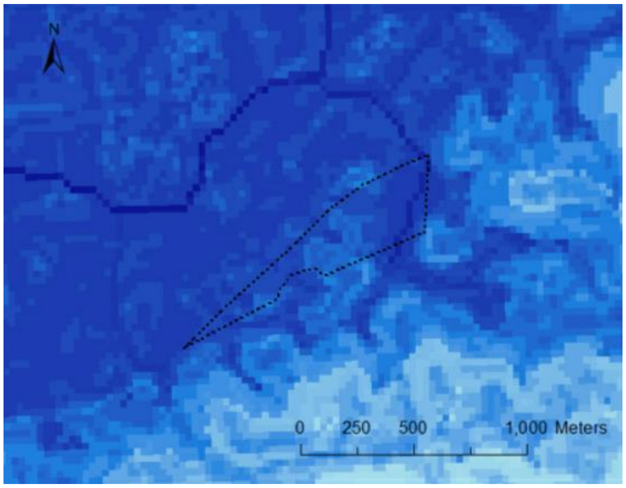


Figure 22, flooding potential in the site, deeper color shows higher flooding hazard, source: 2018 Shenzhen campus workshop, by Duoduo Lin

Viewshed

The viewshed study shows the areas that can see the mountain and the areas that can see the highway on the site. It helps the designers to understand the opportunity of the mountain and the challenge of the highway in terms of viewing in the site.

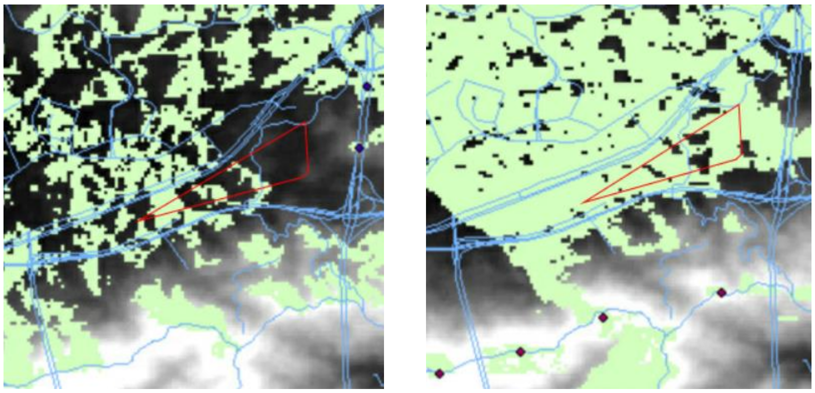


Figure 23, viewshed analysis, the left images shows the area can see the highway, and right images show area can see the peak of the mountains to the south of the site; source: author

Summary

The site is complicated, with the interval between flat and hilly area, the juxtaposition of concrete site and orchard, and the "convergence" of highway and railway. Instead of generating developable and undevelopable area for the site like Ian McHarg, the research outcome is presented to the designers directly, because the goal of this basic Geospatial analysis is to demonstrate the current condition rather than to limit the possibility of design. Since the site is complicated, the designers are forced to develop spatial strategies to mitigate, adapt, or overcome the status quo. The complexity can become opportunities.

2) Introduction to the Parametric Model

The geodesign framework of the Shenzhen Campus workshop introduces a new model—the parametric model. The goal of this model is to generate multiple choices for the design model to enhance the performance of the design outcome in the assessment model. The parametric model is based on the platform of Rhino and Grasshopper. In the algorithm, the multiple choices can be produced with the input of prototype scheme and the rules of variables. The research team develops a spreadsheet for the design groups to control their variables (Shenzhen Campus Workshop, 2018). The spreadsheet is shown below. Building typology, building density, building size, FAR, building programming, allowable ranges, and other factors are involved in the spreadsheet. The parameters in the spreadsheet form the rules to control the variable, and the multiple schemes are generated based on those rules.

Building Type	Number	fAR_ratio	Length Min	Length Max	Width Min	Width Max	Height Min	Height Max	Separation Min	Separation Max	Color
1	1	1	20	40	30	38	39	42	20	80	
2	1	1	55	65	12	15	39	42	20	80	
3	1	1	40	45	20	25	39	42	20	80	
4	1	1	25	40	30	35	19	22	20	80	
5	1	1	65	70	10	15	29	32	20	80	
6	1	1	180	185	10	20	29	32	20	80	
7	1	1	85	80	20	30	29	32	20	80	
8	1	1	35	40	12	15	19	22	20	80	
9	1	1	60	66	12	15	19	22	20	80	
10	1	1	40	45	20	35	19	22	20	80	
11	1	1	50	55	20	25	39	42	20	80	
12	1	1	45	50	12	15	39	42	20	80	

Table 1, the input of parametric model, source: 2018 Shenzhen campus workshop

7. Modifying and Extending the Geodesign Framework I

1) Integration with Geospatial Analysis

The geospatial analysis is the basic study in the geodesign framework. Most of the analysis, such as the slope and the flooding potential, belong to the evaluation models—evaluating the existing condition for the following change models, while some of the analysis belongs to the representation model, such as the landcover, and the distance to different elements. The basic GIS analysis assists the designers to understand the site and offers reasons for their design in the change models. For example, Group A and C discover that the landform of the site might be a strong factor dominating the design, so Group A develops strategies to utilize the topography and Group C overlay their mega-structure according to the hills. In addition, the further geospatial analysis belongs to the assessment model to examine the outcome of the change models. For example, the combination of flow accumulation, slope, and elevation demonstrates can help B to demonstrate why they put land adaptability and stormwater manage as the two most important problems in their constraining model. Therefore, in the representation and evaluation models the GIS analysis helps the designers to understand the site better, and in the assessment model, the analysis questions or supports the outcome of the change model.

Basic geospatial analysis is necessary for the campus design, but it is not enough in such a scale. The most obvious problem is the accuracy of the data. The resolution of the DEM data for most of the raster analysis is 30 meters. For large scale design and geospatial research, 30-meter DEM is capable enough but not for the small-scale site like the Shenzhen Campus. Because of the relatively low resolution, some analysis fails to provide preferable and accurate result for the designers to allocate their design component. Moreover, the shape of the hill is also too rough for locating building which has different types of interaction with the hill.

A more important issue is the role of the Geospatial analysis. In the traditional geodesign model and the even older Ian McHarg way of overlapping map, the GIS study are more likely to provide design guideline for the change model by making rules on developing the land in the large-scale design. For the large-scale projects, this role of traditional geospatial analysis is reasonable because this way of design can effectively influence the whole urban system to achieve the environmental and ecological goals. In some cases of the small-scale project, this role is still effective based on the change model they apply. In the workshop, the interaction between geospatial analysis and change model is most intensive in Group B, then followed by Group A, and Group C has the least intensive interaction. Table 2 indicates the analysis intervening the design of different groups. Since Group B is applying a constraining model, they need the analysis to demonstrate the feasibility of their ranking and to address the problems they identify. The role of traditional geospatial analysis in this model is consistent with the general condition of geodesign. In the anticipatory and participatory models, however, since the elements of the design include aspects which are beyond what the traditional geospatial techniques that can measure or evaluate, there is a gap between the design in the change model and the research in the evaluation and impact models. In the case of Group C, the mega-structure they develop to address the issues such as hydrology and green space in an architectural way which is different from the approaches guided by the geospatial indicators and goes beyond what the traditional geospatial analysis can cover. Therefore, there is a mismatch in the collaboration between the change model and the other models. In some situations, the role of "rule maker" of traditional geospatial analysis might be not enough for supporting the future scenarios in the change model. In the case of Group B, the group needs to integrate the geospatial analysis of the landscape to start their "playground" scenario. However, in this case, the design needs to leverage the topography for forming the future scenario of "playground", which means the design may transfer some of the characteristics of the land which is considered as the challenge in spatial analysis into an identity or advantage. Thus, the comprehensive weighted index method in the traditional geospatial analysis is not suitable and might even be inconsistent with the requirements in the design. The role of traditional geospatial analysis should change, and the geodesign framework should introduce new techniques into the evaluation and impact models.

	elevation	*slope*	*landcover*	*flow accumulation*	*flooding potential*	*distance*	*viewshed*
a	√	√	√			√	
b	√	√	√	√		√	
c	√		√		√		

Table 2, GIS analysis used by each design group

2) The Feedback and Discussion of the Parametric Model

The aim of the parametric model in the new geodesign model is to provide more choices of the morphology and combination of design in the uniform design language or design constant. The parameter provided by the design team can be considered as variables of design language, such as building typology, FAR, building positions, of the parametric design. The schemes provided can one the one hand reserve the characteristics of the original scheme, and on the other hand, develop hundreds of choices which may be time wasted without the help of the parametric model.

This model succeeds in the Disney project (Yang, et al., 2018). In the project, the parametric model develops different adjustments of building typology and numerous combination incorporating building and open space in a constant street network. The parametric model can provide choices on different levels. For example, in the block level, it generates different schemes with the different position of public open space in the block and placement of different building typology in the same FAR. In the neighborhood level, the model generates choices of massing distribution—homogeneous, centralized, or acentric. The designer can improve the change model based on these schemes, while the assessment model can examine these schemes and develop strategies for enhancing the performance of the design. Therefore, the introduction of the parametric design can extend the capability of assessment model in urban ecological design, compared to the simple research-summary-guidance model.

However, the Disney project is a neighborhood scale project, and the platform of parametric model in the project is a 1 km2 square. The size of Shenzhen campus is only about 15% of that parametric planform. The integration between the parametric model and the proposal of different teams varies. The attitude of designers towards the parametric model different. For Group A and B, the designers hold a relatively subjectively attitude and provide the required parameters to the research group, because their designs have a clear differentiation between different components. It is easy for these two groups to develop a set of parameters. For Group C however, the designers are confused by the parametric model. The foundation of their design is a gridiron mega-structure. The building, the open space, and the circulation network are all developed based on the mega-structure and the topography. However, the setting of parametric focuses more on the factors in neighborhood scale urban design, such as FAR, building typology, building placement, so it is not a mega-structure-specific parametric model. The relationship between the parametric model and the design logic is not essential. Therefore, the designers in Group A does not consider that the application of parametric design can effectively enhance their design. To set up the general parameters, the designers prefer that the parametric design can concentrate on developing the possibility of their mega-structure.

The feedback of the design groups reflects the issue of scale, change models, and integration mode of the change model and the parametric model in a small-scale urban design project. The original setting of the parametric model is either neighborhood-scale oriented, like the case of Disney project, or architectural, like those of Zaha Hadid. Hence, it considers little about the design logic which may be important in a smaller scale urban design project. Moreover, unlike the community level, the condition of the campus project might also be different depending on the design concepts and the change models. Group B applies a constraining change model, which develops the spatial structure firstly based on the research of critical issue. Therefore, once there is a solution for the critical issue, the parametric model is able to analyze and address other issues, such as building typology and open space position. Even in the smaller scale, the parametric model and the constraining model are more compatible. On the contrary, Group C applies the participatory model with two strong concepts. The two concepts generate a specific mega-structure, and the system of the whole campus is developed based on that structure. All the factors in the parametric models are dominated by the mega-structure, so the original parametric model has less room for modifying the design effectively. The condition of Group A is more complicated. They apply an anticipatory model and attempt to introduce landscape urbanism into the "playground" concept. However, in their decentralized project, the integration between massing and landscape is not compact. The design is more closed to a typical Chinese campus archetype. As a result, the room for parametric design in their schemes is large, but once they incorporate more landscape urbanism concept and factors into their design, the situation might be more similar to that of Group C.

Therefore, the integrations between parametric model and change models perform differently. Sometimes the parametric model and the change model is not compatible—the parametric model, but it does not mean that parametric model is not suitable for specific change model. Several suggestions are provided in the next section.

3) Modification for Iteration One

There are two recommendations for the current integration between design and science and between the change models and other models: acting a new role and specifying.

According to the study of the integration between analysis and design in this section, the geodesign framework needs to reconsider the role of traditional geospatial analysis in the small-scale project based on the type of change model. For the issue-driven models like constraining model or combinatorial model, the traditional GIS analysis is still appropriate for problem definition and outcome assessment. For the models with certain future, there might be a requirement to change the role of traditional geospatial analysis from rule-making to objectively informing or optionally instructing. In the small-scale project, since the gap between traditional geospatial analysis and the design approaches and outcomes in the change models with future certainty, the guidance produced by the analysis, such as the comprehensive weighted index, is not able to cover the requirements from the change models and is not the only factor that dominates the solutions for the requirement in the change models. As the participation of new techniques, the traditional geospatial analysis can objectively inform the designers in the change models or provide options based on the understanding of the profession to instead of dominating them. The initiative is in the change models for accepting and implementing the information and the options based on their future scenario. The second recommendation is specifying the techniques. For GIS, more analysis can be developed based on the requirement of the design concepts in each design. For instance, a vegetation analysis might help Group A to understand the landscape on the site, while Group B might need a soil analysis to further study the land adaptability. The analysis can also be specified to adopt the change models. For example, the analysis of problem definition can help Group B to further ranking the problems after the most important two in the constraining model.

In the small-scale urban design project, it is necessary to introduce new techniques into the geodesign framework. The new techniques also need to be specified. In the case, the parametric model introduced from the neighborhood scale urban design should be specified in the smaller scale urban design project. Generally, the change models with a clear future scenario will need a more specific parametric model than the change models with more uncertainty. Because of the specificity in design approaches, the consideration of general urban design factors might be not enough for generating multiple parametric outcomes for project modification. The parametric model should set up develop more variables and new rules for each scheme. Nevertheless, the review of the integration between parametric model and change models are based on the feedback of the designers and the induction of the parametric method. The result of the parametric model is not generated yet. Chapter 9 will include the further analysis of the collaboration.

8. Designs in the Iteration Two

After being informed by the research group and the review of the instructors, the three design groups create the second iteration design proposal. This section will introduce their schemes briefly and point out the improvement by integrating with the research in the first iteration and the further application of the change model..

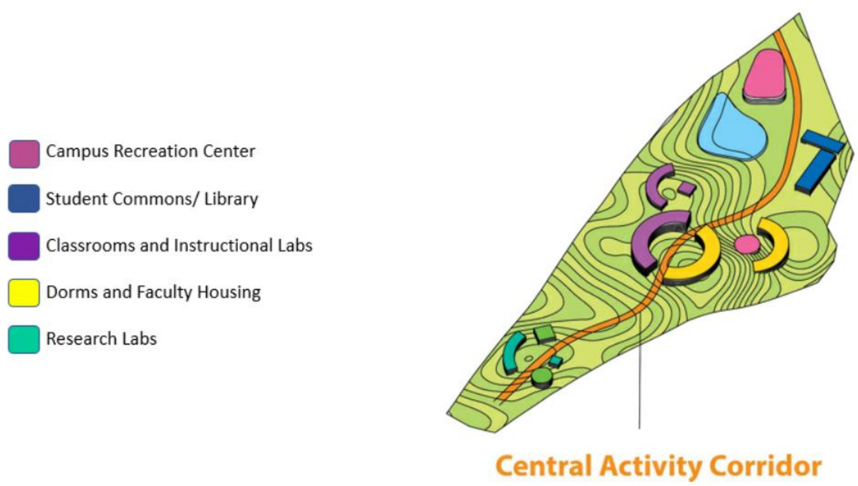


Figure 24, 2nd iteration design of Group A, source: 2018 Shenzhen campus workshop

Group A continues the anticipatory model. They change their design thoroughly but keep the concept of “playground”. Based on the studying of the topology and the landscape of the site, they re-organize the programming according to their design logic. Moreover, they introduce a single primary pathway to connect all the facilities in the campus, while the relationship between building and open space changes along the pathway: large institutional building with plazas, hilly open space, waterfront open space, building plugging in the hills, courtyards, scattering buildings in the forest. Compared to the design in the first iteration, this design allows more diversity of physical space and activities: the enclosed space for promoting the interaction of different groups of users; tranquil and relatively isolated environment for research; and different types of open space for recreation. Therefore, this proposal has a clear answer for the goal of stimulating learning environment. In this design, the designers leverage the topology to create diverse spaces and transfer some of the challenges into advantages. It reflects the perspective mentioned in the last chapter: in the smaller-scale project, GIS analysis and other analysis should not just set up limitation for the design, and the collaboration between research and design should be more resilient based on the specific situation of each case. This case shows the condition that in the geodesign change model, the designer moves back to the prior step in the process of requirements because of new information with the integration of the research.

Figure 25, 2nd iteration design of Group A, source: 2018 Shenzhen campus workshop

Since Group B applies a quasi-constraining change model in the first iteration, and, in this phase, they rank the other issues and form a constraining model. An explicit sequence of issue addressing is seen in their presentation. Firstly, for the land adaptability, they reselect the developable area in the site by referring the GIS flooding potential analysis. They develop a strategy to address the flooding challenge: Aside from site selection, the design group develops a water system including two waterways and two small reservoirs in the high flooding potential area. They rank the traffic circulation as the third issue, so they design a curvy circulation system to avoid the potential flooding area and to be consistent with the first and second issues. Similarly, the landscape issue, which is ranked in the fourth, are developed to serve the first and second issues after designing circulation. However, although they integrate with the research outcome and produce a water management system, this system is not comprehensive enough for addressing the critical problem in the change model, because there is building level strategy which they consider as the least important. Currently, the solutions of the low rakings are serving the high rankings. This situation can help to further address the high-ranking issues but may cause the ignorance of the low-ranking issues per se.

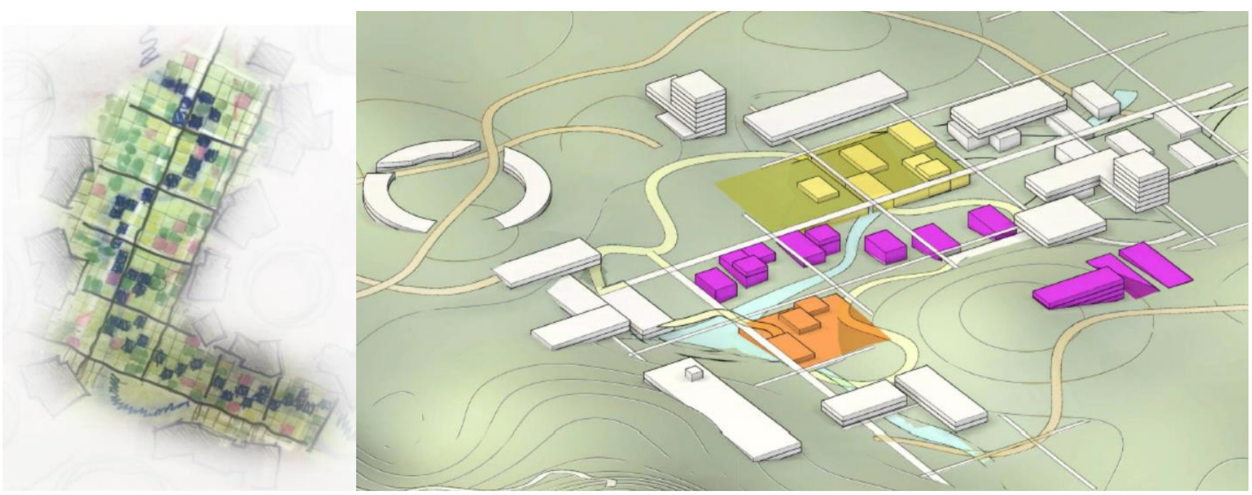


Figure 26, 2nd iteration design of Group A, source: 2018 Shenzhen campus workshop

Group C specifies their design developed from the participatory model to fit the condition of the site and the requirement of the project. In this phase, they introduce a new change mode for further design—the sequential model. They maintain the gridiron comprehensive mega-structure and the distribution of large massing which they develop from the participatory model. After that, they introduce a sequential model—making a series of confident choices that systematically develop into the future design (Steinitz, 2012). They integrate a water system under the mega-structure to form a double-layered system. For the traffic circulation, they introduce an internal circle and incorporate the existing road to form an external circle. With the gridiron mega-structure and the double circles, the two layers in the circulation system increase the connectivity of the design. For the programming, they change the design of the buildings on the perimeter of the mega-structure based on the functions of each building: education, student commons, student services, and recreation. With the application of the participatory and the sequential model, the scheme forms a comprehensive system to achieve the goal of stimulating learning environment and reserve the chance to be net zero. However, compared with Group A and B, although the Group C has the most mature design, the collaboration between the progress and the research outcome is the least intensive. The two design concepts are powerful, and the designer can improve their design based on their experience and the concepts in the later sequential model, while the traditional Geospatial analysis plays a less important role in the design process, the process of requirements in the geodesign change models. Therefore, the research needs to incorporate more tools and more topics to meet the requirement of the design. Some of the preferred analysis will be implemented in the research in the second iteration.

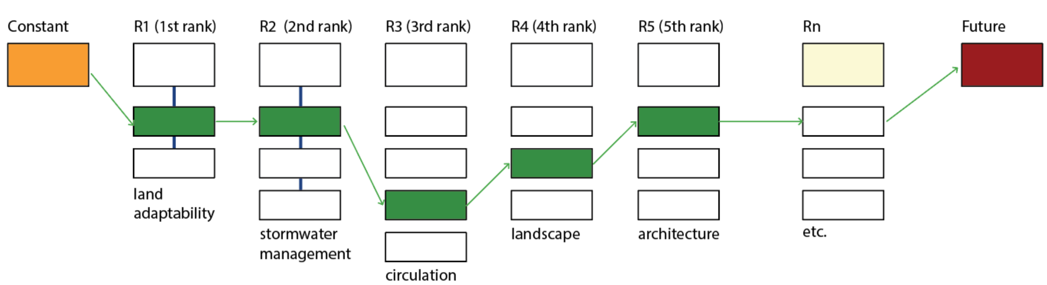


Figure 27, the anticipatory change model of Group A

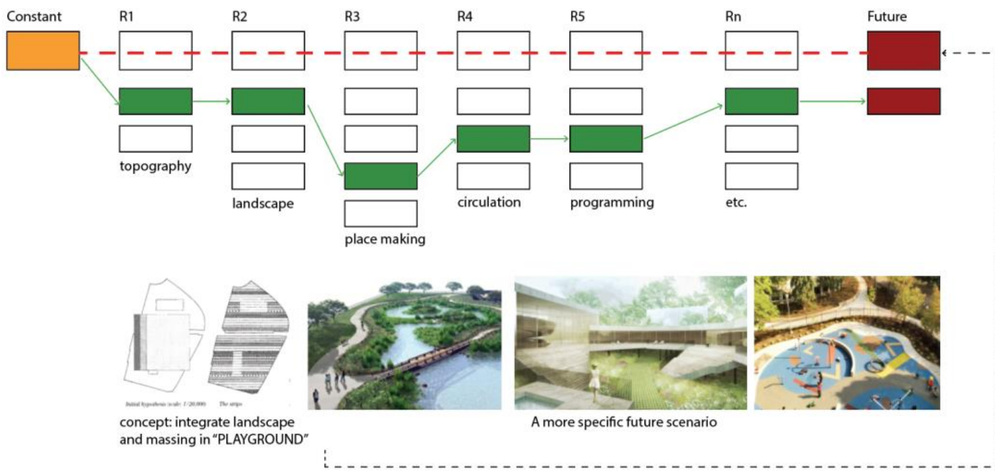


Figure 28, the constraining change model of Group B

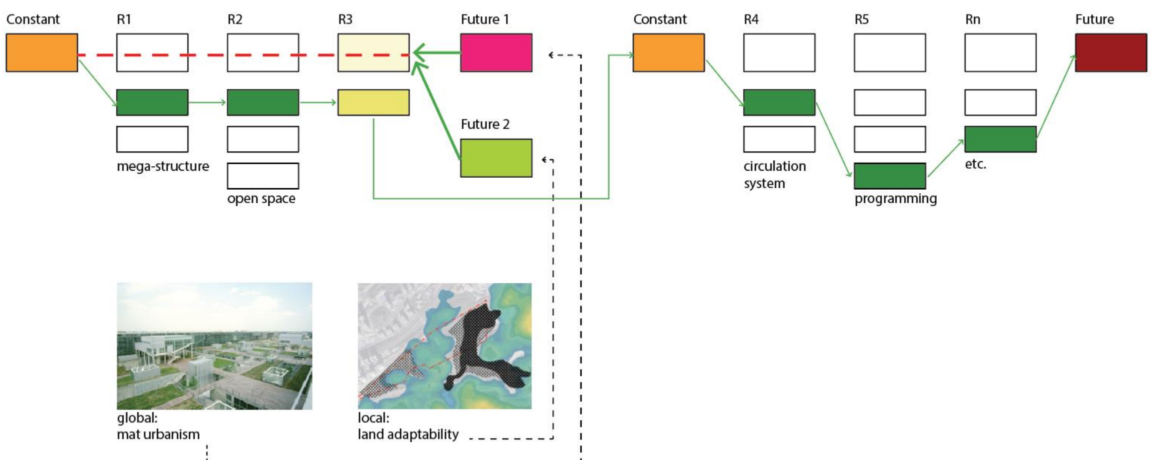


Figure 29, the mixed (participatory and sequential) change model of Group C

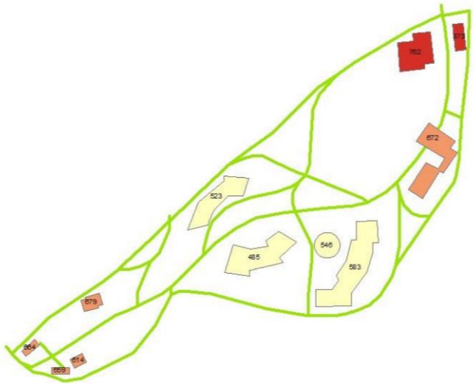
9. Research in the Impact and Parametric Models

Compare to the research in the first iteration, the research in the second iteration focuses on studying the outcome of the research groups. In other words, the research changes the concerns from the evaluation models to the impact model in the geodesign framework. The GIS analysis mainly includes the network analysis and path selection that evaluate and compare the accessibility and efficiency of networks in the design proposals. Moreover, there are techniques discipline in the second iteration—the result of parametric modeling will be discussed, and the energy modeling for the building typology included in the design proposal will be presented. Finally, this section will discuss the further improvement of the application of the new techniques.

1) Geospatial Analysis in Impact Model

The network analysis is generated from the OD matrix tools in Arc GIS. Because the network includes multimodal traffic, the measurement of accessibility is in meter. The value of the building shown in Figures 30-35 is the average distance from the building to the selected destinations. There are two types of average distance: Figures 30, 32, and 34 show the average distance of each building to every other building, while Figures 31, 33, and 35 indicate the inter-relationship between the public buildings (classrooms, libraries, or labs) and the dormitories. The value of the public buildings is the average distance from the building to every dormitory, and vice versa. The first type of average distance shows a common property of the network, and the second type indicates more substantial meanings— in campus design, the designers concern mostly about the connections between the dormitory and the public buildings, or between the living area and the educational area.

The site boundary of Group A and B is similar, so the result is more comparable. The maximum distances between public buildings and dormitories of these two networks are similar, around 900 meters, but the values of each building are different: the value of A is lower than that of B; moreover, the buildings in the northeast corner of A generate the highest value, while the highest value of B occurs in the southwest corner. The network analysis shows the difference of the topology of these two networks. Since the site boundary of C differentiates with A and B, the result is less comparable. The gridiron pattern in the mega-structure and the overlapping loop together results in a more compact connection. For the integration, the designers need to consider whether the real performance of the network is consistent with their intention and to conceive adjustment based on the analysis result. The detail of the integration will be discussed in the next chapter.



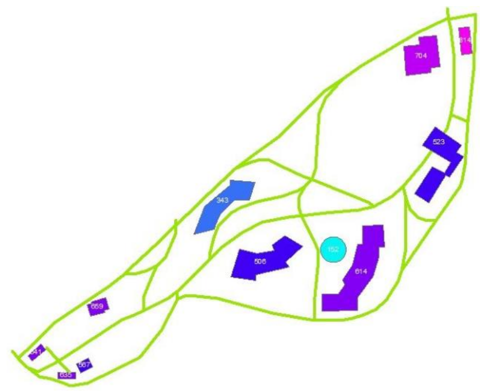
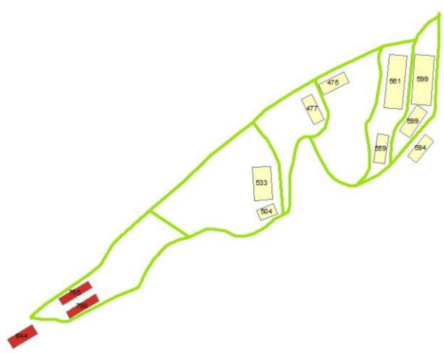


Figure 30 (left), average distance of each building to every other building for A, source: author
Figure 31 (right), average distance between public buildings and the dormitory for A, source: author



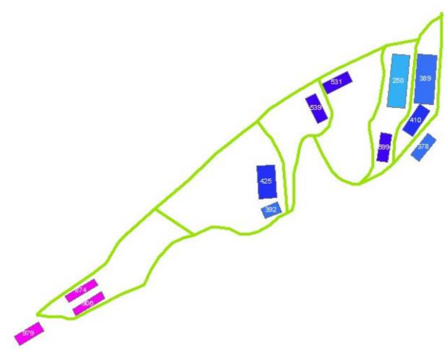


Figure 32 (left), average distance of each building to every other building for B; source: author
Figure 33 (right), average distance between public buildings and the dormitory for B; source: author

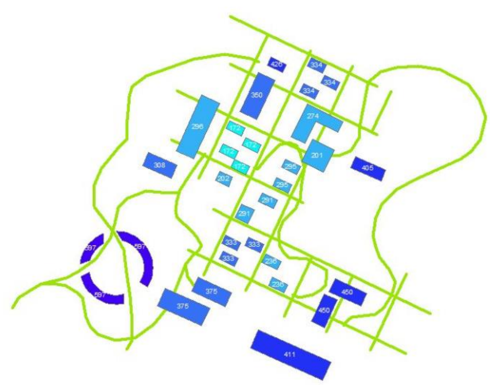


Figure 34 (left), average distance of each building to every other building for C; source: author
Figure 35 (right), average distance between public buildings and the dormitory for C; source: author

The network analysis considers the Euclidean distance instead of the real distance, but the landform of the site is complicated. The path selection in the next part will discuss the influence of the topography as a supplement of the network analysis for evaluating the networks.

The cost path analysis calculates the lowest "cost" trail between two points. In the model, distance and slope are the two factors that affect the generation of the trail. The lower cost means that the path is shorter and has less variation in topography. The points are the centroids of each massing zone in the design schemes. The model focuses on calculating the connection between the dormitory areas and the educational areas. This analysis can evaluate the design network consideration the elevation of the site as the supplement of the network analysis. According to the result, the network A can reduce the cost with a slight adjustment without large changing. The situation of C is similar, and the only questionable connection is the one between the library and the dormitories. However, the result highly questions the loop circulation of Group B. Again, it shows the problem that in the constraining model, the group design the loop for land preservation and stormwater management, but it is weak at addressing the issue per se.

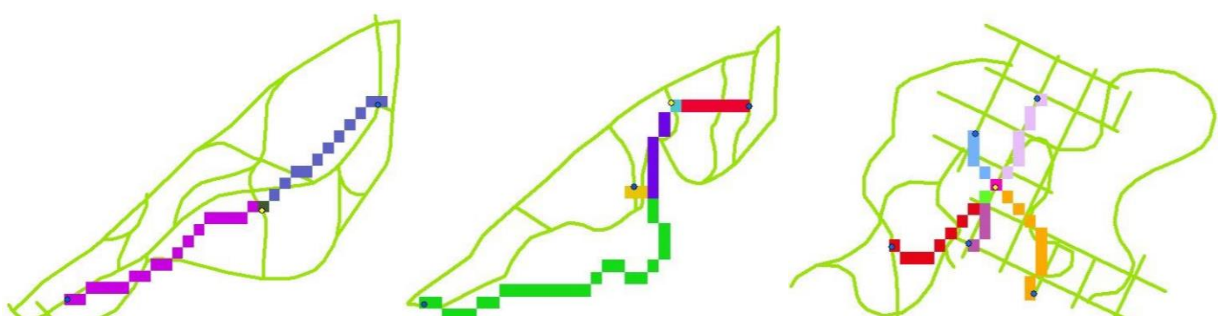


Figure 36, from left to right, the path of lowest cost between the centroids of dormity area and public buildings for A, B, and C, source: author

2) The Result of Parametric Model

According to the feedback of the design group, the researcher adjusts and specifies the parametric model to adapt the property of each design instead of applying a general study for all three groups. Group A proposes a decentralized layout, so the research goals for this group is to generate variants of different combinations of decentralization in a constant total FAR and GFA for each programming. However, because currently there is not a specific logic of decentralization, the results of the parametric study are randomly distributed in form and function-mixture. For a more instructional outcome, the designer should provide a clear logic system for the parametric model about how does the massing decentralized, and how the landscape interacts with the massing.

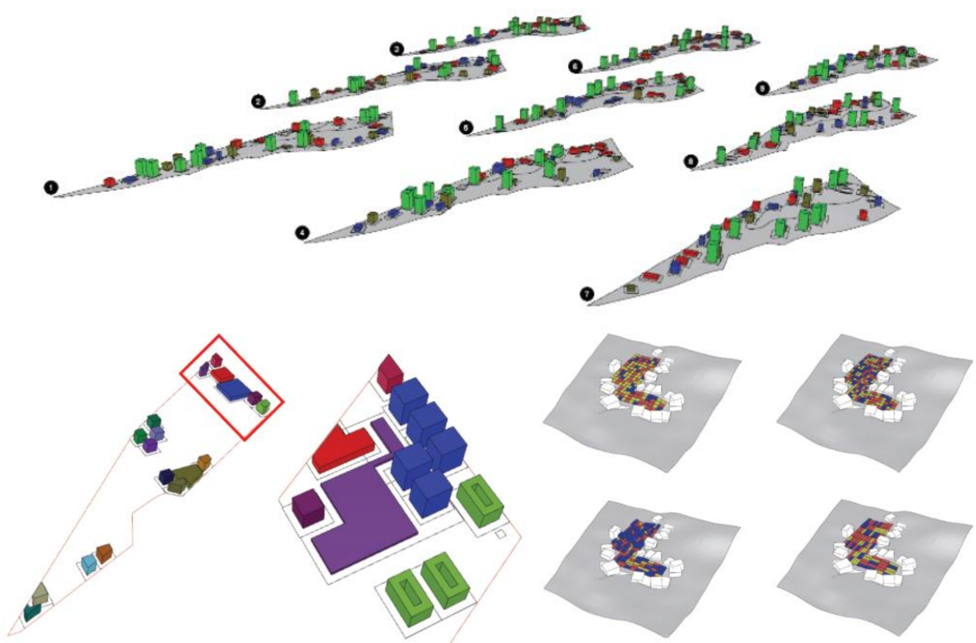


Figure 37, top: the selected result of A, bottom left: B, bottom right: C, source 2018 GT Shenzhen Campus workshop, produced by Nirvik Saha

On the contrary of Group A, Group B has a clear logic in massing distribution since they apply the constraining model and consider land adaptability as the prior issue. As what has been mentioned before, the group ranks building as the last important issue and the solution is not powerful and detailed enough in their proposal. The parametric model is helpful to address this problem because the model can provide multiple combinations of building combination in each developable area. The combination can help the designers to develop the urban form of the campus. The bottom left of Figure 37 indicates that the parametric model generates three kinds of urban forms: cubes, courtyards, and mixed.

For Group C, the designers concern more about the possibility of the mega-structure instead of the whole urban form. Therefore, the parametric model focuses on the grid in the structure instead of all the buildings. The results vary the dimensions, the sizes, the density, and the FAR of the grid to provide choices to the designer. For the designers, the results are helpful for further develop their sequential model, while for the impact model, the results can provide multiple samples to examine the possibility of performance of mega-structure.

The parametric model successfully transfers from general to specific and fit the requirements of different change models in the workshop. However, the deeper and more useful integration requires the introduction of detailed design logic to the parametric model. The energy consumption modeling in the next section may be an approach to address this issue.

3) Energy Consumption Modeling

The research of energy performance is important for the net-zero goal of the project. The energy consumption modeling in this chapter is the initial for achieving the goal. The study will focus on the energy consumption of each building typology. The goal of the study is not to figure out the "best" building typology and to confine the designers by choosing building types. Instead, the goal is to search ways for the designer to improve the energy performance of their urban form without intervening the design concepts. Therefore, the vertical comparison between the variants of each building type should be applied aside from the horizontal comparison between each building type. Moreover, there is a preliminary association between the energy modeling and the change model: the building typology included in the modeling is summarized from the three design schemes provided by the change models. They are the simplified or normalized version of the building which exists in the schemes.

The study assigns three categories: large public building, small public building, and dormitory, which are the three most common types in campus design: library, public classroom, student commons as large public buildings, and faculty classroom, labs, offices as small public buildings. In the simulation, for studying the building typology, all the buildings share the same value in other variables which are required in the energy modeling: material, power of the machine, infiltration rate, the target temperature for air conditioning, weather data (EPW file), and window placement (placing in all facades in 40%). There are two schedules: public schedule for all the public buildings and residential schedule for dormitory. In addition, the lighting and equipment requirements for all the public buildings are the same, and so are the dormitory. It is notable that the energy consumption includes the lighting, equipment, and cooling. Heating is not contained in the modeling for climate reason. The simulation controls a constant gross floor area or both gross floor and ground floor area in each category. The study assigns the constant area based on the general condition in Chines campus buildings.

For the large public building, there are five types: rectangle, courtyard, U-shape, L-shape tower-podium, and setback. The ground floor area and the gross floor area are constant within each typology separately in 2400m2 and 9600 m2. For rectangle, courtyard, U-shape, the buildings are all 4 floors, while for the L-shape and setback, the number of floors in a building varies from 2 to 6. For small public building, the gross floor area of the two typologies small box and small tower are the same in 2400m2, but the ground floor area of small box is 600 and small tower is 300, which means that small box is 4 floors and small tower is 8 floors. For the dormitory, there are slabs, rectangle (D), courtyard (D), and cross. The first three share the same ground floor area in 1000 and gross floor area in 8000, and the cross, a tower typology, has a same gross floor area in 8000, but the ground floor area is the half in 500.

The study changes the building typology in three ways for vertical comparison in three types of variant: aggregation—the massing of the building typology is more closed to the centroid; decentralization—the massing is more evenly distributed; and angle—to rotate the origins clockwise 23 degrees, which is consistent to the main orientation of the building in Group C's design. Hence, there are two comparisons: comparing the origins, the aggregations, and the decentralizations; and comparing the origins and the angles.

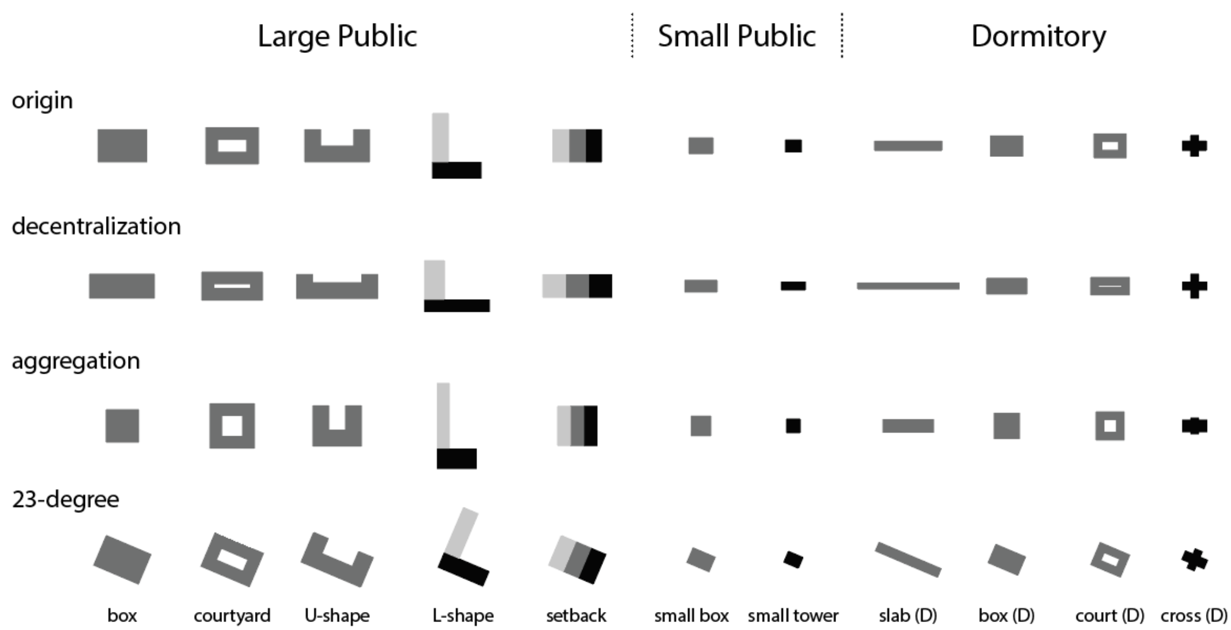


Figure 38, building typology and variation for energy modeling, source: author

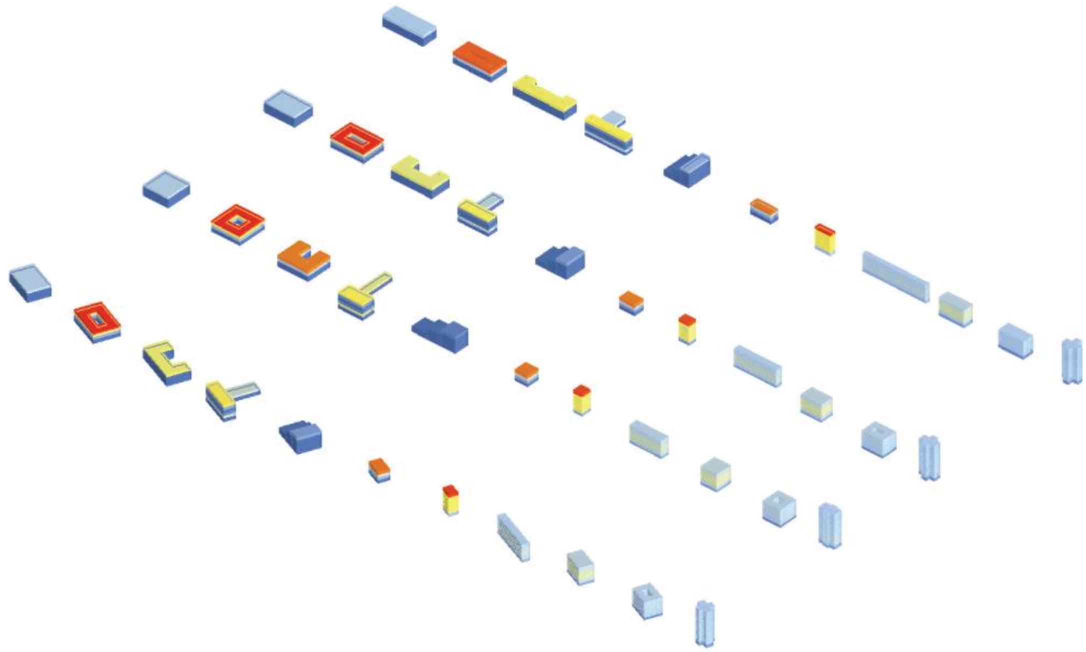


Figure 39, visualized energy modeling result, blue shows low energy consumption per square meter, yellow shows median energy consumption, and red shows high energy consumption, source: author

Although the result is not calibrated, the results of building in the same schedule are comparable. According to the results, the variations (up to 40%) of large public building is larger than those of small public building (up to 1%) and dormitory (up to 5%), though the geometric patterns of variants in large public and dormitory are similar. For the large public building, the rectangle and setback consume the least energy, and the courtyard consumes the most. The difference between each variant is smaller (up to 6%) than the difference between each typology. Surprisingly, the energy performance of variants is not unidirectional—for rectangle, setback, and courtyard, the decentralization performs better; but for the other two types, the origin is better. The 23-degree change slightly increases the energy consumption about 1-2%. For the small public building, even though the area of each floor is 50% smaller in small tower, the energy consumption is similar between small box and small tower. For the dormitory, the performance is unidirectional—all the decentralized variants perform better. In this category, the 23 degrees angle slightly reduce the energy consumption except for the cross tower, which is different from the condition of the large public buildings. Similar to the small public building, the decrease of areas in each floor has little impact on the performance. It is notable that the top floor of all the buildings consumes at least 20% more energy than the other floors in the same building. Therefore, a roof strategy is necessary for reducing the energy in the building design stage. The details of the energy consumption modeling are presented in the table below:

Category		Larnge Public Building					Small Public Building		Dormitory			
Building Typology		box	court	U-shape	L-shape	setback	small box	small tower	dorm-slab	dorm-box	dorm-court	dorm-cross
orgin	length/width	60/40	65/45	80/40	60/20+60/20	60/40	30/20	20/15	83.3/12	40/25	40/30	30/26
	energy consumption	66.42895	88.47931	80.93217	92.50657	68.27871	98.94365	98.36696	81.47316	82.99035	79.92926	78.50333
decentralization	length/width	80/30	75/35	100/30	80/15+48/25	84.88/28.28	40/15	30/10	125/8	50/20	48/22	30/30
	energy consumption	66.97953	93.45401	79.50626	91.8311964	68.14234	97.90254	96.39539	81.9993	83.22597	80.55521	79.17013
aggregation	length/width	48.9/48.9	55/55	60/50	48/25+80/15	48.9/48.9	24.5/24.5	17.32/17.32	62.5/16	31.62/31.62	35/35	30/20
	energy consumption	67.2353	95.45507	87.99313	93.0252634	67.62444	98.47441	97.03346	82.57074	83.34166	80.66178	81.04289
23-degree	length/width	60/40	65/45	80/40	60/20+60/20	60/40	30/20	20/15	83.3/12	40/25	40/30	30/26
	energy consumption	67.51788	94.08814	80.10399	92.7145079	68.46801	98.86992	97.58448	81.93157	83.13798	80.48567	79.22954
Ground Floor Area		2400	2400	2400	2400	2400	600	300	1000	1000	1000	500
Gross Floor Area		9600	9600	9600	9600	9600	2400	2400	8000	8000	8000	8000

Table 3, energy modeling result, source: author

The result indicates a complicated condition in the large public buildings: compared to small public and dormitory buildings, the differences between each typology are large, indicating that the rectangle and setback are prevailing over other types. For the vertical comparison, it is necessary to implement more study to analyze why the result is not unidirectional: for some types, the mediocre consumes even less energy than the extreme in both sides, but the result is helpful for the designer to adjust their building geometry in the most efficient way in terms of energy consumption if the building size are similar. The modification for different types of building varies. On the other hand, the condition in small public building is simple: since the variation between different types are small and the vertical comparison is unidirectional. The current outcome recommends the designer to decentralize their small public and dormitory building in any types. Moreover, the energy modeling demonstrates the angle for the design of Group C because the rotation has little influence on the energy consumption.

However, the energy modeling is in building level. Future study needs to extend the modeling to an urban level to study the overall performance of the campus. The simple aggregation of optimal building typology may not mean the optimal result of urban form. Moreover, the modeling only contains the consumption but neglects the production because solar energy production simulation mostly varies in the urban level which contains buildings in different heights. More importantly, the variants of each building type are generated manually by the author without a rigid control of the parameters of the geometry. A more profound research requires multiple variants with controlled parameters. The parametric model mentioned above can address this problem.

10. Modifying and Extending the Geodesign Framework II

Chapter 9 demonstrates how the research in the impact model and parametric model, and how they enhance the three designs. This section will illustrate the advantages and defects of these research. More importantly, this section will discuss the effect of the research on the geodesign framework and the possible way for improving the research to extend or specify the geodesign framework.

The network analysis in the impact model provides a quantitative outcome based on analyzing the network and the programming. On the other hand, the cost path analysis ignores the network and proposes lowest cost path based on the spatial feature of the massing. Therefore, the GIS analysis evaluates the design in both critical and instructional ways. With the data of programming and the schedule of the people in the campus, GIS can also model a quasi-dynamic traffic flow by tools in network analysis. The distance as an indicator of accessibility, the generation of a low-cost path, and the traffic flow which is absent in the research together form a comprehensive network assessment approach in the impact model. However, the tools in network analysis and cost path are designed for geography scale project. the mismatch of the scale of the tools makes the result of these research not accurate enough even the DEM model is precise—the research ignores some factors in the smaller scale each might affect the network, such as the placement of steps and escalators, the design of the sidewalks, and the interaction between indoor and outdoor. The research reflects a common problem in the current urban design—there are quantitative indicators, but they are staying at the fundamental level, while the indicators of the details and advanced factors are staying at the descriptive level. Moreover, the analysis focuses on the "optimized outcome" (the lowest distance, the lowest cost, etc.), but multiple "alternatives" may coexist simultaneously in a design. The research is less capable of studying the properties of the alternatives, compared to working on the optimized outcome. New techniques are preferred to address this issue.

The parametric model is a new section in the innovated geodesign framework. The parametric study in this research generates preliminary variants for the design. Therefore, the current model is not comprehensive enough for translating the design logic into parameters and providing the change model feedback. The advantage of the parametric design is obvious—it is easy to acquire thousands of results in a short time without manual operations. The model saves time for the geodesigners. However, without assigning a comprehensive design logic in the inputs, the results may be random rather than instructional to the design--the condition in Group A is a concrete example: the outcome is the variation of random decentralization. There are three ways to address this issue: the usual way can be seen in Group B: to assign a rigid the design logic, unless at the fundamental level. Because the designers apply the constraining model, the critical issues have been solved before the intervention of parametric model, and the parametric model can focus on the generating urban form in each area. The case of Group C shows the second approach: before the implementation of the parametric model, the designers provide feedback to the researcher for specifying the inputs based on the design strategies. Therefore, the researchers change the general model into a specific one for the design to produce an instructional result. The first method is suitable for change models that rank the problems and have more uncertainty in the physical design, such as constraining, combinatorial. The second approach is suitable for the change models with clear strategies in the physical environment or with a clear future scenario, such as participatory, anticipatory, and rule-based model.

The third way is to figure out a logic in new realms, such as to associate with the energy modeling. On the one hand, when the parametric model lacks enough information from the designers to develop a systematic logic, the logic of optimizing the energy performance can fill this blank. For example, the "decentralization" strategies identified from the energy modeling can be a logic to control the building dimensions in the parametric model. Even there is a clear logic like the case of Group C, the parametric model can also develop multiple options for the energy modeling to evaluate the performance. On the other hand, the variants of building form in the energy modeling are generated manually without a quantitative control of the parameters. Although the study can help to improve the energy performance of the design, the study is not efficient enough for developing the optimal scheme in each design concept or design logic. The manual control in the urban level is more different, especially in the campus project with less constant in the design. Therefore, the integration between energy modeling and parametric model is a win-win interaction. For the parametric model, the energy modeling in building level can help to develop another systematic logic besides the preference of the designers. The parametric model can help the energy modeling implement at the urban level to study the overall performance. More importantly, the parametric model can facilitate the association between energy modeling and spatial logic of each. The energy modeling, thus, can explore the optimal urban form of different spatial design logic instead of being circumscribed by the urban form prototype. In addition. The integration of parametric model and energy modeling can be applied in the study of energy production because the modeling of solar energy production is only instructional at the urban level with the combination of different building typology.

11. Conclusion

This chapter will first summarize the three change models in the two iterations and state the advantage and disadvantage of these change models to campus design project. Secondly, the modification and specification of the geodesign framework based on the three change models will be discussed. Thirdly, this chapter will discuss the limitation of this study.

There are three change models in the campus design workshop: the anticipatory model of Group A, the constraining model of Group B, and the mixed model of Group C with the anticipatory and sequential models. The constraining model is the model design with an uncertain future, while the other two models are designing with certainty. The former type of model has a more intensive association with the traditional geospatial analysis because the analysis can examine the rationality of the ranking to the problems, which are required in both constraining and combinatorial models, and can help designers to develop basic solutions for the prior problems. However, the geospatial analysis is less capable at place-making and building level, and this type of model focuses on high ranking issues, while the factors in the low-ranking issues might serve the high ranking and the low-ranking issues per se might be downplayed. For the latter type of model, the association with geospatial analysis is less intensive because of the intrinsic property of the change models and the design approaches in the smaller-scale project. Since the design might introduce elements and approaches which go beyond the measurement of traditional geospatial analysis and new techniques may participate into the geodesign framework, the geospatial analysis in the models in the assessment stage should be subjective informing or optionally instructing instead of rulemaking. Thus, the change models can have the initiative to integrate the information and options into their design on the foundation of their future scenario. In addition, the new technology introduces should be specified to suit the change models as well. Moreover, In the impact model, the geodesign framework needs to specify the contains or to develop a specified metric juxtaposing with the change model to fulfill the requirement of the campus project. There are three iterations in the geodesign framework (not the Shenzhen workshop), the second iteration is in an opposite sequence to figure out how to study the question. The specified evaluation model can be developed in this iteration and applied in the third iteration.

These modification helps the geospatial analysis to be more appropriate for the campus design project. However, the intrinsic property limits geospatial analysis to intervene at the small-scale level. Moreover, geodesign is not simply GIS plus design, and this platform is capable to contain new techniques. This paper studies the parametric analysis as a new model and the energy simulation in the impact model for the outcome of the change model. The parametric model is introduced from the community level or city level urban design project. Similar to the geospatial analysis, the model should be specified based on the design elements and design concepts in the change models. The model should not be confined by the general urban design components such as streets, blocks, open spaces, FAR, building typology in the large-scale urban design project because the factors in campus design are more heterogeneous by case. Moreover, the parametric model requires systematic design logic as input to generate meaningful results. The design logic at campus level is more difficult to summarized than in urban level.

The energy modeling is a capable way to examine the energy performance of the campus design with the goal of net-zero energy balance. However, only staying in the impact model circumscribes the ability of the energy modeling to optimize the energy performance since the variants are not enough. Facing the requirement of the parametric design and the potential of the energy simulation, a thorough interaction between the two is a beneficial way to address the issues in both sides by providing design logic for the parametric model and generating plural results for energy modeling. Therefore, for the net-zero campus design, the paper proposes to integrate the energy modeling into the parametric model. The overall modification is shown in the figure below.

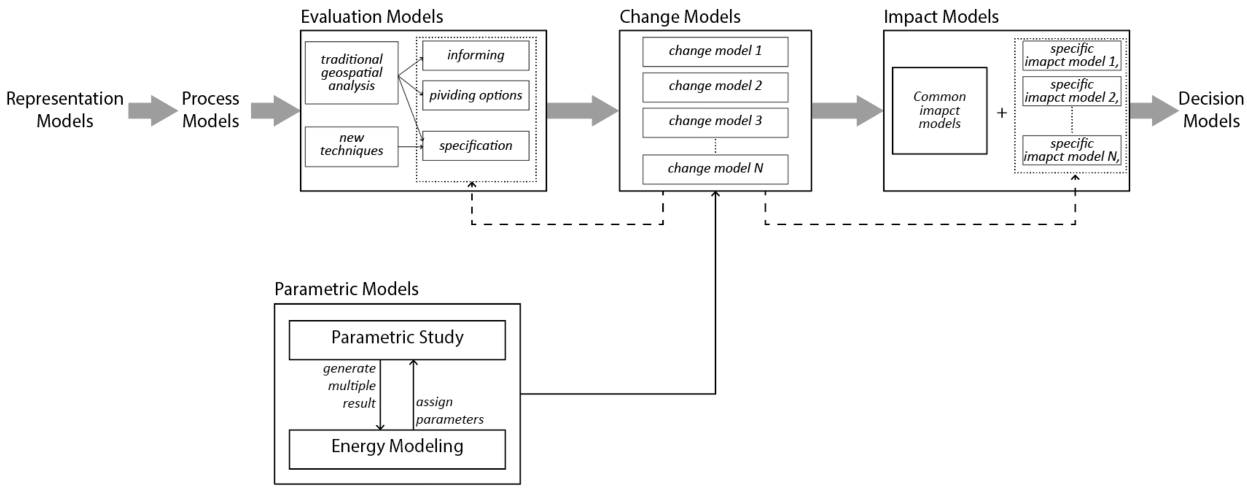


Figure 40, the modification and extension of geodesign framework for campus design project

Finally, the study and the outcome in this paper is only a small part of extending and modifying the geodesign framework in the small-scale campus design project. The workshop studied by the paper is not a whole three iteration geodesign framework, and this paper mostly focuses on the change models and the relationship between the change models and the assessment stage and the impact models. The feedback of the stakeholder and the research on the decision models are ignored in the study. Thus, this is a remaining area for the future research for modifying the geodesign framework. Moreover, because of the limitation of the data and the techniques, only a few techniques are introduced into the geodesign framework. In the future, the study can introduce more tools and data to enrich the contains the geodesign framework for net-zero campus.

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References

Artz, M., 2010. New Concept or New Name. *Geospatial Today,* Volume January, pp. 34-35.

Batty, M., 2007. *Planning support systems: progress, predictions, and speculations on the shape of things to come.* s.l.:s.n.

Batty, M., 2013. Defining geodesign (= GIS plus design?). *Environment and Planning B: Planning and Design,* Volume 40, pp. 1-2.

Campagna, M., 2014. The geographic turn in Social Media: opportunities for spatial planning and Geodesign. *International Conference on Computational Science and Its Applications,* Volume June, pp. 598-610.

Dangermond, J., 2010. *Geodesign and GIS–designing our futures.* Anhalt University of Applied Science, Germany, Peer Reviewed Proceedings of Digital Landscape Architecture.

Ervin, S. M., 2016. Technology in geodesign. *Landscape and Urban Planning,* Volume 156, pp. 12-16.

Fisher, T., Orland, B., Perkl, R. & Steinitz, C., 2017. *Changing our global infrastructure: notes toward a collaborative set of geodesign research studios among universities and technical support companies and stakeholders,* s.l.: Esri.

Flaxman, M., 2010. Fundamentals of geodesign. *Proceedings of Digital Landscape Architecture,* Volume 2, pp. 28-41.

Goodchild, M. F., 2010. Towards geodesign: Repurposing cartography and GIS?. *Cartographic Perspectives,* Volume 66, pp. 7-22.

Hoeger, K. & Christiaanse, K., 2007. *Campus and the city: Urban design for the knowledge society.* s.l.:gta Verlag.

Huang, G. & Zhou, N., 2016. Geodesign in Developing Countries: The example of the Master Plan for Wulingyuan National Scenic Area, China. *Landscape and Urban Planning,* Volume 156, pp. 81-91.

Klosterman, R., 1997. Planning support systems: a new perspective on computer-aided. *J Plan Educ Res,* Volume 17, pp. 45-54.

Klosterman, R. E., 2008. *A new tool for a new planning: The What If? TM planning support system.* Cambridge, MA: Lincoln Institute of Land Policy .

Li, Z., Quan, S. & Yang, P., 2016. Energy performance simulation for planning a low carbon neighborhood urban district: A case study in the city of Macau. *Habitat International,* Volume 53, pp. 206-214.

Lynch, K. & Hack, G., 1984. *Site Planning.* 3rd ed. Cambridge: The MIT Press.

Martin, L., 2000. The grid as generator. *arq: Architectural Research Quarterly,* Volume 4.4, pp. 309-322.

McHarg, I. L., 1969. *Design with nature.* New York: American Museum of Natural History.

Nyerges, T. et al., 2016. Geodesign dynamics for sustainable urban watershed development. *Sustainable Cities and Society,* Volume 25, pp. 13-24.

Paradis, T., Treml, M. & Manone, M., 2013. Geodesign meets curriculum design: integrating geodesign approaches into undergraduate programs. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability,* 6(3), pp. 274-301.

Ratti, C., Baker, N. & Steemers, K., 2005. Energy consumption and urban texture. *Energy and Buildings,* Volume 37, pp. 762-776.

Ratti, C., Raydan, D. & Steemers, K., 2003. Building form and environmental performance: archetypes, analysis and an arid cliamate. *Energy and Buildings,* Volume 35, pp. 49-59.

Steemers, K., 2003. Energy and the city: density, buildings and transport. *Energy and Buildings,* Volume 35, pp. 3-14.

Steiner, F. R. & Shearer, A. W., 2016. Geodesign—Changing the world, changing design. *Landscape and Urban Planning,* Volume 156, pp. 1-4.

Steinitz, C., 2012. *A framework for geodesign: Changing Geography by design.* Redlands: ESRI.

Steinitz, C., 2014. Which Way of Designing?. In: D. J. Lee, E. Dias & H. J. Scholten, eds. *Geodesign by Integrating Design and Geospatial Sciences.* Columbus, OH: Springer, pp. 11-42.

Waldheim, C., 2006. Landscape as Urbanism. In: C. Waldheim, ed. *The landscape urbanism reader.* New York: Princeton Architectural Press, pp. 35-53.

Yang, P., 2014. Energy Resilient Urban Planning. In: D. J. Lee, E. Dias & H. J. Scholten, eds. *Geodesign by Integrating Design and Geospatial Science.* Columbus, OH: Springer, pp. 43-54.

Yang, P., 2015. Energy resilient urban form: a design perspective. *Energy Procedia,* Volume 75, p. 2922 – 2927.

Yang, P., Chi, C., Wu, Y. & Quan, S., 2018. A Geodesign method of human-energy-water interactive systems for urban infrastructure design: 10KM2 near zero district project in Shanghai. *Engineering,* Volume 4 (2018).

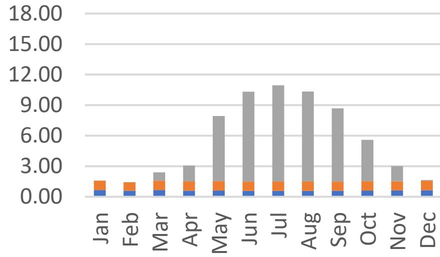
Yang, P., Quan, S., Castro-Lacouture, D. & Stuart, B., 2018. A Geodesign method for managing a closed-loop urban system through algae cultivation. *Applied Energy.*

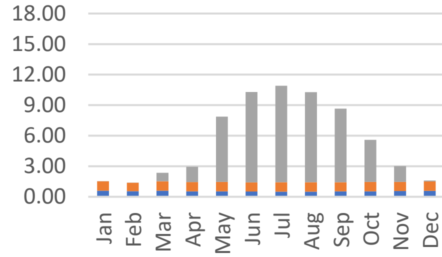
Yang, P. & Yan, J., 2016. Modeling Urban Design with Energy Performance. *Energy Procedia,* Volume 3-8, p. 88.

Attachment

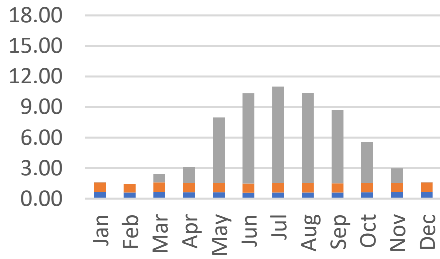
Attachment 1, Result of Energy Modeling
(grey: cooling, blue: lighting, orange: equipment)
Large Public Buildings:

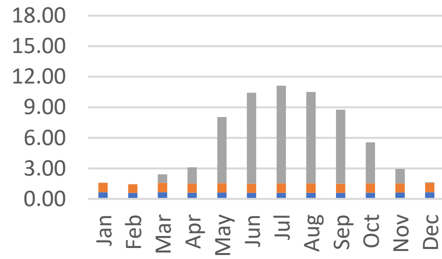
Box:





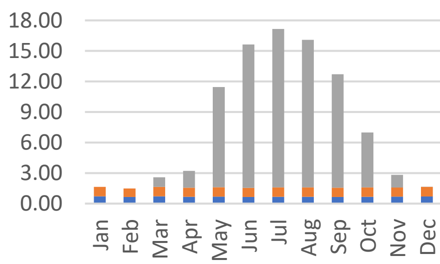
Left: origin; Right: decentralization.

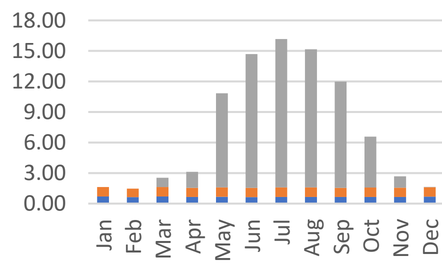




Left: aggregation; Right: angel.

Courtyard:





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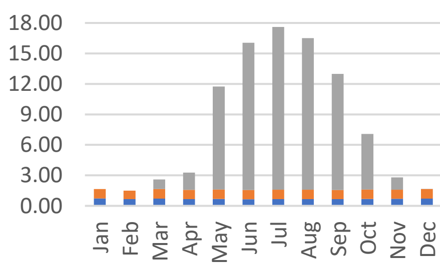

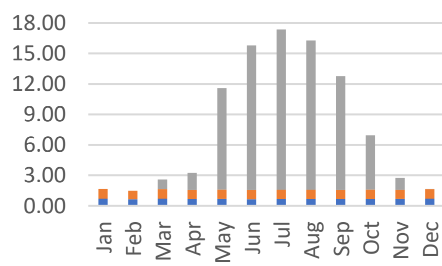

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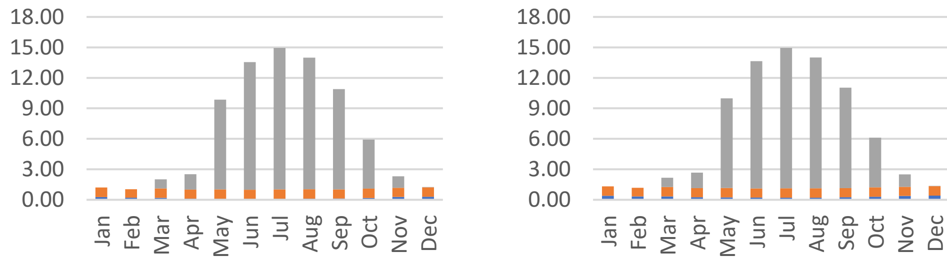
U-shape:



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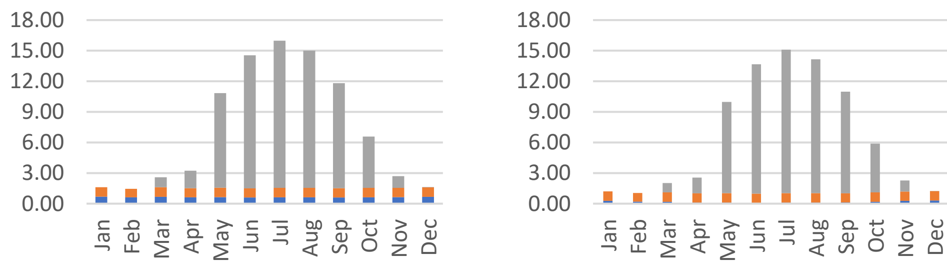

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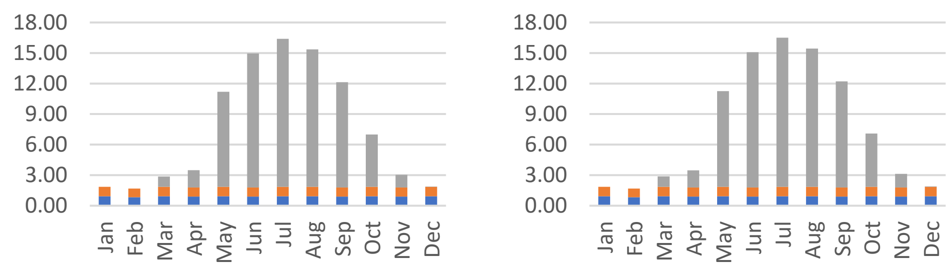
L-shape:



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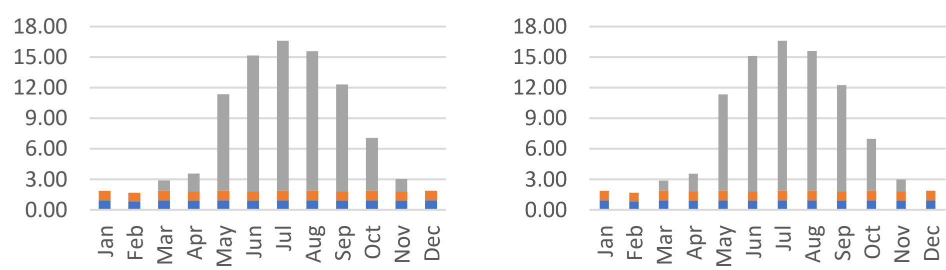

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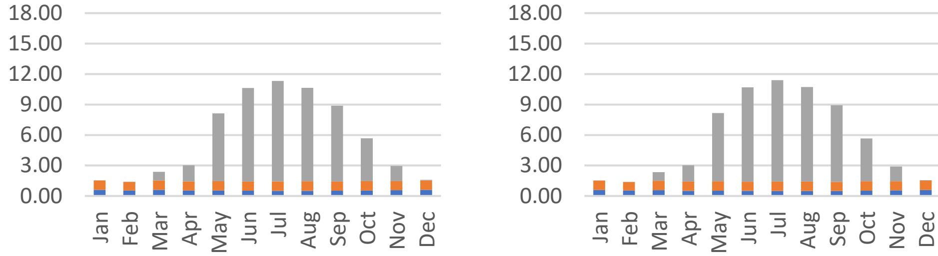
Setback:



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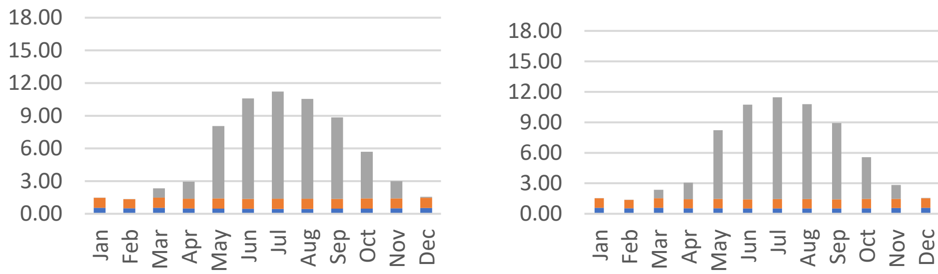

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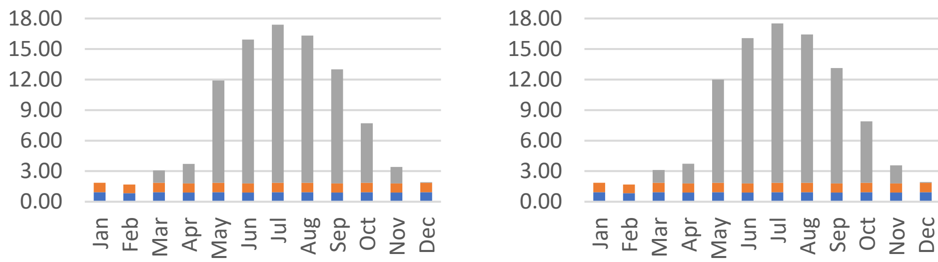
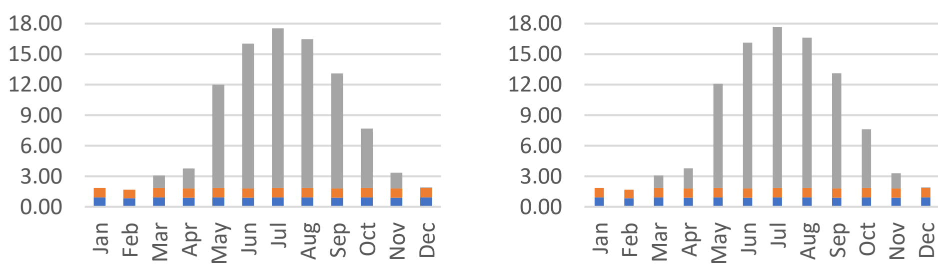
Small Public Buildings:

Small Box:

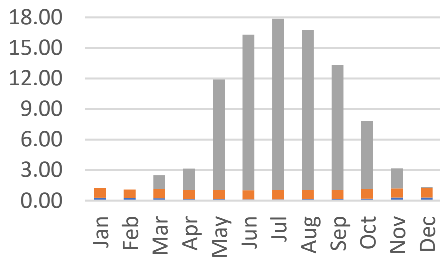


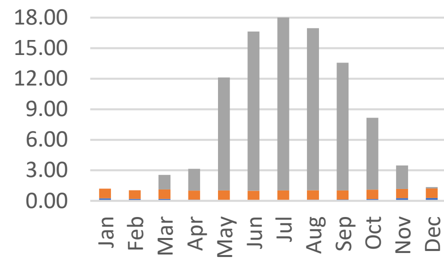
Left: origin; Right: decentralization.



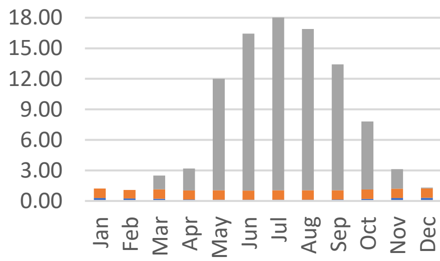
Left: aggregation; Right: angel.

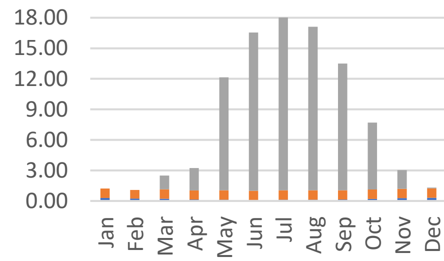
Small Tower:





Left: origin; Right: decentralization.

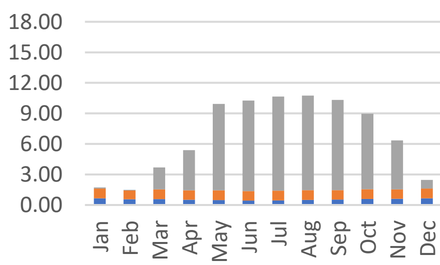


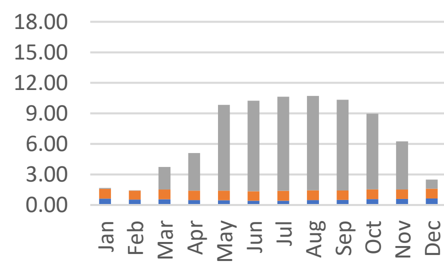


Left: aggregation; Right: angel.

Dormitory

Slab (D):





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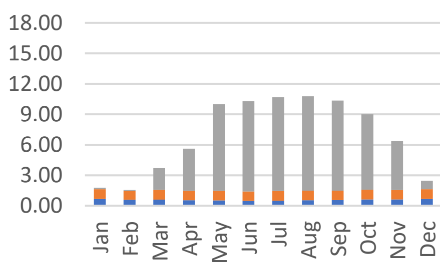
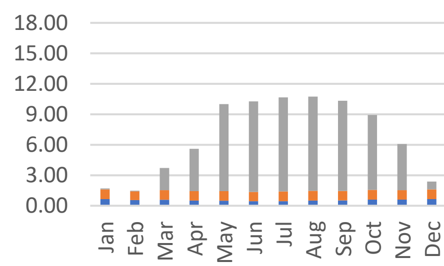
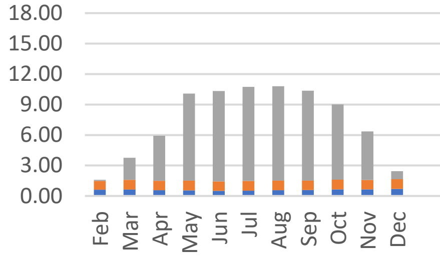
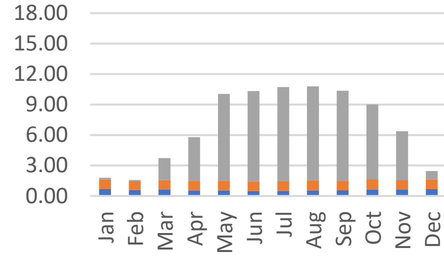




Left: aggregation; Right: angel.

Box (D):





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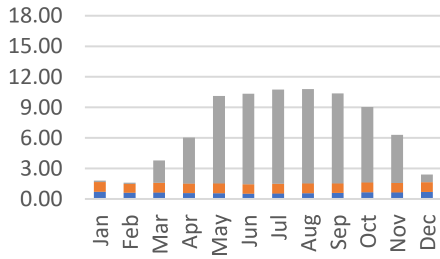
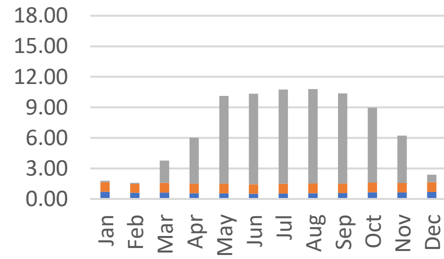
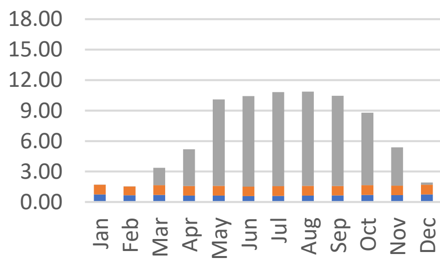
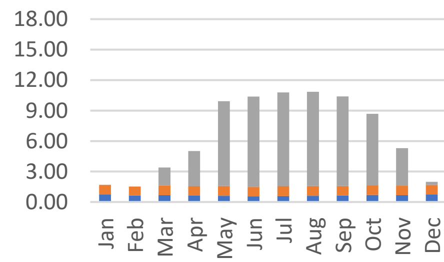




Left: aggregation; Right: angel.

Courtyard (D):





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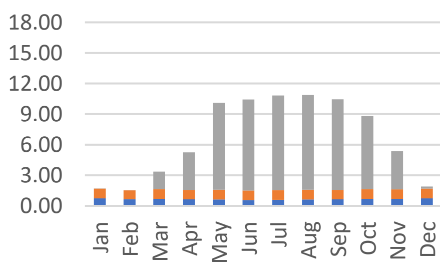
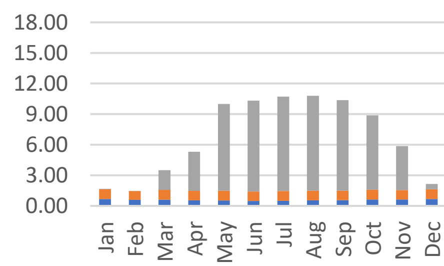
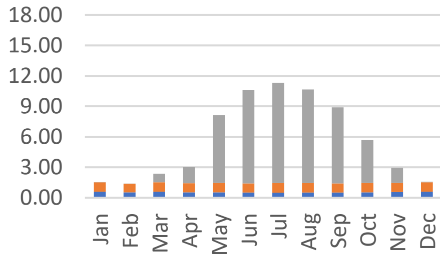
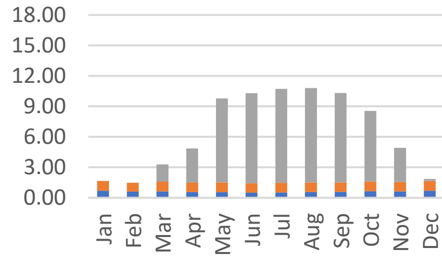




Left: aggregation; Right: angel.

Cross (D):





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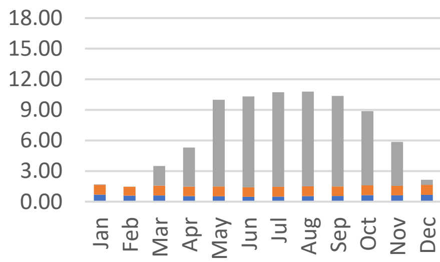
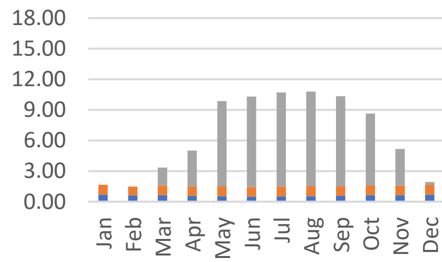
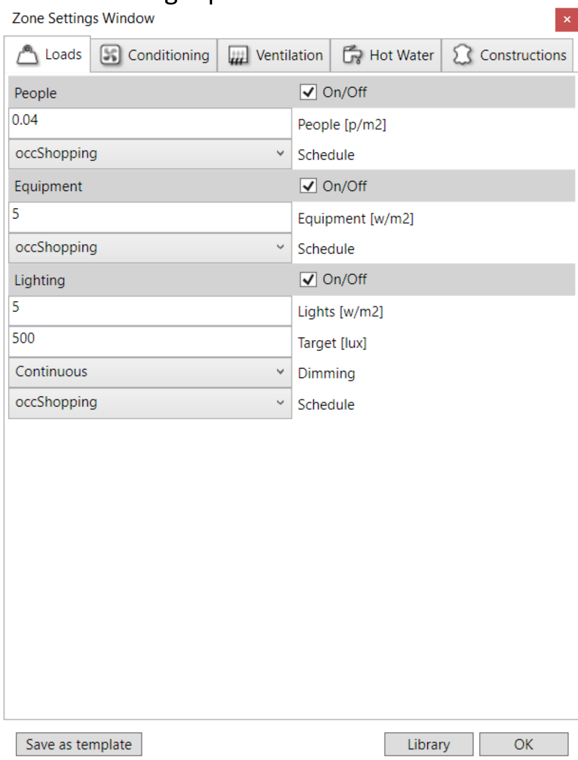


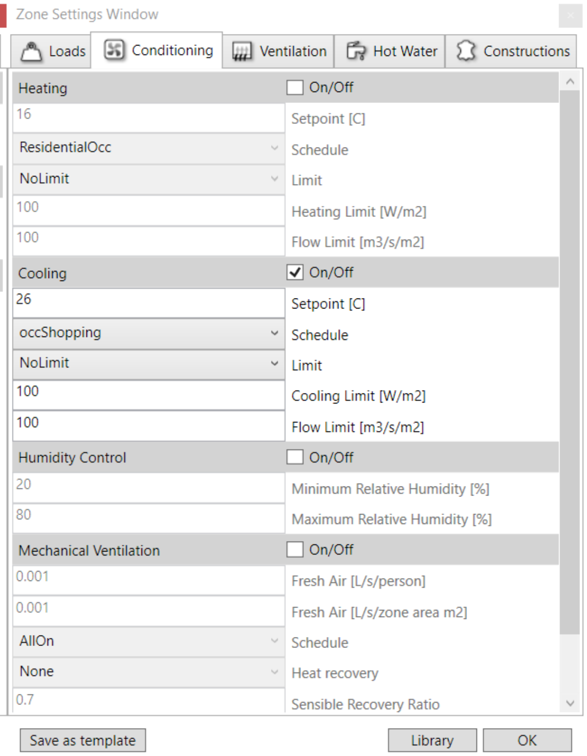


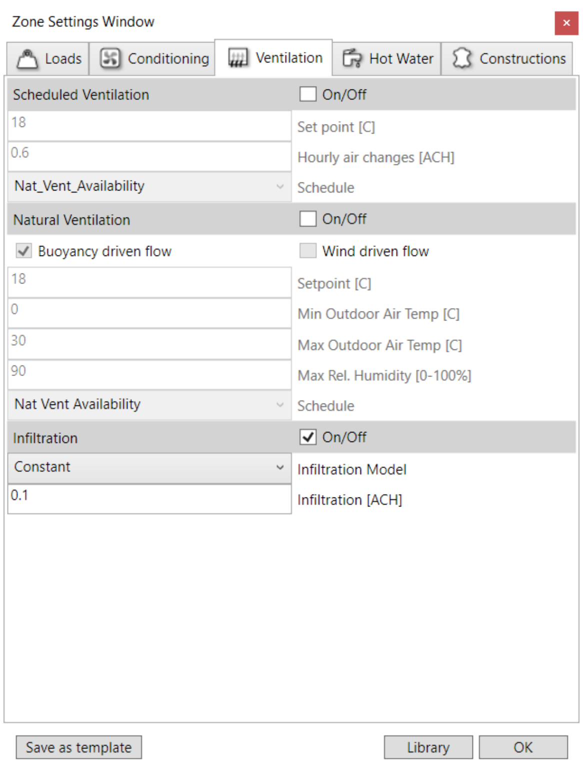
Left: aggregation; Right: angel.

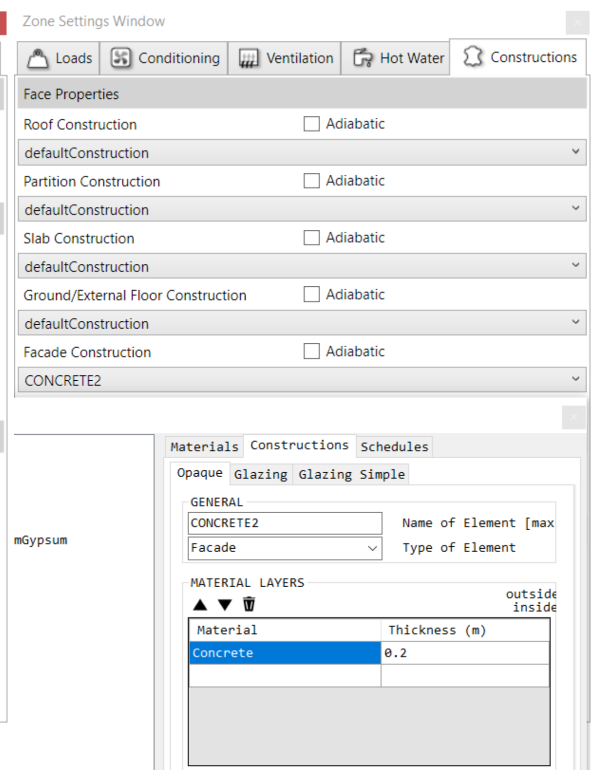
Attachment 2, Inputs in ArchSim Energy Modeling

Public Building Inputs









Dormitory Inputs