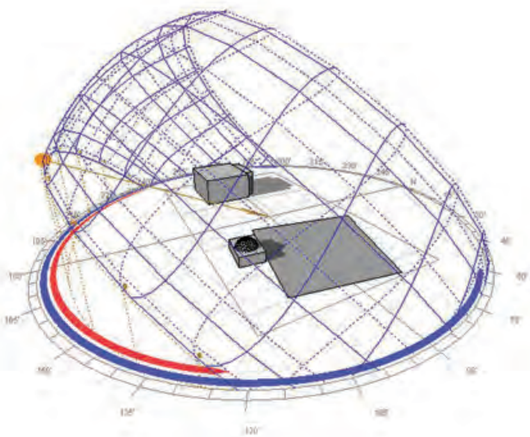
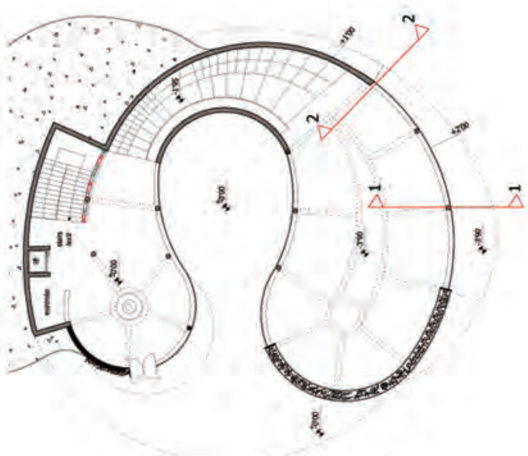
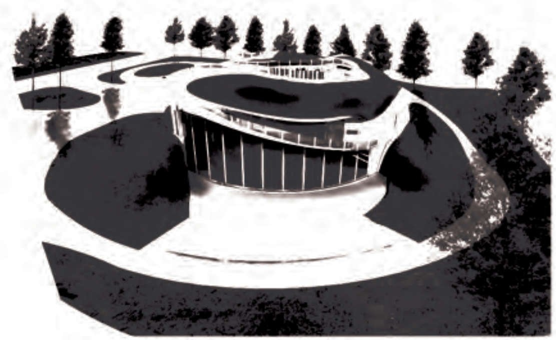
International Design Studio 2012







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International
Design Studio 2012
YTU Children Science Center

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UNIVERSITY OF TWENTE.

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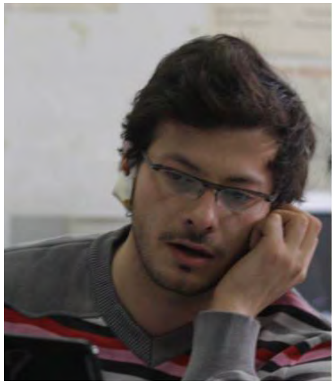

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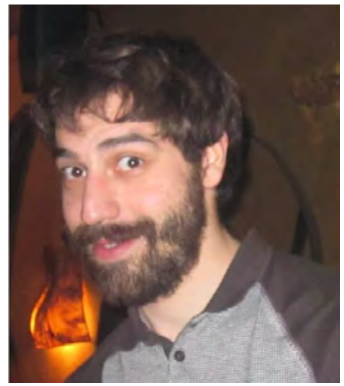

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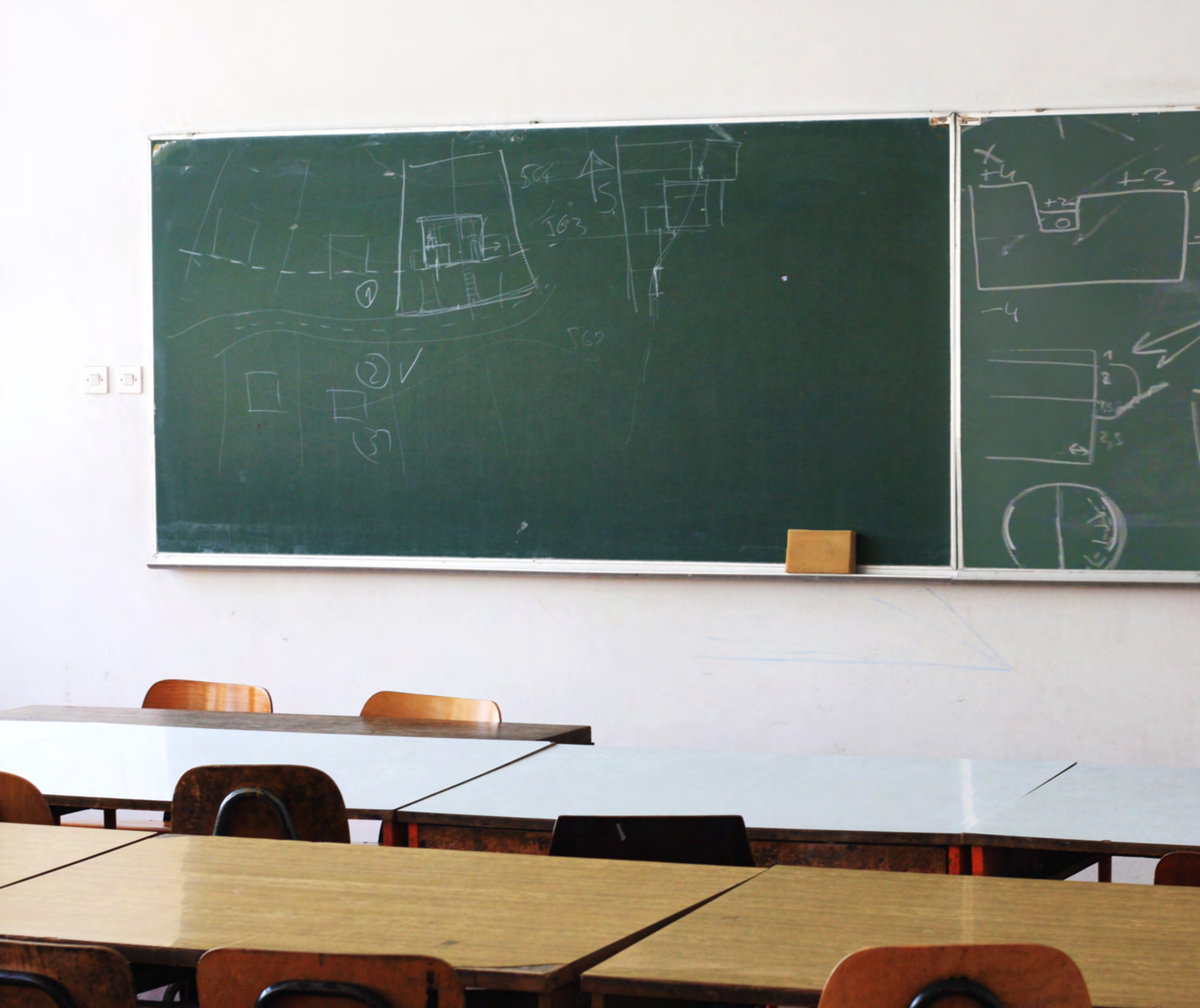

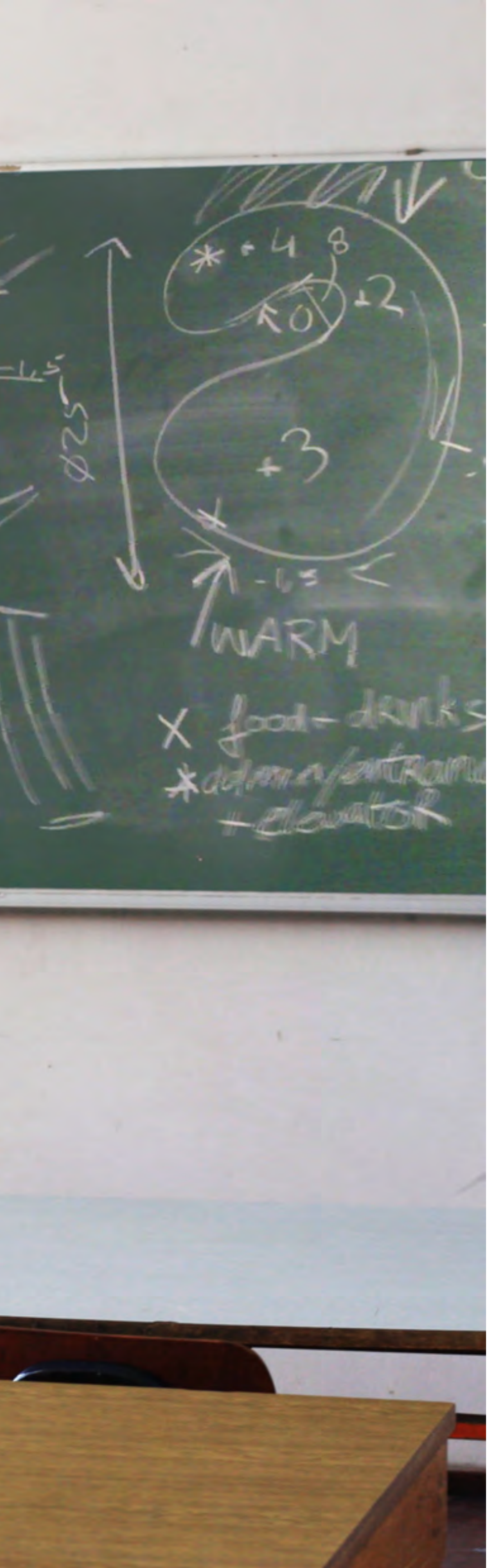

Introduction

Chapter zero

The project presented in this publication is a result of an international cooperation between University of Twente from Enschede, Yildiz Technical University from Istanbul and University of Sarajevo that has started in 2008.

This international cooperation has been structured around the theme of sustainable and flexible building concepts and solutions. Projects that were done within this cooperation are linked to the platform for innovation in green and transformable concepts and techniques that were set up at the University of Twente in 2009. This program aims at integrating issues of flexibility, multi-functionality, energy and material recovery, and reuse into one green design strategy for the 21st century. The innovation platform is organized around the design for disassembly strategy as an important element of transformation of the existing design and construction methodologies and forms a platform for collaboration between the industry and educational institutions.

For the last two years students of architecture and industrial design engineering from the three universities were working on the design of a green and transformable building structure that has formed a base for the development and construction of the experimental Green Transformable Building Lab (GTBL) at the University of Twente. The designed building is a dynamic structure that will allow yearly reconfigurations and upgrading of the building.

Besides, GTBL is also a showcase of an energy positive, C2C and flexible /multi-purpose building whose parts could be dismantled, replaced or reused in different configurations. This year's International Design Studio was dealing with the integration of principles developed within the Green Transformable Building Lab at the University of Twente into a design of a Children Science Center (CSC) at Yldiz University in Istanbul.

The main requirement for a CSC building was to design a building that will be educative in itself. The buildings should illustrate (to the children) the relationship between the built environment and the natural systems. On the other hand the building should also show how natural systems can become a part of building systems. The aim was to design a building as a showcase of green technologies that is presented through a playful and educative manner to the children.

The book illustrates the design process through a number of decision making stapes and gives a detailed overview of the final design through its spatial and technical configuration as well as through applied green concepts.

dr. Elma Durmišević

Foreword

Dr. Elma Durmišević

Background
The most compelling question for any designer today is how to design for a sustainable future? In response to this question, 21st century architectural challenge lays in solving tensions that are related to the two key dilemmas in building design:

1. The impact of acceleration of short term changes within societies on design of buildings that form a long term core of the identity and continuity of the place (in other words: flexibility versus continuity)

2. The impact that changing climate conditions, resource depletion and transition towards green economy have on the design of a building and on the decision making regarding the reduction of energy and resources use in buildings (in other words: energy and resource use prevention by design)

These two issues are interrelated and the level of their synergy will be a measure of success of architecture and its durability in the future.
At the same time this brings a focus on the "factor time in the built environment" involving the life cycle design approach in design of time resistant building stock.

Life Cycle Design requirements imposed on building design and engineering will require fundamentally different way of design and construction in the future. Buildings in the 21st century need to be more proactive in terms of energy production, water reuse, adaptations to the necessary comfort level, individual user demands and material reuse. Building structures will need to be put together in an intelligent way so that different climate, energy, aesthetic, spatial and material concepts can be integrated into the building structure in the course of time. Buildings in the future will become open platforms, where new technologies and requirements can easily be integrated and adopted. Instead of demolishing parts of the building or whole buildings and systems in order to upgrade them and increase their performance it should be possible to reconfigure them without demolition and material/energy waste. Their systems need to be replaceable and reconfigurable and materials up-cycling. Basically buildings in the future will need to posses embodied transformation capacity on three levels: spatial, structural and material.
Design methodology need to adopt the Design for Disassembly approach in order to provide such high transformation capacity of buildings. In other words, new alternative building methods are required that will provide a precondition for such dynamic and adaptable structures.

Green Transformable Buildings is a long term strategic program at the University of Twente which aims at transformation of architectural practise and construction industry towards a green industry.
The aim of the initiative is to set up a trend for building construction in the 21st century together with

the construction industry by developing new building methods and systems and implementing them in an experimental Green Building Lab project at the campus of the University of Twente.
This strategic program is financially supported by the Dutch government and Dutch province Twente/ Overisel. The concept of Green Transformable buildings has been developed together with Dutch construction companies and educational institutions concept in a different country on a new site. Design of Green Transformable building lab is a long term project at the University of Twente (centre for green transformable buildings) that works towards implementation of educational and research results into practical development of green transformable building concepts and products for the 21st century together with the construction industry. The main challenge of this development has to do with mastering the transformation process of buildings, systems and materials and the impact of transformation on perception/behaviour and culture on one hand, material and energy use on the other.
During International design studios in 2010 and 2011 the design concepts have been developed for the construction of the green transformable building lab at the University of Twente.

In last four years joint International Design studios (organised by University of Twente, Yldiz University and University of Sarajevo) were dealing with design of green and transformable architecture as a showcases of the new trends in design in 21st century.
This year's international design studio is continuation of "Green Transformable Building" and will lean on green systems design methodology developed by E. Durmisevic. The idea of this year IDS is to implement the principles of Green Transformable Building into a different country (Turkey).

Project Objectives

The theme of this year project is "Green Transformable Children Science Center" building. The science center will be located in Yıldız Technical University Davutpasa Campus in İstanbul.
The task of the IDS is to develop an integrated design concept for a Children Science Center building of maximum 700m2 building and 800m2 open area that will actively interact with new climate, energy/water and material recycle concepts and be a showcase of for green transformable structures in Yıldız Technical University Davut Pasa Campus.

Children Science Center building is aiming to be the first building in YTU campus with a LEED certificate, an internationally recognized certification system for green buildings.
The aim of the studio is to design energy neutral, and flexible multi-purpose green "Children Science Center" building whose parts can be dismantled, replaced or reused in different configurations based on Design for Disassembly approach to buildings.

The IDS studio focuses on the design and construction of a flexible building which can be transformed for different purposes and whose systems and components can be reconfigured and reused again for different functions

The building's structure will be transformed in winter and summer seasons adapting itself to the new climate and use scenarios. This means that a flexible and dynamic structure needs to be put in place that will make different additions, replacements and upgrade of use, energy and climate concepts possible.
A total of 15 students from three universities (Twente, Istanbul and Sarajevo) will work in mixed teams. The collaboration will be structured around the workshops in Istanbul, Sarajevo and Enschede. During the last workshop in Enschede students will work on finalisation of their own design.

The building will be assembled on the Davutpasa campus of YTU as show case for Green Transformable building in Turkey. Once assembled on the site, the building will be transformed based on the seasons adapting itself to the climate condition and functional requirements. The main feature of the building must be that the structure provides enough transformation capacity for new additions and transformations.

Project requirements

The math and science skills, innovation and creativity through design and science integration are necessary for kids to compete in the 21st century workforce. YTU Children's Science Center is committed to inspire and grow future scientists and engineers to ensure the continued prosperity of the high-tech industry in İstanbul region. (Birgul Colakoglu)

With the university's engineering disciplines and knowledge incubator Technology Park, YTU Children's Science Center aims to play a vital role in being a space for learning by playing for STEM (Science, Technology, Engineering and Mathematics) for the kids between age of 7 to 13th. (Birgul Colakoglu)

The task of the IDS 2012 is to develop an integrated design concept for "Children Science Center" building of maximum 700m2 that will actively interact with new climate, energy/water and material recycle concepts and be an example for green transformable structures. The concept of green transformable buildings address issues such as flexibility, design for disassembly, energy production, closed material/ water cycles in construction and use of ICT in design and construction.

International design studio will address the following:

- The complex relationship between transformation of structures and functions, energy, climate, water and material concepts.
- Streamline interaction processes between design, engineering, analysis and manufacturing.
- Integration of individual systems into an open platform concept.
- The development of new materials and production for interactive skins of buildings.
- A design, development and prototyping of building systems.
- Life cycle design methodology.
- Green certified building construction.

THE KEY REQUIREMENTS AND CRITERIA

The key requirements for Green and Transformable Children Center are:
The building should have capacity to transform from one use scenarios to another on seasonal basis and functional requirements without demolition and additional material reuse. The structure should accommodate different functions and its components should be removable and reusable in different situations or configurations. Both multi-functionality of space and components should be taken into account.

Design has to integrate following criteria:

- The Children Science Center with its design (form, envelope) and building systems should provide attraction point in the Campus.
- The building itself should be learning example of Green approach for children (Visible building systems) (teaching children about utilized green systems by designing them partially or totally visible)
- Multi-functionality, (The building should provide transformation capacity: for different inner configuration and for climate based envelope transformations)
- Adaptability for different functions
- Transformation and disassembly criteria
- Building should be at all times energy positive. That means that the need for energy use should be minimized and needed energy should be produced by renewable energy sources.
- Separation and reuse of water streams in the building should be provided
- Building should be made of industrialized components
- Comfort in terms of air temperature, light, air quality
- The base of the structure should provide enough capacity so that parts and units can be added/ attached, removed and reconfigured.

Design for Disassembly

One long-standing conviction held by many is that buildings last longer when made of more durable materials. However, everyday demolition practice proves the opposite. Buildings are designed to last 70-100 years, yet today buildings with an age of 15 years are demolished to give way to new construction. Developers and real estate managers warn that there is a miss-match between the performance of the existing building stock and the dynamic and changing demands with respect to the use of buildings and their systems. 50% of investments in building construction in the Netherlands are spent on adaptation and 42% of new construction is due to the replacement of demolished buildings. Besides, European building industry accounts for 40% of the waste production, 40% of the energy consumption and CO2 emissions and 50% of material resources taken from the nature are building related (CSB 2007).

Demolition in general can be defined as the process in which the building is broken up, with little or no attempt to recover any of the constituent parts for reuse. Most buildings are designed for such end-of-life scenarios. They are designed for assembly but not for disassembly and recovery of components. Different functions and materials comprising a building system are integrated (during construction) in one closed and dependent structure that does not allow alterations and disassembly. The inability to remove and exchange building systems and their components results not only in significant energy and material consumption and increased waste production, but also in the lack of spatial adaptability and technical serviceability of the building.

If the building sector is to respond to global environmental and economic challenges it needs to adopt new ways of construction.

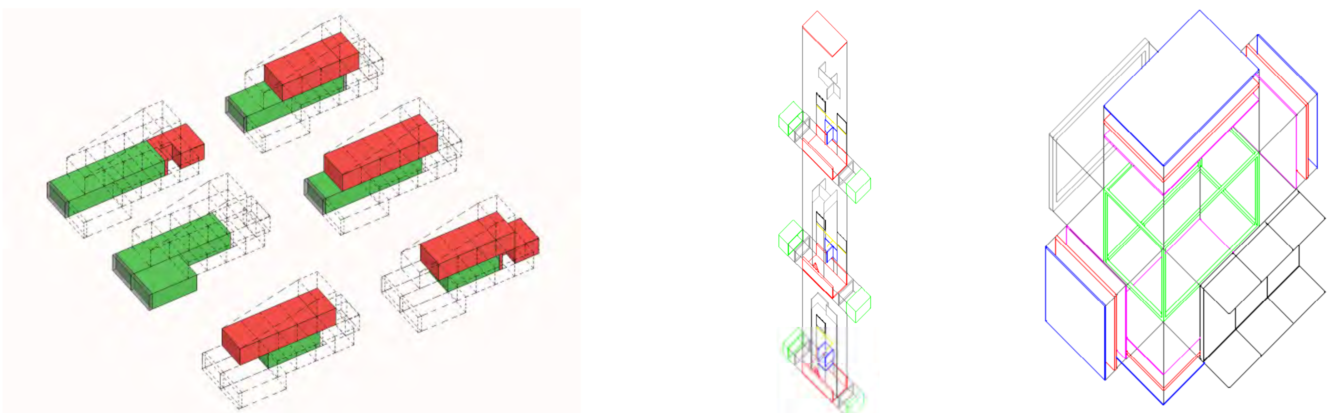

Figure 1 left: 4D architects amsterdam – transformation study; right: Richard Horden European House

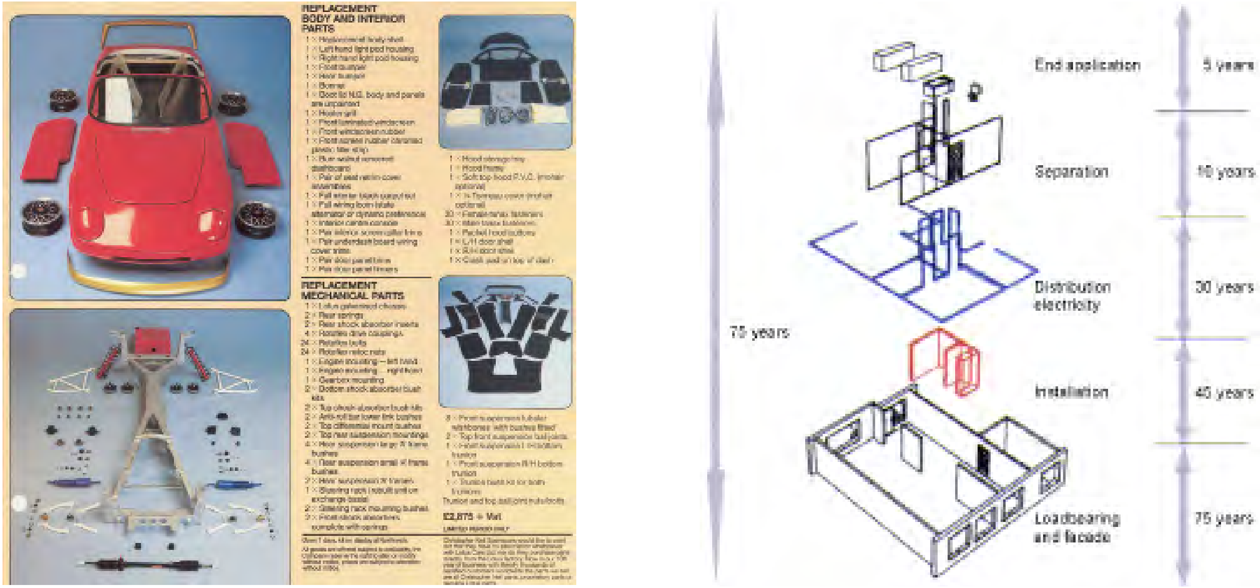

Figure 2: design for disassembly in car industry translated to the building construction (one concept)

Rather than destroying structures and systems while adapting buildings to fit into new requirements, it should be possible to disassemble sections back into components and to reassemble them in new combinations. This means that we must consider how we can access and replace parts of existing building systems and components, and accordingly, how we can design and integrate building systems and components in order to be able to replace them later on.

Re-configurable building structures with high disassembly potential

The moment when buildings start to transform is the moment when structures can be reconfigured and reused, or simply demolished and sent to waste disposal sites. At that moment, the nature of the technical composition of buildings is crucial for the life cycle of buildings and materials. The focus in the debate regarding the durability of structures should involve not only materials, but interfaces, arrangements of materials and technical composition of structures. It is not only a type and durability of material(s) but more importantly an arrangement of materials that determines the life cycle of buildings and their products.

Building components and systems have different degrees of durability. While the structure of the building may have a service life of up to 75 years, the cladding of the building may only last 20 years. Similarly, services may only be adequate for 10 years, and the interior outfit may be changed as frequently as every three years. Nevertheless, it is quite normal for parts with short durability to be fixed permanently, preventing easy disassembly.

Therefore, at the end of components or building service life there is usually little option but for demolition, with associated waste disposal.

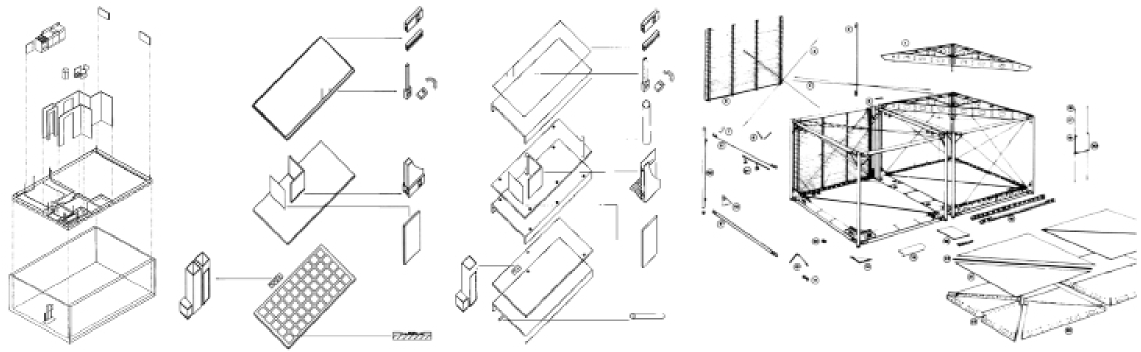

Figure 3: different transformation scenarios correspond to different arrangement and hierarchy of subsystems and components

If we recognise the potential of disassembly, it is possible to divert the flow of materials from disposal to reuse and save not only materials but also the energy embodied in materials. One believes that energy embodied in materials will probably become a greater problem than the operational energy of buildings.
Taking this into account the design of sustainable building is in danger of being carried out on an ad hoc basis without disassembly aspects of the building structure being an integral part of the design process. One can argue that the sustainability of design in the future will relay strongly on disassembly potential of building assemblies.

The Design for Disassembly (DfD) aims at design of transformable building structures made of components assembled in a systematic order suitable for maintenance and reconfiguration of variable parts. Every scenario for transformable building or systems results in different technical compositions and different hierarchies of parts (figure 3). This DfD concept affects design of all material levels that are accounted for the technical composition of buildings and accentuates interdependent relations between the transformation process and disassembly technologies. Considering this, one can say that this concept introduces three dimensions of transformation in the buildings namely spatial, structural and material transformation. The key to each dimension of transformation and ultimately towards a three dimensional transformable building is disassembly. By adoption of the concept of design for DfD, spatial systems of a building become more amenable to modifications and change of use. New steps in exploitation of the structure by reuse and reconfiguration can be achieved and conscious handling of raw materials through their reuse and recycling is stimulated(Durmisevic 2006).

Main characteristics of buildings designed for disassembly are:

0) Setting the boundary conditions for transformation and specification of the long and short term use scenarios,

1) Separation of material levels, which correspond to independent building functions as presented in figure 3,

2) Creation of open hierarchy of distinct subassemblies,

3) Use of independent interfaces as intermediary between individual components,

4) Application of parallel instead of sequential assembly/disassembly processes,

5) Use of dry - mechanical connections instead of chemical connections.

In order to achieve this, a fundamental change in architect's perception of buildings is needed in terms of:

- Conceiving a building not as a static but a dynamic and open structure that can easily adapt to the changing requirements,
- Extending the transformation capacity of buildings and systems by considering the whole life cycle of the building and building systems,
- Treating building materials as a long-term valuable asset through their whole life cycle by utilising reconfiguration, reuse and remanufacturing options on building, system and material level,
- Considering waste and demolition as a design error,
- Decoupling fixed function-material relationship in buildings by design of reconfigurable systems,
- Involving construction industry into the whole life cycle of the building and building systems,

A typology of the technical configuration of a building is an indicator of building sustainability. A major shift towards green design and engendering involves a shift from design of closed building systems and assemblies towards design of open and transformable building structures with a high disassembly potential. These structures are made of independent and exchangeable building components and systems. Such a concept allows for future alterations to external screening, and to internal partitioning. It allows for services to be independent of the fabric, to provide for accessibility, servicing and alteration. It creates the precondition for reuse and recycling and opens the way for designs of greater diversity.

dr. Elma Durmišević

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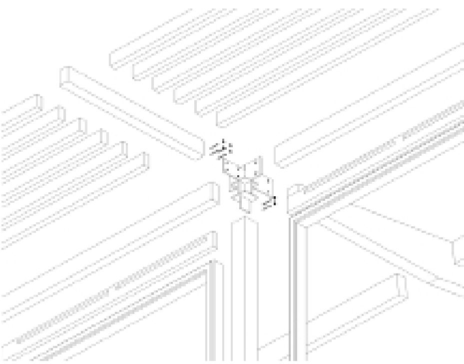
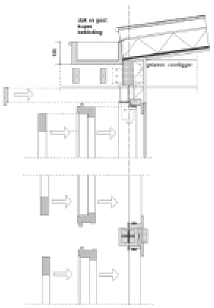
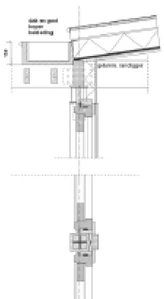
CSB 2007: Center for Building Statistics in the Netherlands – Bouwvergunningen, huur-en koopwoningen, 2007







Multi-criteria Design Matrix

The Multi Criteria Design Matrix (MCDM) used in the design process of the YTU Children Science Center is based on eight design aspects, each of them with several criteria. The matrix consists of two mayor types of criteria: subjective and objective nature. The subjective criteria have been analyzed by expert group, and a number of assessment and measurement tools are available to measure objective criteria. Additionally some sub criteria were defined in order to evaluate the concepts from the objective point of view.

The criteria list has resulted into the list of requirements that design should meet in order to achieve required performance. Technical requirements help to get better understanding of the meaning of each criteria. Technical requirements were defined in the MCDM for the majority of the criteria presented. As a result this matrix allows a unanimous and objective interpretation.

Following a description of the eight design aspects is given:

1. Architectural quality
This category can be seen as the aesthetics part of the building. Here social, esthetics and more subjective criteria are analyzed.

Quality is defined as: 'The classifiable characteristics of a material or product as demanded by use or suitability' [1].

Based on the previous definition, the product to classify is the building. The suitable characteristics are the criteria selected for this category: identity, scale and proportions, integrity and coherence, inviting building and expression of transformability.

2. Multi-functionality
Multi-functionality defines building's potential to accommodate different functions. Multi-functionality is also related to the internal flexibility and replaces ability of functions within the space. Some of the sub criteria evaluated in this aspect are: adoptability to different functions, suitability for internal flexibility, installation capacity, structural capacity, and possibility to install equipment.

3. Transformability
Transformation indicates in general a change of shape, form, or structure without loss of substance. This design aspect is translated for the building into some sub criteria that are:

- Easy transformation from one use concept to another.
- Possibility to combine or separate multiple functions.
- Extending/shrinking of space
- Transformation of open area into closed area and opposite
- Adaptability to the weather and day/night configuration
- Adaptability to different inner climate concepts

4. Energy, water & materials
This aspect analyses the energy performance, water supply/reuse and materials used, focusing on the positive impacts of these factors on the environment. The sub criteria defined in this aspect are related to energy positive performance concepts of the building, material transformation, Cradle to Cradle, and reuse of different water streams.

5. Comfort & health
Comfort can be translated as a person's satisfaction with the ambient. Environmental conditions such as temperature, humidity, sound and air quality might be considered. This design aspect takes care of keeping those conditions in allowable ranges without interference or harm to human health. Here the sub criteria are related to the thermal comfort during summer and winter, indoor air quality, acoustics, and visual comfort.

6. Constructability and handling of components
This aspect seeks to assess the feasibility of the components from the standpoint of manufacturing, transportation, assembly, disassembly and reuse. One of the criteria considers for instance the transportability of the components/systems from the factory to the site.

7. Cultural and local site context
This aspect seeks to link the culture of a place and the context in which the building will be located. The culture of a place may be influenced by social and political issues. Therefore one could say that user behavior is culture dependent. For instance a criteria here assesses whether the most important elements of user behavior are consistent with the design of the building.

8. Costs
This design aspect evaluates the cost relate to the project. Its evaluation includes investment costs, annual exploitation costs, and life cycle costs.

This aspect will be evaluated and considered in the further development of the project. Therefore no analysis of this aspect is presented here.

The MCDM includes the eight design aspects mentioned above, each of them related to different criteria and consequently to some sub criteria. Each sub criteria is illustrated with an explanation, variable, unit and value which seem to make a more objective analysis (see complete MCDM, table 5.1-5.5, page 103-106). These requirements give an output to the designers about the boundaries of the project and will help to evaluate the final concept at the end. In some cases it is not possible to comply with all the values set forth, therefore the students and the coordinators should prioritize those criteria that have a higher importance.

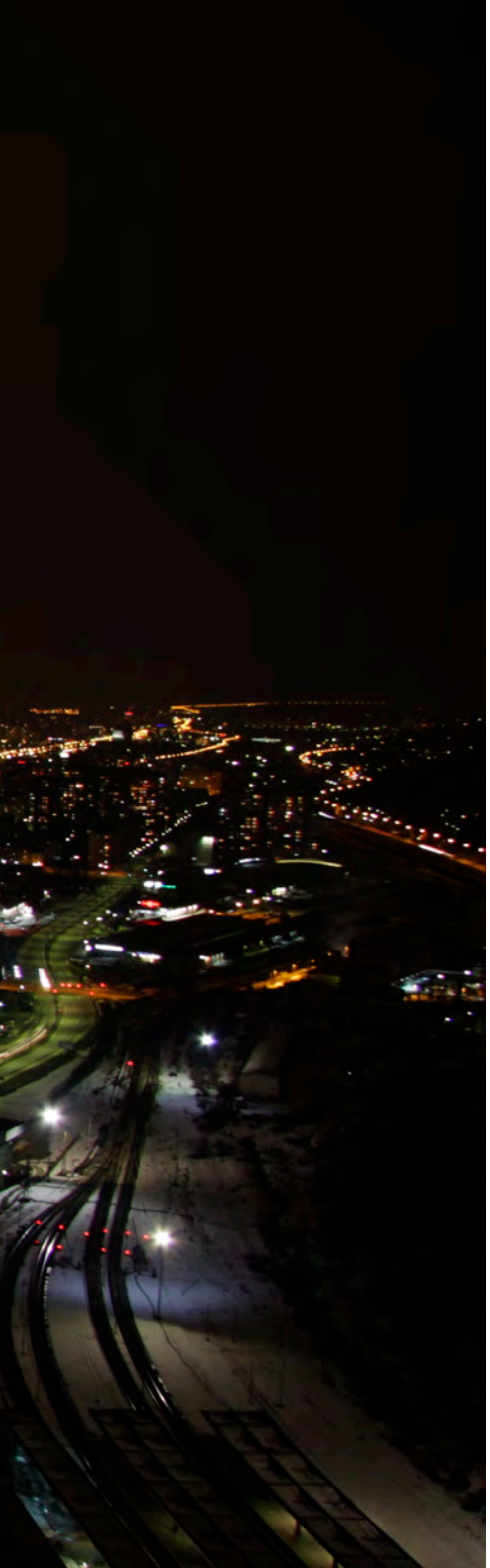
References:

[1] Davies, N., Jokiniemi, E., 2008, Dictionary of architecture and building construction.
[2] Geraedts, R., Future value of Buildings.

Design aspects	Criteria	Sub-criteria
Architectural quality	**Identity**	Inviting building
		Expression of transformability
		Education for children
		Appearance of spatial adaptation
		Green
	Scale & proportions	Balance
		Integrity & coherence
		Occupation
Multi-functionality	**Spatial transformation capacity**	Suitabilty for internal flexibility
		Adoptability to different functions
		Safety
	Technical transformation capacity	Installation capacity
		Structural capacity
		Possibility to install equipment
		Safety
Transformability	**Spatial transformation**	Easy transformation from one use concept to another
		Possibility to combine or separate multiple functions
		Extending/shrinking of space
		Transformation of open area into closed area and opposite
	Time bound transformation	Adaptability to the weather & day/night configuration
		Adaptability to different inner climate concepts
	System transformation	Reliability of the integration of and connection between components
		Second-use scenario for each component
		Decoupling and reassembly of parts/units of the building with different functions
		Flexible integration of systems (building HVAC)
		Reconfigurable building systems
Energy, water & materials	**Energy performance of the building**	Energy positive
		Renewable energy
		Stimulus for low energy user behavior
	Material transformation	Low environmental impact of used materials
		Second-use scenario for each material
		Reusability of disassembled components and materials
	Cradle to Cradle	Local materials
		C2C certified materials.
	Reuse of different water streams	Separate water streams on building level
		Reuse water

Table 0.1 | MCDM

Design aspects	Criteria	Sub-criteria
Comfort & Health	Thermal comfort (summer)	Summer indoor air temperature
		Summer indoor airflow
	Thermal comfort (winter)	Winter indoor air temperature
		Winter indoor airflow
	Indoor air quality	Indoor air freshness/ventilation per person
		Indoor air freshness/ventilation
		Indoor moisture content
	Acoustics	Building systems noise
		Interaction noise
		Acoustics
	Visual comfort	Iluminance
		View
Constructability and handling of components	Ease of (dis)assembly	High level of industrialization and prefabrication for fast assembly/disassembly
		Easy to assemble, disassemble and reassemble
		Easy reconfiguration of the prefabricated components for reuse
	Transport	The weight of most of the components allows them to be carried by 2 people.
		Transportability of the components/systems
Cultural and local site context	Primary users	Adaption to childrens perception
		Adaption to childrens behaviour
		Adaption to childrens size
	Secondary users	Adaption to secondairy users (students and staff) perception
		Adaption to secondairy users (students and staff) behaviour
		Adaption to secondairy users (students and staff) size
	Cultural aspects	Integration of cultural aesthetic qualities
		Integration of cultural and behavioral aspects to the design
Costs	Investment costs	
	Annual exploitation costs	
	Life cycle costs	



Urban Analysis

Chapter one

Site conditions play a major role when designing a green building. The orientation, the climate, the position of sun, wind directions and shadows from trees and surrounding buildings are important determining factors of green architecture. In order to get a better understanding of the site where the building will be situated, an analysis was conducted during the first workshop in Sarajevo. These analyses included also dimensions, traffic routes and parking opportunities. Furthermore weather conditions were analyzed as well. These consist of wind direction, hours of sunlight, and temperature. Due to the fact that the location changed for the YTU Children Science Center a new analysis was conducted during the second workshop in Istanbul. This chapter illustrates the analyses of the new location.

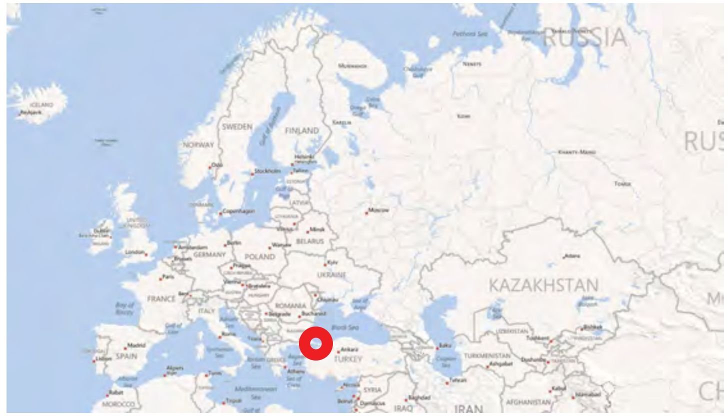
Location

The YTU Children Science Center will be located at the Davutpasa campus of Yildiz Technical University in Istanbul. Istanbul is situated in the North West of Turkey within the Marmara Region. This is the largest city in Turkey and has a population of 13.4 million and is therefore one of the largest cities in the world. Istanbul is the only city in the world located on two continents. One third of the population lives in Asia while the cultural and historical center is located in Europe.

The Davutpasa campus is a completely new campus for Yildiz Technical University and is now under construction. The University campus has served as a military base in the Ottoman Empire in the 19th century. Now the campus itself is considered as a historical site.

The location for the YTU Children Science Center is near the library and close to the campus' entrance. An old ruin behind this location can be found and must not be demolished.

Images of the location for the YTU Children Science Center are displayed in the figure 1 zooming in from a continental perspective to the exact location.



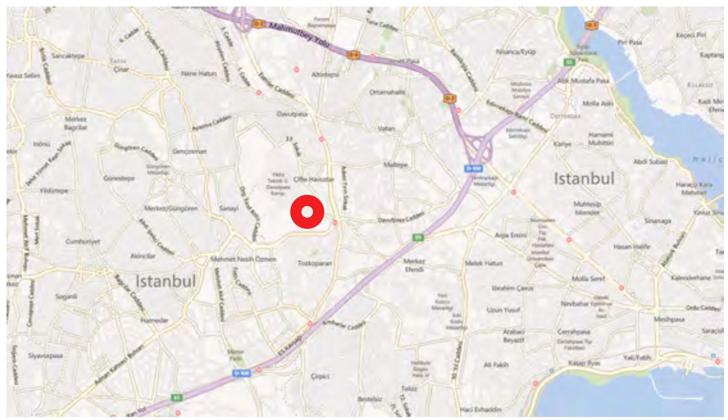
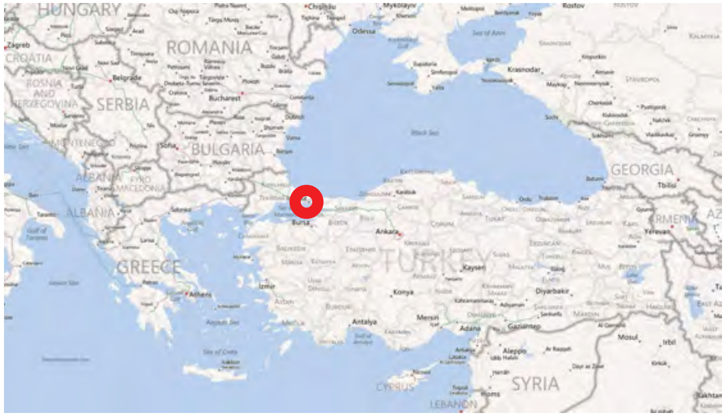


Figure 1.1 | The location from a global to local perspective


HUNGARY
ROMANIA
CROATIA
SERBIA
BULGARIA
ALBANIA
GREECE
GEORGIA
ARMENIA
TURKEY
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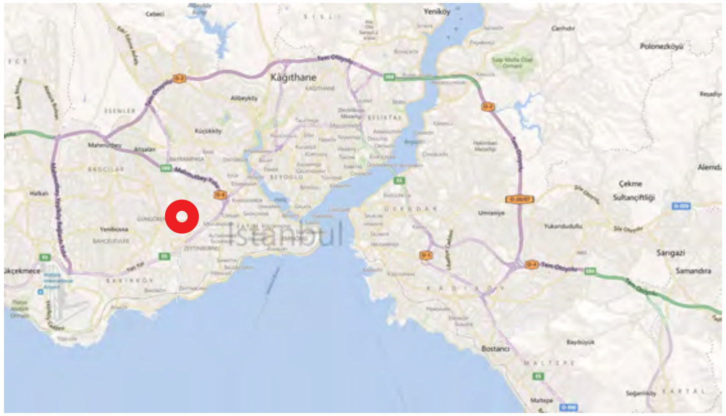
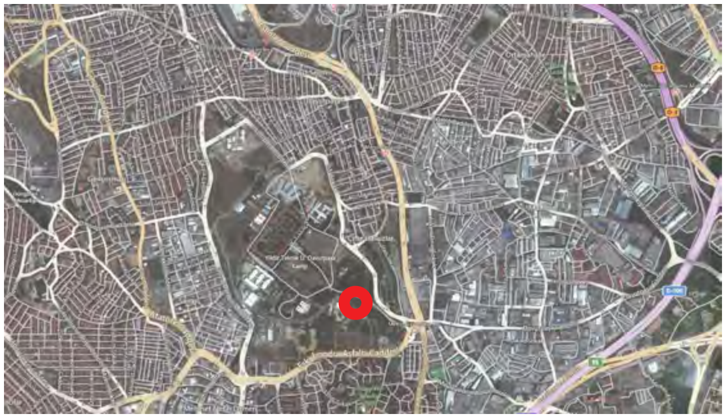
Adana
Tbilisi
Aleppo


Kağıthane
İstanbul




Ali Rıza Gürcan Caddesi

Routes

Davutpasa Campus is located on the European side of Istanbul, approximately 5 kilometers away from the historical center of the city. Visitors to YTU Children Science Center can use the Metro (Rail System) and stop at Davutpasa-Yildiz Teknik Universitesi statiton. The main entrance of the campus is near to this metro station and to a bus stop. Using these public transportations, pedestrians can follow the path that leads them to the building. Furthermore there are two parking areas that might be used when visitors are travelling by car or bus. Since the West and North routes of the location are not congested routes, it is not necessary to build a parking area next to the location. The existing parking areas are suitable for visitors; a group of children can safely walk to the building accompanied by an adult.

Figure 1.2 | Satellite map of Istanbul

Figure 1.3 | Satellite image of the exact location

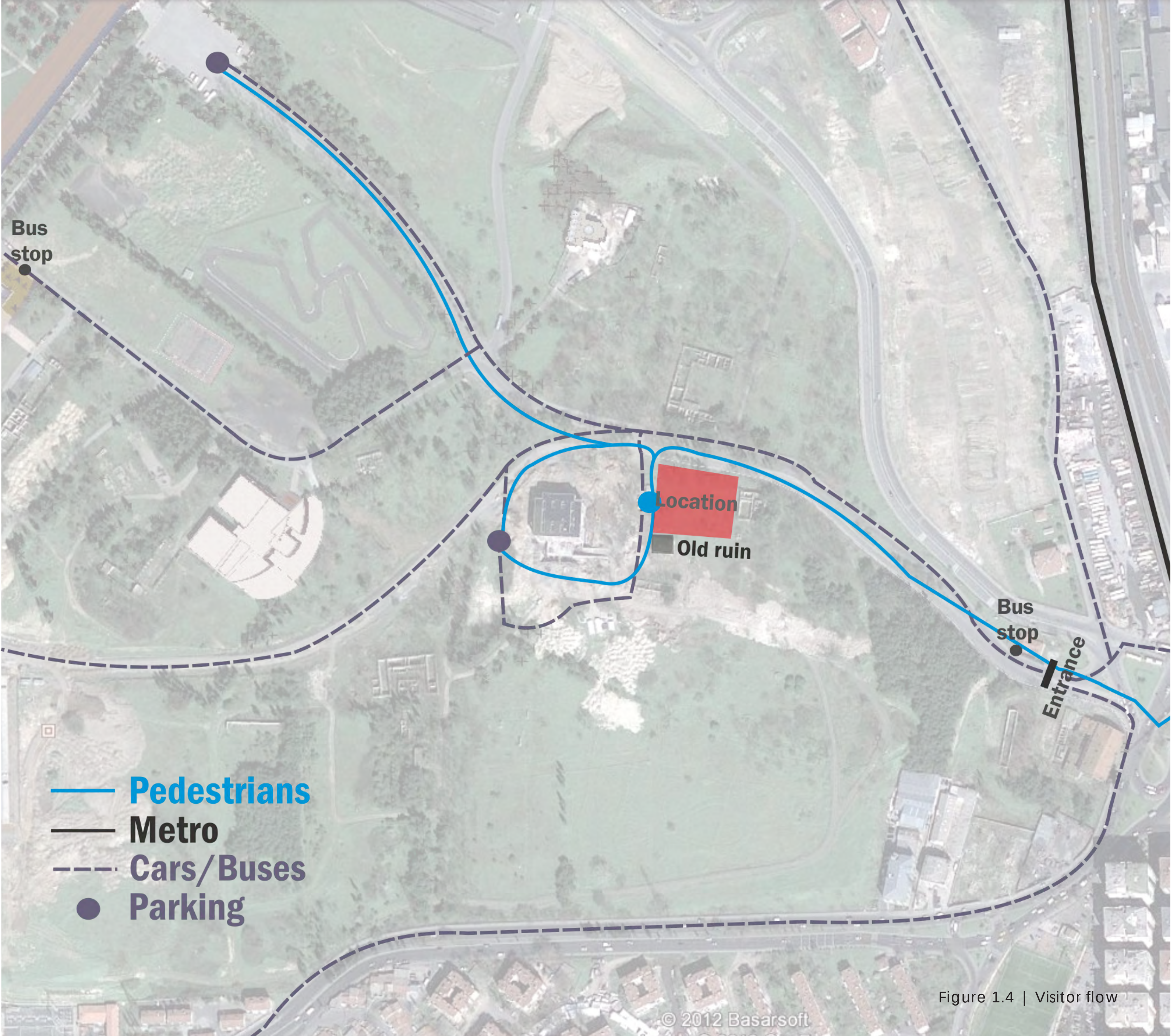


Figure 1.4 | Visitor flow

Impacts of the sun-path on the location

These images illustrate the shadows generated by the library and the old ruin building, which are the closest constructions to the location. From March to August these buildings do not generate shadow on the location. This means that YTU Children Science Center should provide shadow itself to the visitors on areas where necessary. On the other hand if solar panels are integrated, it could be said that on these months they will be able to collect more solar energy.

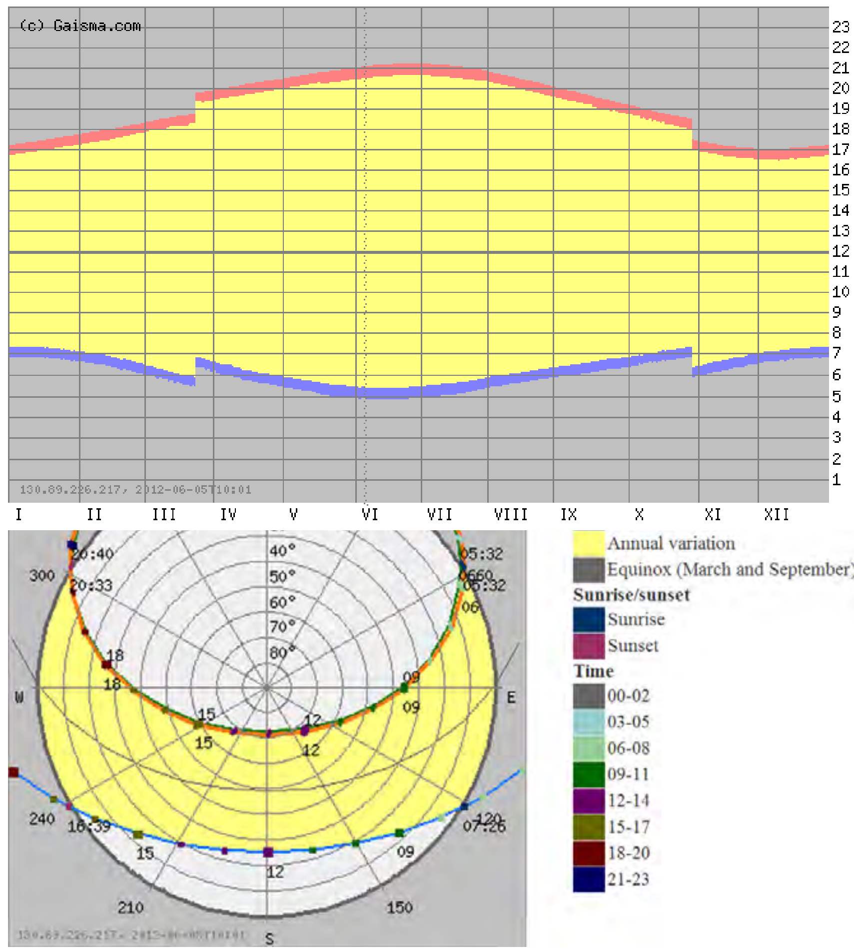


Figure 1.5 | Sun analysis

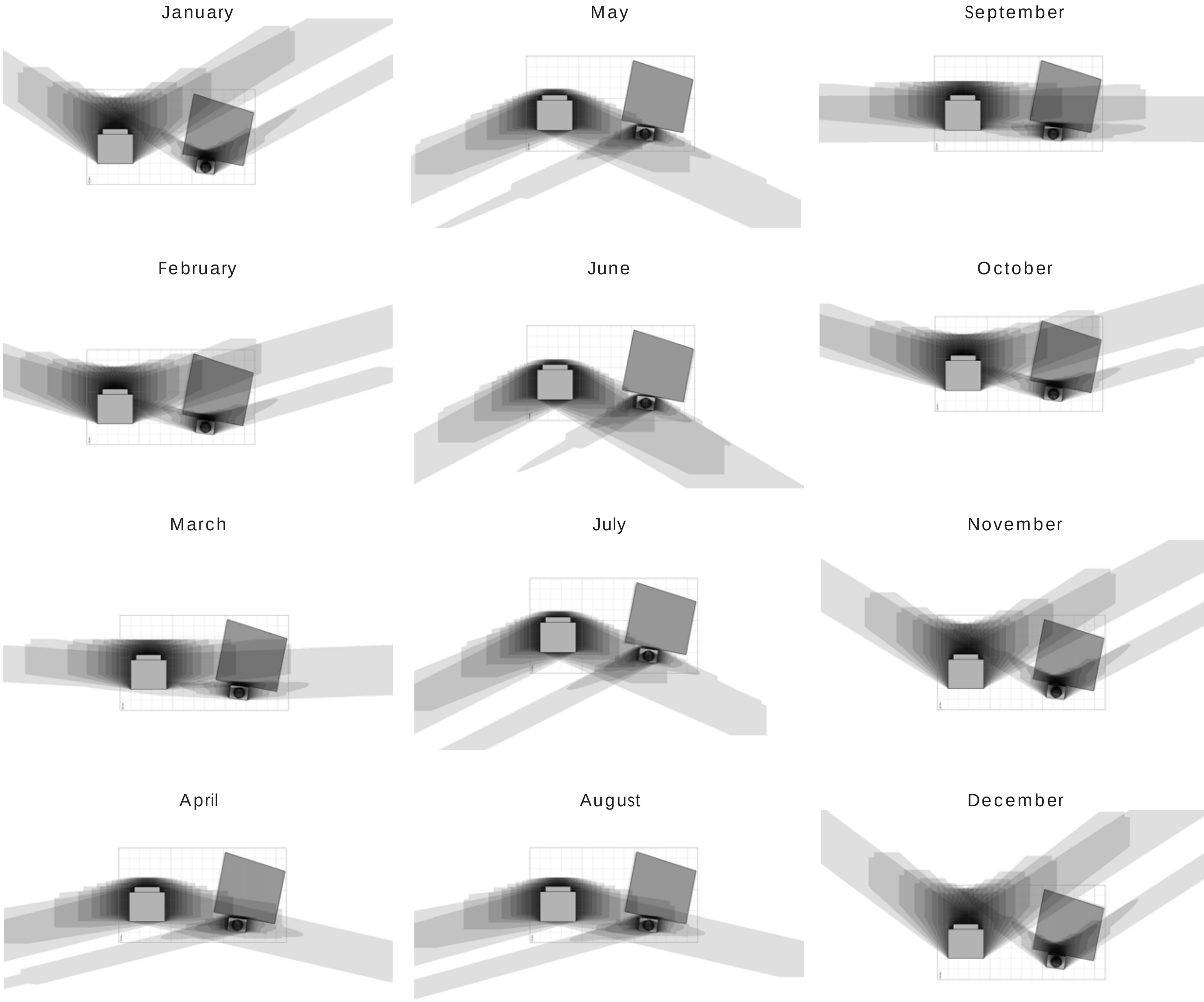


Figure 1.6 | Shadow analysis

Sun Angle

The images on these pages show the movement of the sun on 41° latitude.

The diagram below shows the results of solar access analysis during the year which calculates total, direct and diffuse solar radiation falling on objects. It shows that a 30 degree angle is the most suitable angle for photovoltaic panels.

The diagram on the top right shows the effect of the sun angle to project site on 21st of June at 12:00.

The diagram on the bottom right shows the effect of the sun angle to project site on 21st of December at 12:00.

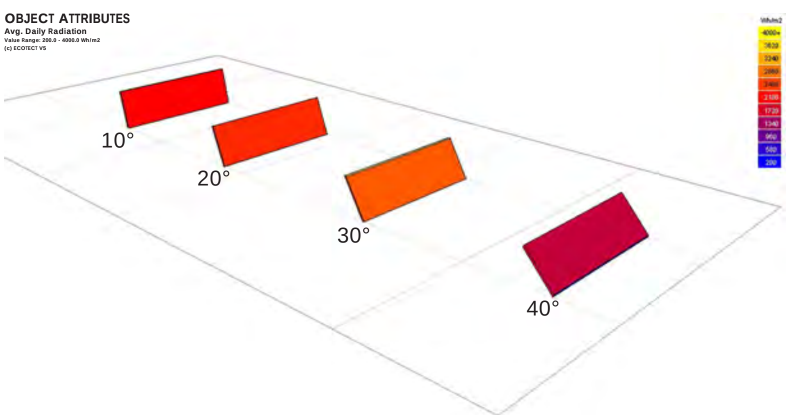


Figure 1.7 | Sun angle

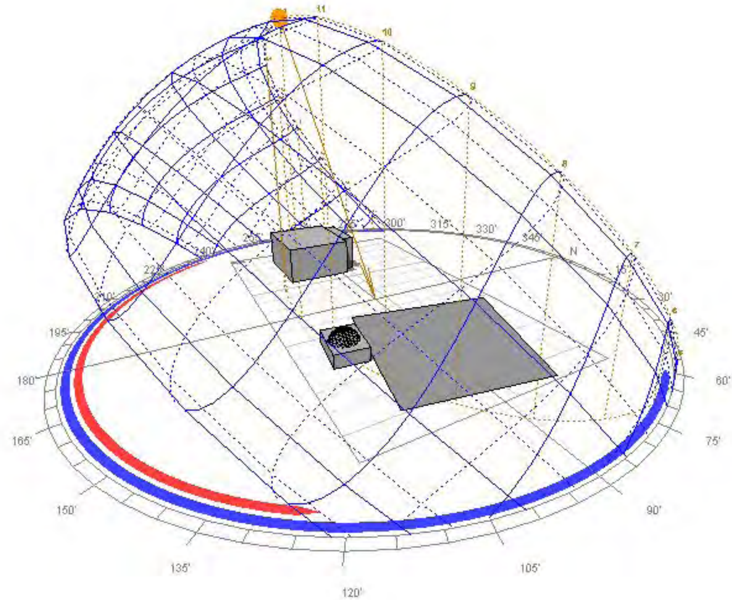


Figure 1.8 | 21st of June at 12:00

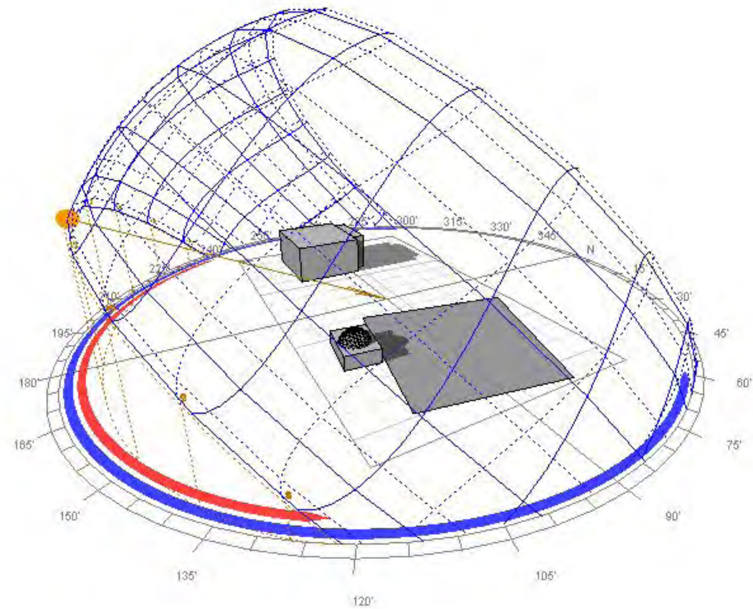


Figure 1.9 | 21st of December at 12:00

Weather conditions and temperature

Istanbul has a latitude of +41.1 (41°06’00”N) and a longitude of +29.0 (29°00’00”E). Istanbul has a warm Mediterranean climate with hot and dry summers and wet and not to cold winters. The humidity is often very high, especially in the morning. Istanbul experiences rain and also snow is not uncommon, but the snow normally does not last long. February is considered the coldest month of the year, whereas July and August are the hottest. Table below presents the average temperature among others factors for each month of the year.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg temp	6°C	6°C	8°C	12°C	17°C	21°C	23°C	23°C	20°C	16°C	12°C	8°C
Min temp	3°C	3°C	4°C	8°C	12°C	16°C	18°C	18°C	15°C	12°C	8°C	5°C
Max temp	8°C	9°C	11°C	17°C	21°C	26°C	28°C	28°C	25°C	19°C	15°C	11°C
Rain	99.1mm	66.0mm	61.0mm	48.3mm	30.5mm	20.3mm	20.3mm	25.4mm	40.6mm	71.1mm	88.9mm	121.9mm
Daily sun hours	3	4	4	6	9	11	12	11	8	6	4	3
Wind direction	nne	nne	sw	nne		nne	nne	nne	nne	nne	ssw	ssw
Wind speed	5 m/s	6 m/s	5 m/s	5 m/s	5 m/s	5 m/s	6 m/s	5 m/s	5 m/s	5 m/s	5 m/s	6 m/s
Humidity AM	82%	82%	81%	81%	82%	79%	79%	79%	81%	83%	82%	82%
Humidity PM	75%	72%	67%	62%	61%	58%	56%	55%	59%	64%	71%	74%

Table 1.1 | Weather conditions in Istanbul. *(www.weather.com, www.windfinder.com, www.bbc.co.uk)*

Wind directions

The wind direction and temperatures that must be taken into account for the design of the building are those occurring during summer and winter.

Considering the wind characteristics for both seasons allows covering the spectrum for the complete year. The wind temperature in summer for the location is between 20°-30° and the dominant direction is North East with a speed less than 30 kilometers per hour.

In winter the wind temperature is between 5°-10° and there are two wind directions, a main direction from North-east and a secondary direction from Southwest.

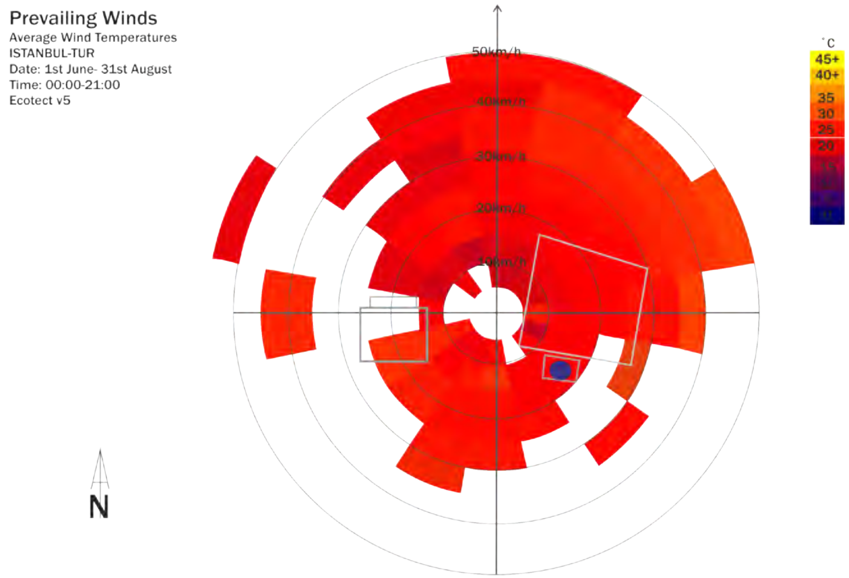


Figure 1.10 | Average wind temperatures June - August

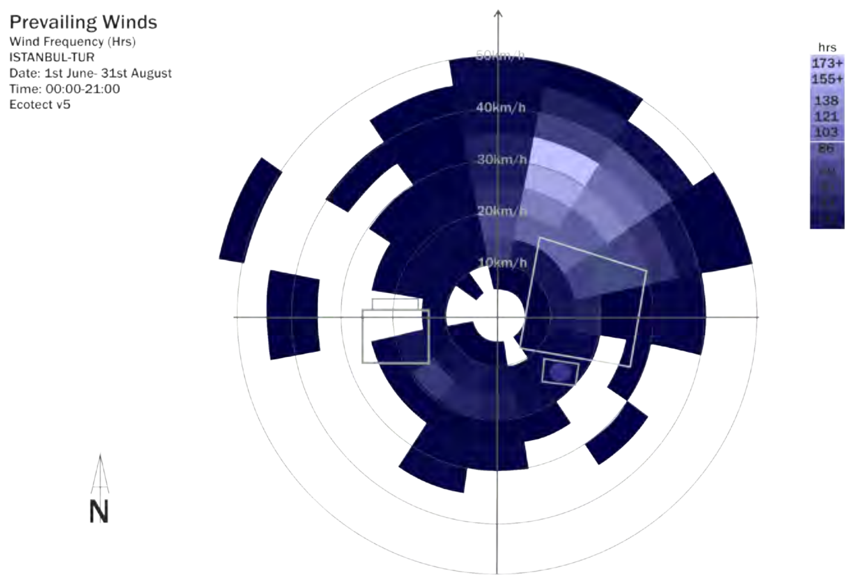


Figure 1.11 | Wind frequency June - August

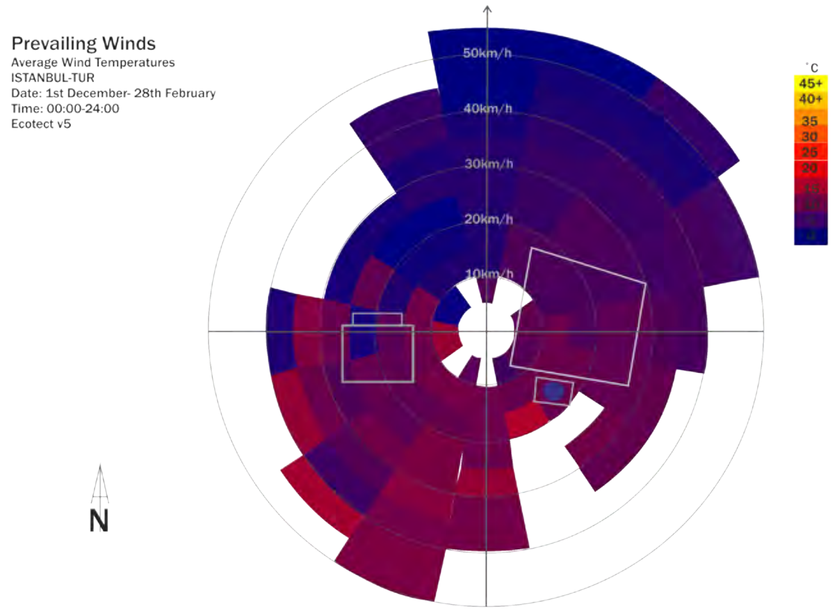


Figure 1.12 | Average wind temperatures December - February

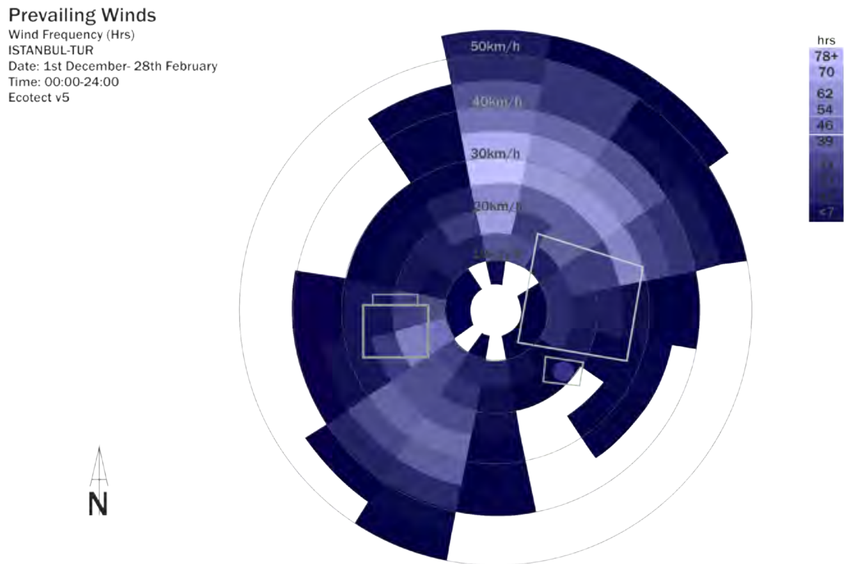


Figure 1.13 | Wind frequency December - February














Concept Design

Chapter two

After the analyses in Sarajevo, the three groups started developing concepts in line with the requirements from the MCDM, resulting in multiple concepts per group. Each concept was evaluated based on the key design criteria. From these three concepts one was chosen to be developed further by each group. In between workshops each group was working on improving the design of the chosen concept which had the most potential to meet the desired requirements. This resulted in a very interactive process of shaping, reshaping and sometimes completely redesigning the concepts. All this time the analyses from the first workshop were used for guidance in the process, finally resulting in one final concept per group.

In this chapter several important steps presenting this process are shown, to give a general idea about the followed design route. However, the chapter predominantly focuses on explaining and illustrating the final concept per group.

Group One

The first group initially developed the three concepts which can be seen on the right. Since all concepts were developed in one day, they were not that much worked-out, but still give a nice idea of how the building should look like. After the concepts were presented the best concept was chosen to be developed further.

In the first concept a part of the building can be extended by rotating a whole room. This way an atrium can be created in the center of the building. Even though this gives a lot of flexibility, the construction needed will probably be extremely difficult to design since a complete room needs to be moved.

The second concept was a pyramid-like shape with a large glass part on top. The front wall is covered in grass and is not too steep so it is possible for visitors to sit on and relax. The glass part is used at day to get lots of sunlight inside, while at night light from inside the building can be seen from far away through the glass part, this way functioning like a beacon. The building is fairly high, this way creating the possibility to have several floors inside.

The last concept resembles a stadium. The roof is going down to the middle of the building, this way creating a tribune for visitors to sit on, as well as lots of space to put solar panels. Inside, the building is shaped in a circular manner so that people can walk around. The outer walls can partly be removed in favor of an open exhibition.

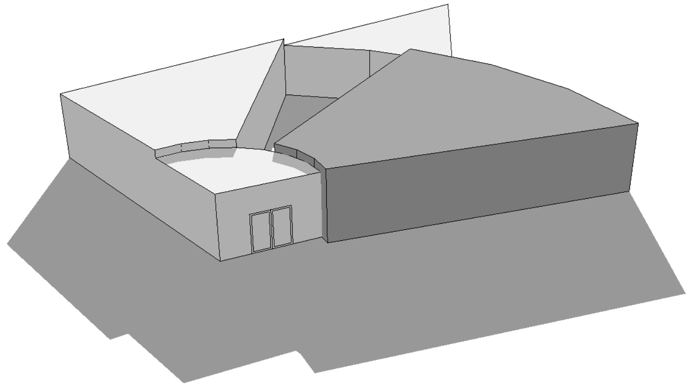


Figure 2.1 | Concept one

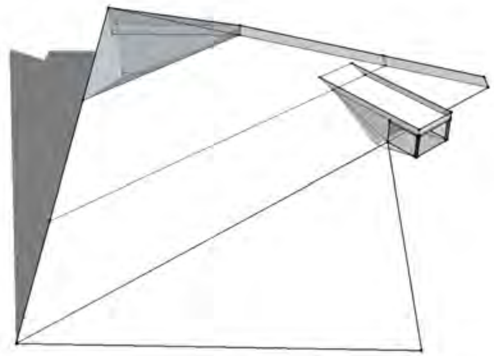


Figure 2.2 | Concept two

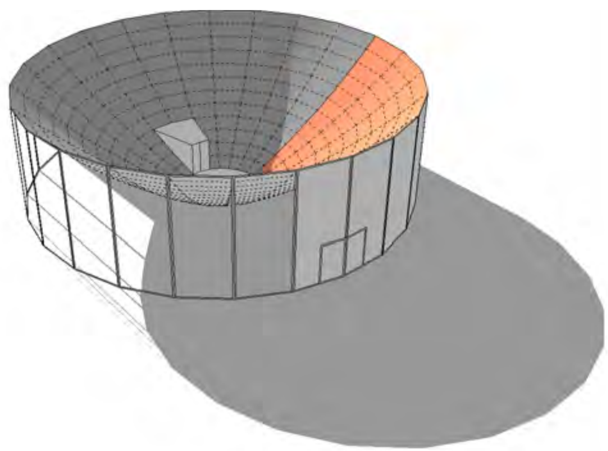


Figure 2.3 | Concept three

Multi-Criteria Design Matrix

Design Aspects	Concept 1	Concept 2	Concept 3
Architectural quality	+-	++	-
Multi-functionality	+	++	+
Transformability	+	+-	+
Energy, water & materials	-	+	+-

Table 2.1 | Multi-Criteria Design Matrix

All three concepts were reviewed using the Multi-Criteria Matrix. In concept one architectural quality does not stand out, but its multi-functionality and transformability can have a lot of potential. The building however is not very sufficient when it comes to material use since it is very massive.

The second concept is much better in terms of its architectural appearance. The glass rooftop which can act like a beacon at night creates a nice reference point for the campus. Because of the height of the building the multi-functionality scores really well. Transformability is a bit difficult, because the building is pretty fixed, however, because of all other good aspects this concept has been chosen for further development where other aspects that do not score well should be better integrated.

Concept three lacks architectural quality, but the multi-functionality and transformability are fine, although they do not stand out.

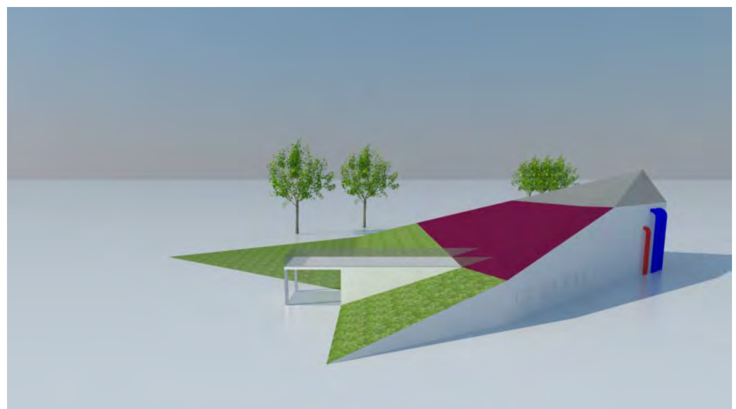


Figure 2.4 - Chosen concept

Design Process Group One

On the right the design process of group one can be seen. It started with the pyramid with a green roof at the South-side. The second design looked less artificial and was more organic, blending a bit more into the landscape. The final concept is almost completely underground. The focus is put on landscaping, letting the building blend in with the natural environment. This way it does not compete in a visual way with the library which can be seen as a landmark. During the approach from the main road, the building itself is not visible. The only things which can be seen are some hills with colored domes. This triggers the children to explore the mysterious area. The domes are all in different colors to create an interesting atmosphere inside. The glass domes on the roof can be opened so a natural airflow is created.

Underground the building contains two large open spaces. The spaces are rounded in a natural way to give a more organic look to the building.

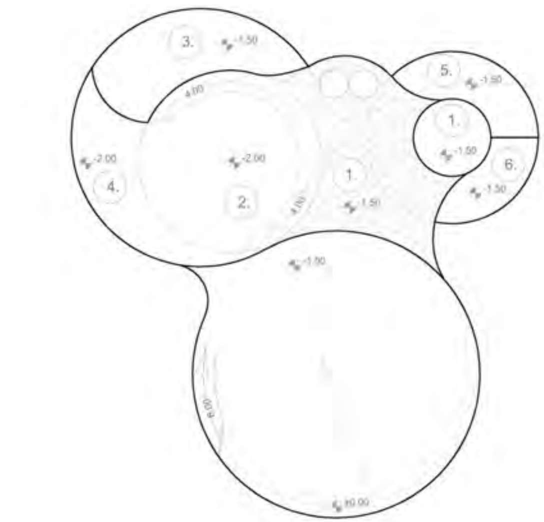


Figure 2.5 | Top view

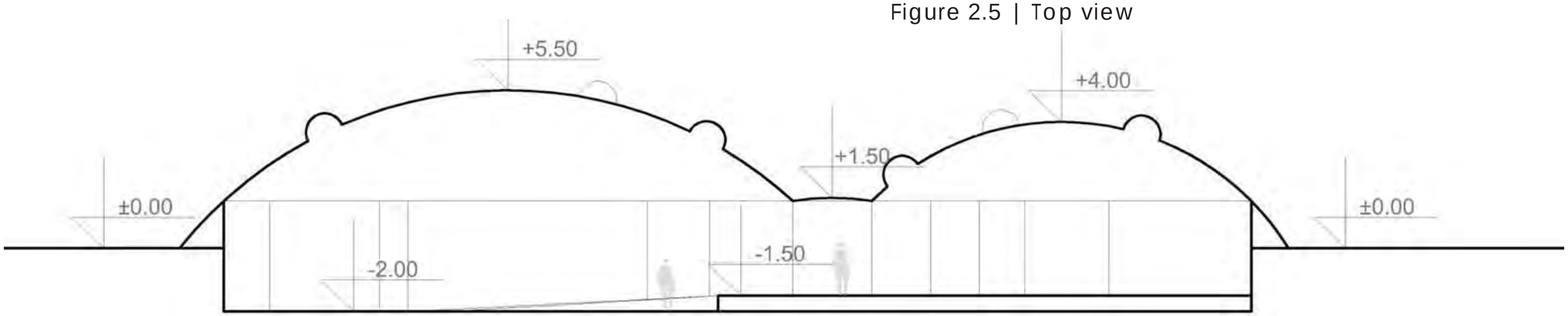


Figure 2.6 | Section view

Figure 2.7 | Pyramid rear

Figure 2.8 | Evolved organic design

Figure 2.9 | Building as a landscape

Group Two

In comparison to group one, group two developed not three, but two concepts as shown on the right.

The first concept was derived from the Rubix Cube. By shaping the building with the Rubix Cube as a reference the building would be recognizable to all. It would link the function of the building as a Children Science Center to the form as a Rubix Cube. Because of the shape people will associate the building with childhood and more importantly, by the representation of a complex puzzle made easy. The building consists of a fixed steel construction and is made transformable by giving the possibility to add or remove 'blocks' from the construction.

The second concept was more focused on the integration in the landscape. This was realized by going partly underground and letting the roof at the back literally flow from the earth. Because of the access path sloping down, the visitors get sucked in at the entrance. At the back they can exit the building again and can sit or walk on the roof of the building.

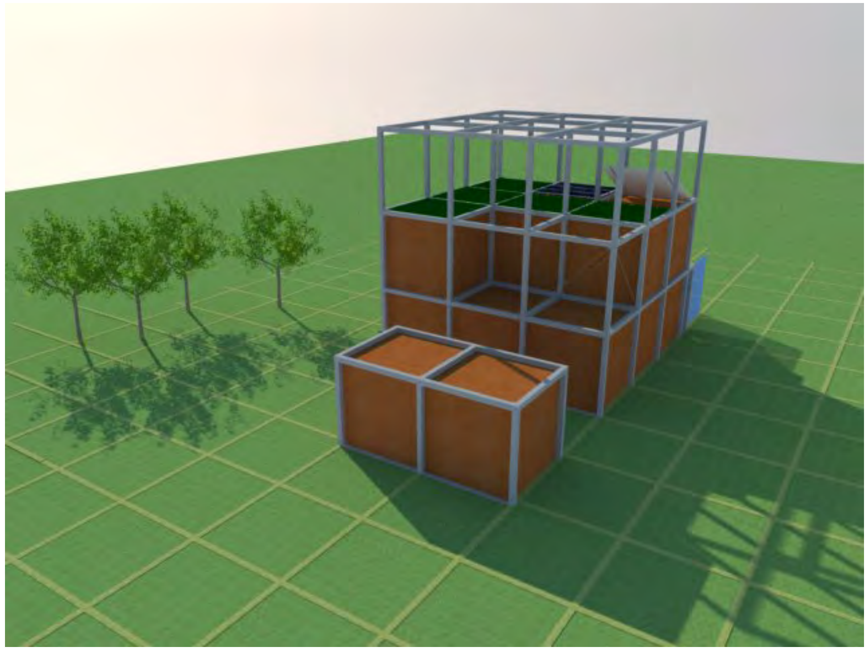


Figure 2.10 | Initial concept

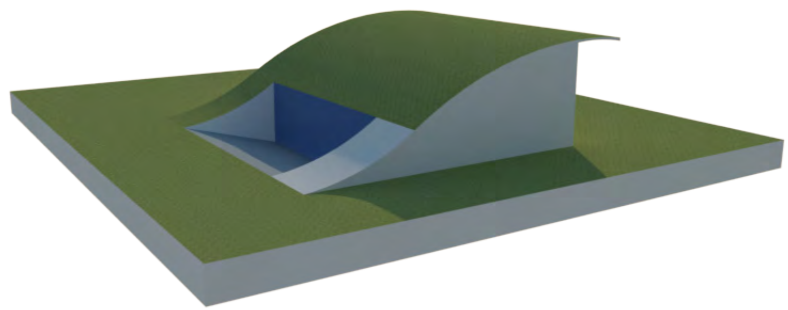


Figure 2.11 | Second concept

Multi-Criteria Matrix

Design Aspects	Concept 1	Concept 2
Architectural quality	+-	+
Multi-functionality	++	+-
Transformability	++	-
Energy, water & materials	+	++

By reviewing the two concepts using the Multi-Criteria Matrix the good and bad aspects of both concepts were revealed. The first concept scores high on the multi-functionality and transformability aspects. By being able to add and remove wall panels the possibilities are endless. The building can be as big or small as is desired, making it very multi-functional. This is also why this concept was chosen to be further developed.

The second concept is way less multi-functional and the transformability is not as good either, since the building is very fixed. The building is situated partly underground and this way the constant temperature of the soil can be used to keep energy costs low. Therefore scoring good on Energy, water & materials.

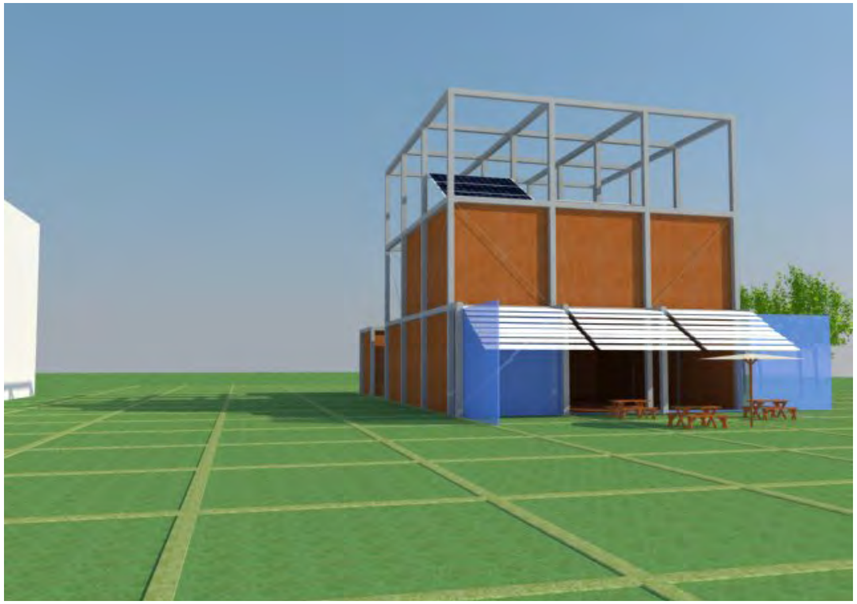
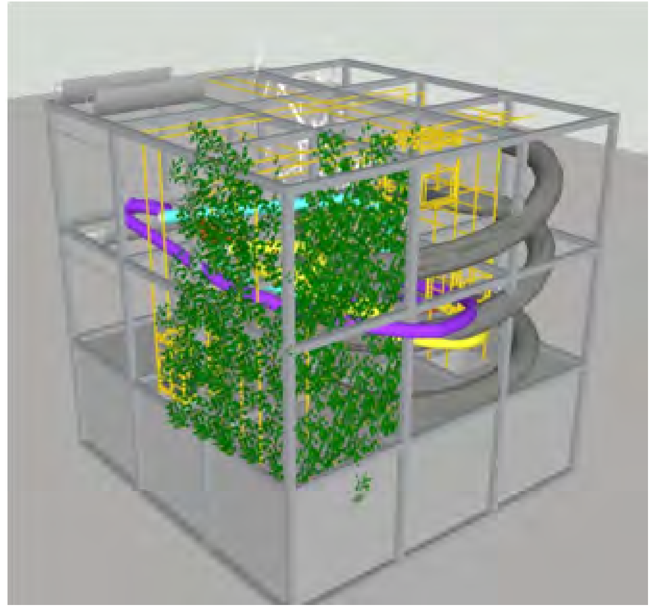


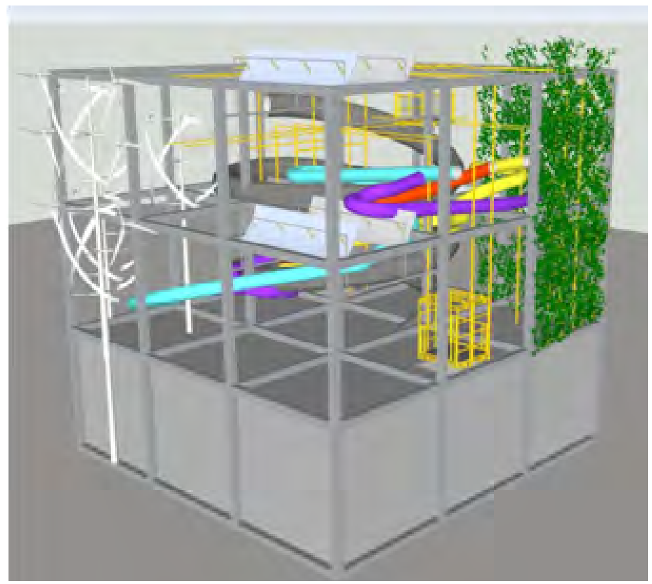
Figure 2.12 | Rear view

Design Process Group Two

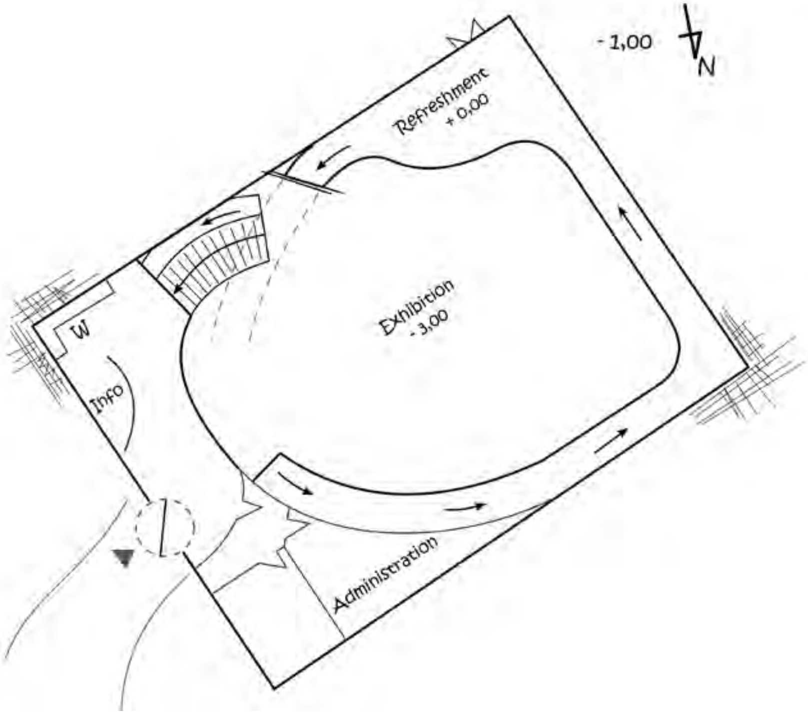
On these two pages the design process of group two can be followed. At first the Rubix Cube got further developed. Following the basic design remained, only the focus shifted more to the experience of the kids; playful and educational. In the final design the Rubix Cube is abandoned, but the playfulness and educational value are kept. The building is an exhibition in itself by introducing the five elements as the theme; earth, water, wind and sun as well as the additional element man. The building will create awareness about these four environmental elements and how the children themselves have an impact on them. A large open exhibition space (man) was created underground. On top a web of ramps and platforms introduce the children to the four elements. On the platforms physical principles are explained to the children by bringing the (invisible) inner workings to the outside; making them visible. This inside-outside contradiction is also shown in the envelope and creates a better integration in the landscape.



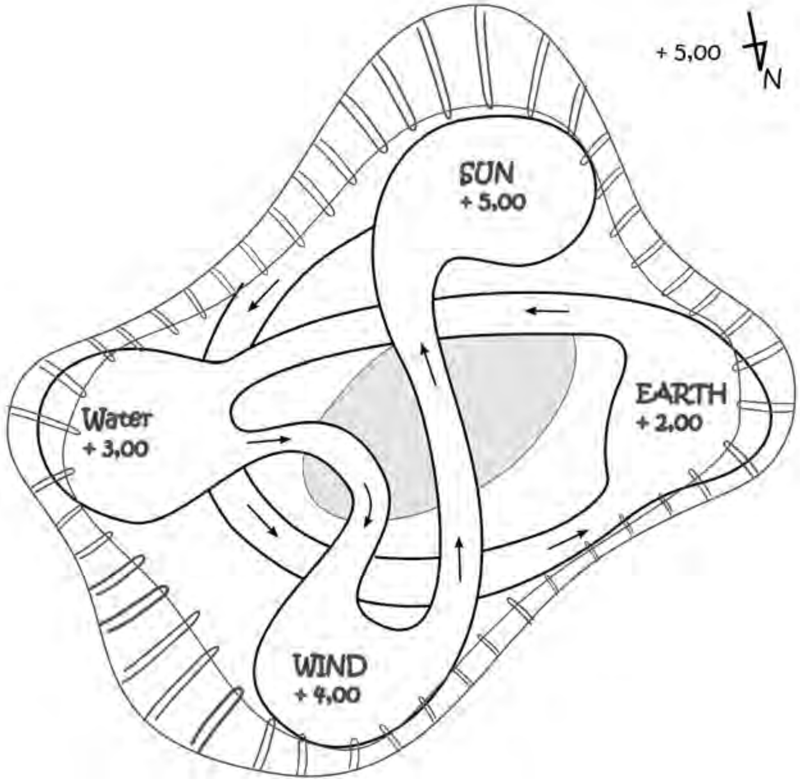
Picture 2.13 | Open cube



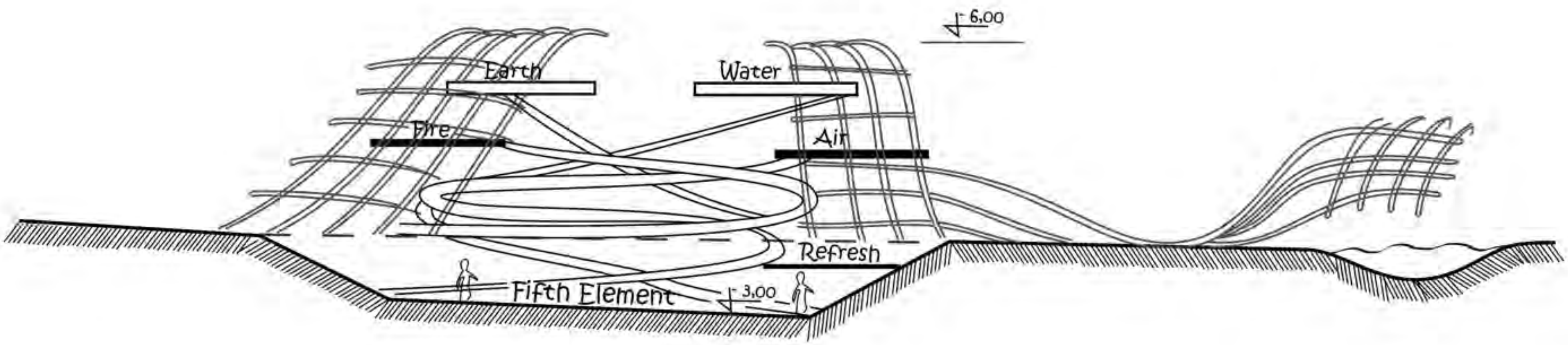
Picture 2.14 | Open cube rear view



Picture 2.16 | Inside



Picture 2.17 | The different elements



Picture 2.18 | Section

Group Three

The concepts generated by group three focused on including a children program in its exhibition area. This program includes for instance exhibitions such as biology, astronomy, environment recycling, human body, robotic and technology. Additionally the areas to be included in the building were: administration, lab, information, toilets, refreshment, multimedia room and workshops.

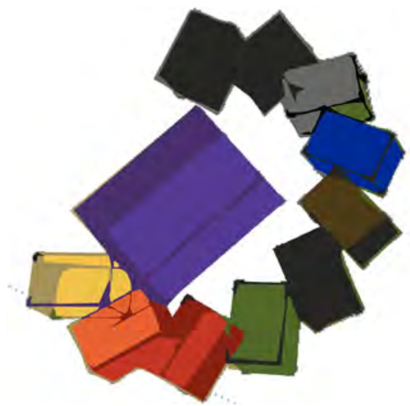
Considering the aspects mentioned before, the students of group three proposed modular concepts that allows transformation based on the needs of the users. The modules suggested in these concepts represented each of the area needed. Base on the modules' configuration the building can create bigger or smaller areas, connecting or disconnecting the modules between each other.

After an analysis on the modular configurations for the building a linear configuration was chosen. This linear configuration intends to connect the different modules with a large hall. The hall leads visitors from the entrance to the end of the exhibition path, approaching the different modules.

Two options were created for the transformability of the areas. Option one proposes a connection of two modules using a connection element that can go inside or outside the module itself. Option two presents folding walls that connect or disconnect the modules.

Picture 2.19 | Configuration one

Picture 2.20 | Configuration two



Picture 2.21 | Configuration three

Multi-Criteria Matrix

Design Aspects	Concept 1
Architectural quality	+-
Multi-functionality	++
Transformability	++
Energy, water & materials	-

The concept was evaluated based on the main aspects of the Multi-Criteria Design Matrix. In the architectural quality aspect, the modular identity gives the impression of transformability, but it does not have the green identity, nor does it suggest the playfulness of a building that is made for children related activities. The entrance is the biggest element of the building and welcomes and invites visitors to enter, but the hall that they reach afterwards is not playful and inspiring for them.

The multi-functionality and transformability of the concept is related to the modules, which allow spatial and technical transformation with any of the proposed transformation options.

It is necessary to defined energy and water systems that contribute to performance of the building. In this phase of the design process these systems and materials were not well specified. As a result a further development of the concept is needed.

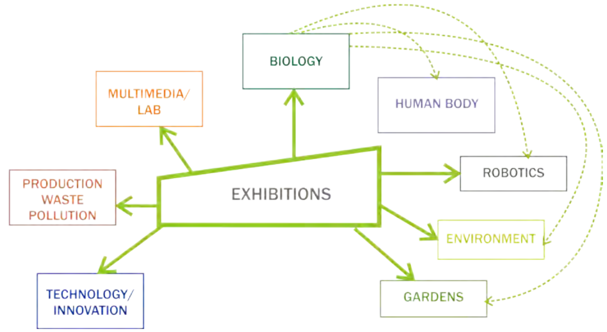


Figure 2.22 | Programs

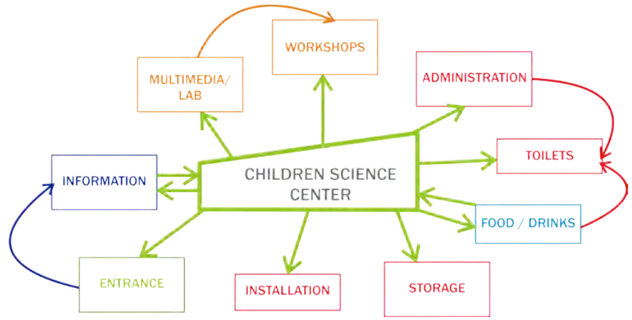


Figure 2.23 | Areas

Figure 2.24 | Concept birds eye view

Design Process Group Three

A redesign of the previous concept was necessary. The design team focused on the improvement of the architectural quality and the energy, water and material aspects. The expo area inside allows transformation to the different scenarios. Dividing walls transform the space into six smaller rooms and can also be moved outside enlarging the total volume. The west façade offers an open space in summer or closed space in winter. During the day the building can be cooled through the open glass façade. The secondary wood façade helps to control the amount of wind desired into the building.

The concept proposes different renewable energy systems. With the use of these, it aims to generate more energy than is being used. A rain water collector is installed underground to provide water to the services inside the building. Solar panels are integrated in the green roof and plants are placed in an internal garden to purify the air.

Now the main attributes of the building's identity are the colorful modules, the rectangular shape and green roof. The secondary wood façade reveals some bright colors. In this way the kids feel invited to enter and discover the colorful exhibition that is inside.

A further analysis and a change of the location of the building lead to the proposal of a green wall on the north side instead of the wood façade. The green roof was integrated to the landscape with an outside ramp. A lighter transparent building construction was necessary in order to use the sun as a source of natural light.

Visitors entering the building on the west side can find a information desk and ticket service. In this module the administration room is located and the internal exhibition space is longitudinal. The refreshment area is located on the East part of the building. This area can be extended outside during warmer months of the year.

Exhibition space can still be divided with light removable walls allowing to adapt to different scenarios.

On the north side of the internal exhibition space green building systems are integrated into the green wall. Some of these installations positioned on the North side break the green facade, making it possible for the visitors to get a glimpse of the inside before they enter the building.

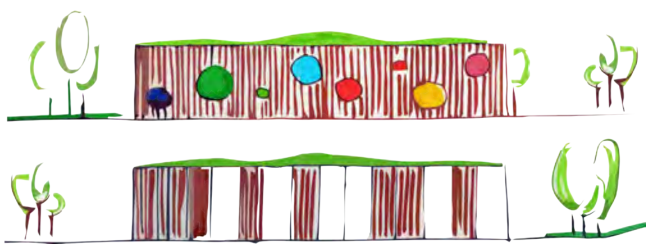


Figure 2.25 | Facade sketches

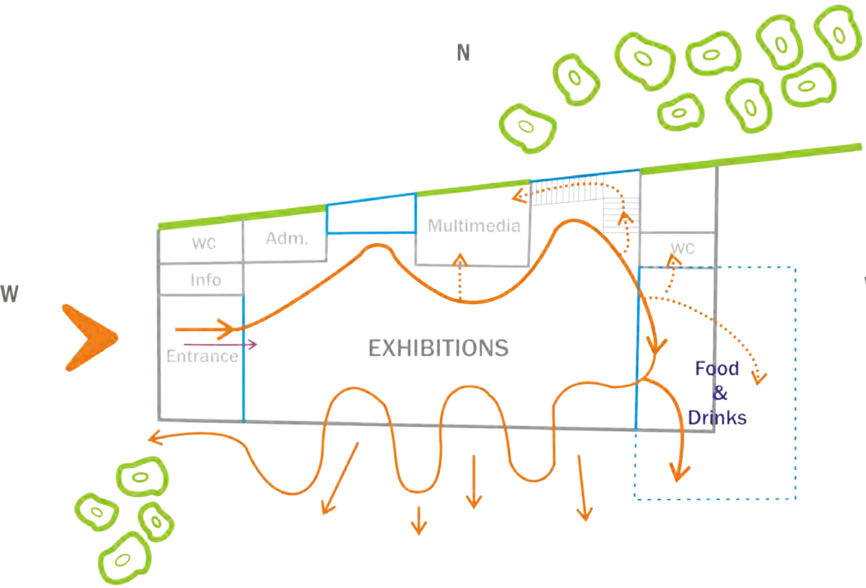


Figure 2.26 | Visitor flow

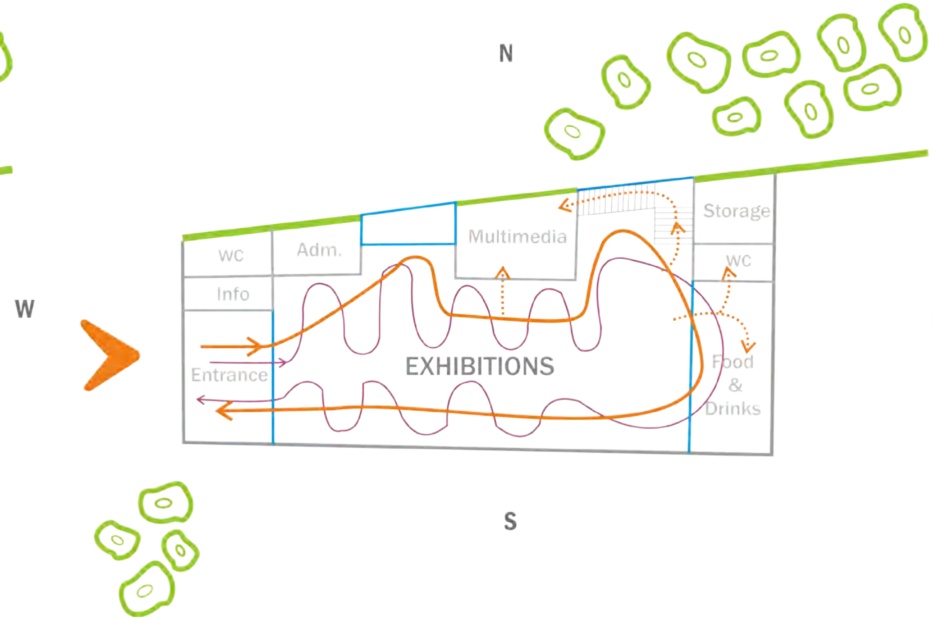


Figure 2.27 | Visitor flow


Figure 2.28 | Transformations option one

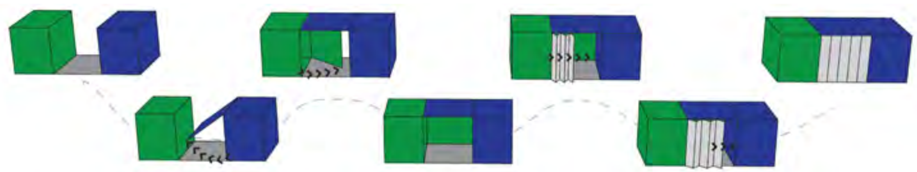


Figure 2.29 | Transformations option two

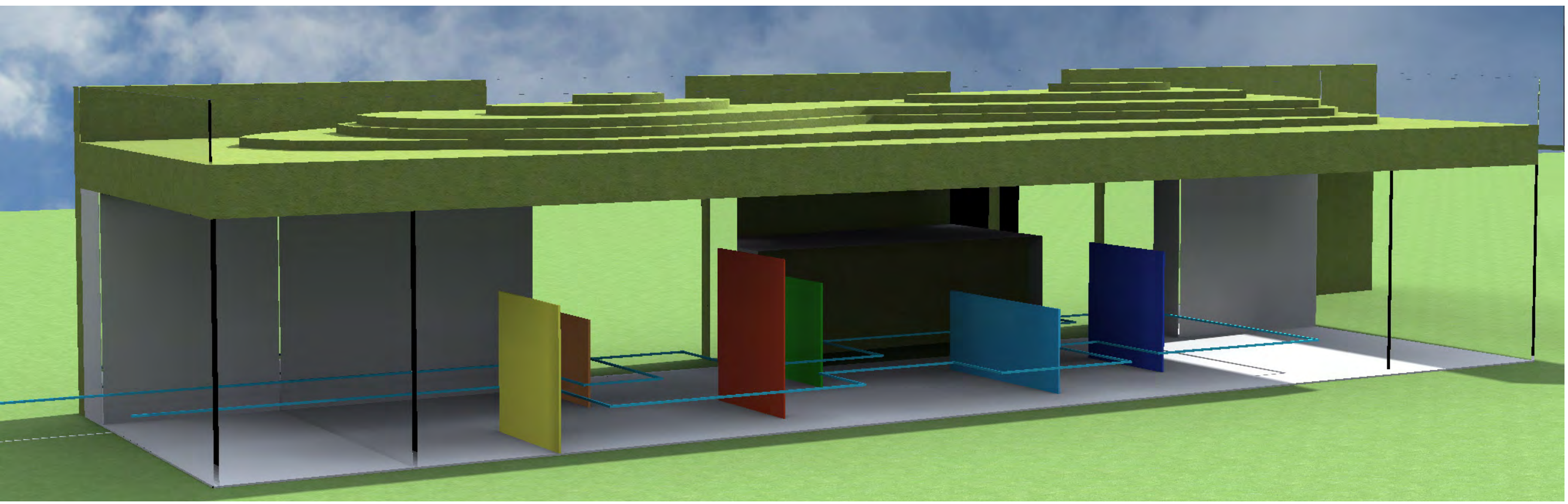


Figure 2.30 | Concept render

Combination of Concepts

Each group has presented their concepts. Evaluation of each proposed concept was done and one concept with the most potential per group should be chosen for further developed. However, every group had put their focus on some specific design criteria therefore a combination of the best elements of each group was integrated in order to get to the final design for the building.

The best element of the concept from group 1 is the fact that it really blends into the landscape, creating a more organic structure and making it fun for children since this is not a regular building. Furthermore in this way the building does not compete with the library, which can be considered as a landmark. The approach to the building can be an exploration on its own by having a curved path going through the hills, slowly revealing the building inside these hills.

From group 2 the dynamic, challenging and inviting spatial configuration from the perception of a child was chosen. The building will contain various experiences on different platforms. These platforms will be placed on different levels and ramps will connect them. As a result a playful 3D exhibition can be created and children will be amazed to follow the creative path that leads inside. Additionally the building should have different scenarios inside and outside and its transformations must be a logical part of the total concept.

From group 3 the green aspects were chosen to be integrated. These aspects include different systems that contribute to the energy performance of the building. An air purification system at the green façade collects the CO_2 emissions. A rain water purification container distributes the treated water to the different services inside the building. Solar panels allow the use of renewable energy in the systems and natural ventilation can be used instead of artificial ventilation. Taking advantage of the fact that a part of the building is underground, geothermal energy should be used for instance in the heating system. The green aspects mentioned before should be integrated in a logical way of the total volumetric, programmatic and ultimately architectural concept.

In conclusion, the final design for the building should blend well into the landscape, this way creating an organic structure where the approach to the entrance is already an exploration. Furthermore the spatial configuration inside should be design with the perception of a child kept in mind. A 3D exhibition with platforms on different levels will make the way through the YTU Children Science Center really fun for children. At last the green aspects that contribute to the energy performance of the building should be well integrated into the architectural concept.

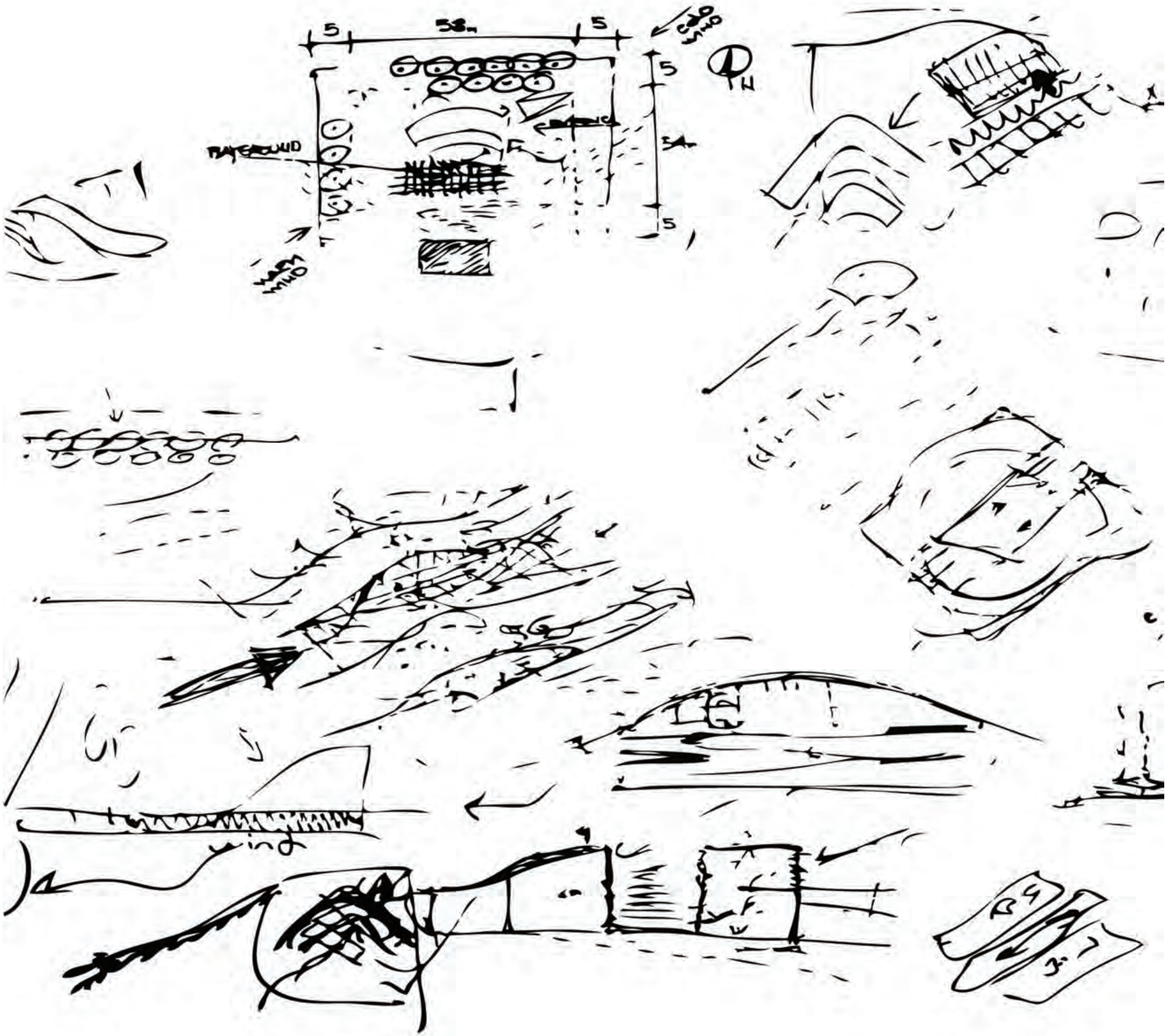


Figure 2.31 | Whiteboard


EFES


YILDIZ SEM


YILDIZ TEKNİK
ÜNİVERSİTESİ


concerts


31 MART
15 NISAN
2012
TURKCELL
TAKSİM - TÜNEL


CHILDREN
SCIENCE
CENTER

Progress
Chapter three

When all groups finished their concepts the best elements of all concepts where combined in order to get to a final concept. The process of going from all good elements to one final model that includes all these elements was very intensive and this process really defined the final shape of the building. Although the organic shape of group one has been accentuated as an important starting point, the first integrated proposals were rather orthogonal and have lost many qualities that previous concepts had. It took some time for all students to start working as one big team instead of three individual teams and to get a consensus on how to reintegrate the qualities from these three concepts in a proper manner. During this process the building has been changed several times and this chapter includes all different concepts that were proposed in this phase. As can be seen in this chapter the building slowly evolved from a more straight shape to a more organic shape, which better integrates in the landscape and can be seen as more playful for children.

Figure 3.1 - Grin Grin

Inspiration

The source of inspiration for the YTU Children Science Center was a building designed by Toyo Ito Associates Architects. This building can be found in Japan and is named Grin Grin. The building consists out of three domes covered in green. The building blends nicely into the landscape just as desired for the YTU Children Science Center. Furthermore the building was designed in a playful and organic way which will be compelling to the children. Different concepts were developed with the source of inspiration kept in mind. These can be found on the upcoming pages.

References:

Toyo Ito Associates Architects, www.toyo-ito.co.jp

Figure 3.2 | Grin Grin birdseye view

Figure 3.3 | Grin Grin from below

Progress

Different aspects from the three final concepts, presented in the previous chapter, were combined into one design. From group one the main aspect was the building as an extension of the landscape, from group two, the 3D exhibition and indoor organization and from group three the green concepts as a logical part of the building.

Considering these aspects and the building Grin Grin as a source of inspiration, a redesign process followed. The images displayed in this chapter exemplify this redesign process. The first attempt consists of one box-like building which is partly underground and is situated in a hill. On the South-side a large glass façade can be found were children can take a look inside before they enter the building. When the visitors arrive by bus they first follow a path which leads them to the entrance. From the bus stop and the North-side street the building itself is not visible. The children only see the big hill. When approaching the entrance, the building will slowly reveal itself up until the point that the whole South façade becomes visible.

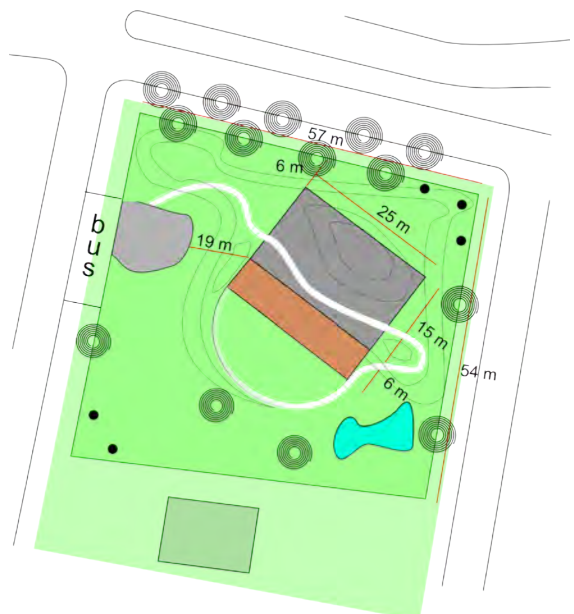


Figure 3.4 | Site plan

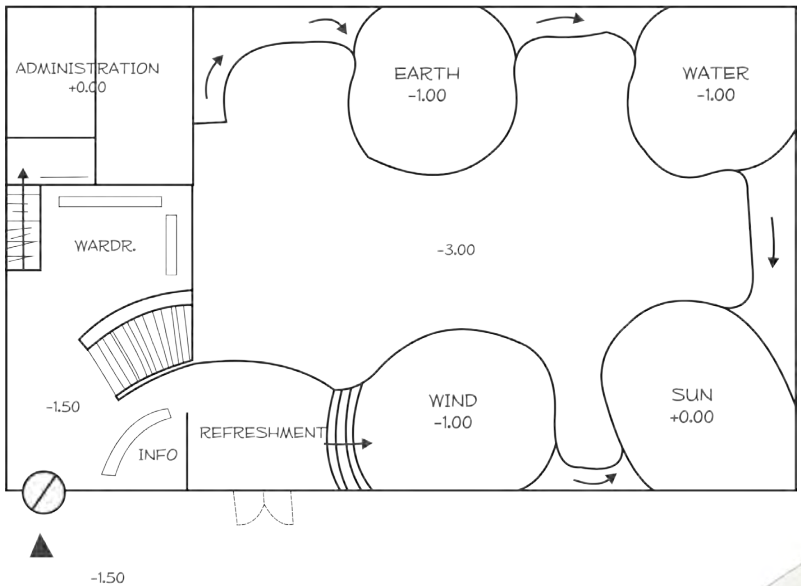


Figure 3.5 | Program

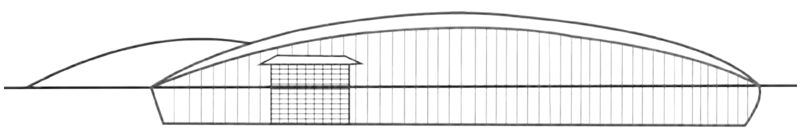


Figure 3.6 | Section

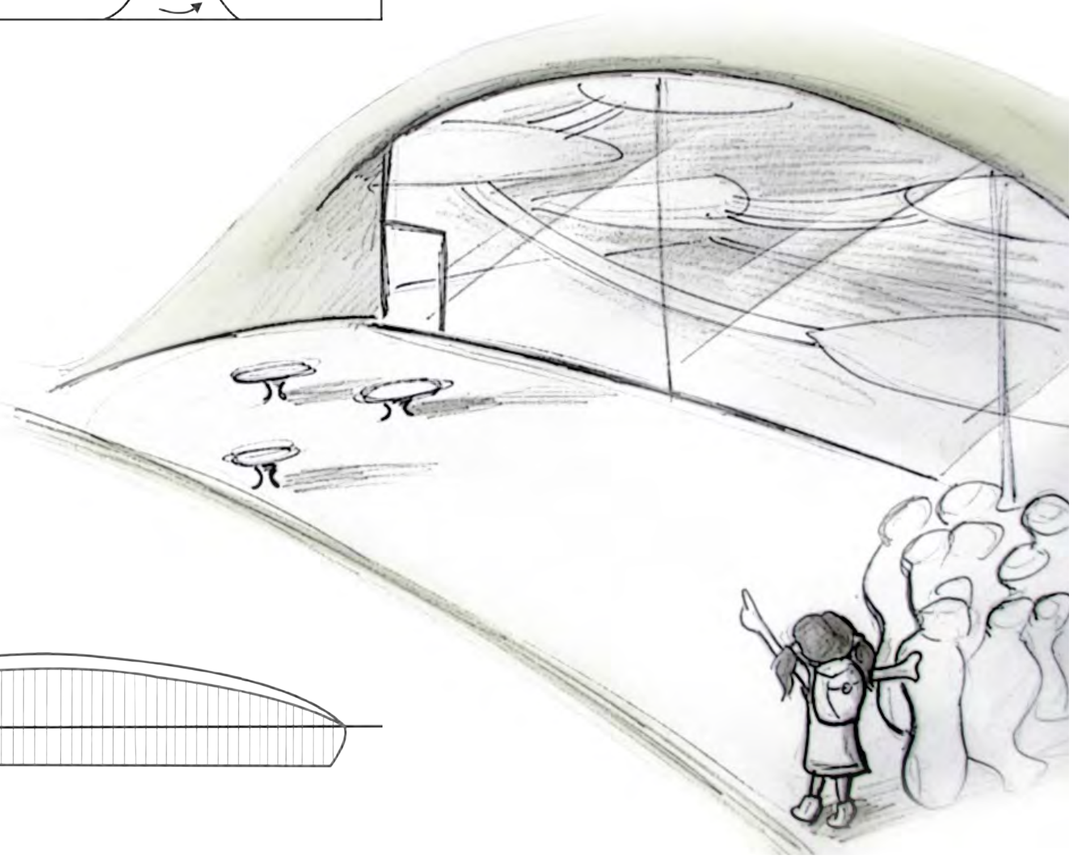


Figure 3.7 | Artist impression

Inside the building, a rectangle shape contains different departments on different levels. One of the disadvantages of this box-like concept is the lack of coherence between the organic shaped hill and the rectangle shape for the interior part. The rectangle shape does not represent a challenge or proposes a playful configuration suitable for children. Furthermore the path leading toward the entrance seems to be more a physical barrier than an architectural added value. Therefore a redesign is necessary to design an organic shape and a playful path that visitors would be pleased to follow.

The redesign of the previous concept began to look more like an organic building with rounded edges and less rectangular forms. This concept consists out of two buildings or modules above ground which are connected as one module underground. Instead of following an explorative path to reach the entrance, this concept proposes now a simplified path that leads to it. Therefore the entrance is now better to understand.

Inside the building different platforms are connected and together form the exhibition area, this way making it more fun to explore for children since everything can be found on different levels. Outside at the South-side an amphitheater is located for children to see a presentation for instance, or students to watch a movie projected on the façade. Even though this concept is more organic than the previous one, it still looks artificial in the landscape. In other words this concept does not fit with the surroundings very well.

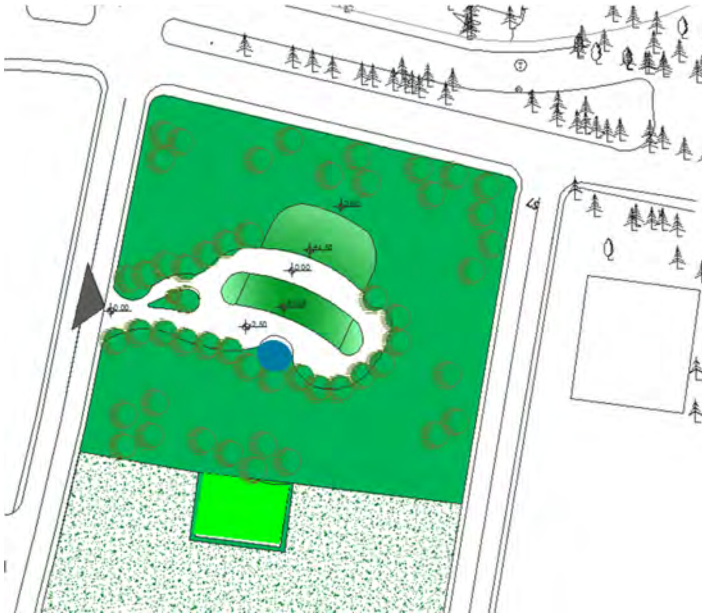


Figure 3.8 | Plan redesign

An improvement was made using the space between the two modules of the building. Here the concept proposes a path that goes through the two modules and leads to the entrance at the amphitheater area. As a result the children follow an organic path while exploring the area in an interesting way. In addition this path encourages the visitors to look at the technical and green façade that the concept presents. The idea of these facades is the representation of the green and technical aspects used in the building. Children can learn for instance how a green house (green façade) can purify the building absorbing the CO_2 emissions.

The internal area of this concept is quite similar to the previous concept, although now it is even more curved and none of the existing lines are straight. The proposal of an amphitheater at the South-side was kept. Now this area presents a more rounded shape, fitting better into the landscape.

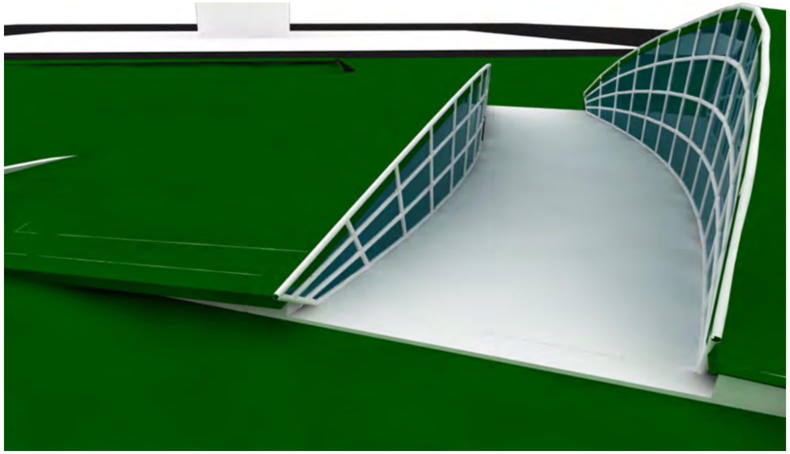


Figure 3.9 | Combination of concepts view one

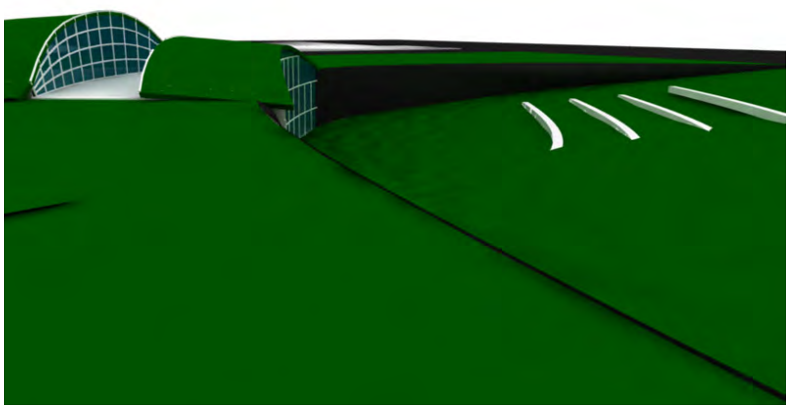


Figure 3.10 | Combination of concepts view two

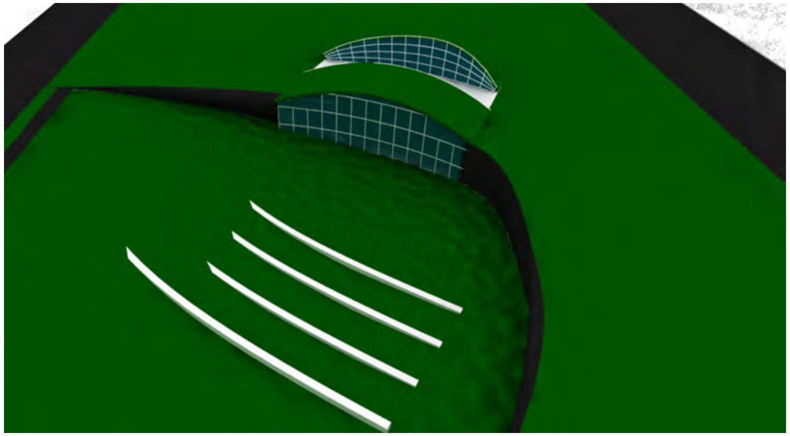


Figure 3.11 | Combination of concepts view three

An evaluation of the previous concepts proposes two parts or modules above ground that are connected to each other instead. Underground they continue forming one large area for the different exhibitions and departments. The architectural quality of this concept is more in balance with the landscape. Now it is an organic and playful shape and is more compelling to children.

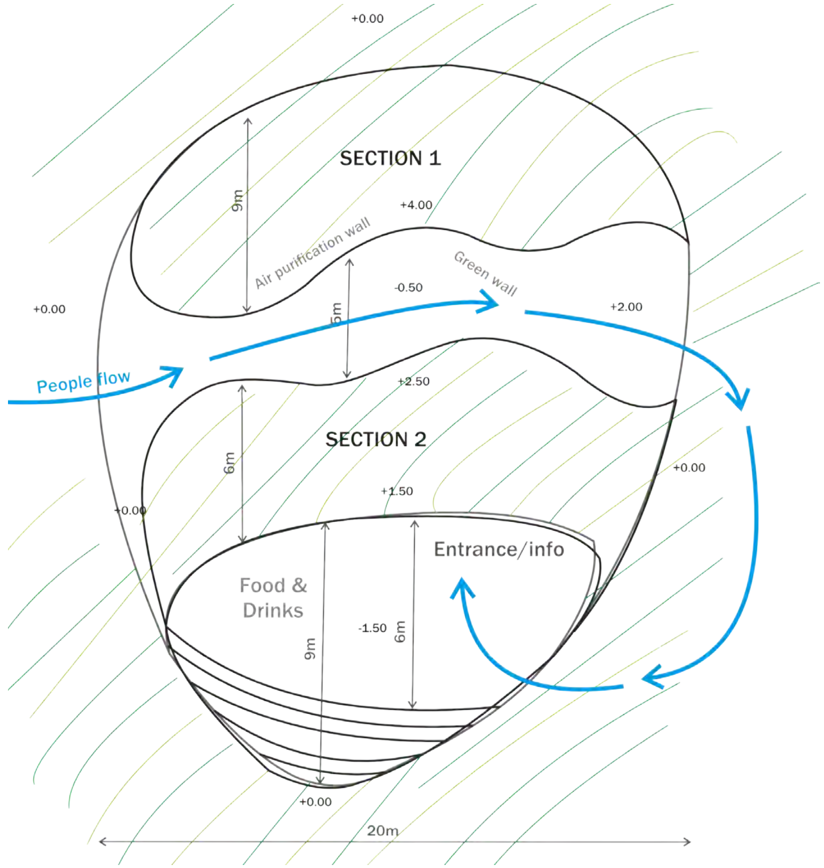


Figure 3.12 | Plan top view

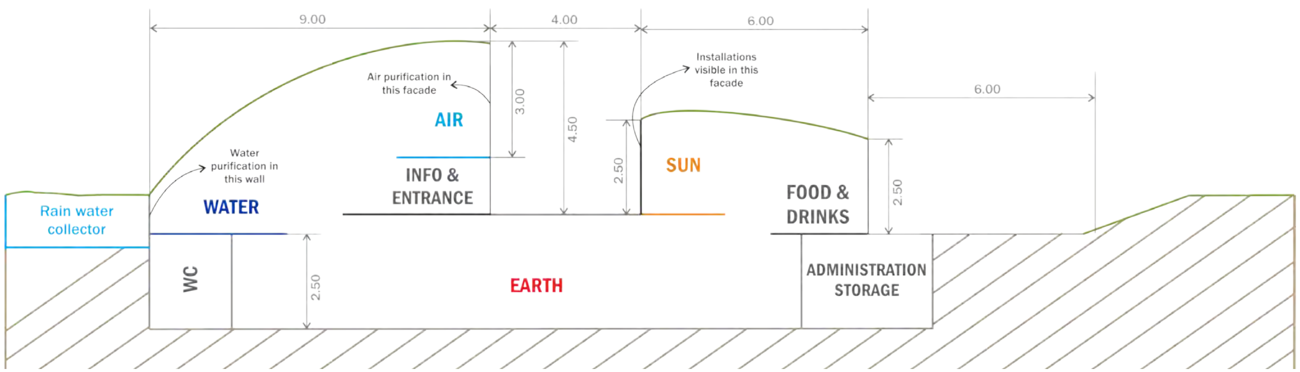


Figure 3.13 | Section

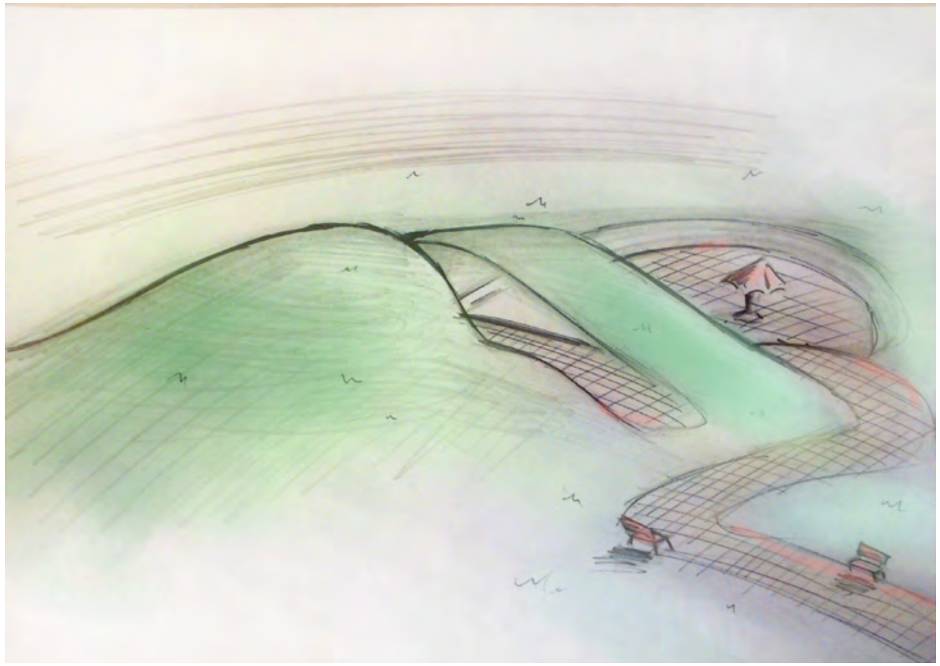


Figure 3.13 | approach

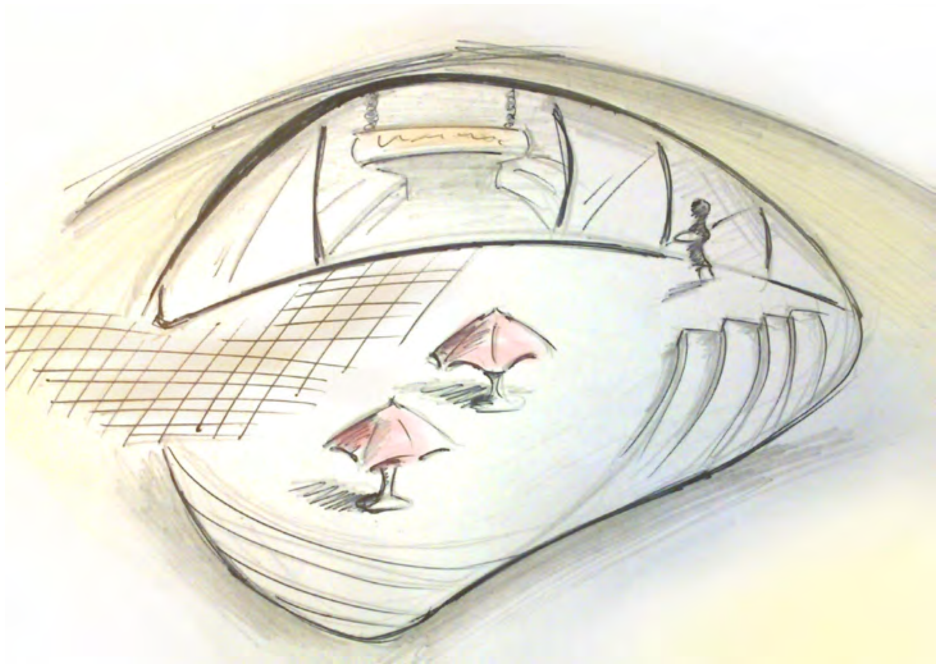


Figure 3.14 | Terrace

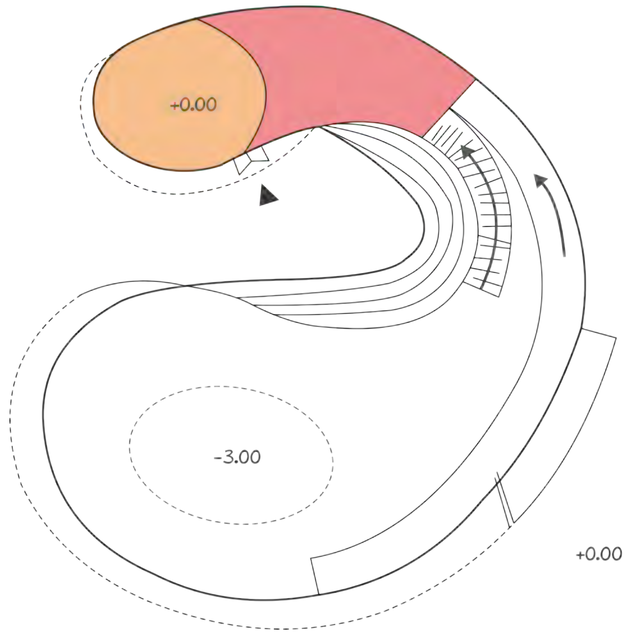


Figure 3.16 | Levels

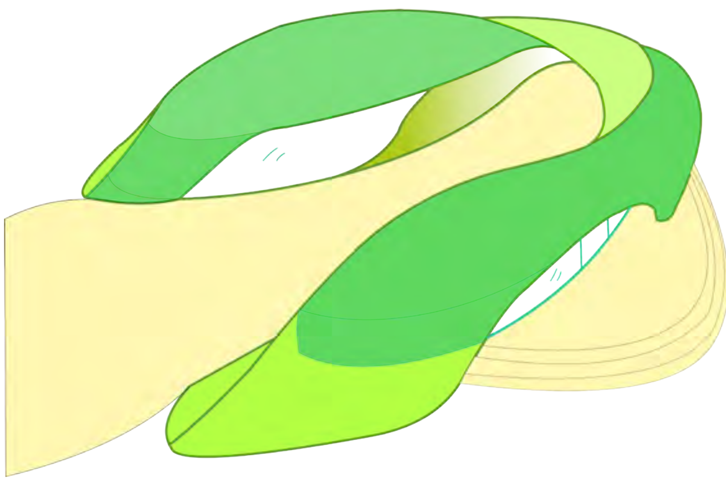


Figure 3.15 | Organic shape

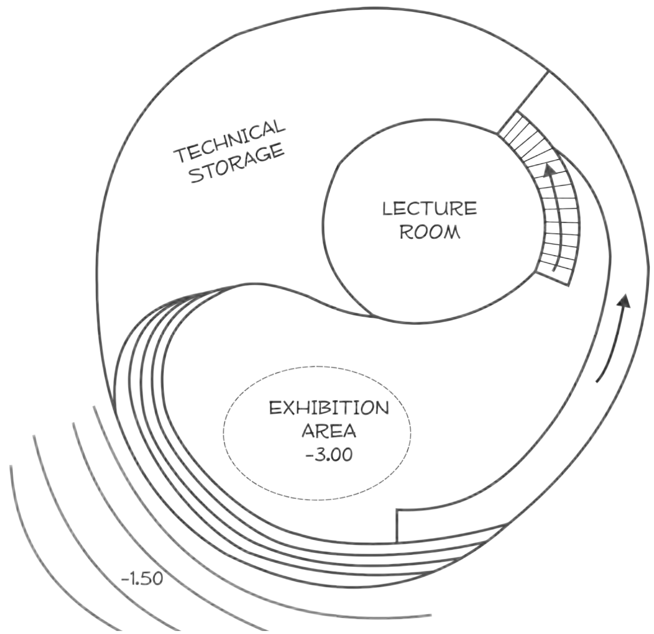


Figure 3.17 | Program

Conclusion

The final concept, after the redesign process, consists out of a small construction or module where the entrance is placed. The entrance was changed to this place so it does not interfere with the big amphitheater and the presentations given there. The space between the two modules can be used as a sitting area for visitors while looking at the green and technical facades. In the big construction or module above the ground the exhibitions area, lecture rooms and a refreshment area can be found.

This final proposal will be used in the detailed design process that can be found in the following chapter.

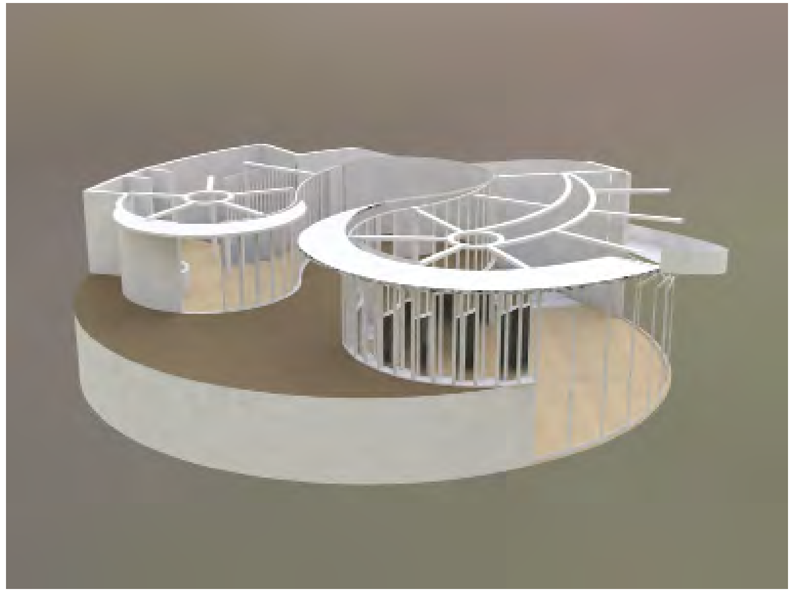


Figure 3.18 | Render one

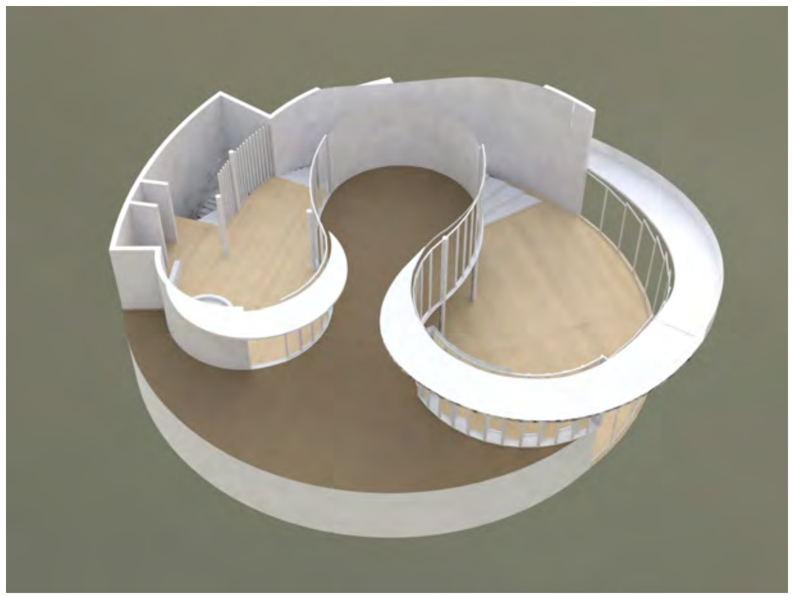


Figure 3.19 | Render two

Final design

Chapter four

Now the basics of the final concept are clear, all details need to be specified. This has been done during the last workshop in Enschede. During this week all groups worked together to finalize the design and explain every detail. In this chapter all information about the final design can be found, such as the floor plans, the climate concept, the Cradle to Cradle aspects, as well as many more aspects. By seeing also the 3D model the looks of the building should be clear to everyone.

Climate Concept

One of the main criteria for the Children's Science Center is to create an energy positive building that has a positive footprint. To actually create a building that produces more energy than it uses is a tough job to achieve, especially considering a building with an open space and rooms of these dimensions. This doesn't mean this is impossible though. The creation of a building with a positive footprint can be done in several ways. Besides the used climate systems and techniques, the building also has a very big positive footprint in a social perspective. The building educates the visitors, who bring that knowledge home, spread it and apply some aspect they have learned in their daily lives: the pay it forward effect. Besides the educational function the climate concept also consists of several issues as discussed in the chapter below.

Energy

The most important factor for creating an energy positive building is to become self-sufficient by the generation of energy and by the use of naturally present energy. This can be done by using solar and wind energy, as well as the thermal mass of the building and the surrounding soil in which the building is submerged.

Solar

The sun is an enormous and endless source of energy, not only in the form of light, but also in the

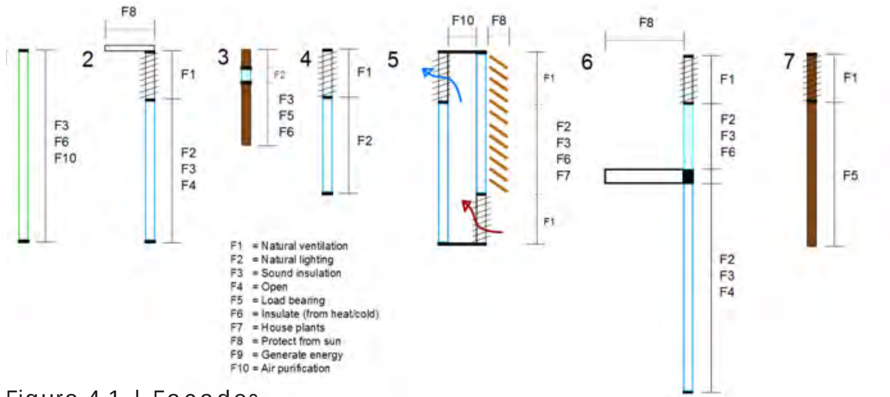


Figure 4.1 | Facades

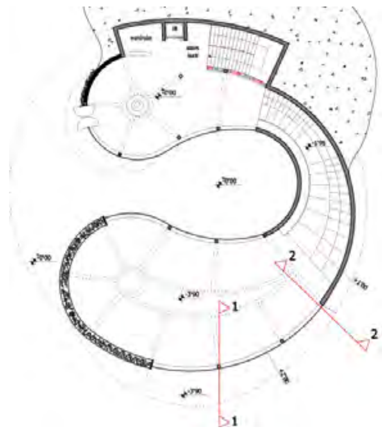


Figure 4.2 | Facade types

form of thermal energy. Sunlight is used to generate electrical energy, by using solar panels, as well as to provide natural light for the inner spaces. However, direct sunlight is too bright and undesirable, especially in summer. Therefore sun shading is used to only let indirect natural light enter the building. The natural light will enter the glass façades on the south façades and the north façade of the larger part of the building, as well as through the glass roof parts and smaller windows spread across the other façades.

The thermal energy from the sun is used for heating the building during winter. The sun shines through the window, warming the air inside like a greenhouse. This is realized by putting large glass panels in the south façades, as well as an innovative air purifying green house in the west façade of the larger part of the building. As is schematically shown in figure 4.3 the sun warms up the air between the two glass facades of the greenhouse, providing heat for the inner climate; the air in between the two façades gets heated by the sun. As a secondary effect the cavity of air in between the two glass façades also serves as an insulator, preventing the warmth from the indoor climate from escaping. In summer the same effect occurs, however in a reversed manner; the system will prevent the enormous heat from the sun from entering the inner climate and the cool inner air from escaping through the glass façade.

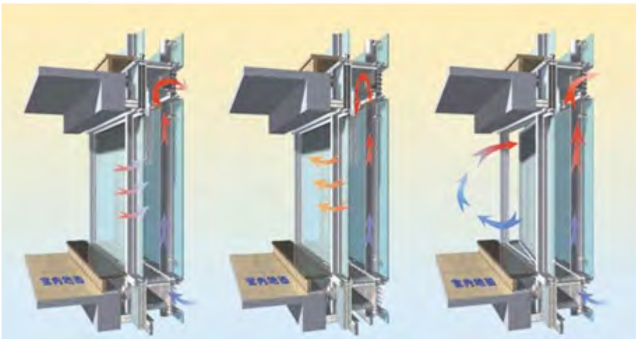


Figure 4.3 | Two glass facade

Wind

Wind is also a big source of energy, from which can be greatly benefitted, considering the windy climate of Istanbul. Therefore wind turbines can be built in the landscape to generate large amounts of electrical energy.

Thermal mass

The Children's Science Center is built partly underground, it therefore is in direct contact with the subsoil. This subsoil has a constant temperature during the year of around 12 °C. In summer this can be used for cooling the building. The building radiates its' heat to the soil surrounding the walls, therefore lowering the temperature inside.

Energy saving

Besides generating energy and using natural energy sources, also the saving of energy is essential for giving a building a positive footprint. Hereby needing less energy in the sense of consumption, but also in the sense of reducing the amount of energy needed to be generated to create a positive energy building. There are various ways of reducing the energy use, some are general, but some are also time or season specific.

General

Besides the use of natural sun light, the use of LED lights in the Children's Science Center will limit the amount of electrical energy enormously in comparison to the use of light bulbs or energy saving lamps. Also the use of appliances that require a voltage of 12V instead of 230V, like LED lights, reduces the electrical energy needed, because no converters are needed for converting the energy generated from sun and wind (12V) to high voltage levels.

Figure 4.4 | Light types

Summer

In summer the saving of energy mostly consists of reducing the need for cooling. For instance this is done by the application of shading on large glass surfaces that come in contact with direct sunlight. On the south façade of the smaller part of the building this is done by shading that consists of connected wooden beams, overgrown with greenery. The shading on the other southern façade is formed by the ramp going to the top of the roof. Above this ramp, the glass of the façade is replaced by a Smart Skin.

This material filters the sun light and consists of polycarbonate tubes filled with water that block heat flows but are still translucent. The shading of the green house on the other hand, is situated at the inside of the façade this to ensure that the green house will function properly. The shading of the glass roof is situated on the inside as well. At this part, the shading is done by using a translucent fabric that filters and diffuses the light. Besides that, the cold wind flows that are present in summer are used for the cooling of the building.

Figure 4.5 | Smartskin

Figure 4.6 | Smartskin implementation

Analysis

To effectively use the needed shading and to define the exact dimensions of the canopies, a shadow analysis is carried out. The passive design of the building is mainly based on this analysis, using the orientation of the façades and the angle of the roof and shading elements in an optimal way. This resulted in canopies with a width of 3 meters, as can be seen in the analysis of figure 4.7.

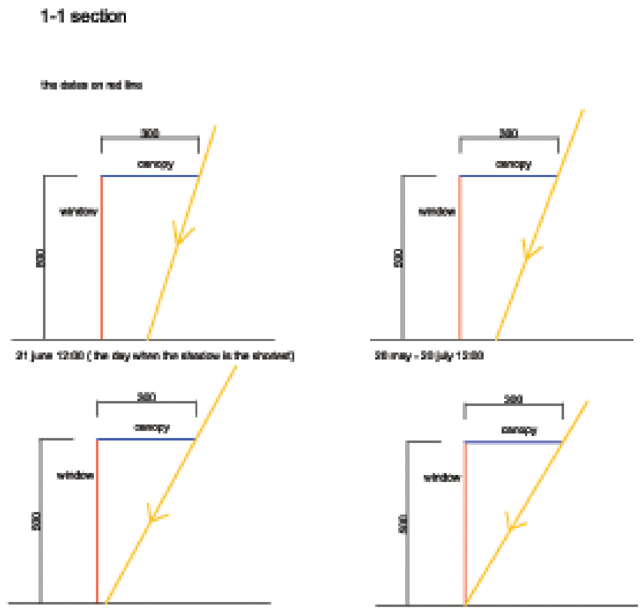


Figure 4.7 | Section 1-1 shading

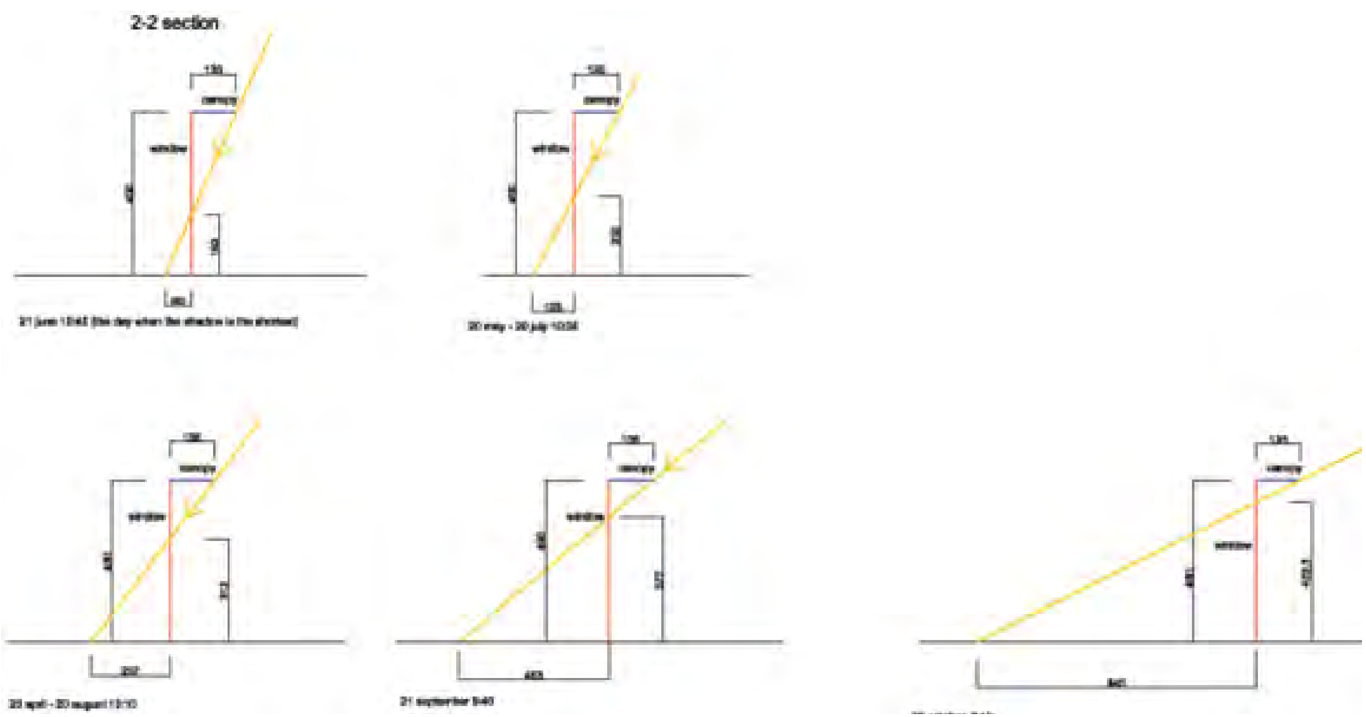


Figure 4.8 | Section 2-2 shading

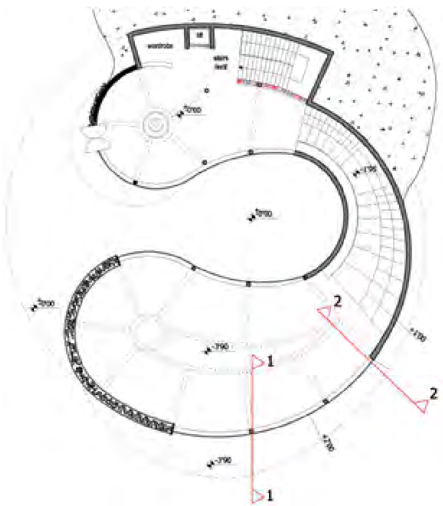


Figure 4.9 | Section overview

Winter

In winter most of the energy saving consists of the prevention of heat loss, as well as the reduction of the need for heating. The prevention of heat loss is realized using several techniques. One is the closing of the glass façades, as well as the glass roof parts. This will prevent hot air from flowing out. Also the implementation of heat exchangers at all ventilation grids will reduce the loss of heat to the environment.

The green roof will serve as insulation and all solid facades, window frames and gaps will be insulated. The Smart Skin mentioned earlier also serves as an insulator in winter, using the same principle as in summer. Also the application of floor heating reduces the energy use.

The green roof will serve as insulation and all solid facades, window frames and gaps will be insulated. The Smart Skin mentioned earlier also serves as an insulator in winter, using the same principle as in summer. Also the application of floor heating reduces the energy use.

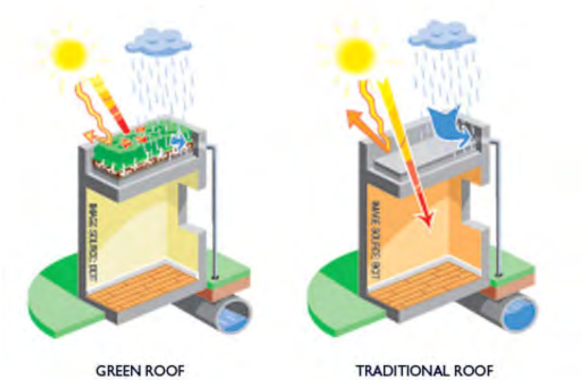


Figure 4.10 | Green- vs traditional roof

In contrast to the cold wind flows in summer, the wind flows in winter are warmer, which provides a natural way of reduction of heat loss using natural ventilation. While in summer the temperature of the soil is used to cool the building, in winter this will result in the loss of highly needed heat. To prevent this, a second wall is placed in front of the underground outer walls, between which a pneumatic wall is placed, thereby creating a flexible insulating wall.

Ventilation

As mentioned, ventilation will be natural throughout the building, only the toilets will contain mechanical ventilation. Istanbul in general has two dominant wind flows, cold wind flows in summer and opposite, warmer wind flows in winter. By the implementation of ventilation grids at the top of the southern and northern façades, the natural wind flows are captured to create natural ventilation inside. Because the wind flows are opposite during summer and winter, ventilation rosters are on opposite sides of the building, functioning as inlet as well as outlet in the other season. In summer the glass roof parts are opened, to create additional ventilation.

Air

The basic idea underlying Cradle to Cradle is to reduce waste and to have a positive footprint instead. Several innovative techniques help to achieve the goal for this project. A part of the façade, the greenhouse, fig 4.11, makes use of plants to purify the air by converting the exhaled CO2 from visitors into O2. The plants need CO2¬ to grow and purified air will be given back to the environment. The cycle is closed again. The system is composed of two glass façades with 80cm of space in between. Ventilation grids on the bottom and upper parts determine the flow of air. The greenhouse façade functions as a showcase where children can see how air is purified using the nature, see beautiful flowers and see butterflies fly around. During the winter, the façade acts as a greenhouse, providing heat to the building.

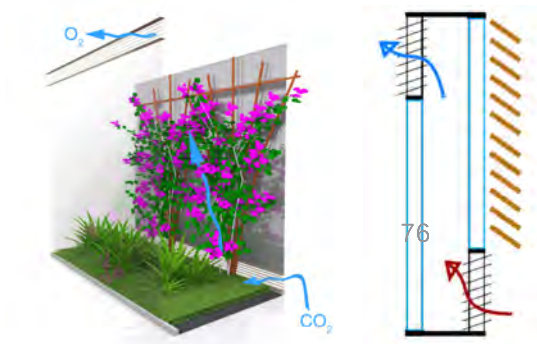


Figure 4.11 - 4.12 | Green house facade

Water

In Western countries the use of helophyte filters for decentralized wastewater treatment is increasing because there are sustainable, ecological and cheap to apply. At the children museum, the captured ‘grey’ rain water can be transformed into clean water by using Helophytes. These plants live in or at the water’s surface and are capable of purifying water. In order to use Helophytes to filter waste water from toilets, special filters are required to separate solid and liquid waste. There will be a pond filled with Helophytes embedded in the landscape. Besides that, there are also types of Algae that can be used to recover almost 100 percent of nitrogen and phosphorus nutrients from manure. After a while, the dried-out algae can act as slow-release fertilizer. The Algae have to be separated from the Helophytes because they quickly cover the whole water surface.

Conclusions

In order to successfully implement the concepts above, the requirements have to be specified. The inside air temperature, speed and ventilation rate are important factors to take into account. These values depend on several factors like the availability of air conditioning systems or the use of passive design. When a building is cooled by natural ventilation using operable windows, visitors will feel comfortable at higher temperatures.

	Requirements	Generation/ central installations	transport	Release	Reasoning
Air	-Airspeed <0.25 m/s -Ventilation rate administration area: 2-4 (300m^3) Ventilation rate exhibition area: 1,5-4 (1700m^3)	**Natural ventilation** for inlets. Mechanical outlets.	Ceiling panels or heat transfers ease transition of cold air coming into the warm room (or the other way around)	Main inlets near ceiling on south side of northern part. Diffuse distribution realized by ceiling panels	Exhibitions are near walls and ceilings, therefore diffuse distribution
Heating	-Max temp. = outside temperature + 3 C -Min Temp. = 16 C (low because of exercising children) -Area to be heated (+/-650 m^2, 2000m^3)	**Central, air-water based system.** Water pumps and solar collectors generate heat	Water from water pumps and/or solar collectors is integrated into the heating system	Water based floor heating.	Dispersed release needed since exhibitions are near walls and ceiling (radiators have too high temperature differences). Water from energy generators used.
cooling	-Max temp. = outside temperature + 3 C -Min Temp. = 16 C (low because of exercising children) -Area to be cooled (+/-650 m^2, 2000m^3)	**Air conditioning** units in offices. Induction (fans) in exhibition spaces. (or **heat pumps** can be used)	Circulating air caused by fans and natural ventilation transport coolness.		Condensing water on cooling units will be used in toilets and exhibition (*Elma's idea, such a system exists)

Table 4.1 | Climate systems

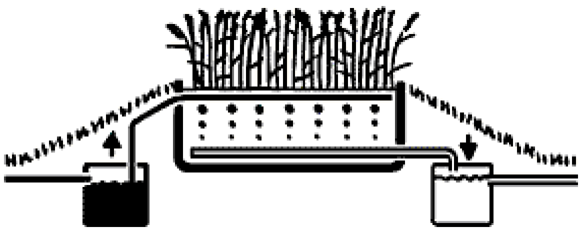


Figure 4.13 - Helophytes

Cradle to Cradle

In 2002 architect William McDonough and chemist Michael Braungart have introduced their view on sustainability, called: “Cradle to Cradle”. The basic idea is that after the useful life of a material in a certain product, it could be used in another product, under the condition that there is no loss of quality or so called ‘down cycling’ and all residuals should be reused or neutral to the environment. This closes the cycle, turning waste into food. There is a strict separation of two cycles: The biosphere, including all natural, bio-degradable, non-toxic materials and the technosphere, which contains high-specification materials that should be kept apart from the environment.

> *“We increasingly see buildings as raw materials banks, in which valuable raw materials are kept for future re-use – Thomas Rau, architect.”*

Now C2C is becoming more widely accepted, it offers possibilities for the theory to be implemented in the design of the museum. When you look at a building as a living organism, it should draw the nourishment and energy it needs from its immediate surroundings. This was translated into the wish for the museum to become energy positive. Braungart considers the earth as a closed system, fed by solar energy. Waste is never gone and therefore always causes damage elsewhere. When you consider that the building industry forms a substantial share, approximately 30% of the total waste mountain, the importance of closed cycles becomes clear. Although it is still nearly impossible for a whole building to become C2C certified, the subsystems or components can be C2C certified. Unfortunately, there are not sufficient certified building materials available. To solve this, some materials and systems are used that are in line with C2C, but not certified. Our vision on the quality of the interior space and the positive footprint corresponds with C2C, making it interesting to apply. Besides that, one of the main goals is to learn children about having a positive impact on the environment, in which C2C could help. Sustainability should not be based on guilt or the assumption that we should consume less. It should be about having a positive impact and celebrate diversity.

In the design of the museum C2C mainly applies to the design of the climate systems and the propagation of the positive message. In order to see what the possibilities are, a diagram was made, assigning façade & energy related elements to the biological- or technical cycles to keep the cycles closed and the materials separated. These elements include: Glazing to provide daylight, wall- & roof panels, a green roof and a green wall for heating, insulation and purification, a water pump, heat transformer and an algae pond. These systems will be further discussed in Climate Systems.

Figure 4.14 | Green wall system

Figure 4.15 | Cradle to Cradle logo

Figure 4.16 | C2C cycles (via mbdc.com)

Landscape

The location is surrounded with streets at the four cardinal directions. The main route is at North-side, where public transport transit during the day. East and West routes are secondary and not congested streets. South-side route is not close to the location, hence this is considered to be a passive and not active route for the building. The pedestrian path that leads visitors to the entrance starts in the West-street, next to the location.

When reaching the YTU Children Science Center by vehicle, users can use two parking areas. One parking area is next to the library of the Davutpasa campus and the second one is near to the base army building located as well inside the campus. Since the West and North routes of the location are not congested routes, as mentioned before, it is not necessary to build a parking area next to the location. Even though the existing parking areas are not situated next to the location, a group of children can safely walk to the building accompanied by an adult.

At the South-side of the location an old building has influence on the YTU Children Science Center. This old construction is considered as an historical building that cannot be demolished. Therefore aspects such as the minimum space between the buildings and the shadow that this old construction generates must be considered.

An artificial hill on the North-side of the building prevents visitors to see the building when approaching from the North route. This keeps children exited and curious to discover the building they are visiting. Furthermore this hill fits well with the surroundings that are mainly characterized by a green environment.

The landscape presents an open area for exhibitions. Elements of different shapes and actions can be part of the open exhibitions which teach for instance about mechanics, physics, mathematics and environmental technology. A lake below the hill purifies the water to be use inside the building.

On the South side of the building an open amphitheatre can be found. This area proposes different scenarios for the warmer months of the year. Some of these scenarios include lectures, shows, experiments, and a cinema using the facade to place the screen.

A ramp is leading from the East ground level to the green roof of the building. Following this playful path children can have a different perspective of the surroundings and learn about the benefits of the green roof. The path finishes near the lake which can be used as a exhibition area to explain the water purification system.

The area in the middle of the two modules above the ground is an open space that can be used during summer as a plateau for exhibitions. Opening the

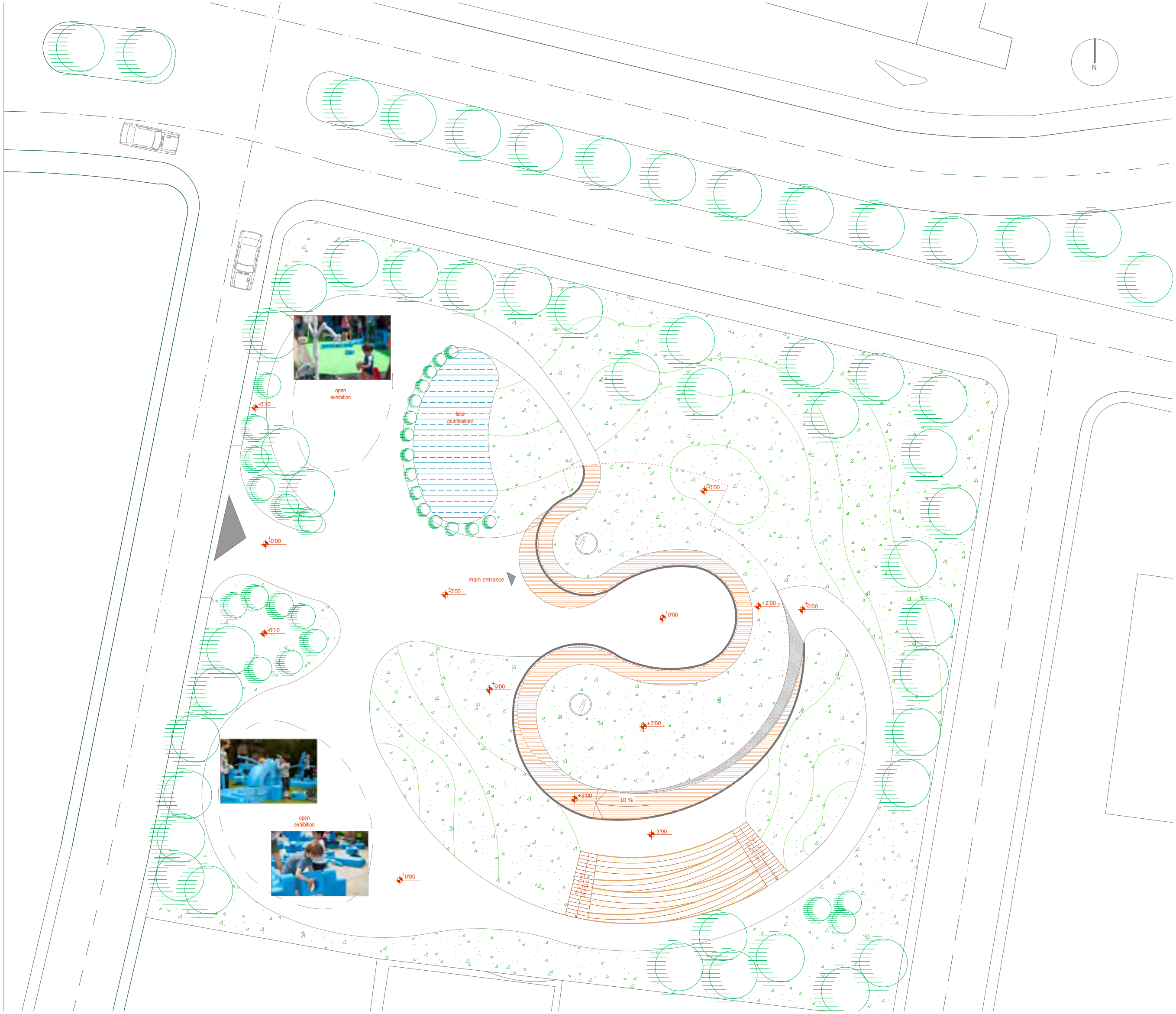


Figure 4.17 | Landscape

West facade of the smaller module above the ground, allow enlarging the area for summer exhibitions. In a similar way the West facade of the bigger module above the ground can be open on the warmer months to enlarge the Food and Drinks area. This area is the most suitable for open exhibitions and for Food and Drinks extension because it has shadow and blocks the coldest wind.

Floor plans

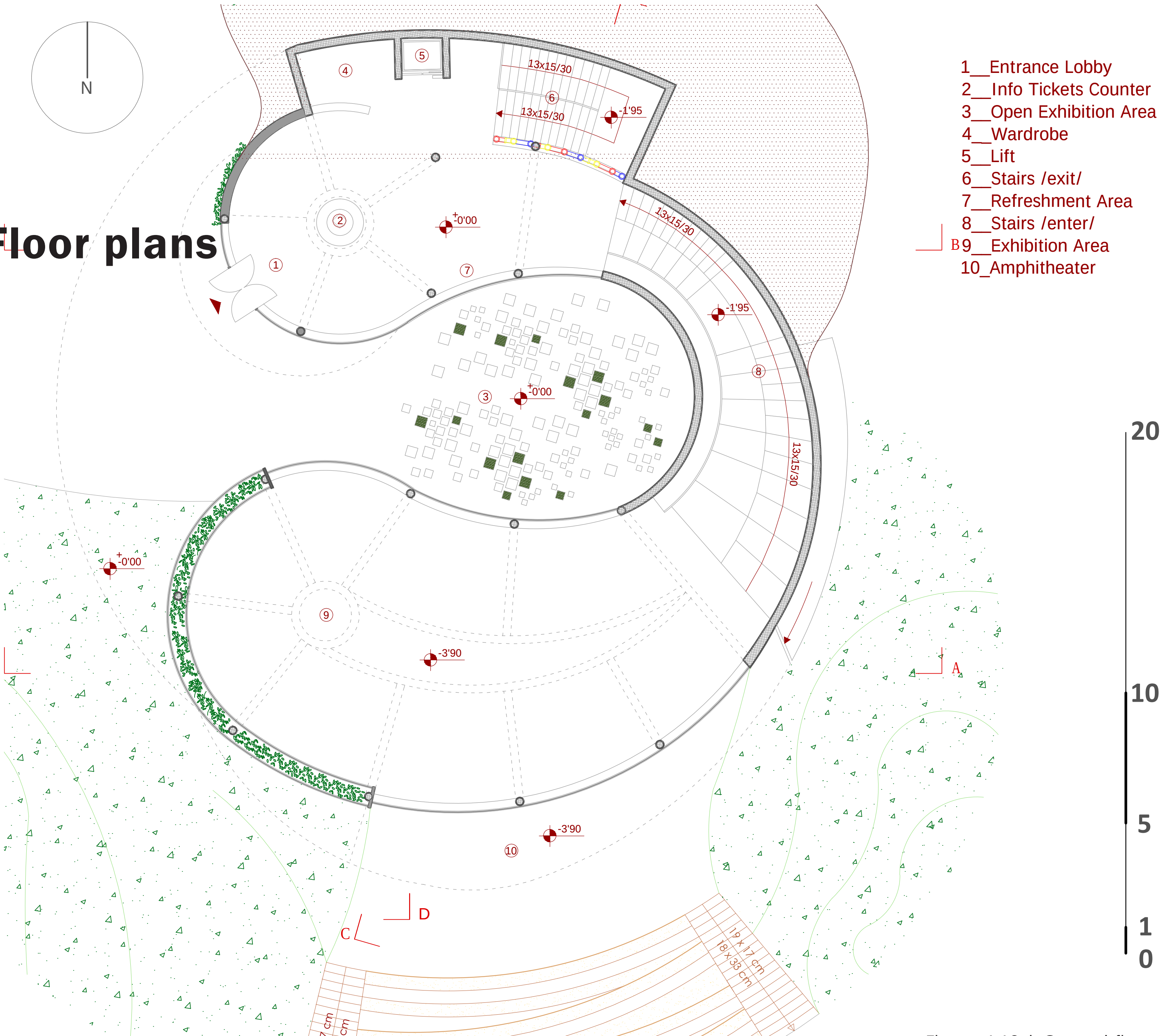


Figure 4.18 | Ground floor

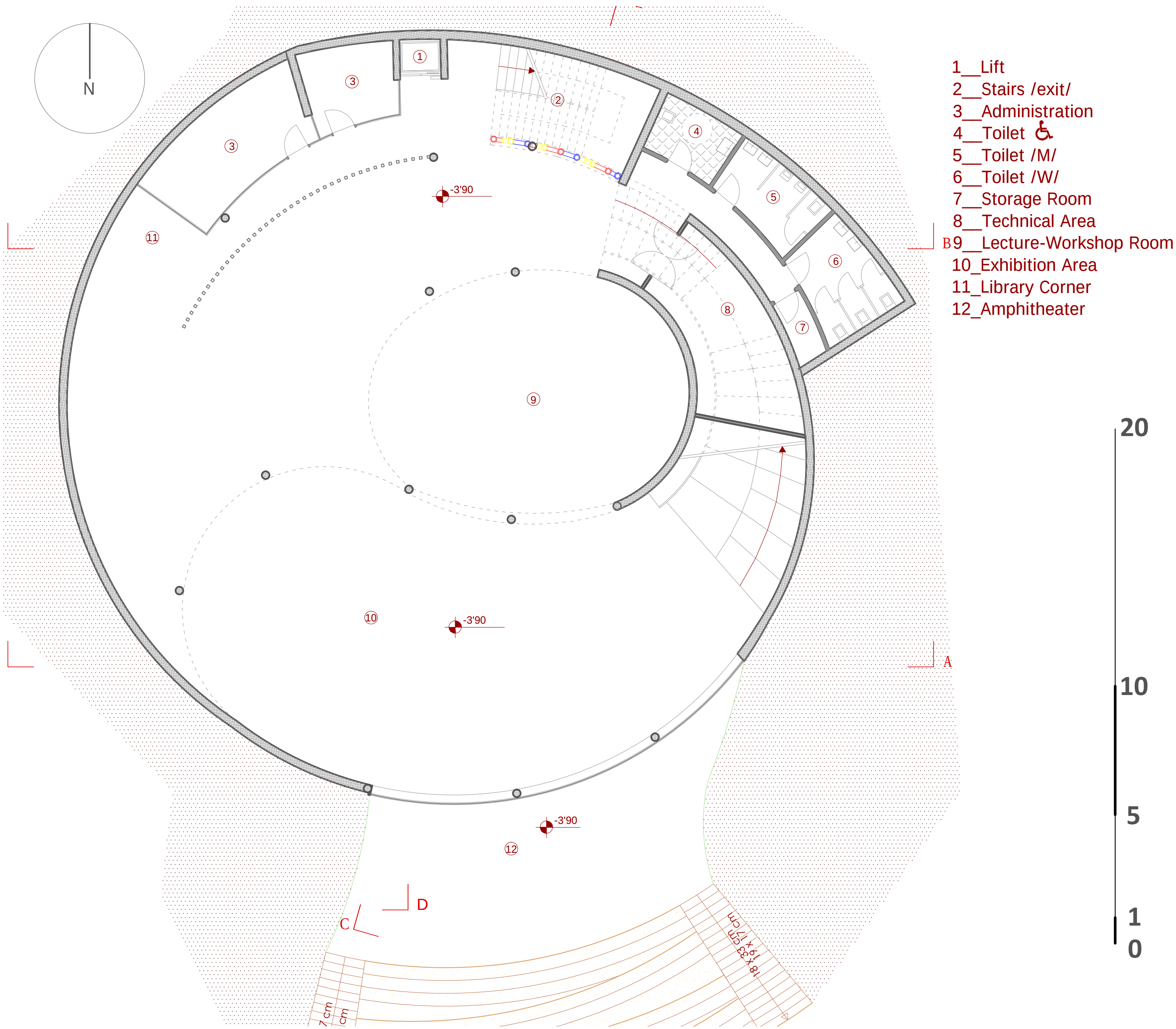


Figure 4.19 | Underground floor

Sections

The fact that the YTU Children Science Center is partly underground is clearly visible on these images. At the backside the amphitheater can also be used as a stairway, leading the visitors from the underground level to the ground level. From here the visitors can explore the gardens around the building. The building is partly hidden in the hill on the North side of the building. This way the building is not clearly visible from the main road, but will reveal itself slowly when visitors approach. On the South side a ramp going to the roof acts also as a canopy to hide shield the South façade from direct sunlight.

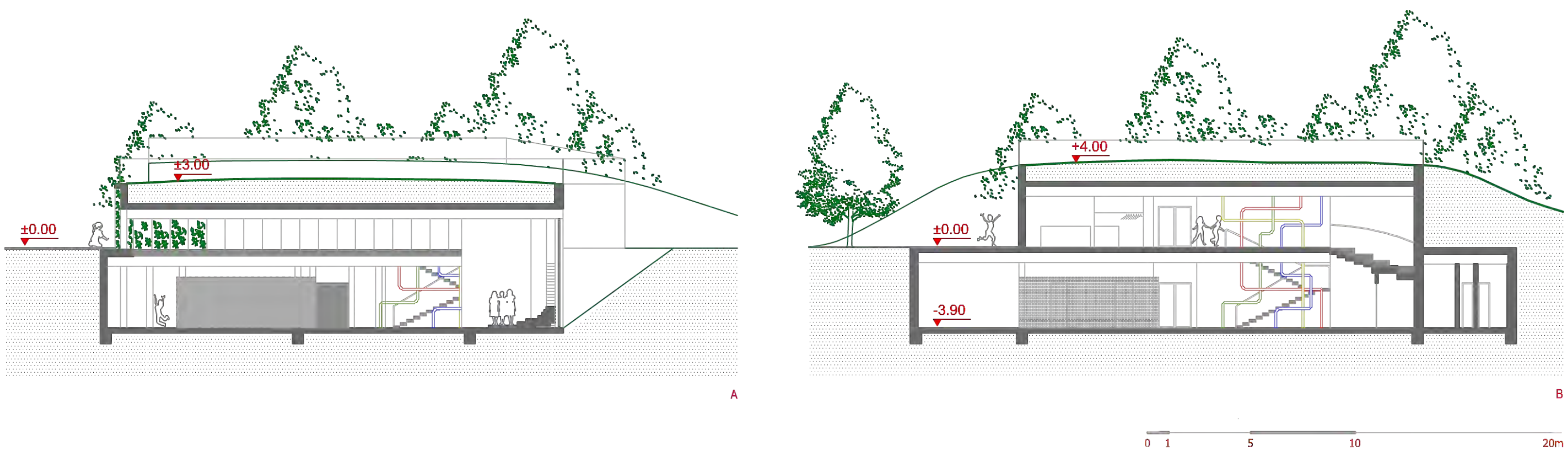


Figure 4.20 | Sections

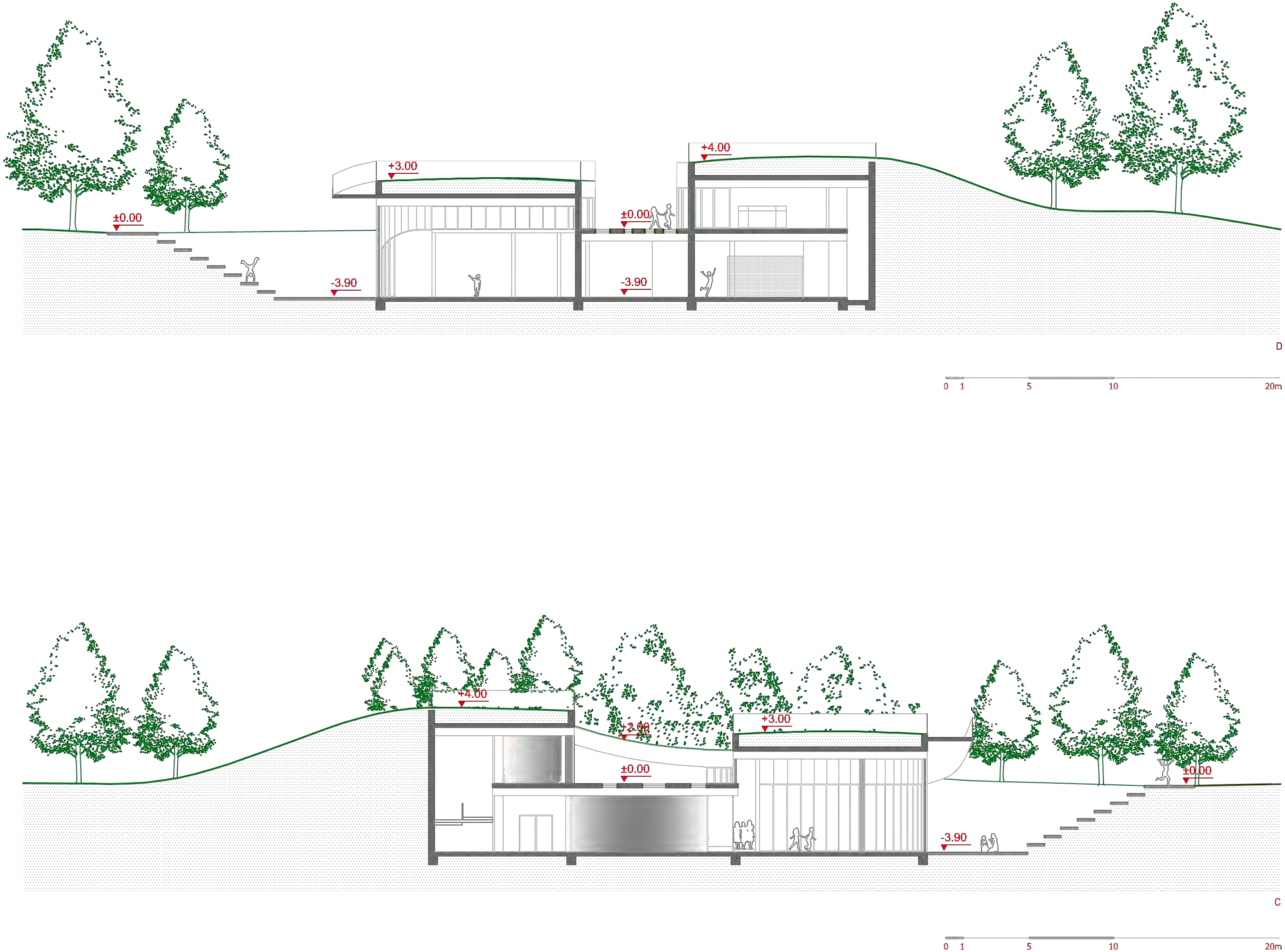


Figure 4.21 | Sections

Scenarios

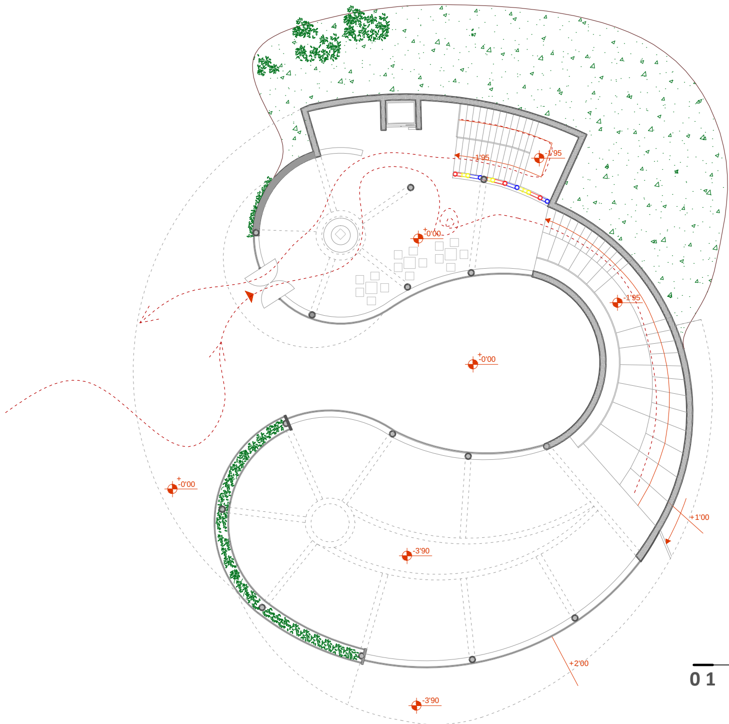
Winter scenario 1

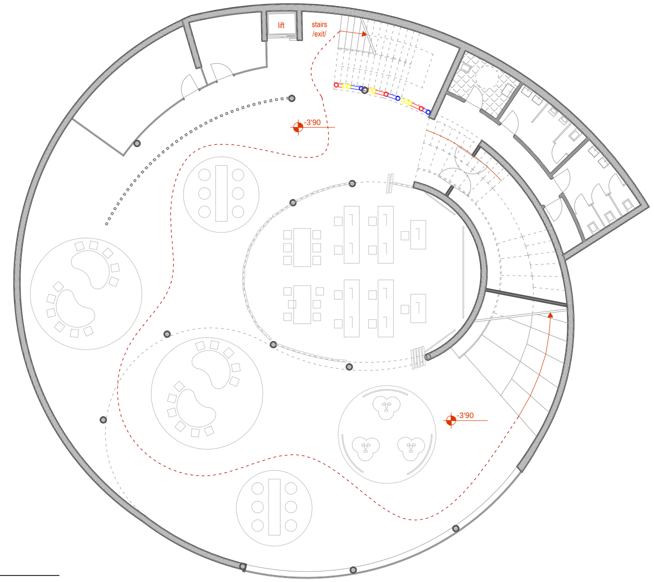
On the ground level of the North part of the building a food and drinks or refreshment area has been planed that can be extended all the way to the stairs. Visitors could sit on these stairs or go to the -3,9 m level. The staircase forms a sort of tribune/audience for the events that are taking place on the underground level. The space on the underground level is used for different workshops organized around a closed multimedia room.

Winter scenario 2

The refreshment area is located next to the entrance. The staircase leading to the -3.9 m level is used as an exhibition area itself. Sub-terrain level is used for open exhibitions and workshops. Additionally a lecture area located in the center of the room allows dividing the area into two when necessary.

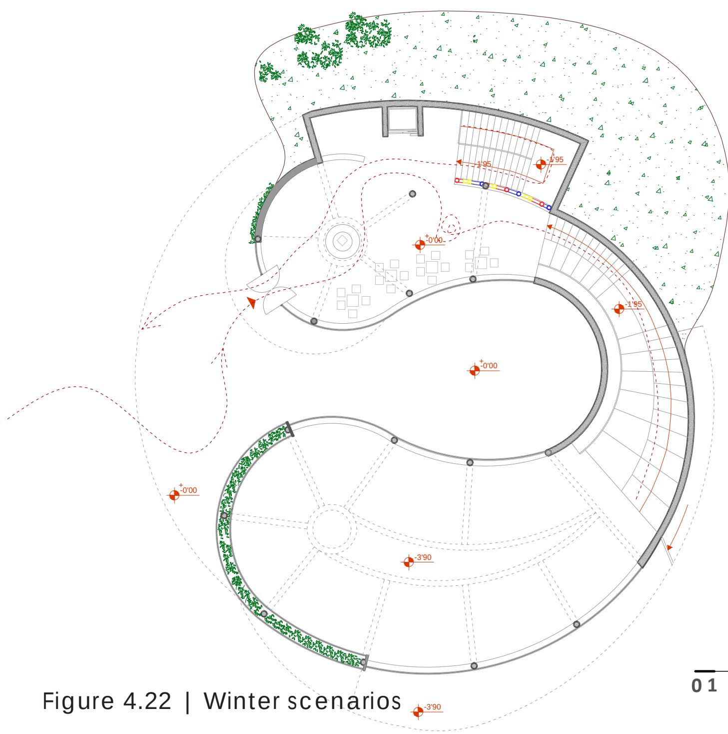
Winter scenario 1

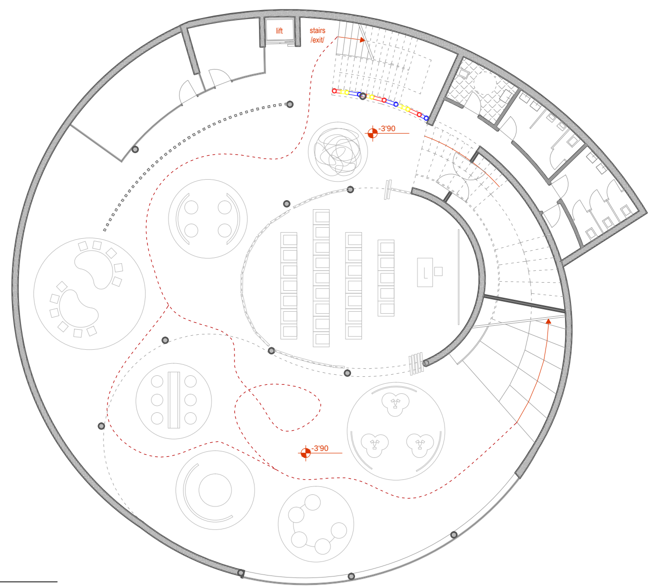




0 1 5 10 20

Winter scenario 2





0 1 5 10 20

Figure 4.22 | Winter scenarios

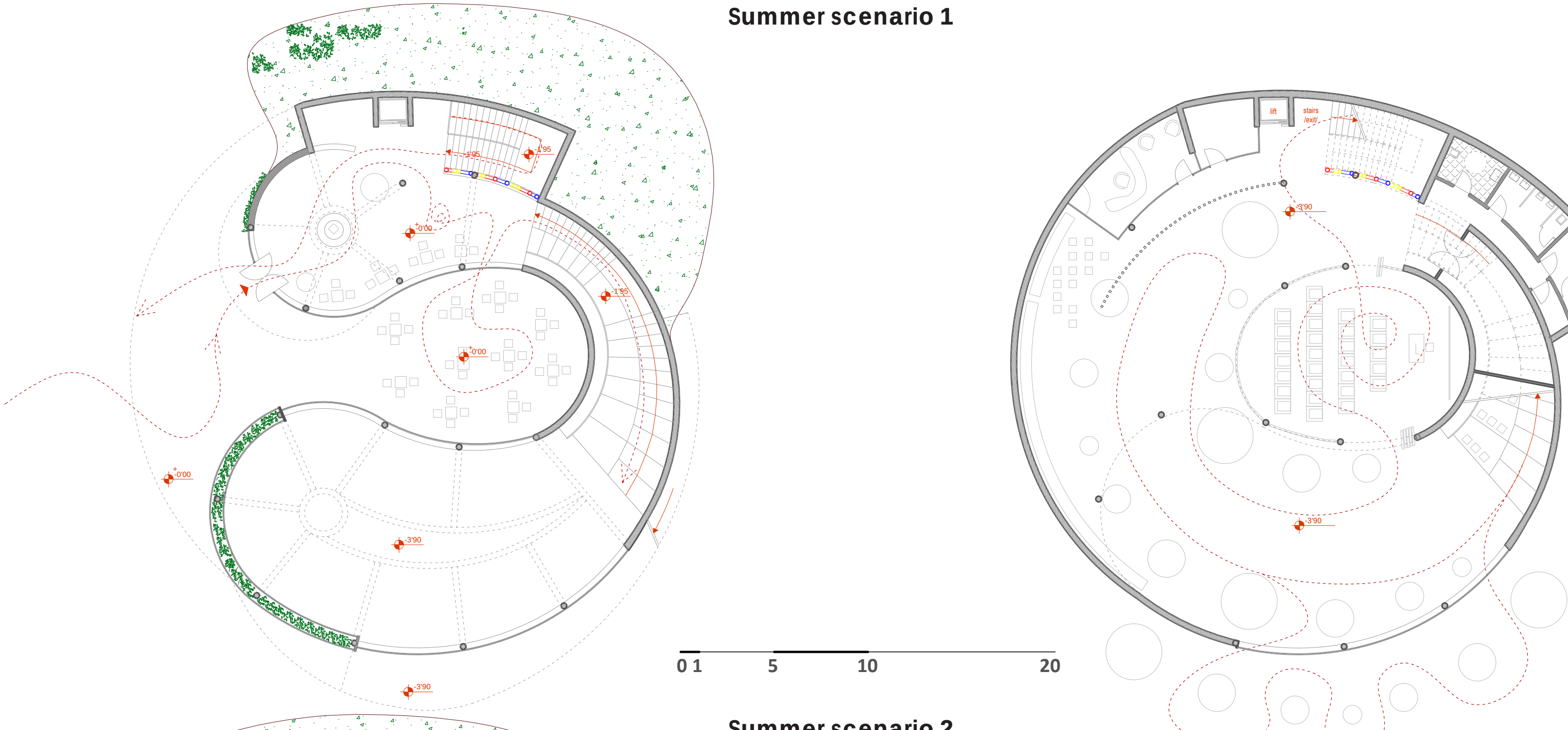
Summer scenario 1

During the summer the refreshment area, which is placed behind the entrance to the building, can be extended into a part of outside space (the space between the North and South part of the building above the ground). The -3.9 m level of the building is used as an exhibition space. This area could be extended to the outside area on the South side. A closed lecture room is located in the central part of the building.

Summer scenario 2

The space between the North ant the South part of the building above the ground is used for open workshop spaces. The lower level has a semi organized exhibition with an internal closed workshop area. The outside area on the South side can be used for lectures or open events.

Summer scenario 1



Summer scenario 2

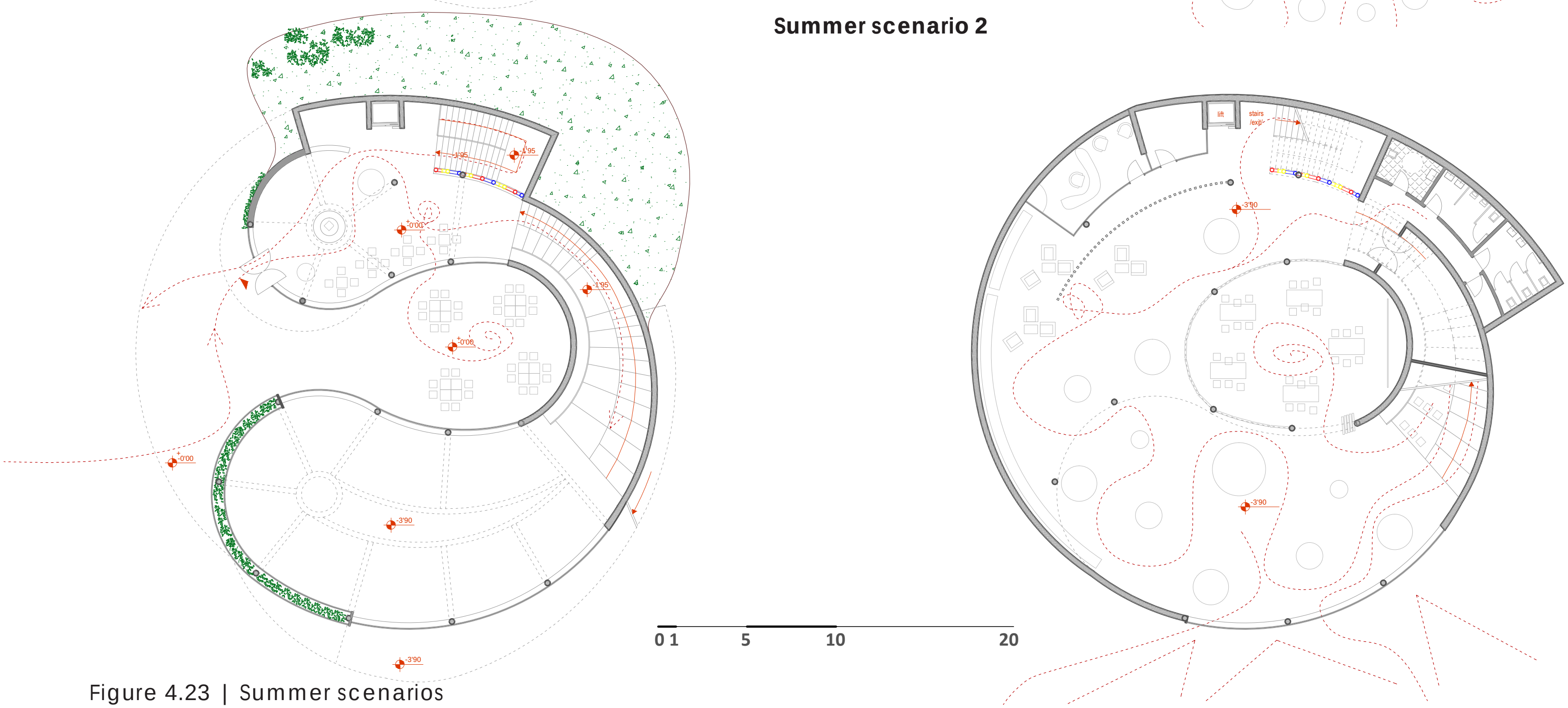


Figure 4.23 | Summer scenarios

Summer scenario 3

The refreshment area next to the entrance is extended on the open space between modules above the ground. The lower level of the building has an open exhibition that circles around the central sitting area dedicated to short video projections informing about the exhibition.

Summer scenario 3

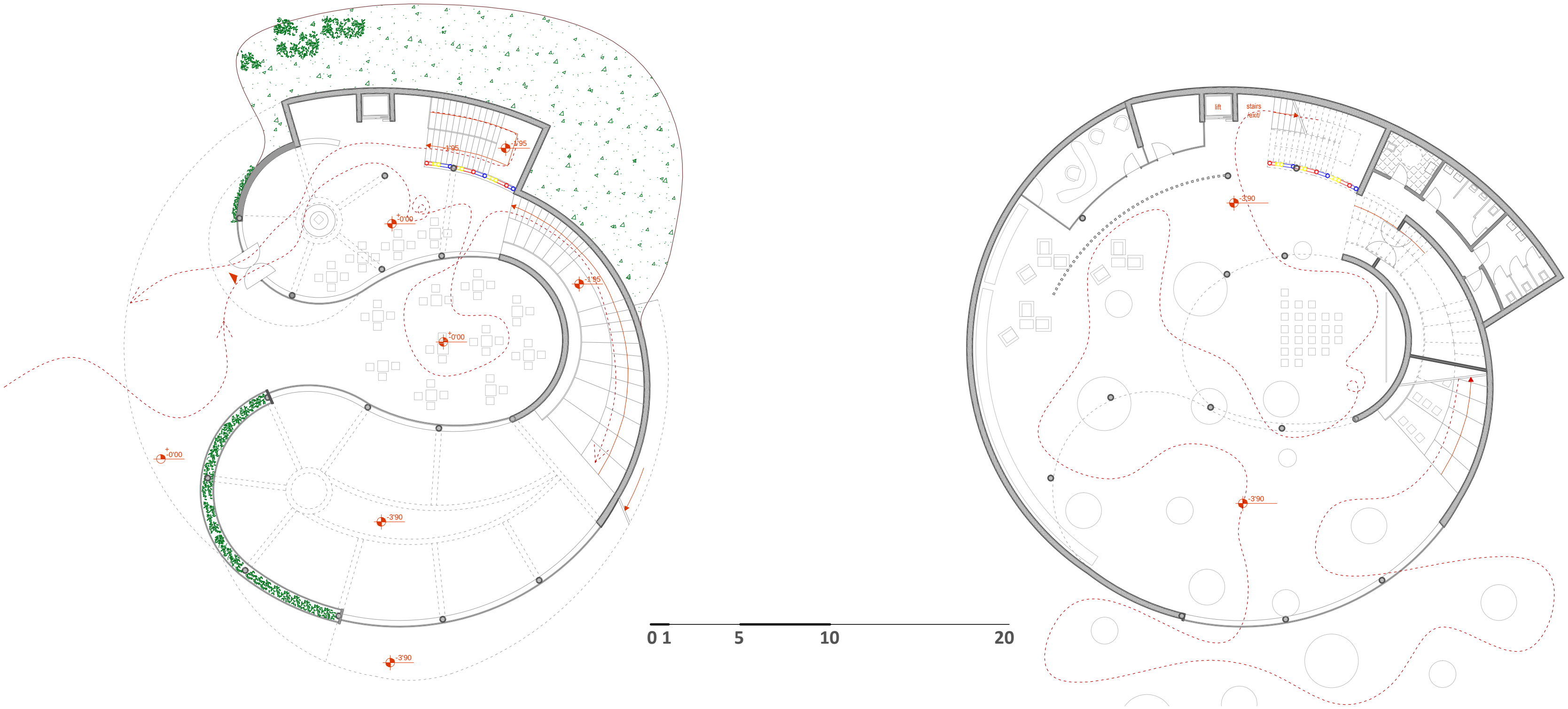


Figure 4.24 | Summer scenario 3

Load Bearing Structure

Laminated pine wooden beams and pillars form the load bearing structure of the upper part of the building. The pillars are connected with the concrete floor using steel plates that are screwed into a floor-slab. Steel plates are also used to connect the different segments of the wooden structures. To create a more spacious effect, and to follow the natural curves of the landscape, the beams are connected under a slight angle. In this way the load-bearing structure is totally demountable and parts can be reused on other place as well.

The beams in the two partial domes are connected using a circular steel beam with protruding steel plates.

Horizontal beams connect the pillars. These fixed connections create stability in the structure, but not enough. Extra stability is created with steel tension beams in at least 3 of the wall panels.

The green and technical façade, not being supported by beams, will be made out of a truss-like structure. This will help distributing the forces caused by the self weight of the dome, the useful loads caused by children standing on the green roof and the possible weight of snow on the roof.

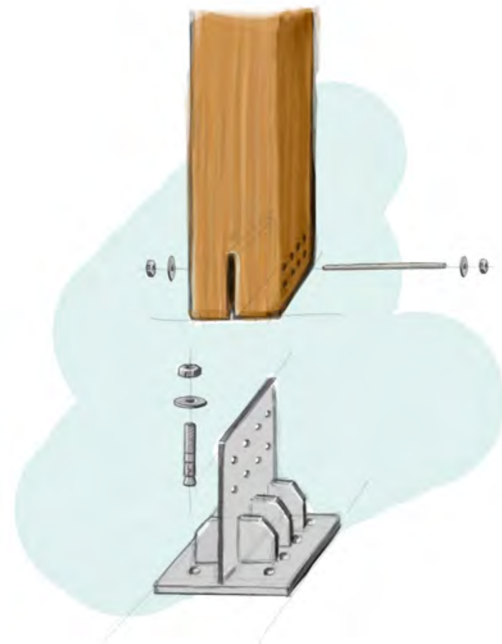


Figure 4.25 | Connection to the concrete

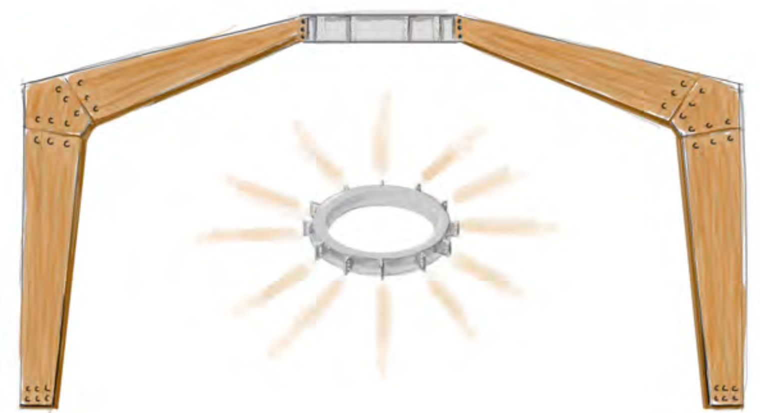


Figure 4.26 | Circular beam

Figure 4.27 | Circular beam

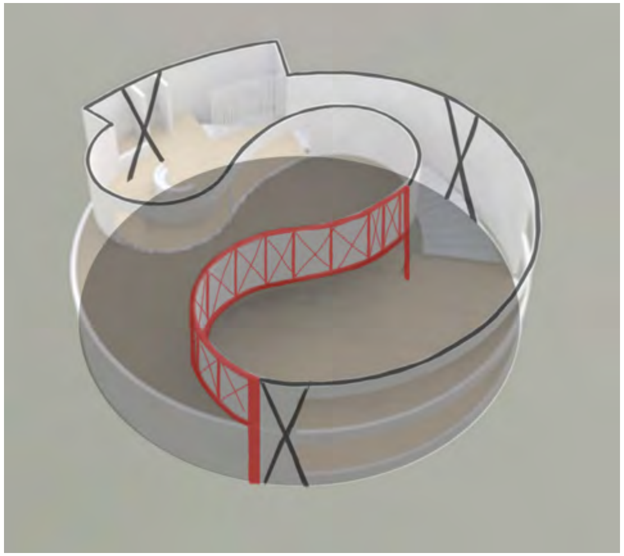
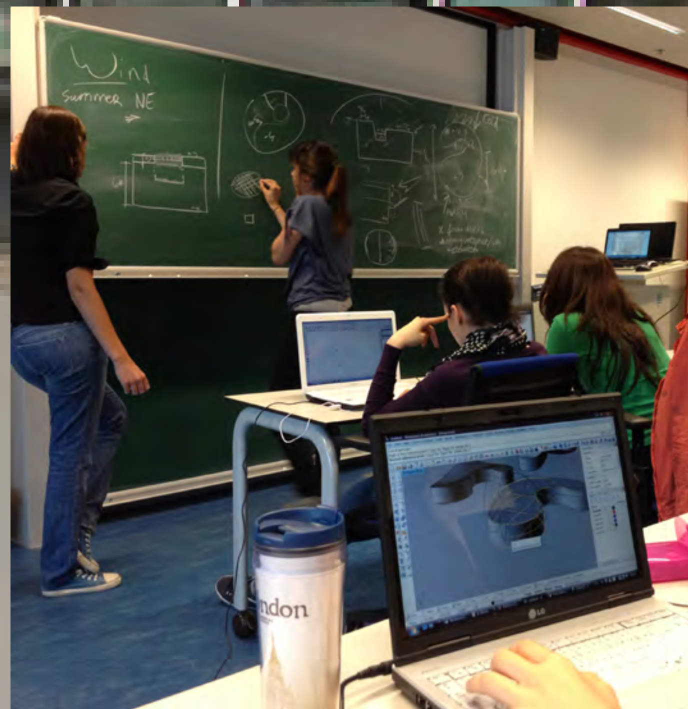


Figure 4.28 | The red part shows the truss-like structure for the green and technical façade


Wind




Conclusion

Chapter five

The design of YTU Children Science Center was done within four months. All students from three different universities from three different countries worked together and used their different backgrounds to design a green building that fits nicely in the surrounding landscape and is really compelling to children.

The way this project went, and probably all projects go, was different than was expected on several points. Things as a sudden change of building location, change of the capacity of the building and a change of size are aspects which are almost impossible to take into account from the beginning. But these are probably the things that you learn from the most.

In the end a building was designed that is fun and a point of inspiration for children and can be seen as a landmark for the Davut Pasa Campus, while at the same time it is not taking too much attention away from the library next to it. The building is very sustainable and is designed while keeping all climate aspects in mind. This way the building handles aspects as temperature and fresh air supply in a very efficient way.

Collaborative Design Learning

Dr. Birgul Colakoglu

Current trends in architectural practice such as an increased focus on sustainable design, integrated design, and the globalization of architecture are increasing the need for practitioners that are skilled in collaboration. A new business rule not only in Architecture Engineering and Construction (AEC) but for all industries for competitiveness is to "collaborate or perish." Tapscott and Williams, (2007) Collaboration fosters innovation and creativity. It is a key operating principle for the 21st century and an important skill that an architecture student must be exposed to.

The design and implementation of simplest architectural projects requires collaboration of various individuals each highly trained in their respective areas working together to realize the projects. However, contrary to the highly collaborative nature of architectural practice, the education of an architect has been a highly individualized pursuit, focused on the development skills set. Architecture students are being prepared in a manner that is contrary to the highly collaborative nature of the architectural practice they will enter.

The change in knowledge generation and creative problem solving is transforming education towards collaborative learning forcing architecture and engineering schools to address new course structures with "collaborative" aspect.

The concept of collaborative learning, the grouping and pairing of students for the purpose of achieving an academic goal, has been widely researched and advocated throughout the literature. The term "collaborative learning" refers to an instruction method in which students work together in small groups toward a common goal. "Collaborative learning is based on the idea that learning is a naturally social act in which the participants talk among themselves (Gerlach, 1994). It is through the talk that learning occurs."

Collaborative design learning is based on the methods of collaborative learning that is adapted for design teaching. Collaborative design has been applied in many engineering design practices such as aircrat, software, electronic devices, automotive industry, etc. The subject has been integrated in related school curriculums and research about collaborative design teaching pedagogy has been investigated.

Design is the crucial subjects in the school of architecture and design studio is the fundamental course of architecture education in which the students are expected to be trained in the actual collaborative environment of architecture making. However, the education of an architect has been highly individualized and based on the personal skill development rather than collaborative engagement that is inherent in the process of design making. Architecture occurs in collaborative environment. It is widely acknowledged that collaborative skills are necessary foundation for successful architecture projects.

Collaborative design requires multi-designer and multidisciplinary involvement in which the individuals act collectively as single body. In collaborative group work the students are responsible for one another's learning as well as their own. Participants work together to solve a problem.

Collaborative studio is based on student - centric and student to student learning rather than teacher centric guided learning. Former allow students to engage more actively on exercises and reflect on a material being learned, and requires students to be active and responsible participants on their own learning.

In order to have effective collaboration students are required to develop basic skills as identified by Bosworth (1994): Interpersonal skills; Group management skills; Inquiry skills; Conflict resolution skills; Synthesis and presentation skills. Group members must want to help each other learn, feel as group member and have a personal stake in the success of the group. They also must have the skills necessary to make the group work effectively and be able to regularly analyze the group's strengths and weaknesses to make adjustments as needed. The students should understand that collaborative design learning is a skill, and like any other skill, it must be learned (Straus 2002). In the early stages of a studio that uses a collaborative model the instructor must help the students to develop the requisite teamwork skills to be successful in the studio.

The initial step to collaborative design in the studio is the establishment of design groups or teams. Barkley (2004) establishes three basic topic areas that must be considered when forming design learning groups: group types, group size, and group membership. It is important to understand the different types of design learning group structure and how they can be the most effective. Barkley establishes three typologies for groups: formal, informal, and base. The group format is determined by the studio instructor according to required design exercises. Informal groups are groups with shorter duration that can be quickly assigned. Usually they are formed at the beginning of the design project. They play an important role at the beginning of the design process for students to get know each other.

Formal groups are often formed when the pursed design task become more complex. The formal group is assembled based on the task assignment and participants continue to work together until the task is completed. Based on design task complexity the duration for a formal group can range from a period of several studio classes to several weeks. Typical sizing for both groups is between two and five participants.

The base group can be formed for the full length of design studio with maximum three to four participants. However, fixing groups from the beginning of the design studio can cause studio work to stuck because of human interaction problems. Dynamic forming of the groups based on the pursued design assignment give flexibility to students to work in different substages of the design task.

One of the biggest problems of a group situation is the balance of power. More problems occur when one person is dominant, not willing to trust the abilities of others in the group. This results in a lack of cooperation amongst the group members. Usually quiet people not feel comfortable in group work they are shy or reserved and feel awkward when working with others. Sometimes the students personalities clash. This leads to arguments, causes waste of time and lead to an unproductive group.

The difficulties in collaboration are communication, compromise, and coordination as pointed in (Bosward 1994). Communication in design collaboration is one of the most common problems, since the team members are from multiple disciplines working together. A common language and method must be used for optimum communication among the team members, and the communication channel must be open at all time.

Another problem faced in design collaboration is that each discipline will have different opinions and interpretations of the problem, and therefore have different methods in approaching them. One of the most difficult jobs in collaborative design is organizing and coordinating the program for the diverse disciplinary teams. The instructors are responsible for the program coordination among diverse discipline teams.

An instructor must also act as facilitator of collaboration in order to create collaborative environment. This requires new profile of instructor who gives responsibility of learning to the students group while he/she is focusing effort on maintaining the overall structure of the course. The instructors preparation plays a key role in the the maintaining the structure of the studio. Each phase of collaborative activity should be carefully planned and followed by the instructor. The instructor should be trained or be skilled in conflict resolution. The main obstacles in international collaborative design learning set up are cultural, social and educational clushes among the participants. Many times these clushes are solved among the students however, there could be cases that would require instructor intervention in order to maintain the structure and work of the studio.

The instructors should monitor project content on regular base and note individual failures. They need to reinforce the notion of 'team' when discussing project development and point out the importance of collaborative effort in the success of the project.

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MCDM evaluation

The MCDM was intended to play an important role on the development of the project. As it was explained in the Multi-criteria Design Matrix section, the information contained in this matrix should have lead to an unanimous and objective interpretation of the requirements. This was necessary due to the differences on nationalities, cultures and backgrounds of the students involved in the project.

However only the students with a product design engineering background were familiar with this kind of methodology and it turned out to be difficult to make use of the complete matrix during the process. Since the students were not used to this methodology, it was indispensable that the coordinators lead them inside the different requirements that were defined in the matrix.

Special focus was put on the following key aspects: Architectural quality, Multi-functionality, Transformability, and Energy, water & materials. Concepts created by the different groups were evaluated using these key aspects. The others design criteria, as well as the key aspects, were considered in the final concept, except for the criteria of Costs since in this phase is not possible to give an accurate estimation of the different costs.

Even though the MCDM was not used by the students as it was intended, they became aware of this kind of methodology to design and evaluate a building. Furthermore, it can be concluded that it is necessary to synthesize the information that the matrix contained or make a small version of it. In this way the students will be more willing to use it during the process.

Design aspects	Criteria	Sub-criteria	Specification	Variable	Units	Value
Architectural quality	**Identity**	Inviting building	The architecture of the building invites visitors to enter	Characteristics	Characteristics (subjective)	Open doors Inner visibility (subjective)
		Expression of transformability	The architecture shows that the building can be transformed.	Characteristics (e.g. geometry)	Characteristics (subjective)	Modularity (subjective)
		Education for children	The architecture is inviting for children	Characteristics (e.g. geometry)	Characteristics (subjective)	Modularity (subjective)
		Appearance of spatial adaptation	The possibilities of transforming a room are visible and the actions to be undertaken are instinctive.	Characteristics (e.g. geometry)	Characteristics (subjective)	Modularity (subjective)
		Green	The building has the identity of Green (eco - friendly)	Characteristics	Characteristics	Modularity
	Scale & proportions	Balance	There is a balance between the proportions and scale that makes the building attractive in an aesthetic sense.	Geometry	(Subjective)	(Subjective)
		Integrity & coherence	There is a clear geometry through the building that supports the special functions of the different areas. Does the design blend in with neighboring buildings and the surrounding landscape?	Characteristics (e.g. geometry)	Pattern (subjective)	Straight lines (subjective)
		Occupation	The building can occupy a certain number of people, specific per room function	Number of people	Number	60 lecture room - 15 presentation room
Multi-functionality	**Spatial transformation capacity**	Suitabilty for internal flexibility	Building systems, non -supporting walls, equipment and furniture per room can be (re)moved and (re)used on different locations within the building	Percentage of locations where the systems can be reused	%	= 90% reuse on = 50% of locations
		Adoptability to different functions	The space allows the transformation to the different functions or scenarios	Number of functions	functions / space	= 2
		Safety	The building meets safety legislation in each of the scenarios	Safety legislation	Safety legislation	see legislation 'inner spaces safety'
	Technical transformation capacity	Installation capacity	Installations, separating walls etc. have the capacity to meet flexible requirements	Characteristics	Depends on requirements	
		Structural capacity	The load bearing system supports the different configurations of the building	Supported weight and location, max span	Newton & meters	= X ton
		Possibility to install equipment	Rooms have the capacity to adapt when equipment is added	Availability of supply and outlet - access points	Number of access points for installations	= X
		Safety	The building meets safety legislation in each of the scenarios	Safety legislation	Safety legislation	see legislation 'inner spaces safety'

Table 5.1 | MCDM part 1

Design aspects	Criteria	Sub-criteria	Specification	Variable	Units	Value
Transformability	Spatial transformation	Easy transformation from one use concept to another	Few (re)installation steps are needed for a room to change function	Number of steps	Number	max 10
		Possibility to combine or separate multiple functions	The building allows combining and separating functions; building components shall be connected in a flexible way	Functions per component	Number	=2
		Extending/shrinking of space	Non-supporting walls can be moved to change a rooms geometry	Number of configurations	Number	>7
		Transformation of open area into closed area and opposite	Walls can be replaced/adapted to change the geometry and number of open areas in a rooms shell	Number of configurations	Number	>7
	Time bound transformation	Adaptability to the weather & day/night configuration	The building has adequate facilities for the weather and offers the right atmosphere by day and night.	Percentage of people comfortable by the indoor climate	%	90%
		Adaptability to different inner climate concepts	The building meets all requirements of the functions of each scenario	Percentage of requirements met	%	100%
	System transformation	Reliability of the integration of and connection between components	The connection between components complies with all safety precautions	List	Safety precautions	list of safety precautions
		Second-use scenario for each component	Components and systems should have a second - use scenario besides their main scenario	Number of possible use scenarios	Number	>1
		Decoupling and reassembly of parts/units of the building with different functions	The parts/units allow decoupling and reassembling between them	Percentage of parts that allows decopling and reassembling	%	>80%
		Flexible integration of systems (building HVAC)	The geometry of installation system components is so that they can be flexibly connected; multiple (lockable) vents & access points	number of layouts per room	Number	>X
		Reconfigurable building systems	The layout of installation systems can be changed to fulfill the climate requirements for the rooms	Number and location of points for supply and outlets	Number	>X

Table 5.2 | MCDM part 2

Design aspects	Criteria	Sub-criteria	Specification	Variable	Units	Value
Energy, water & materials	Energy performance of the building	Energy positive	More energy is generated than is used	Percentage self-generated energy related to use	%	>100%
		Renewable energy	A high percentage of the total energy comes from renewable source as: solar heating, biofuels, wind, etc.	Percentage of renewable energy	%	>80%
		Stimulus for low energy user behavior	The building encourages and helps the user to keep low energy consumption	(Subjective)	(Subjective)	(Subjective)
	Material transformation	Low environmental impact of used materials	No materials used are harmfull for the environment or highly energy consuming, during use and production	Apply life cycle assessment	Apply life cycle assessment	Apply life cycle assessment
		Second-use scenario for each material	Materials should have a second -use scenario besides their main scenario	Number of possible use scenarios	Number	>1
		Reusability of disassembled components and materials	A high percentage of disassembled components are reused	Percentage	%	>80%
	Cradle to Cradle	local materials	All materials are locally obtained	Kilometers	Km	=200
		C2C certified materials.	The materials follow a cyclic system during its life cycle; use of C2C certified materials	C2C certified materials.	%	>80%
	Reuse of different water streams	Separate water streams on building level	Keep all different qualities of water streams separated	Number of separate water streams	Number	=5
		Reuse water	A high percentage of water streams can be used in all the scenarios	Percentage	%	>25%

Table 5.3 | MCDM part 3

Design aspects	Criteria	Sub-criteria	Specification	Variable	Units	Value (exhibition)
Comfort & Health	Thermal comfort (summer)	Summer Indoor Air Temperature	The indoor air temperature in summer will be comfortable	temperature	Degrees celcius	22+/-2
		Summer Indoor Airflow	The indoor airflow in summer will be comfortable	draught	max. m^3/s	0,25
	Thermal comfort (winter)	Winter Indoor Air Temperature	The indoor air temperature in winter will be comfortable	temperature	Degrees celcius	20+/-2
		Winter Indoor Airflow	The indoor airflow in winter will be comfortable	draught	max. m^3/s	0,15
	Indoor air quality	Indoor Air Freshness/Ventilation per person	The indoor air freshness will be good according to high standards	air replacement per person	l/s	10-20 per m2
		Indoor Air Freshness/Ventilation	The indoor air freshness will be good according to high standards	air replacement	m^3/h	72
		Indoor Moisture content	The indoor relative humidity will be good according to high standards	relative humidity	%	50
	Acoustics	Building systems noise	The systems shall not vibrate to create noise	Decibels	db	-
		Interaction noise	The interactions with the systems shall not produce noise	Decibels	db	-
		Acoustics	The building will have good accoustics, specific for every room	reverb. Time	Seconds	0.8 - 1.1
	Visual comfort	Iluminance	The lighting system complies with the required values of illuminance; No direct sun light in rooms.	Luminance	lux	500
		View	The view is in balance with the function of the room	Square meters of windows	m^2	-

Table 5.4 | MCDM part 4

Design aspects	Criteria	Sub-criteria	Specification	Variable	Units	Value
Constructability and handling of components	Ease of (dis)assembly	High level of industrialization and prefabrication for fast assembly/disassembly	High percentage of components can be industrialized and prefabricated for fast assembly/disassembly	Unit	%	?80
		Easy to assemble, disassemble and reassemble	The assemble, disassemble and reassemble between components is easy	Number of steps	Number	max 10
		Easy reconfiguration of the prefabricated components for reuse	The reconfiguration of the components for reuse is done in minimum number of steps	Number of steps	Number	=10
	Transport	The weight of most of the components allows them to be carried by 2 people.	The weight of most of the components allows them to be carried by 2 people.	Weight	kg	=60 kg
		Transportability of the components/systems	The components and systems can be transported via road	Geometry	m	
Cultural and local site context	Primary users	Adaption to childrens perception	The museum should be attractive to children	Characteristics	Characteristics (subjective)	Adaptability
		Adaption to childrens behaviour	The museum should be safe for children and children-proof	Characteristics	Characteristics (subjective)	Adaptability
		Adaption to childrens size	Everything should be reachable for children	Geometry	m	
	Secondary users	Adaption to secondairy users (students and staff) perception	The museum should also be suitable for secondairy use	Characteristics	Characteristics (subjective)	Adaptability
		Adaption to secondairy users (students and staff) behaviour	The environment should be suitable for secondairy users	Characteristics	Characteristics (subjective)	Adaptability
		Adaption to secondairy users (students and staff) size	The building is also suitable for secondairy users. Not just children	Geometry	m	
	Cultural aspects	Integration of cultural aesthetic qualities	For the design of the museum cultural aesthetic qualities are taken into account	Characteristics	Characteristics (subjective)	Adaptability
		Integration of cultural and behavioral aspects to the design	For the design of the museum cultural aspects are taken into account	Characteristics	Characteristics (subjective)	Adaptability

Table 5.5 | MCDM part 5

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